Pak. J. Bot., 56(5): 1831-1840, 2024. DOI: http://dx.doi.org/10.30848/PJB2024-5(41)

ASSESSING THE ROLE OF PUBLIC INSTITUTIONS IN CARBON SEQUESTRATION THROUGH WOODY VEGETATION UNDER ARID CONDITIONS: A CASE STUDY OF BAHAUDDIN ZAKRIYA UNIVERSITY, MULTAN, PAKISTAN

GHULAM YASIN[1], MUHAMMAD SHOAIB[1], MUHAMMAD FARRAKH NAWAZ[2], SABIR AZIZ[3], MUHAMMAD FAROOQ AZHAR[1], MUHAMMAD TALHA IMTIAZ[1] AND SADAF GUL[4*]

[1]*Department of Forestry and Range Management, Bahauddin Zakariya University, Multan, Punjab, Pakistan*
[2]*Institute of Environmental Studies, University of Karachi, Karachi, Pakistan*
[3]*Department of Horticulture, Bahauddin Zakariya University, Multan, Punjab, Pakistan*
[4]*Department of Botany, University of Karachi, Karachi, Pakistan*
**Corresponding author's email: sadafgpk@yahoo.com*

Abstract

Urban green spaces, specifically trees, have enormous potential for reducing the effects of climate change in cities by removing carbon dioxide (CO_2) from the air. Developing such green spaces on large university campuses can help mitigate the effects of rising greenhouse gas emissions and provide several other benefits. A case study was conducted to estimate the carbon stock and carbon sequestration potential (CSP) through the non-destructive approach, in the aboveground and belowground components of all live trees situated on the main campus of the Bahauddin Zakariya University (BZU), Multan. We measured tree height and diameter at the breast height (DBH) of individual trees and applied allometric equations for the estimation of carbon storage. The campus harbors an extensive variety of 35 distinct tree species, collectively contributing to the total CSP of around 564.9 tons. Total tree biomass ranged from 247.29 tons to 35.26 tons across the whole study area. The findings also indicate that the highest total carbon (20.12 tons) was estimated for *Eucalyptus camaldulensis* followed by *Vachellia nilotica* (19.15 tons), *Morus alba* (15.12 tons), *Azadirachta indica* (12.82 tons) respectively. The lowest carbon storage capacity (0.12 tons) was demonstrated by *Thevetia peruviana*. This study emphasizes the significance of trees in addressing the challenges faced by colleges and universities in reducing carbon emissions in Pakistan as well as in other regions. It provides a contextual understanding of the broader role of green areas, specifically trees, in contributing to the global movement towards sustainable universities and campuses.

Key words: Allometric equations, Biomass, Carbon stock, Climate change, Urban green space.

Introduction

Cities are the centers of economic development and growth (Sharma *et al*., 2020). According to the United Nations Development Programme (UNDP) in 2019, urban areas in Pakistan are responsible for generating 55% of the nation's overall Gross Domestic Product. Currently, urban areas accommodate approximately 50% of the global population (Thomas, 2008). The phenomenon of rapid urbanization is widely recognized as a significant catalyst for various global transformations, including the loss of biodiversity (Newbold *et al*., 2015), the contamination of air and water (Hoekstra *et al*., 2021), changes in land use patterns (Song *et al*., 2018), and the degradation of ecosystems (Haddad *et al*., 2015). The sudden and substantial changes have a notable impact on both individuals and the natural surroundings worldwide (Li *et al*., 2021; Nagendra *et al*., 2018). The contribution of carbon emissions originating from urban areas and the associated changes in land use patterns are increasingly recognized as influential factors in the progression of climate change (Wigginton *et al*., 2016; Li *et al*., 2022). The urban areas are accountable for the generation of over 70% of anthropogenic carbon dioxide (CO_2) emissions (Li *et al*., 2020). The per capita CO_2 emissions in Pakistan, are 0.87 tons which is 0.06 tons higher as compared to 2015 per capita CO_2 emissions (Zubair *et al*., 2022).

Urban green spaces encompass a wide range of green areas within urban agglomerations, such as forests, parks, private gardens, allotment gardens, cemeteries, brownfields, arable land, meadows, and greenery along railway tracks. These spaces may be managed by the city, private owners, or other arrangements (Beirnacka & Kronenberg, 2019). Ramaiah and Avtar (2019) argue that urban green spaces play a crucial role in mitigating air pollution and addressing climate change. In addition to their various ecosystem services, trees play a vital role in carbon sequestration, noise reduction, biodiversity conservation, mitigation of urban heat islands, soil stabilization, and groundwater replenishment (Jo, 2002; Shah & Gavali, 2017; Jim & Chen, 2006). Vegetation plays a crucial role in maintaining the balance of CO_2 and oxygen in urban air by sequestering CO_2 and producing oxygen through photosynthesis (Wu & Su, 2002). The rate of photosynthesis and respiration directly affects the carbon dioxide storage and oxygen release capacity of urban forests (Li *et al*., 2002). Furthermore, urban green areas provide various cultural services, including spiritual and religious activities, recreational opportunities, ecotourism, and aesthetic experiences (Chang *et al*., 2017).

In urban areas, trees, play a significant role in capturing carbon and act as a sink (Amoatey & Sulaiman, 2022). Because of their impressive growth rates, the trees show immense potential in absorbing CO_2 and effectively addressing climate change (Byrd *et al*., 2018). These trees can also contribute to Pakistan's goal of reducing CO_2 emissions by 50% in 2030 (Komal *et al*., 2022). Many cities across the country are currently grappling with environmental challenges as a result of inadequate planning for green infrastructure in urban areas (Zubair *et al*., 2022). The effectiveness of trees in combating global warming depends on their ability to store carbon. The amount of carbon concentration in a tree can be calculated by determining the biomass accumulated within the tree. The biomass is predominantly found in stem wood and branches, with a smaller amount in leaves. It is typically estimated using allometric equations, as demonstrated in previous studies (Nandal *et al*., 2023; Yasin *et al*., 2023).

The recognition of five carbon pools within the terrestrial ecosystem involving biomass has been acknowledged by the Intergovernmental Panel on Climate Change. These pools include aboveground biomass, below-ground biomass, litter, woody debris, and soil organic matter. According to Vashum & Jayakumar (2012), the above-ground biomass is the predominant component of the carbon pool when considering all carbon pools. Urban green spaces can sequester carbon through three distinct mechanisms. Firstly, trees undergo the process of converting carbon into biomass and subsequently sequestering it. Secondly, the presence of soil plays a significant role in carbon sequestration. Thirdly, urban vegetation plays a crucial role in mitigating the need for cooling systems by offering shade and ventilation, thereby reducing heat generation within residential structures. The mitigation of carbon emissions can be achieved by decreasing the reliance on fossil fuels for electricity generation, as supported by previous studies (Jo, 2002; Sharma *et al*., 2020; Yasin *et al*., 2019).

Despite the well-established and documented significance of forested areas in carbon sequestration, limited attention has been given to exploring the potential of trees in urban environments. The estimation of the carbon sequestration potential of urban centers is of significant importance to comprehensively understand and highlight the significance of urban green spaces in mitigating local CO_2 emissions. University campuses with expansive grounds provide ample opportunities for the establishment of extensive urban tree plantations, which have the potential to serve as a viable measure in mitigating the adverse effects of climate change. Understanding the carbon sequestration potential of urban green spaces is valuable due to its capacity to mitigate emissions and amplify the significance of greenery (Yasin *et al*., 2018; Sharma *et al*., 2020; Komal *et al*., 2022).

Throughout the years, certain universities have successfully attained carbon-neutral status by promoting afforestation and reforestation activities at their campuses. In 2014, the Leuphana University of Luneburg Germany achieved carbon neutrality, successfully meeting its goal that was set seven years prior. In 2016, Charles Sturt achieved the remarkable milestone of becoming the first carbon-neutral university in Australia. In 2019, the University of San Francisco, USA, achieved carbon neutrality, surpassing its initial goal of reaching this milestone by 2050. Similarly, the University of Bristol in the UK has set a target of 2030 to become carbon neutral (Mustafa *et al*., 2022; Clabeaux *et al*., 2020). Apart from this, a significant number of prominent universities worldwide are considering the implementation of green infrastructure as a viable approach to achieving sustainable development (Yumnam & Namrata, 2022; Yasin *et al*., 2023). A number of studies have been conducted across the globe to estimate the carbon sequestration potential at university campuses (Deb *et al*., 2016; Tiyarattanachai & Hallmann, 2016; Mark & Khary, 2017; Sharma *et al*., 2020). Limited research has been conducted in Pakistan regarding the carbon sequestration potential of trees within university campuses (Ajani & Shams, 2016). However, to date, no study has been undertaken specifically examining the carbon sequestration potential of trees within the campus of Bahauddin Zakariya University (BZU) in Multan. The objective of the present study is to evaluate the carbon sequestration potential and to compare the carbon sequestration capacity of various tree species within the campus environment with the ultimate goal of identifying and recommending the most suitable species for plantation at BZU, University, Multan.

Material and Methods

Description of study site and sampling procedure: The current study was carried out at the Multan campus of Bahauddin Zakriya University (BZU) in Punjab, Pakistan (Fig. 1). The university under consideration is the second largest educational institution in the Punjab region, encompassing a total land area of 389 hectares. The campus is adorned with lush greenery, including gardens and trees, and is home to various facilities such as academic buildings, administrative offices, and hostels. The primary campus is situated in the central region of Multan city, positioned at a latitude of 30°15′ 49″ N and a longitude of 71° 30′ 35″ E. The urban area is situated at an elevation of 122 meters above sea level and experiences a desert climate. The city experiences minimal annual precipitation. The city exhibits an average annual temperature of 25.6°C, accompanied by an average annual precipitation of 175 mm. October is characterized by being the month with the lowest amount of precipitation, with a recorded average of 2 mm. According to meteorological data, January is characterized by the lowest temperatures, with an average of 13.2°C. The amount of precipitation exhibits a variation of approximately 48 mm between the month with the lowest precipitation and the month with the highest precipitation. Temperatures exhibit a variation of 22.3°C over the year (Fig. 2). The assessment of carbon sequestration potential in terrestrial ecosystems by estimating biomass has been extensively pursued and has been regarded as the most suitable method for a considerable period of time (Yumnam and Namrata, 2022). In this study, the estimation of biomass and carbon stock was done through a nondestructive approach (allometric equations) using field data. The study was subdivided into various plots and in each plot, random quadrates of 20 m×20 m were laid for collecting the inventory data of all the trees. A total of 50 quadrants were laid down on the campus. Species identification of trees was obtained by visual inspection, and suspect specimens were collected and preserved in a herbarium for later identification by taxonomists.

Estimation of biomass and carbon: For the estimation of tree biomass and carbon, inventory data was collected from January 2023 to May 2023. The diameter at breast height (DBH) of each tree within the quadrat was directly measured using a measuring tape whereas a Haga altimeter was used to measure the tree height. Species-specific allometric equations were used to estimate the above and belowground tree biomass. Species having no allometric equation for measuring belowground tree biomass, belowground tree biomass was assumed to be 26% (Cairns *et al*., 1997; Ravindranath *et al*., 2007; Yasin *et al*., 2021). Total tree biomass was computed by adding the above and belowground tree biomass. In assessments conducted at the local, regional, and global scales, it has been commonly assumed that carbon content accounts for 50% of tree biomass. However, this assumption is not accurate due to significant variations in carbon content observed among different tree species and tissue types. For instance, there are distinct differences in carbon contents between coniferous and broad-leaved species. Based on the findings of Thomas & Martin (2012), it has been observed angiosperms in subtropical climates possess a carbon content of approximately 48.1% in their live tissues. Therefore, for calculating carbon contents, tree biomass was multiplied by 48.1%.

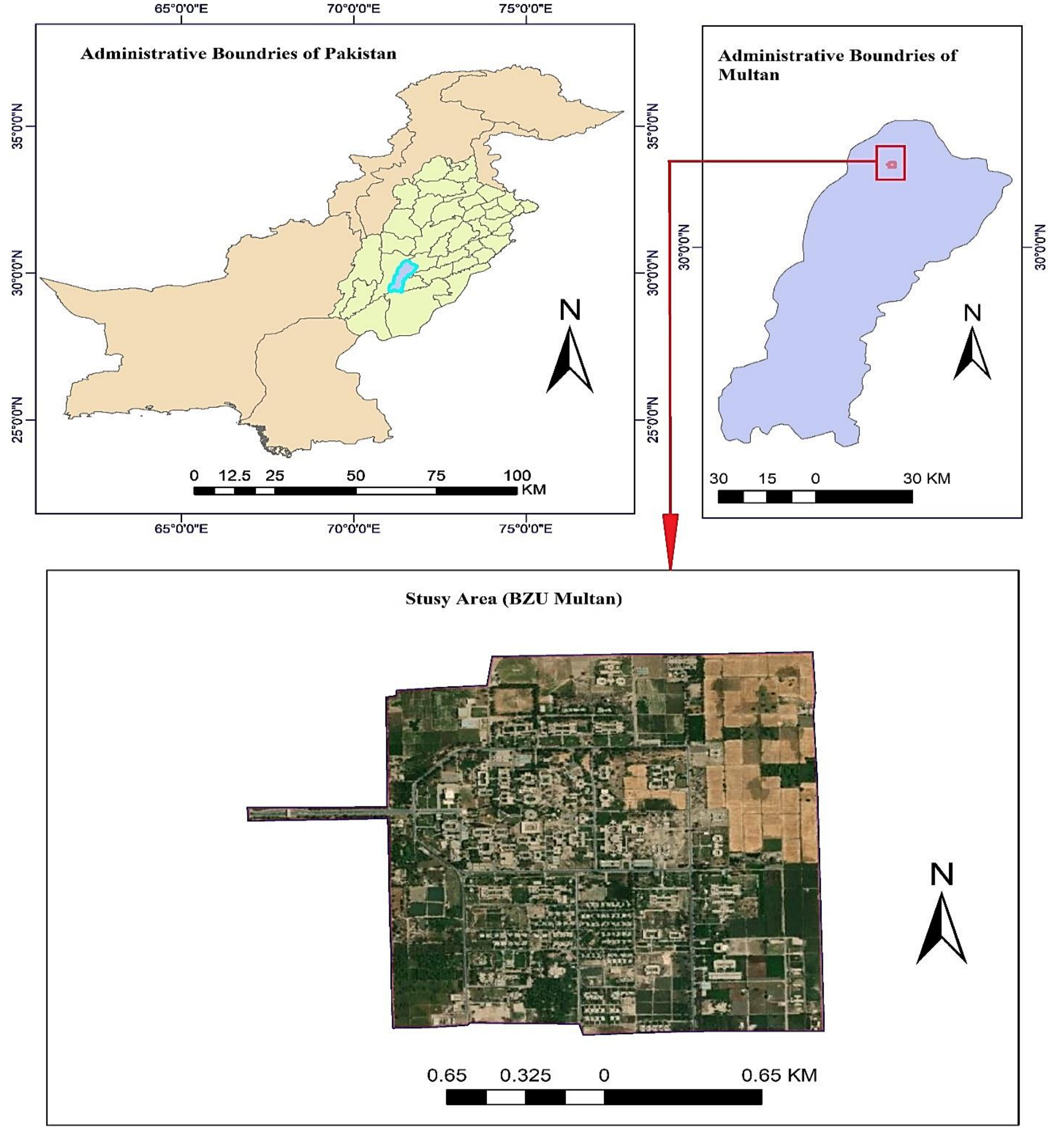

Fig. 1. Study Area Map indicating Bahauddin Zakariya University (BZU) Campus, Multan.

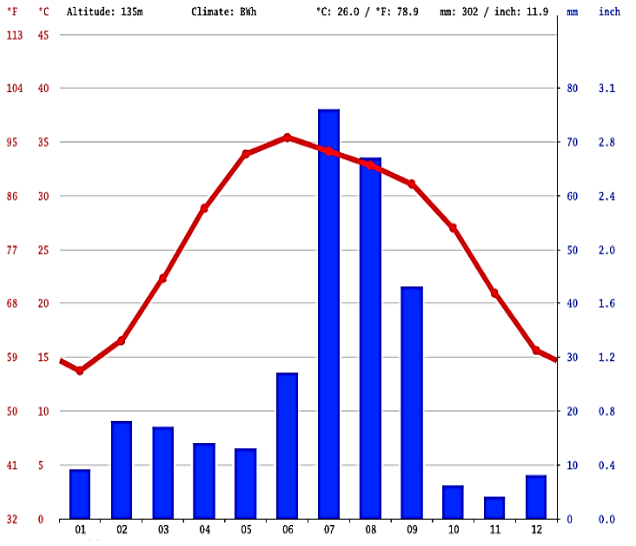

Fig. 2. Climate of Multan City (https://en.climate-data.org/asia/pakistan/punjab/multan-3783/).

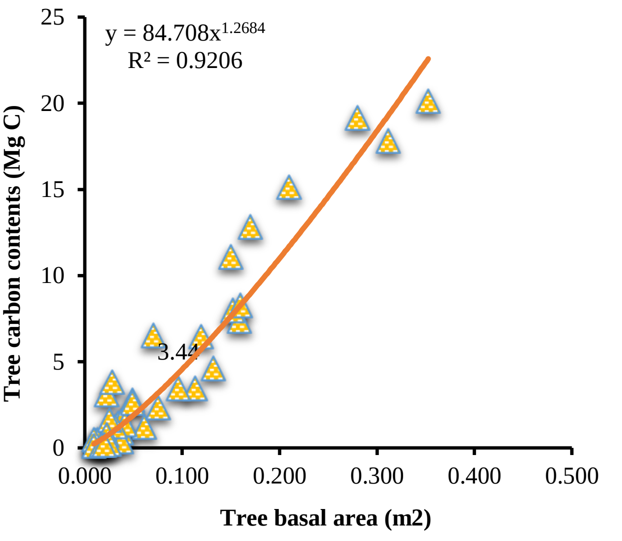

Fig. 3. Relationship between tree total carbon stock (Mg C) and tree basal area (m^2) for all tree species at the BZU campus.

Statistical Analysis

Correlation analysis of qualitative traits in variables of different tree species was done in XLSTAT 2023. PCA plots based on qualitative data and Cluster analysis of 35 different tree species were also done XLSTAT 2023 (Wang *et al*., 2020).

Results

Growth parameters: The results regarding growth parameters such as diameter at breast height (DBH), tree height, and basal area of 35 different tree species enumerated at the BZU Campus, Multan are presented in (Tables 1&2). The maximum DBH (31.12 cm) was noted for *D. sissoo* as compared to all other tree species present at the campus. *D. sissoo* DBH was 13.45%, 14.28%, 38.43%, and 38.68% higher than the other prominent species such as *F. virens*, *E. camaldulensis*, *Plumeria rubra*, and *A. procera*, respectively. The lowest DBH (7.10 cm) was computed for *P. guajava* as depicted in table 2. The maximum tree heights (21.14 m) among all the tree species were measured for *P. dactylifera*, followed by *B. ceiba* (9.69 m), *T. arjuna* (9.31 m), *E. camaldulensis* (9.15 m), *D. sissoo* (9.11 m) whereas the minimum tree height was estimated for *J. curcas* (2.99 m) and *P. guajava* (2.91 m), respectively. Similarly, the highest tree basal area (0.145 m^2) was measured for *E. camaldulensis* while the lowest basal area (0.004 m^2) was estimated for *P. guajav* as indicated in (Table 2).

Table 1. Comparisons of diversity indices of tree species at BZU Campus, Multan.

Diversity indices	Values
Simpson_1-D	0.94
Shannon_H	3.17

Tree biomass, carbon stock and CO_2 equivalent: The results regarding tree biomass enumerated that the highest amount of the total tree biomass was estimated in *E. camaldulensis*, (41912.15 Kg) followed by other prominent species such as *V. nilotica* (39894.46 Kg), *M. alba* (31502.77 Kg), *A. indica* (26702.35 Kg). This indicates that *E. Camaldulensis* showed a reasonable increase in terms of tree biomass accumulation than the aforementioned prominent species, having an increase of 5.06%, 33.046%, 56.96% than, *V. nilotica*, *M. alba*, *A. indica*, respectively (Table 3). The lowest total tree biomass (259.24 Kg) was stored by *T. peruviana* among all the species, followed *P. indica* (352.86 Kg) and *S. tetrasperma* (372.12 Kg) respectively. The highest amount of above and belowground carbon (15966.53 kg & 4151.30 kg) was measured for *E. camaldulensis* whereas the lowest amount of above and belowground carbon was stored by *T. peruviana* (98.76 kg & 25.66 kg). Some other prominent species at the university campus were also sequestering a reasonable amount of carbon such as *V. nilotica* (15197.89 kg & 3951.45 kg), *M. alba* (12001.06 kg & 3120.27 kg) and *D. sissoo* (9420.90 kg & 2449.43 kg) as depicted in (Table 3).

The maximum CO_2 equivalent was found in *E. camaldulensis* (73.77 Mg C) among all the tree species present at the campus. The CO_2 equivalent of *E. camaldulensis* was 5.08 %, 33.06%, 56.77%, and 69.508% higher than the other prominent species such as *V. nilotica*, *M. alba*, *A. indica*, and *D. sissoo*, respectively. The lowest CO_2 equivalent was noted for *T. Peruviana* (0.46 Mg C) followed by *P. indica*, *S. tetrasperma*. having the amount of CO_2 equivalent of 0.62 Mg C, 0.65 Mg C, respectively as represented in (Fig. 4). A positive and strong linear relationship was observed between tree carbon stock (Mg C) and tree basal area (m^2) for the tree species at the campus (R^2= 0.80) as depicted in (Fig. 3).

Correlation, PCA and cluster analysis: Correlation analysis of qualitative traits in variables of different tree species showed the positive correlation (0.903) of tree basal area with total tree biomass, belowground tree biomass, aboveground tree biomass, total carbon, belowground carbon, aboveground carbon followed by diameter at breast height (0.688) and 0.385 for Height for the all selected tree species; however, not a single variable showed negative correlations (Table 4).

In the scree plot, all 35 tree species were analyzed for 10 traits in multivariate analysis. As a result of PCA analysis, all parameter variations were covered in the first two components explaining 95% variation. The first factor contributed to 84% variability with maximum variation contribution by Basal Area traits followed by total tree biomass, belowground tree biomass, aboveground tree biomass, total carbon, below-ground carbon, and above-ground carbon. The second factor contributed 11.94% variation and recorded the highest loading in plant height followed by diameter at breast height and other traits showed negative loading as shown in (Fig. 5).

PCA plot based on qualitative data of different tree species showed that species of *D. sissoo* and *V. nilotica* were highly diverse and varied from each other (Fig. 6). *A. indica*, *M. alba*, *M. indica*. 063 were close to each other for various traits. *B. ceiba*, *T. arjuna*, *F. virens*, *E. camaldulensis* were more closely related (Fig. 6). PCA biplot of all different tree species showed that *D. sissoo*, *T. arjuna*, *F. virens* showed a strong association between basal area, height, and diameter at breast height (DBH) while *V. nilotica* had a strong association between CO_2 Equivalent (Fig. 6).

Cluster analysis of 35 different tree species. (Fig. 7) revealed the dendrogram which clustered the 35 different tree species into four enormous correlated clusters. The first cluster contained three *M. alba*, *V. nilotica* species whereas, 29 species can be allocated into 2 groups in the second cluster. 29 species which can be allocated into 2 groups. The group confined species such as *A. scholaris*, *B. ceiba*, *F. virens*, *M. indica*, and *T. arjuna*. Based on the dendrogram the *M. alba* and *V. nilotica* species were closely related to each other; while *C. viminalis* and *C. erectus* were distantly related species.

Table 2. Growth parameters: Diameter at breast height (cm), Tree height (m) and Tree basal area (m^2) at BZU Campus, Multan.

Sr. No	Species name	DBH (cm)			Height (m)			Basal area (m^2)		
		Mean	Range	SD	Mean	Range	SD	Mean	Range	SD
1.	*Dalbergia sissoo*	31.12	17.13-63.21	5.43	9.11	3.69-14.90	3.65	0.108	0.023-0.312	0.04
2.	*Morus alba*	19.09	9.61-33.62	3.71	6.40	3.05-6.84	2.11	0.035	0.006-0.210	0.06
3.	*Vachellia nilotica*	22.12	13.32-51.01	6.09	5.70	3.46-9.52	2.09	0.071	0.013-0.280	0.08
4.	*Eucalyptus camaldulensis*	27.37	22.39-67.43	4.98	9.15	5.24-16.95	3.05	0.145	0.038-0.353	0.09
5.	*Ficus religiosa*	16.01	10.46-28.70	2.33	8.37	4.10-13.79	3.54	0.028	0.008-0.062	0.003
6.	*Ficus bengalensis*	14.51	18.12-31.56	1.98	6.27	4.97-12.05	2.76	0.045	0.025-0.075	0.005
7.	*Ficus benjamina*	11.19	6.09-17.09	3.22	3.17	2.04-3.79	1.01	0.010	0.003-0.023	0.03
8.	*Ficus virens*	27.43	12.56-45.01	2.65	6.53	5.12-11.24	2.19	0.057	0.011-0.159	0.06
9.	*Azadirachta indica*	19.60	8.17-34.22	1.67	6.23	4.40-9.11	2.76	0.028	0.005-0.170	0.01
10.	*Melia Azedarach*	13.26	7.91-25.57	2.54	5.39	3.75-8.13	1.54	0.013	0.004-0.049	0.003
11.	*Zizyphus mauritiana*	16.08	8.67-22.31	4.65	5.93	3.48-7.18	1.08	0.020	0.005-0.038	0.002
12.	*Albizzia lebbek*	20.05	10.53-34.81	5.23	6.51	4.76-9.65	2.01	0.031	0.008-0.150	0.05
13.	*Albizzia procera*	22.44	13.18-44.87	6.78	7.81	5.43-10.49	2.22	0.045	0.013-0.152	0.08
14.	*Syzygium cuminii*	14.78	5.06-21.34	3.91	6.04	3.79-8.71	0.98	0.015	0.002-0.038	0.003
15.	*Cassia fistula*	12.15	6.42-22.61	2.68	5.65	4.09-8.20	1.10	0.011	0.003-0.043	0.001
16.	*Alstonia scholaris*	17.35	8.61-30.59	3.98	6.38	3.01-9.49	1.76	0.023	0.005-0.078	0.009
17.	*Phoenix dactylifera*	17.02	11.77-38.48	5.01	21.14	13.92-27.88	4.81	0.023	0.010-0.113	0.02
18.	*Moringa oleifera*	11.71	6.41-23.41	3.09	5.89	4.13-7.48	1.15	0.010	0.003-0.048	0.004
19.	*Magnifera indica*	13.63	4.09-31.83	2.53	5.76	3.79-9.00	1.38	0.018	0.001-0.160	0.08
20.	*Bombax ceiba*	21.22	9.76-41.04	4.09	9.69	5.09-13.58	2.54	0.042	0.006-0.135	0.007
21.	*Jatropha curcas*	9.07	2.01-12.08	2.01	2.99	2.07-3.79	0.65	0.006	0.003-0.011	0.002
22.	*Conocarpus erectus*	11.25	4.65-19.91	2.76	5.66	3.73-7.14	0.87	0.010	0.005-0.028	0.008
23.	*Plumeria rubra*	22.48	11.43-35.50	2.91	6.06	3.49-8.98	1.34	0.038	0.010-0.096	0.005
24.	*Jacaranda memosifolia*	12.91	7.67-22.33	1.54	6.81	5.25-9.48	2.04	0.011	0.004-0.039	0.002
25.	*Callistemon viminalis*	9.80	4.01-13.47	1.01	4.44	3.05-7.21	0.80	0.006	0.003-0.023	0.003
26.	*Leucaena leucocephala*	13.39	5.78-20.31	3.44	6.23	4.24-9.04	0.52	0.013	0.002-0.041	0.008
27.	*Terminalia arjuna*	20.22	12.56-39.80	4.66	9.31	7.83-14.09	3.24	0.062	0.011-0.129	0.02
28.	*Cordia myxa*	14.31	7.81-18.88	2.60	4.78	3.67-7.11	2.13	0.015	0.004-0.025	0.005
29.	*Psidium guavajava*	7.10	2.07-11.17	1.87	2.91	1.73-4.10	0.19	0.004	0.002-0.010	0.003
30.	*Pongamia pinnata*	16.47	8.61-26.71	3.99	6.50	4.03-8.81	0.77	0.020	0.005-0.049	0.003
31.	*Thevetia peruviana*	8.84	3.88-12.54	1.69	6.06	5.01-8.77	0.92	0.005	0.001-0.010	0.007
32.	*Delonix regia*	11.81	4.61-18.90	2.54	6.57	4.50-10.26	1.72	0.010	0.004-0.029	0.005
33.	*Salix tetrasperma*	10.56	5.01-15.55	3.06	6.19	4.19-9.04	2.26	0.008	0.002-0.020	0.001
34.	*Ailanthus aetisoma*	13.51	9.71-19.42	4.11	7.08	4.81-9.15	1.63	0.013	0.006-0.032	0.002
35.	*Pterospermum indica*	11.06	7.44-16.41	2.75	5.88	3.84-7.87	1.39	0.010	0.004-0.042	0.008

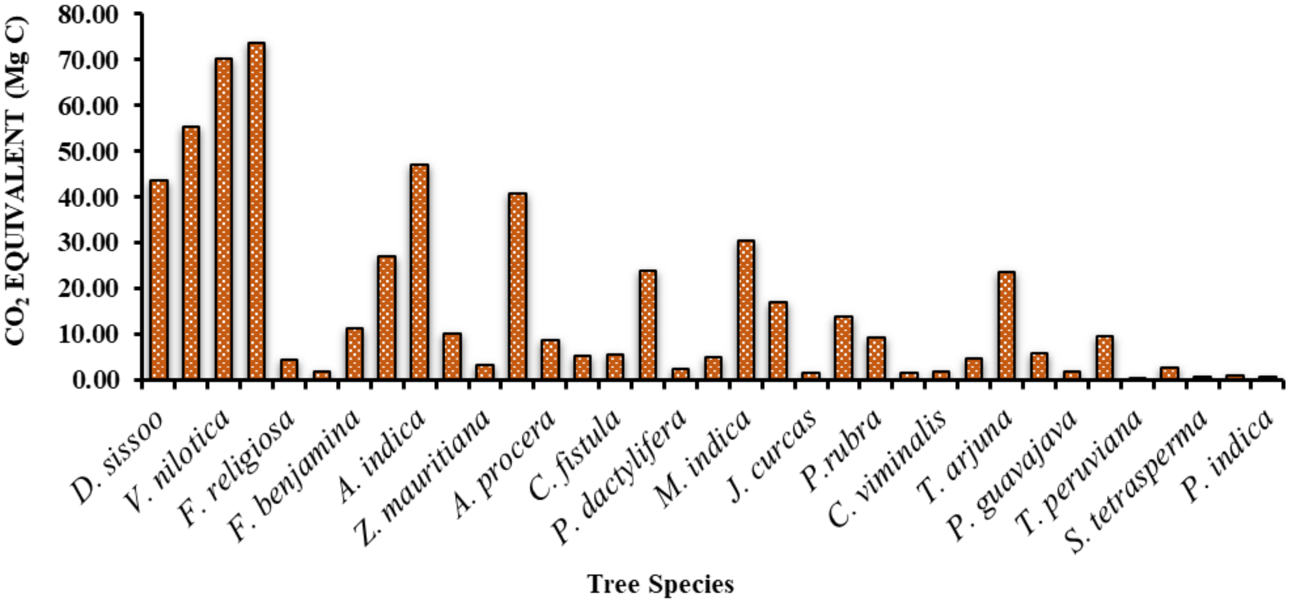

Fig. 4. Annual CO_2 Sequestered by different tree species at BZU Campus, Multan.

Table 3. Tree Biomass and Carbon stocks estimation of various Tree species at BZU Campus, Multan.

Sr #	Species name		Native/Exotic species	Total no. of trees	Tree Biomass (Kg)			Carbon stocks (Kg)		
	Scientific names	Common/Local names			AGB	BGB	TB	AGC	BGC	TC
1.	*Dalbergia sissoo*	Shisham	Native	47	19626.87	5102.99	24729.85	9420.90	2449.43	11870.33
2.	*Morus alba*	Shatoot	Native	210	25002.20	6500.57	31502.77	12001.06	3120.27	15121.33
3.	*Vachellia nilotica*	Kikar	Native	180	31662.27	8232.19	39894.46	15197.89	3951.45	19149.34
4.	*Eucalyptus camaldulensis*	Sufaida	Exotic	112	33263.61	8648.54	41912.15	15966.53	4151.30	20117.83
5.	*Ficus religiosa*	Peepal	Native	27	2000.02	520.01	2520.03	960.01	249.60	1209.61
6.	*Ficus bengalensis*	Bargad	Native	15	760.13	197.63	957.76	364.86	94.86	459.72
7.	*Ficus benjamina*	Weeping fig	Exotic	200	5091.78	1323.86	6415.64	2444.05	635.45	3079.51
8.	*Ficus virens*	Pilkhin	Exotic	41	12176.86	3165.98	15342.84	5844.89	1519.67	7364.56
9.	*Azadirachta indica*	Neem	Native	178	21192.34	5510.01	26702.35	10172.32	2644.80	12817.13
10.	*Melia Azedarach*	Bakain	Native	112	4586.61	1192.52	5779.13	2201.57	572.41	2773.98
11.	*Zizyphus mauritiana*	Beri	Native	20	1481.50	385.19	1866.69	711.12	184.89	896.01
12.	*Albizzia lebbek*	Black Shareen	Native	134	18316.21	4762.21	23078.42	8791.78	2285.86	11077.64
13.	*Albizzia procera*	White Shareen	Exotic	22	3869.83	1006.16	4875.99	1857.52	482.96	2340.47
14.	*Syzygium cuminii*	Jamun	Native	47	2381.73	619.25	3000.98	1143.23	297.24	1440.47
15.	*Cassia fistula*	Amaltas	Native	78	2538.63	660.04	3198.67	1218.54	316.82	1535.36
16.	*Alstonia scholaris*	Devil Tree	Native	123	10793.43	2806.29	13599.73	5180.85	1347.02	6527.87
17.	*Phoenix dactylifera*	Datepalm	Exotic	12	1053.02	273.78	1326.80	505.45	131.42	636.87
18.	*Moringa oleifera*	Moringa	Native	89	2265.84	589.12	2854.96	1087.60	282.78	1370.38
19.	*Magnifera indica*	Mango	Native	334	13677.93	3556.26	17234.20	6565.41	1707.01	8272.41
20.	*Bombax ceiba*	Simal	Exotic	49	7626.16	1982.80	9608.96	3660.56	951.74	4612.30
21.	*Jatropha curcas*	Jatropha	Exotic	45	685.67	178.27	863.94	329.12	85.57	414.69
22.	*Conocarpus erectus*	Conocarpus	Exotic	247	6288.35	1634.97	7923.32	3018.41	784.79	3803.19
23.	*Plumeria rubra*	Gul e Cheen	Exotic	24	4221.64	1097.63	5319.26	2026.39	526.86	2553.25
24.	*Jacaranda memosifolia*	Jacaranda	Exotic	19	618.38	160.78	779.16	296.82	77.17	374.00
25.	*Callistemon viminalis*	Bottle brush	Exotic	51	777.09	202.04	979.14	373.00	96.98	469.99
26.	*Leucaena leucocephala*	Ipil ipil	Exotic	50	2047.60	532.37	2579.97	982.85	255.54	1238.39
27.	*Terminalia arjuna*	Arjun	Native	78	10661.67	2772.03	13433.71	5117.60	1330.58	6448.18
28.	*Cordia myxa*	Lasura	Native	52	2635.11	685.13	3320.23	1264.85	328.86	1593.71
29.	*Psidium guavajava*	Amrood	Exotic	76	781.77	203.26	985.04	375.25	97.57	472.82
30.	*Pongamia pinnata*	Sukh chain	Exotic	58	4296.34	1117.05	5413.39	2062.25	536.18	2598.43
31.	*Thevetia peruviana*	Yellow oleander	Exotic	17	205.75	53.49	259.24	98.76	25.68	124.44
32.	*Delonix regia*	Flame tree	Exotic	49	1247.49	324.35	1571.83	598.79	155.69	754.48
33.	*Salix tetrasperma*	Indian willow	Exotic	15	295.34	76.79	372.12	141.76	36.86	178.62
34.	*Ailanthus aetisoma*	Varnish tree	Exotic	9	368.57	95.83	464.39	176.91	46.00	222.91
35.	*Pterospermum indica*	Kanak champa	Exotic	11	280.05	72.81	352.86	134.42	34.95	169.37
		Total			254777.77	66242.22	321019.99	122293.33	31796.27	154089.60

AGB= Aboveground Biomass; BGB= Belowground Biomass; TB= Total Biomass; AGC= Aboveground Carbon; BGC= Belowground Carbon; TC= Total Carbon

Table 4. Correlation analysis of qualitative traits of different tree species at BZU Campus, Multan.

Variables	AGB	BGB	TB	AGC	BGC	TC	CO_2 Equivalent	DBH	Height	Basal area
AGB	**1**									
BGB	1.000	**1**								
TB	1.000	1.000	**1**							
AGC	1.000	1.000	1.000	**1**						
BGC	1.000	1.000	1.000	1.000						
TC	1.000	1.000	1.000	1.000	1.000	**1**				
CO_2 Equivalent	1.000	1.000	1.000	1.000	1.000	1.000	**1**			
DBH	0.688	0.688	0.688	0.688	0.688	0.688	0.688	**1**		
Height	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.385	**1**	
Basal Area	0.903	0.903	0.903	0.903	0.903	0.903	0.903	0.858	0.329	**1**

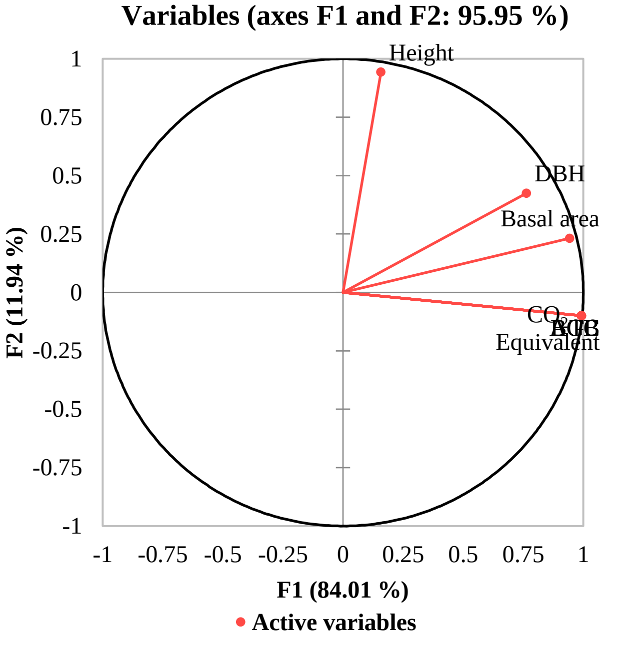

Fig. 5. PCA analysis of qualitative traits of different tree species at BZU Campus, Multan.

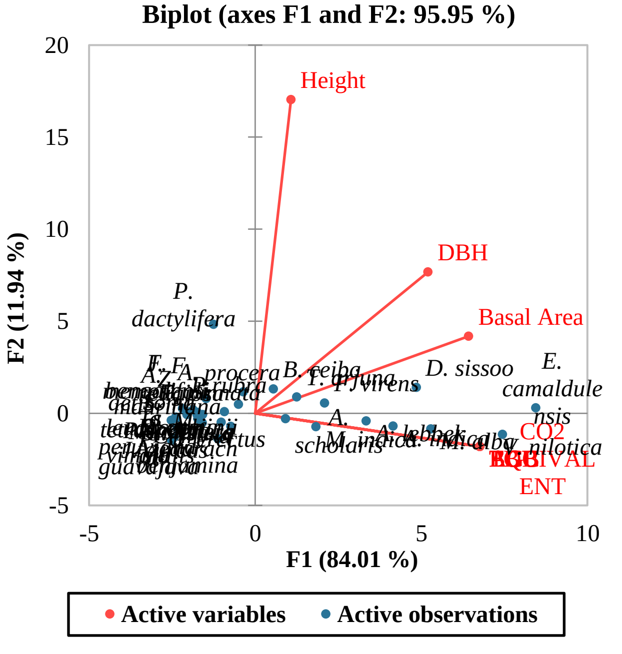

Fig. 6. PCA biplot of all different tree species at BZU Campus, Multan.

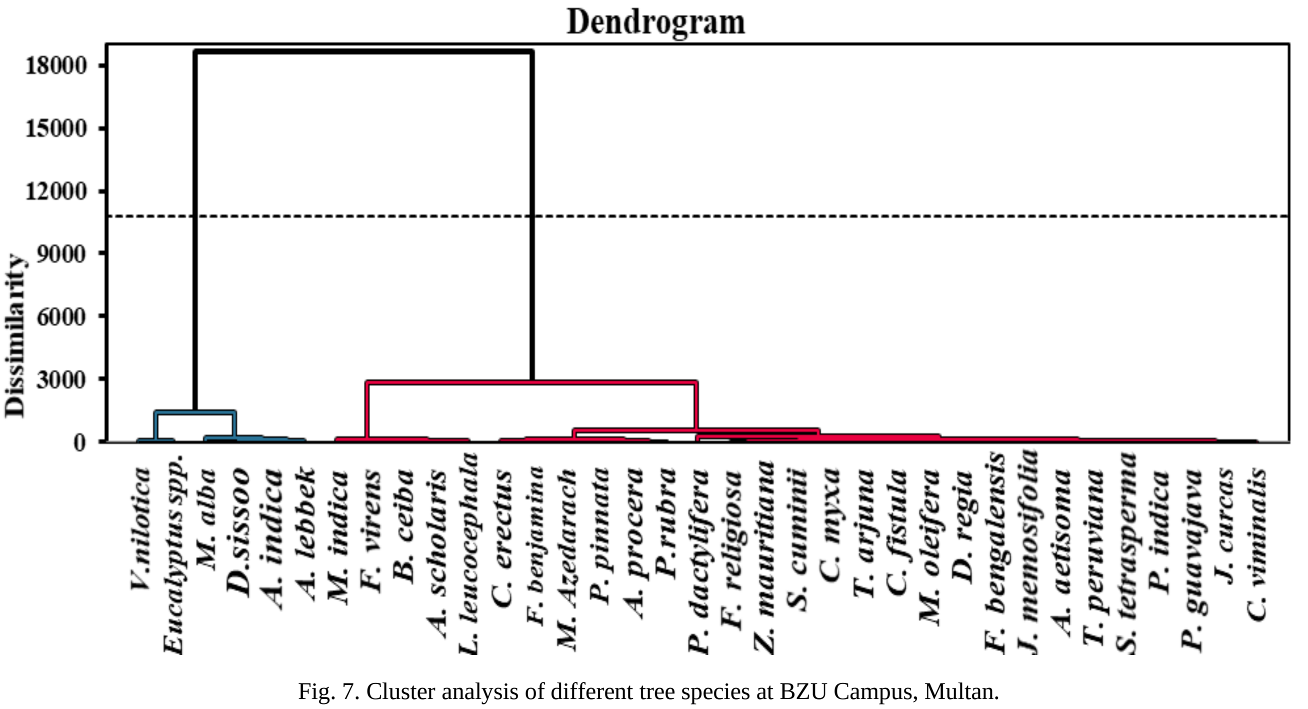

Fig. 7. Cluster analysis of different tree species at BZU Campus, Multan.

Discussion

The increase in atmospheric carbon dioxide levels, resulting in global warming and climate change, has become a matter of significant global concern in recent times. So far, several studies have been conducted around the globe in response to the pressing necessity of quantifying the carbon stock of urban trees to enhance the monitoring and management of tree biomass carbon (Tamang *et al*., 2021; Nandini *et al*., 2017). The present study showed that Bahauddin Zakriya University (BZU) campus is endowed with diverse tree species which not only play a vital role in conserving biodiversity but also mitigating global warming and climate change through carbon sequestration. A total 2831 numbers of individual trees of 35 different species were found on the campus, contributing around 321019.99 kg of tree biomass as given in (Table 3). The significance of estimating tree biomass lies in its role in carbon inventories and mitigation projects, as it plays a crucial part in regulating atmospheric carbon concentration. The estimation of tree biomass is advantageous for comparing structural and functional characteristics in various ecosystems where woody trees are the dominant species (Tamang *et al*., 2021; Vashum & Jayakumar,2012). The total carbon stock in the study area was estimated to 154089.60 kg indicating the substantial role of various tree species in capturing carbon across the ecosystem (Table 3). The potential of trees outside the forest to sequester carbon is significant and warrants consideration in global climate mitigation strategies (Sundarapandian *et al*. 2013, 2014). The utilization of tree phytomass serves various purposes, including the provision of timber resources, the facilitation of nutrient cycling, and the absorption of carbon dioxide as a sink (Yasin *et al*., 2023; Sharma *et al*., 2020). The decline in global forest coverage has resulted in a reduction in tree biomass, highlighting the potential significance of urban trees in mitigating emissions in the future (Chang *et al*., 2017).

The estimated carbon stock in the present study varies with other university campus carbon stock studies. The study conducted by Nandini *et al*., (2017) reveals that the trees on the Bangalore University campus have successfully sequestered a total of 200.931 metric tons of carbon per hectare in an area spanning 449.74 hectares. Similarly, the carbon stock in Pondicherry University campus, encompassing both above-ground and below-ground components of all mature trees, amounted to 2590.48 metric tons, with an average carbon density of 8.7 metric tons per hectare across a land area of 297 hectares. According to a study conducted by Pragasan and Karthick in 2013, the *Eucalyptus* plantation and mixed species plantation in the Bharathiar University campus at Coimbatore sequestered a total carbon stock of 27.72 and 22.25 t ha^{-1}, respectively. Another study was carried out in eight specifically chosen sample plots within the region. Each plot had a size of 0.1 hectare and was situated in the tropical dry forest of the Chinnar Wildlife Sanctuary in Kerala, which is located in the Southern Western Ghats. The findings of the study revealed that the average tree biomass and carbon density of the vegetation in these plots were measured to be 64.13 t ha^{-1} and 30.46 t-C ha^{-1}, respectively (Padmakumar *et al*., 2018). In the present study, species like *E. camaldulensis* and *V. nilotica* emerged as the dominant contributor, accounting for a collective carbon stock of 25%. This phenomenon can be attributed to the significant increase in the population size. If a significant proportion of dominant tree species exhibit immaturity in terms of low diameter at breast height (DBH), their contribution to the overall carbon stock is diminished, despite their dominance within the study area. Although the aboveground tree biomass carbon measured in this study falls within the acceptable range for tropical dry forests, the findings are relatively lower when compared to the reported values in other Indian and global tropical dry forests (Navar, 2009).

The biomass and carbon stock in urban forests is mainly accumulated in the form of vegetation, litter, and soil carbon stock. We measured the biomass and C stock from one component only: vegetation. The total tree biomass (32.102 t ha^{-1}) and C stock (15.408 t ha^{-1}) in the present study were quite high as compared to Tripura University where the biomass storage capacity of the trees was around 11 Mg C ha^{-1} and the carbon stock was 5.36 Mg C ha^{-1} (Deb *et al*., 2016). The TCS values of the present study were faintly closer to carbon stocks at the Jnana Bharathi Campus, Bangalore University (Kumar *et al*., 2021). Similarly, the findings of the present study align with the results of those reported by Nandal *et al*. (2023) explaining that urban trees play a significant role in climate change mitigation by capturing 78.67 Mg C ha^{-1}. The present findings are also similar to those reported by Wang *et al*., (2021) at Shenyang Institute of Technology, China. In the recent past, urban trees are also regarded as an appealing option for mitigating climate change. The carbon exchange between trees and the atmosphere is subject to influence from both natural and anthropogenic disturbances. To effectively choose forest management strategies that promote carbon sinks and mitigate carbon sources, it is essential to comprehend and measure the consequences of disturbances. This understanding is crucial for ensuring the preservation of ecological, social, and economic advantages alongside carbon-related objectives, as disturbances are considered the primary mechanism that changes ecosystems from carbon sinks to sources based on Fluxnet synthesis (Baldocchi, 2008). In comparison to studies conducted in various parts of the world, our findings exhibited a relatively higher magnitude in relation to the natural forests across the globe (Tamang *et al*., 2021; Khamari *et al*., 2021; Sharma *et al*., 2021; Chaturvedi *et al*. 2011; Ravindranath, 2007). Therefore, for mitigation and policy interventions, these types of carbon stock inventory studies require long-term observation. In addition, these results can serve as a benchmark for future assessments of the campus's carbon sequestration capacity across the country.

Furthermore, to effectively understand the role of urban green spaces in universities for carbon capturing and sequestration, the government must establish organizations similar to project trust funds. These organizations would be responsible for overseeing and ensuring the sequestration of carbon, offering technical assistance, facilitating carbon payments, and selling carbon credits to international buyers. It would be beneficial to initiate a few pilot projects that have never been attempted before in the field of investigation or even in the entire country. These projects would help to understand the responsibilities of a trust fund, such as project design, provision of technical and material assistance, conducting carbon measurements, and establishing a baseline. Indeed, these types of research studies play a crucial role in advancing carbon sequestration through afforestation in urban agglomerations nationwide. In addition to this, the forest sector can work together with educational institutions to actively promote plantations on campuses. This will not only help increase carbon stock but also improve the overall environment of the institutions by reducing pollution, conserving biodiversity, and improving air quality.

Conclusion and Future Recommendations

The current study is a sustainability endeavor aimed at conducting an inventory of the trees present on the campus of BZU and calculating their capacity for carbon storage. Tree biomass and carbon stocks were estimated through a non-destructive approach. The campus has documented a total of 2831 trees, which encompass 35 distinct species. These trees possess a carbon sequestration potential of 564.9 tons. The findings of this study shed light on the significance of urban trees, not solely as ornamental and aesthetic plantations, but also in their ability to alleviate the effects of climate change at a regional scale. The findings of this study hold the potential for informing future initiatives aimed at enhancing sustainability on university campuses, particularly in relation to tree planting efforts. Additionally, these results can serve as a foundational reference point for future evaluations of the campus's carbon sequestration capacity. Education institutions have the potential to position themselves as catalysts for societal transformation and influence student behavior by implementing sustainable green initiatives within their campuses. In this study, the results are obtained through the use of various biomass allometric equations using a non-destructive method, which may result in slight variations. In the future, it would be highly beneficial to focus on estimating biomass and carbon stock using more advanced and accurate methods, which would greatly enhance the reliability of the results. Therefore, it is recommended to develop species-specific allometric equations and greenhouse gas emission factors through extensive investigations. These tools would be valuable for accurately measuring carbon levels in educational institutions and other urban green spaces across the country.

References

Ajani, A. and Z.I. Shams. 2016. Comparative status of sequestered carbon stock of *Azadirachta indica* and *Conocarpus erectus* at the University of Karachi Campus, Pakistan. *Int. J. Environ*., 5(2): 89-97.

Amoatey, P. and H. Sulaiman. 2020. Quantifying carbon storage potential of urban plantations and landscapes in Muscat, Oman. *Environ. Develop. Sustain.*, 22: 7969-7984.

Baldocchi, D. 2008. Breathing of the terrestrial biosphere: lessons learned from a global network of carbon dioxide flux measurement systems. *Aust. J. Bot*., 56: 1-26.

Biernacka, M. and J. Kronenberg. 2019. Urban green space availability, accessibility and attractiveness, and the delivery of ecosystem services. *Cities and the Environment* (*CATE*)., 12(1): 5-12

Byrd, K.B., L. Ballanti N. Thomas, D. Nguyen, J.R. Holmquist, M. Simard and L. Windham-Myers. 2018. A remote sensing-based model of tidal marsh aboveground carbon stocks for the conterminous United States. *J. Photogram. Rem. Sens*., 139: 255-271.

Cairns, M.A., S. Brown, E.H. Helmer and G.A. Baumgardner. 1997. Root biomass allocation in the world's upland forests. *Oecologia.*, 111: 1-11.

Chang, J., Z. Qu, R. Xu, K. Pan, B. Xu, Y. Min, Y. Ren, G. Yang and Y. Ge. 2017. Assessing the ecosystem services provided by urban green spaces along urban center-edge gradients. *Nat. Sci. Rep*., 7: 11226.

Chaturvedi, R.K., A.S. Raghubanshi and J.S. Singh. 2011. Leaf attributes and tree growth in a tropical dry forest. *J. Veg. Sci*., 22(5): 917-931.

Clabeaux, R., M. Carbajales-Dale, D. Ladner and T. Walker. 2020. Assessing the carbon footprint of a university campus using a life cycle assessment approach. *J. Clean. Prod*., 273: 122600.

Deb D, S. Deb, J. Debbarma and B.K. Datta. 2016. Tree species richness and carbon stock in Tripura University Campus, Northeast India. *J. Biodiv. Manage. For*., 5(4): 1-7.

Haddad, N.M., L.A. Brudvig, J. Clobert, K.F. Davies, A. Gonzalez, R.D. Holt, T.E. Lovejoy, J.O. Sexton, M.P. Austin and C.D. Collins and W.M. cook. 2015. Habitat fragmentation and its lasting impact on Earth's ecosystems. *Sci. Adv*., 1: e1500052.

Hoekstra, A.Y., J. Buurman and K.C.H. van Ginkel. 2008. Urban water security: A review. *Environ. Res. Lett*., 13: 053002. https://doi.org/10.1787/weo-2008-en.

Jaiswal, D.G., C.R. Maheta, Y.B. Patel and H.A. Pandya. 2014. Carbon stock estimation major tree species in Attarsumba range, Gandhinagar forest division, India. *Ann. Biol. Res*., 5(9): 46-49.

Jim, C.Y. and W.Y. Chen. 2006. Recreation-amenity use and contingent valuation of urban green spaces in Guangzhou, China. *Landsc. Urban Plan*., 75: 81-96.

Jo, H.K. 2002. Impacts of urban greenspace on offsetting carbon emissions for middle Korea. *Environ. Manage*.**,** 64(2): 115-126.

Khamari, A., A. Mansingh and A. Pradhan. 2021. Assessment of biodiversity and biomass carbon stock from an urban forest: A case study of Sambalpur university campus forest. *Int. J. Environ. Sci. Technol*., 3(1): 423-429.

Komal, N., Q.U. Zaman, G. Yasin, S. Nazir, K. Ashraf, M. Waqas, M. Ahmad, A. Batool, I. Talib and Y. Chen. 2022. Carbon Storage Potential of Agroforestry System near Brick Kilns in Irrigated Agro-Ecosystem. *Agriculture*, 12: 295.

Kumar, A., S. Tewari, H. Singh, P. Kumar, N. Kumar, S. Bisht, S. Devi and R. Kaushal. 2021. Biomass accumulation and carbon stock in different agroforestry systems prevalent in the Himalayan foothills, India. *Curr. Sci.*, 46: 1083-1088.

Li, G., C. Fang and W. Qi. 2021. Different effects of human settlements changes on landscape fragmentation in China: Evidence from grid cell. *Ecol. Indic*., 129: 107927.

Li, H., X. He, W. Chen, W. Xu, W. Zhu and Z. Ning. 2002. Current status and future outlook of urban forestry research in China. In Advances in Urban Forest Ecology, (Eds.): He, X. and Z Nings. pp. 75-83. China Forestry Publishing House, Beijing.

Li, X., L.C. Stringer and M. Dallimer. 2022. The impacts of urbanisation and climate change on the urban thermal environment in Africa. *Climate.*, 10(11): 164.

Li, Y., S. Schubert, J.P. Kropp and D. Rybski. 2020. On the influence of density and morphology on the Urban Heat Island intensity. *Nat. Commun*., 11: 2647.

Marak, T. and N. Khare. 2017. Carbon sequestration potential of selected tree species in the campus of SHUATS. *Int. J. Sci. Res. Dev*., 5: 63-65.

Mustafa, A., M. Kazmi, H.R. Khan, S.A. Qazi and S.H. Lodi. 2022. Towards a carbon neutral and sustainable campus: case study of NED university of engineering and technology. *Sustain*., 14(2): 794.

Nagendra, H., X. Bai, E.S. Brondizio and S. Lwasa. 2018. The urban south and the predicament of global sustainability. *Nat. Sustain*., 1: 341-349.

Nandal, A., S.S. Yadav and A.J. Nath. 2023. Trees outside forests as climate change mitigation champions: evaluating their carbon sequestration potential and monetary value in Maharshi Dayanand University, Rohtak (Haryana), India. *Environ. Monitor. Assess.*, 195(8): 995.

Nandini, N., M. Kumar and T. Suchitra. 2017. Assessment of carbon sequestration in trees of Jnanabharathi Campus-Bangalore. *Ecol. Environ. Conserv*., 15(3): 503-508.

Navar, J. 2009. Allometric equations for tree species and carbon stocks for forests of northwestern Mexico. *For. Ecol. Manage*., 257: 427-434.

Newbold, T., L.N. Hudson, S.L.L. Hill, S. Contu, I. Lysenko, R.A. Senior, L. Börger, D.J. Bennett, A. Choimes, B. Collen and J. Day. 2015. Global effects of land use on local terrestrial biodiversity. *Nature*, 520: 45-50.

Padmakumar B, N.P. Sreekanth, V. Shanthiprabha, J. Paul, K. Sreedharan, T. Augustine, K.K. Jayasooryan, M. Rameshan, M. Mohan, E.V. Ramasamy and A.P. Thomas. 2018. Tree biomass and carbon density estimation in the tropical dry forest of southern western Ghats, India. *Ind. For.*, 11(4): 534-541.

Pragasan, L.A. and A. Karthick. 2013. Carbon stock sequestered by tree plantations in University campus at Coimbatore, India. *Int. J. Environ. Sci*., 3(5):1700-1710.

Ramaiah, M. and R. Avtar. 2019. Urban green spaces and their need in cities of rapidly urbanizing India: A review. *Urban Sci*., 3(3): 94.

Ravindranath, N.H. and M. Ostwald. 2007. Carbon Inventory Methods: Handbook for Greenhouse Gas Inventory, Carbon Mitigation and Roundwood Production Projects; Springer Science & Business Media: New York, NY, USA, Volume 29. pp. 23.31.

Ravindranath, N.H., I.K. Murthy, P. Sudha, V. Ramprasad, M.D.V. Nagendra, C.A. Sahana, K.G. Srivathsa and H. Khan. 2007. Methodological issues in forestry mitigation projects: a case study of Kolar district. *Mitig. Adapt. Strateg. Glob. Chang*., 12: 1077-1098.

Shah, D.R. and D.J. Gavali. 2017. Floral diversity in Vadodara gardens, Gujarat, India. *Int. J. Conserv. Sci*., 8: 113-120.

Sharma, R., L. Pradhan, M. Kumari and P. Bhattacharya. 2020. Assessment of carbon sequestration potential of tree species in Amity University Campus Noida. *J. Environ. Sci.*, 3(1): 52.

Song, X.P., M.C. Hansen, S.V. Stehman, P.V. Potapov, A. Tyukavina, E.F. Vermote and J.R. Townshend. 2018. Global land change from 1982 to 2016. *Nature*, 560: 639-643.

Sundarapandian, S.M., S. Amritha, L. Gowsalya, P. Kayathri, M. Thamizharasi, J.A. Dar, K. Srinivas and S. Gandhi. 2013. Estimation of biomass and carbon stock of woody plants in different land-uses. *For. Res*., 3(115): 2-6.

Sundarapandian, S.M., S. Amritha, L. Gowsalya, P. Kayathri, M. Thamizharasi, J.A. Dar, K. Srinivas, D. S. Gandhi and K. Subashree. 2014. Biomass and carbon stock assessments of woody vegetation in Pondicherry University campus, Puducherry. *Int. J. Environ. Biol.*, 4(2): 87-99.

Tamang, B., N.A. Pala, G. Shukla, M. Rashid, M.M. Rather, A.J. Bhat and S. Chakravarty. 2021s. Trees outside forest (TOFs) aids in mitigating global climatic change through carbon sequestration: Example from academic institutional landscapes. *Acta Ecol.Sin.*, 41(4): 351-357.

Thomas, S. 2008. Urbanisation as a driver of change. Urbanisation as a driver of change. The Sustainable City V: Urban Regeneration and Sustainability, 5: 95.

Thomas, S.C. and A.R. Martin. 2012. Carbon content of tree tissues: A synthesis. *Forests*, 3: 332-352.

Tiyarattanachai, R. and N.M. Hollmann. 2016. Green campus initiative and its impacts on quality of life of stakeholders in green and non-green campus universities. *Springer Plus*, s5(84): 1-17.

Vashum, K.T., S. Jayakumar. 2012. Methods to estimate above-ground biomass and carbon stock in natural forests-a review. *J. ecosyst. Echograp.*, 2(4): 1-7.

Wang, X., Y. Wang, X. Qu, B. Huang, Z. Li, J. Sun, X. Wei and X. Yang. 2021. Urban trees in university campus: structure, function, and ecological values. *Environ. Sci. Pollut. Res.*, 28: 45183-45198.

Wang, Q., W. Wang, Z. Zhong, H. Wang and Y. Fu. 2020. Variation in glomalin in soil profiles and its association with climatic conditions, shelterbelt characteristics, and soil properties in poplar shelterbelts of Northeast China. *J. For. Res*., 31(1): 279-290.

Wigginton, N.S., J. Fahrenkamp-Uppenbrink, B. Wible and D. Malakoff. 2016. Cities are the future. *Sci*., 352(6288): 904-905.

Wu, Y. and Z. Su. 2002. Present state of Chinese city green areas and estimation of its value in ecology and economy. *J. Sichuan Teach. Colleg.* (*Natural Science*), 23(2): 184-188.

Yasin, G., S. Ur Rahman, M.F. Nawaz, I. Qadir, M. Zubair, S. Gul, M.S. Hussain, M. Zain and M.A. Khaliq. 2021. Estimating carbon stocks and biomass accumulation in three different agroforestry patterns in the semi-arid region of Pakistan. *Carbon Manag*e, 12: 593-602.

Yasin, G., M.F. Nawaz, T.A. Martin, N.K. Niazi, S. Gul and M.T.B. Yousaf. 2019. Evaluation of agroforestry carbon storage status and potential in irrigated plains of Pakistan. *Forests*, 10: 640.

Yasin G., M.F. Nawaz, M. Zubair, M.F. Azhar, M. Mohsin Gilani, M.N. Ashraf, A. Qin and S. Ur Rehman. 2023. Role of traditional agrofostry systems in climate change mitigation through carbon sequestration: An Investigation from the Semi-Arid Region of Pakistan. *Land.*, 12(2): 513.

Yasin G, M. Nawaz, M. Siddiqui, M.T. Siddiqui and N.K. Niazi. 2018. Biomass, carbon stocks and CO_2 sequestration in three different aged irrigated *Populus deltoides* bartr. Ex marsh. Bund planting agroforestry systems. *Appl. Ecol. Environ. Res*., 16(5): 6239-6252.

Yumnam, J.Y. and N. Dey. 2022. Biomass and Carbon Stock of Trees Growing in Cotton University, Guwahati, Assam, India. Proceedings of the National Academy of Sciences, India Section B: *Biol. Sci.*, 92(4): 853-859.

Zubair, M., G. Yasin, S.K. Qazlbash, A. Ul Haq, A. Jamil, M. Yaseen, S.U. Rahman and W. Guo. 2022. Carbon sequestration by native tree species around the industrial areas of Southern Punjab, Pakistan. *Land.*, 11(9): 1577.

(Received for publication 20 October 2023)