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Carbon Sequestration Potential of Trees in Urban Vegetation Islands: A Case Study

Pragya Dadhich ^a, Anita Malav ^a and Poonam Jaiswal ^{a*}

^a Department of Botany, JDB Government Girls College, University of Kota, Kota, Rajasthan, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: Increasing levels of atmospheric carbon dioxide (CO₂) and other “greenhouse” gases contribute to an increase in atmospheric temperature. Trees act as a sink for CO₂ by fixing carbon during photosynthesis and storing excess carbon as biomass. The current study focuses on the contribution of vegetation within Janki Devi Bajaj Government Girls College, Kota towards carbon sequestration potential and climate regulation.

Study Design: Non-destructive method of biomass estimation was used to measure the GBH of individual trees on the campus.

Place and Duration: The study was conducted in Janki Devi Bajaj Government Girls College, Kota in Rajasthan, India from July 2022 to June 2023.

Methodology: Above-ground biomass (AGB) and below-ground biomass (BGB) were calculated with the help of field measures of diameter at breast height (DBH) of the trees using allometric equations and Carbon equivalent was calculated with scientifically verified formula.

Results: The present study enumerated a total of 849 trees belonging to 43 tree species on the campus. The most dominant species was *Syzygium cumini* (L.) Skeels with a total of 163 trees followed by *Phoenix sylvestris* (L.) Roxb (121 trees) and *Eucalyptus obliqua* L'Her (97 trees). The

*Corresponding author: E-mail: poonamjaisdbkota@gmail.com;

above-ground biomass (AGB) and below-ground biomass (BGB) of all the trees on the campus are equivalent to 373937 kg and 56090.54 kg, respectively. The total biomass accumulated is 430027.5 kg and the total carbon content of the campus trees is equal to 215013.75 kg. The total carbon sequestered by all the trees in a year is 788.38 tons. In other words, on average carbon sequestered by an individual tree on the campus is 928.60 kg/year or 0.93 tons/year.

Conclusion: Urban green islands are likely to have a wider impact on biomass accumulation in turn carbon storage and sequestration in comparison to other structural parameters like species richness or density. Thus, in urban areas, the amount of potential carbon storage is positively influenced by increasing biomass.

Keywords: Sequestration; biomass; climate change; carbon.

1. INTRODUCTION

Rapid urbanization has become a major cause of climate change, driving land use change, habitat loss resulting decline in biodiversity, and pollution both within and outside the city [1]. A major part of this pollution is contributed by increasing levels of atmospheric carbon dioxide and other greenhouse gases. Reduction in CO₂ concentrations in the atmosphere can be achieved by increasing the rate of removal of CO₂ by the trees through carbon sequestration which can decrease the atmospheric CO₂ naturally [2]. Recently urban forests & urban green spaces received much attention in combating climate change and reducing biodiversity loss. These urban forests (trees in gardens, parks, and along the streets, roads, canals, etc.) contribute to verdancy in the city [3], play an important role in biodiversity conservation [4], and are important in carbon sequestration [5,6]. These spaces provide a variety of ecosystem services such as improving air quality [7] by reducing air pollution [8], may represent an important carbon reservoir through carbon sequestration [9] and thus play a very important role in limiting the city's carbon footprint [10]. The vegetation and soil of a greenspace can not only sequester carbon, contributing directly to a reduction in atmospheric CO₂ concentration but also affect the carbon balance indirectly, through their effects on the urban energy balance and thus on CO₂ emissions related to energy use [11,12]. Unfortunately, these areas are also being sacrificed in the race for urbanization; there is an urgent need to restore these green patches. Restoration must be carefully planned as sometimes we introduce species that are harmful to the native flora; so, we must use some restoration strategies like those suggested by Dadhich and Jaiswal [13] and Dadhich et al. [14].

According to IPCC [15], the major five carbon pools of a terrestrial ecosystem involving biomass are above-ground biomass, below-ground biomass, dead wood, litter, and soil organic matter. Trees are important sinks for atmospheric carbon i.e., carbon dioxide, since 50% of their standing biomass is carbon itself [16]. Trees and other types of vegetation provide significant local cooling by transpiration, and provision of habitats for flora and fauna [17,18]. The carbon assimilated by trees is retained for a longer duration with little leakage into the atmosphere. Annual rates of carbon sequestration largely depend on the tree's size at maturity, life span, and growth rates [19]. After the trees die, the biomass either enters the food chain or the soil as soil carbon [20].

Though the importance of forested areas in carbon sequestration has been well established and documented, few attempts have been made to address the potential of trees in carbon sequestration in urban cities. Generally, in developing countries, where urbanization is most rapid, the collection of data is very important to represent the correct status of urban vegetation. It is important to study the carbon sequestration potential of urban centres so as to understand and highlight the role of urban green spaces in offsetting carbon emissions at a local level. Large educational institute campuses provide large areas for urban tree plantations that can be a potential solution for climate change mitigation through carbon storage and carbon sequestration.

There are various studies that highlight the importance of educational institutes in carbon stocking [21-29]. The present study was conducted with the objective of collecting adequate data on urban vegetation playing an important role in carbon storage and

sequestration in a prominent educational institute.

1.1 Study Area

The study was conducted in the Janki Devi Bajaj government girl's college, Kota. The campus of this college was established in 1958 and is the largest girl's college in the southeast region (Known as Hadoti) of Rajasthan, India. The campus covers a total area of 57.47 acres. The geographical location of this college is 25.179324° N and 75.853915° E. Kota is situated in southeastern Rajasthan along the bank of river Chambal.

The city experiences cold winters and warm summers, with a temperature ranging from a maximum of 48°C to a minimum of 9°C. It receives very little rainfall throughout the year with an average of around 728 mm per year. The city has witnessed extensive urbanization over the years, with a number of high-rise buildings, corporations, and industries.

2. MATERIALS AND METHODS

Field data of tree species on the campus was recorded. Identification of trees up to species level was done through visual observation and verified by the flora of Singh & Shetty [30].

Non-destructive method of biomass estimation was used to measure the GBH of individual trees on the campus. The girth of individual trees at breast height (1.37 m) was enumerated. The girth was measured using measuring tape. Above-ground biomass (AGB) and below-ground biomass (BGB) were calculated with the help of field measures of diameter at breast height (DBH) of the trees using allometric equations [31]. The below given equation is applicable for dry climates with annual rainfall <1500mm; which makes it ideal for the study area where annual rainfall is 728mm.



Fig. 1. Satellite map of Janki Devi Bajaj Govt. Girls College campus showing dense vegetation

Above ground biomass (AGB): $34.4703 - 8.0671D + 0.6589D^2$

Where, D= DBH (cm.)

Below ground biomass (BGB) = $AGB \times (15/100)$

Total biomass = $AGB+BGB$

Carbon Content = $0.5 \times \text{Total biomass}$ [15]

Carbon equivalent = $(\text{Carbon content} \times 44) / 12$

3. RESULTS

The present study enumerated a total of 849 trees belonging to 43 tree species on the campus. The most dominant species was *Syzygium cumini* (L.) Skeels with a total of 163 trees followed by *Phoenix sylvestris* (L.) Roxb (121 trees) and *Eucalyptus obliqua* L'Her (97 trees). Fabaceae was found to be the most species-rich family with 11 species and all other families were represented by 3 or <3 species. Family Fabaceae represents the most dominant family due to its high adaptability [32]; it is also verified by the work of Jaiswal & Dadhich [33], Dadhich and Jaiswal [34] and Malav and Jaiswal [35]. In terms of density and total individuals, Myrtaceae shows the highest density followed by Fabaceae and Areceae whereas in terms of Total biomass and C equivalent, Family Myrtaceae is followed by Moraceae and Fabaceae. The above-ground biomass (AGB) and below-ground biomass (BGB) of all the trees on the campus are equivalent to 373937 kg and 56090.54 kg respectively. The total biomass accumulated is 430027.5 kg and the total carbon content of the campus trees is equal to 215013.8 kg. The total carbon sequestered by all the trees in a year is 788.38 tons. In other words, on average carbon sequestered by an individual tree on the campus is 928.60 kg/year or 0.93 tons/year.

Fig. 2 shows that Carbon equivalent, Carbon content, and Biomass follow the same trend, which means they have the same correlation between these parameters. Families having higher biomass have higher carbon content as well as carbon equivalent. Whereas species richness, density, and C equivalent per family are not correlated (Fig. 3). Families having higher species richness and density (Fabaceae, Aracaceae) have lower carbon equivalents and family Moraceae and Meliaceae have higher carbon equivalents although have lower species richness and density. These results show that the diameter of the tree has the most significant

effect on the stored carbon rather than density and species richness.

Fabaceae, Myrtaceae, Moraceae, Malvaceae, and Apocynaceae account for almost 50% of the species richness, Fabaceae alone accounts for 1/4th of the species richness. In terms of the number of individuals, Myrtaceae has the highest number of plants as well as density followed by Fabaceae and Arecaceae in both the number of species and density. Myrtaceae has maximum Carbon content, Carbon equivalent as well as Total biomass followed by Moraceae and Fabaceae.

4. DISCUSSION

Results of the study show that biomass has a strong correlation to the potential stored carbon. Several other parameters; tree diameter, stands density, and tree species diversity correlated to increasing tree biomass hence to the increasing of stored carbon [36-39].

Urban cities are responsible for 75% of global CO₂ emissions [40]. Urban vegetation can be seen as a carbon absorber if the total amount of CO₂ absorbed during photosynthesis is higher than the CO₂ released during respiration. The role of forested areas in carbon sequestration is well documented [5, 6]. The development of Urban Forests will contribute to India's decision to sequester 2.5 to 3 billion tonnes of carbon dioxide equivalent in the country's forests [41]. In recent years, preserving and maintaining urban forests and vegetation has recognized its importance in ecological, social, and aesthetic values.

Biomass is an important indicator of carbon sequestration and a tool to access the structural and functional attributes of trees because approximately 50% of the dry biomass of trees comprises Carbon [16,42-44]. Results of the present study indicate that the vegetation of the campus is species-rich, represented by 43 tree species. In urban forests large number of species within very small areas indicates rich biodiversity [45]. Though the college campus has a tree density of 0.004 trees/sqm but contributes significantly to Carbon sequestration in urban areas.

Nowak [46] indicated that 600 trees in the tropics could sequester up to 15 tonnes of CO₂ annually and 40 trees will sequester one tonne of CO₂ each year. Usually, urban forests have relatively

low tree cover, even though they can store comparatively lesser Carbon/hectare (25.1tC/ha) than forest stands (53.5tC/ha). Urban forests due to faster growth rate and a greater proportion of larger trees in urban areas, Carbon storage by urban trees and gross carbon sequestration may be greater than in forest stands on a per unit tree cover basis [46]. Due to more open forest

structure differences in tree diameter distributions between urban and forest areas. This may be the reason that individual urban trees, on average, contain approximately four times more C than individual trees in forest stands [17]. CO₂ stored in biomass by the urban forest amounted to about 0.2 million tons [47].

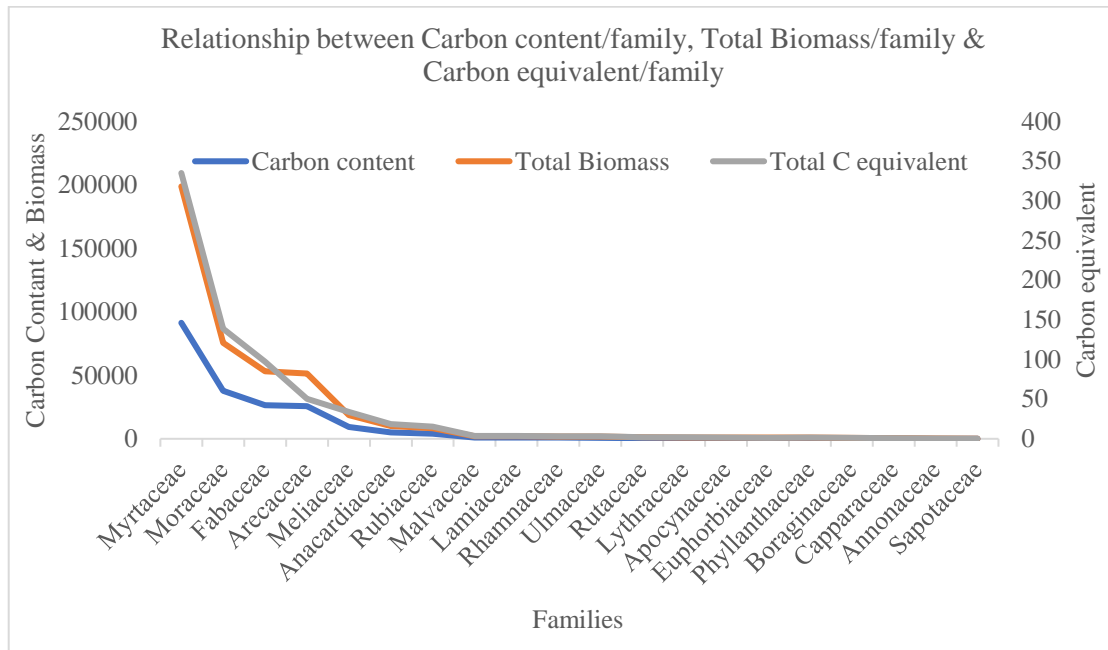


Fig. 2. Relationship between number of plants per family, biomass/family, and Carbon equivalent/family in the sampled area

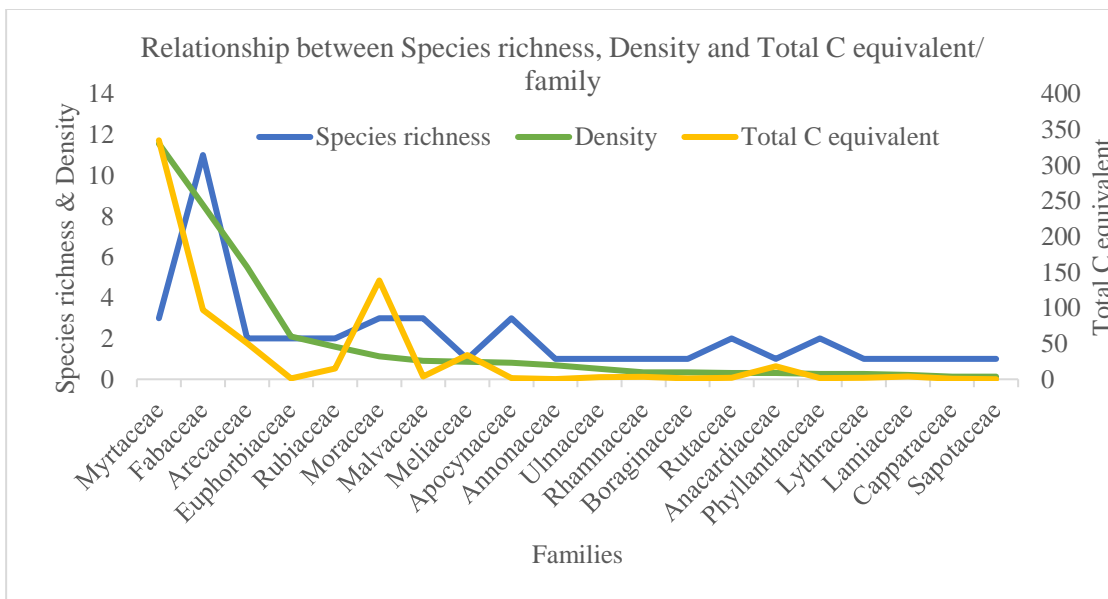


Fig. 3. Relationship between species richness, density, and total c equivalent/ family in the study area

Table 1. Data of Tree species in Janki Devi Bajaj Government Girls College, Kota

S.N.	Tree species	Family	No. of trees	AGB (kg)	BGA (kg)	Total Biomass (kg)	Carbon Content (kg)	Carbon Equivalent	Carbon equivalent (Tons)
1	<i>Acacia nilotica</i> (L.) Willd. Ex Delile	Fabaceae	85	8744.1	1311.62	10055.72	5027.86	18435.487	18.435
2	<i>Aegle marmelos</i> (L.) Correa	Rutaceae	4	966.69	145.0035	1111.694	555.847	2038.106	2.038
3	<i>Albizia lebbek</i> L. Benth.	Fabaceae	5	1401.94	210.291	1612.231	806.1155	2955.757	2.956
4	<i>Alstonia scholaris</i> (L.) R. Br.	Apocynaceae	7	673.92	101.088	775.008	387.504	1420.848	1.421
5	<i>Azadirachta indica</i> A. Juss.	Meliaceae	20	16153.02	2422.953	18575.97	9287.985	34055.945	34.056
6	<i>Bauhinia variegata</i> (L.) Benth.	Fabaceae	14	2745.23	411.7845	3157.015	1578.5075	5787.861	5.788
7	<i>Bombax ceiba</i> L.	Malvaceae	6	120.26	18.03	138.29	69.145	253.532	0.254
8	<i>Caryota urens</i> L.	Arecaceae	7	701.2	105.18	806.38	403.19	1478.363	1.478
9	<i>Cassia fistula</i> L.	Fabaceae	4	452.47	67.8705	520.3405	260.17025	953.958	0.954
10	<i>Cassia siamea</i> Lam.	Fabaceae	13	2482.6	372.39	2854.99	1427.495	5234.148	5.234
11	<i>Citrus limon</i> (L.) Burm. f.	Rutaceae	3	47.36	7.104	54.464	27.232	99.851	0.100
12	<i>Collistemon citrinus</i> (Curtis) Skeels [es]	Myrtaceae	9	4504.09	675.6135	5179.704	2589.852	9496.124	9.496
13	<i>Cordia dichotoma</i> G.Forst.	Boraginaceae	8	572.41	85.8615	658.2715	329.13575	1206.831	1.207
14	<i>Crateva religiosa</i> G.Forst.	Capparaceae	3	319.66	47.949	367.609	183.8045	673.950	0.674
15	<i>Dalbergia sissoo</i> Roxb.	Fabaceae	25	4591.4	688.71	5280.11	2640.055	9680.202	9.680
16	<i>Delonix regia</i> (Boj. Ex Hook.) Raf.	Fabaceae	6	1156.21	173.4315	1329.642	664.821	2437.677	2.438
17	<i>Eucalyptus obliqua</i> L'Her.	Myrtaceae	97	66190.69	9928.604	76119.29	38059.645	139552.032	139.552
18	<i>Ficus benghalensis</i> L.	Moraceae	11	49890.15	7483.523	57373.67	28686.835	105185.062	105.185
19	<i>Ficus religiosa</i> L.	Moraceae	13	15839.77	2375.966	18215.74	9107.87	33395.523	33.396
20	<i>Guazuma ulmifolia</i> Lam.	Malvaceae	8	543.31	81.4965	624.8065	312.40325	1145.479	1.145
21	<i>Holoptelea integrifolia</i> (Roxb.) Planch.	Ulmaceae	12	1447.46	217.119	1664.579	832.2895	3051.728	3.052
22	<i>Jatropha curcus</i> L.	Euphorbiaceae	5	54.21	8.1315	62.3415	31.17075	114.293	0.114
23	<i>Lagerstroemia indica</i> L.	Lythraceae	6	939.38	140.907	1080.287	540.1435	1980.526	1.981
24	<i>Mangifera indica</i> L.	Anacardiaceae	7	8739.92	1310.988	10050.91	5025.455	18426.668	18.427
25	<i>Manikara hexandra</i> (Roxb.) Dubard	Sapotaceae	3	53.56	8.034	61.594	30.797	112.922	0.113
26	<i>Mitragyna parvifolia</i> (Roxb.) Korth	Rubiaceae	32	5965.94	894.891	6860.831	3430.4155	12578.190	12.578
27	<i>Morus alba</i> L.	Moraceae	2	22.84	3.426	26.266	13.133	48.154	0.048

S.N.	Tree species	Family	No. of trees	AGB (kg)	BGA (kg)	Total Biomass (kg)	Carbon Content (kg)	Carbon Equivalent	Carbon equivalent (Tons)
28	<i>Neolamarckia cadamba</i> (Roxb.) Bosser	Rubiaceae	5	1232.56	184.884	1417.444	708.722	2598.647	2.599
29	<i>Peltophorum pterocarpum</i> (DC.) K.Heyne	Fabaceae	29	14847.91	2227.187	17075.1	8537.55	31304.350	31.304
30	<i>Phoenix sylvestris</i> (L.) Roxb	Arecaceae	121	44048.44	6607.266	50655.71	25327.855	92868.802	92.869
31	<i>Phyllanthus emblica</i> L.	Phyllanthaceae	4	778.15	116.7225	894.8725	447.43625	1640.600	1.641
32	<i>Phyllanthus reticulatus</i> Poir.	Phyllanthaceae	2	44.62	6.693	51.313	25.6565	94.074	0.094
33	<i>Pithecellobium dulce</i> (Roxb) Benth.	Fabaceae	4	54.41	8.1615	62.5715	31.28575	114.714	0.115
34	<i>Plumeria pudica</i> Jacq.	Apocynaceae	7	97.77	14.6655	112.4355	56.21775	206.132	0.206
35	<i>Polyalthia longifolia</i> (Sonn.) Wall.	Annonaceae	16	186.5	27.975	214.475	107.2375	393.204	0.393
36	<i>Pongamia pinnata</i> (L.) Pierre	Fabaceae	11	1582.68	237.402	1820.082	910.041	3336.817	3.337
37	<i>Ricinus communis</i> L.	Euphorbiaceae	44	788.79	118.3185	907.1085	453.55425	1663.032	1.663
38	<i>Streculia foetida</i> L.	Malvaceae	7	1109.89	166.4835	1276.374	638.187	2340.019	2.340
39	<i>Syzygium cumini</i> (L.) Skeels.	Myrtaceae	163	102156.6	15323.49	117480.1	58740.05	215380.183	215.380
40	<i>Tabernaemontana divaricata</i> R.Br. Ec Roem. & Schult.	Apocynaceae	5	75.9	11.385	87.285	43.6425	160.023	0.160
41	<i>Tamarindus indica</i> L.	Fabaceae	3	8242.31	1236.347	9478.657	4739.3285	17377.538	17.378
42	<i>Tectona grandis</i> L.f.	Lamiaceae	5	1770.83	265.6245	2036.455	1018.2275	3733.501	3.734
43	<i>Ziziphus mauritiana</i> Lam.	Rhamnaceae	8	1599.82	239.973	1839.793	919.8965	3372.954	3.373
			849	373937	56090.54	430027.5	215013.77	788383.805	788.384

To fulfill the agenda of SDG 2030, [48] institutions of higher education have a significant role to play in a way to develop small vegetation islands that can contribute to atmospheric Carbon sequestration. Thus, green campuses of educational institutes can contribute towards sustainable development goals related to climate actions through regulating services provided by the forest and prevention of terrestrial life forms through the conservation of biodiversity within it. This work will help build up the baseline information about biodiversity within the urban forest islands and the role of these vegetation in regulating the local climate through carbon sequestration.

5. CONCLUSION

The results of the study illuminate the value of urban trees in mitigating the impacts of global warming at a local level. Vegetation of education institutes have an important role in expanding their green cover so as to act as local carbon sinks. The study acts as a baseline for future assessments of the campus carbon sink. Such education institutes can model themselves as agents of fulfilling the agenda of SDG 2030. Urban green islands are likely to have a wider impact on biomass accumulation in turn carbon storage and sequestration in comparison to other structural parameters like species richness or density. Thus, the amount of potential carbon storage is positively influenced by increasing biomass.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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