

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

Authors' contributions

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

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 *Syzygiumcumini*(L.) Skeels with a total of 163 trees followed by *Phoenix sylvestris* (L.) Roxb (121 trees) and *Eucalyptus obliqua*L'Her (97 trees). 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 215013.75kg. 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 in 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.

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, 22, 23, 24, 25, 26, 27, 28, 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.

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.



Figure 1: Satellite map of JDB Govt. Girls College campus showing dense vegetation.

Material 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.

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

Observation & Result: The present study enumerated a total of 849 trees belonging to 43 tree species on the campus. The most dominant species was *Syzygiumcumini*(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.

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>Aeglemarmelos</i> (L.) Correa | Rutaceae | 4 | 966.69 | 145.0035 | 1111.694 | 555.847 | 2038.106 | 2.038 |
| 3 | <i>Albizialebeck</i> L. Benth. | Fabaceae | 5 | 1401.94 | 210.291 | 1612.231 | 806.1155 | 2955.757 | 2.956 |
| 4 | <i>Alstoniascholaris</i> (L.) R. Br. | Apocynaceae | 7 | 673.92 | 101.088 | 775.008 | 387.504 | 1420.848 | 1.421 |
| 5 | <i>Azadirachtaindica</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 | 1578.507 5 | 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>Caryotaurens</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 | 260.1702 5 | 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>Collistemoncitrinus</i> (Curtis) Skeels [es] | Myrtaceae | 9 | 4504.09 | 675.6135 | 5179.704 | 2589.852 | 9496.124 | 9.496 |
| 13 | <i>Cordiadicotoma</i> G.Forst. | Boraginaceae | 8 | 572.41 | 85.8615 | 658.2715 | 329.1357 5 | 1206.831 | 1.207 |
| 14 | <i>Cratevareligiosa</i> G.Forst. | Capparaceae | 3 | 319.66 | 47.949 | 367.609 | 183.8045 | 673.950 | 0.674 |
| 15 | <i>Dalbergiasissoo</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 | 38059.64 5 | 139552.032 | 139.552 |
| 18 | <i>Ficus benghalensis</i> L. | Moraceae | 11 | 49890.15 | 7483.523 | 57373.67 | 28686.83 5 | 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>Guazumaulmifolia</i> Lam. | Malvaceae | 8 | 543.31 | 81.4965 | 624.8065 | 312.4032 5 | 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 | 3430.415 5 | 12578.190 | 12.578 |
| 27 | <i>Morus alba</i> L. | Moraceae | 2 | 22.84 | 3.426 | 26.266 | 13.133 | 48.154 | 0.048 |
| 28 | <i>Neolamarckia cadamba</i> (Roxb.) Bossier | 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 | 25327.85 5 | 92868.802 | 92.869 |
| 31 | <i>Phyllanthus emblica</i> L. | Phyllanthaceae | 4 | 778.15 | 116.7225 | 894.8725 | 447.4362 5 | 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 | 453.5542 5 | 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 . EcRoem. & 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 | 4739.328 5 | 17377.538 | 17.378 |
| 42 | <i>Tectona grandis</i> L.f. | Lamiaceae | 5 | 1770.83 | 265.6245 | 2036.455 | 1018.227 5 | 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 | 215013.7 7 | 788383.805 | 788.384 |

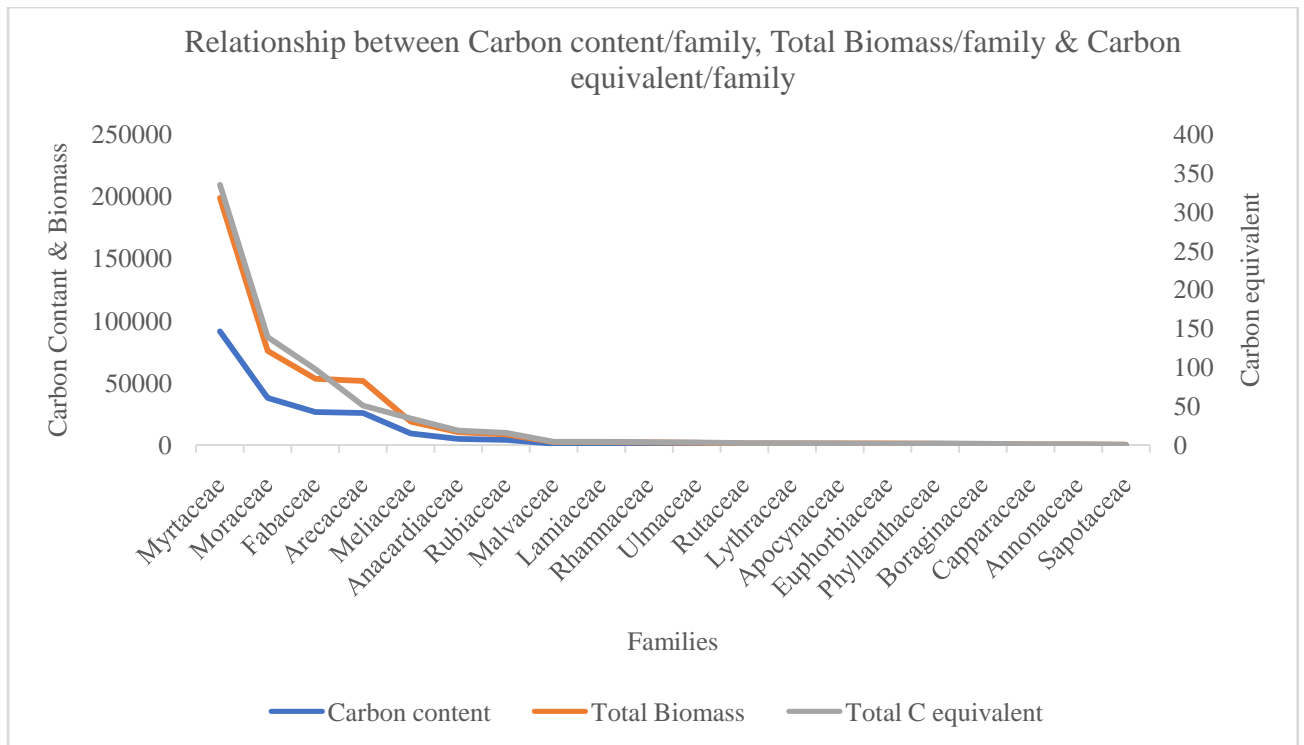


Figure 2: Relationship between number of plants per family, biomass/family, and Carbon equivalent/family in the sampled area.

Figure 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 (Figure 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.

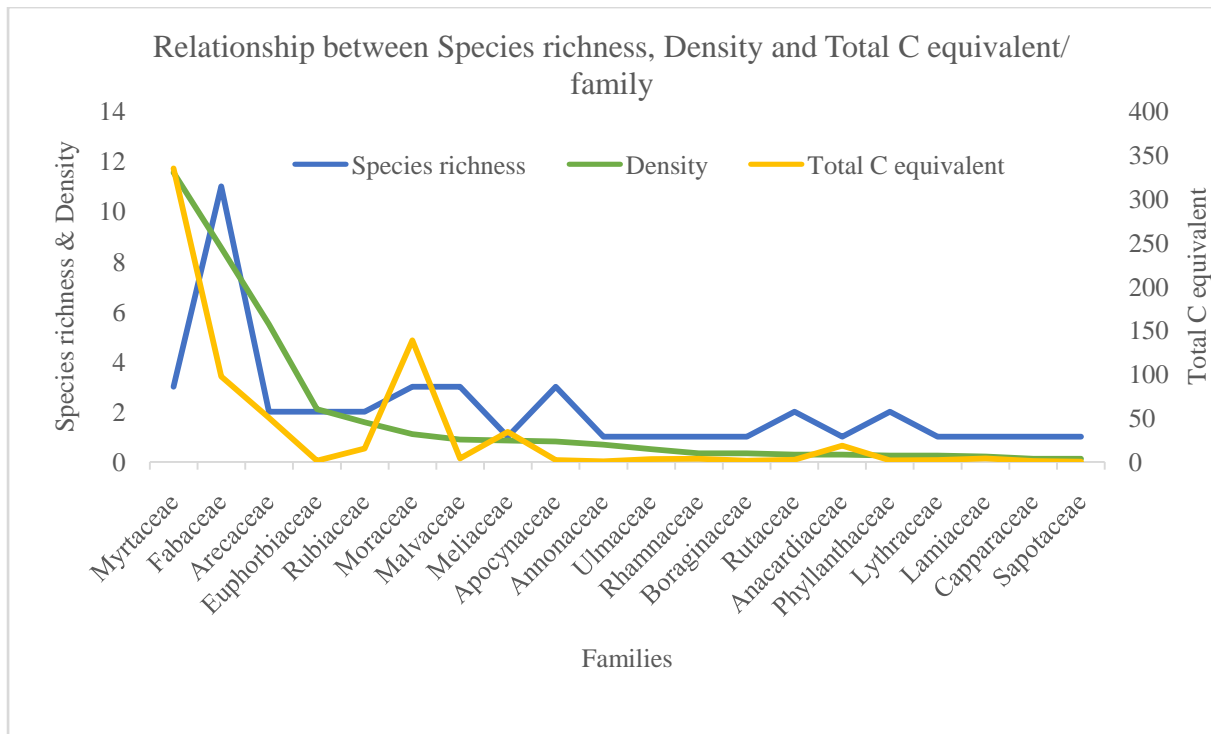


Figure 3: Relationship between Species richness, Density, and Total C equivalent/ family in the study area.

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.

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, 37, 38, 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, 43, 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].

To fulfil the agenda of SDG 2030, [48]institutions of higher education have a significant role to play in a way to develop small vegetation islands which 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.

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 in 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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