

CARBON SEQUESTRATION POTENTIAL OF TREES: A STUDY CASE FROM DAMIETTA UNIVERSITY, EGYPT

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Abstract. The phenological and morphological characteristics of campus trees, specifically height and diameter at breast height (DBH), were systematically measured to estimate their carbon sequestration capacity using established allometric equations. A total of 323 trees, encompassing seven distinct species, were recorded within the study area. Results revealed that *Ficus benjamina* was the most prevalent species, accounting for approximately 29.11 tons of stored carbon, followed by *Platanus orientalis* with an estimated 18.97 tons. The total carbon sequestration potential of all surveyed trees was calculated to be 86.14 tons. Trees are widely recognized as among the most effective terrestrial systems for atmospheric CO₂ absorption. Species with substantial DBH, such as *Ficus benjamina*, serve as significant carbon sinks and hold considerable potential for large-scale urban planting aimed at mitigating the impacts of climate change. Furthermore, green spaces within institutional settings such as universities, hospitals, and industrial facilities play a critical role in climate change mitigation by functioning as natural carbon reservoirs. This study underscores the importance of promoting awareness regarding the ecological value of urban and peri-urban green areas. Universities, in particular, are well-positioned to model sustainable practices through the strategic expansion and maintenance of their green infrastructure. Maintaining and enhancing the carbon sequestration potential of trees requires a holistic approach that considers ecological integrity, socio-economic contexts, and long-term sustainability.

Keywords: Carbon Sequestration, CO₂ equivalent, Climate Change, Above Ground Biomass (AGB), Below Ground Biomass (BGB), and Total Biomass (TB).

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1. INTRODUCTION

The rapid expansion of urbanization, industrial development, economic activity, and population growth has led to a significant decline in global air quality [1 – 4]. Among the various pollutants, carbon dioxide (CO₂) remains the predominant emission associated with these anthropogenic processes, presenting considerable challenges for its reduction, sustainable management, and ecological mitigation [5]. While CO₂ plays an essential role in supporting plant life through photosynthesis, it is also a primary greenhouse gas contributing to global warming and broader climatic disruptions [6 -8].

Carbon sequestration plays a pivotal role in improving air quality, mitigating climate change, and contributing positively to both national and global economies [9]. Trees sequester atmospheric carbon dioxide (CO₂) not only directly through the uptake of CO₂ via photosynthesis but also indirectly by influencing the urban carbon balance, including reduced energy demand and emissions associated with cooling and heating, thereby affecting the urban energy system as a whole [10 – 13].

As emphasized by Sahu et al. [6], the carbon footprint can be assessed and minimized through a combination of strategic planning and scientifically developed models. Trees, particularly in urban settings, serve as the largest terrestrial reservoirs for carbon [6, 14]. The photosynthetically active components of trees—namely, leaves and stems—contribute more significantly to carbon uptake than non-photosynthetic parts such as litter, woody debris, and roots [15, 16]. Younger trees generally demonstrate higher sequestration rates due to their rapid growth and higher metabolic activity during developmental stages. However, as noted by Nowak et al. [17], carbon stored in tree biomass is eventually released back into the atmosphere through decomposition, thereby completing the carbon cycle.

In recent decades, rapid urban expansion and economic development have led to the widespread removal of vegetation—ranging from large trees to low-lying herbs—in favor of infrastructure, replacing natural landscapes with dense urban structures [6]. This transformation has contributed to elevated urban CO₂ concentrations and disrupted the natural balance between carbon sources and sinks, exacerbating the frequency and intensity of heatwaves [17, 18].

Quantifying carbon stored in tree biomass is, therefore, essential for understanding the current carbon status in urban ecosystems and projecting future climate scenarios on both local and global scales [19, 20]. To the best of our knowledge, this study represents the first comprehensive investigation in Egypt—and more broadly in the Middle East—that examines the role of campus trees in carbon sequestration. Accordingly, the primary objective of this research is to catalog existing tree species within the university campus and estimate their total carbon sequestration potential. This effort aligns with Sustainable Development

Goals (SDGs), particularly Goal 11 "Sustainable Cities and Communities", and Goal 13 "Climate Action".

2 MATERIALS AND METHODS

2.1 The study area and Sampling.

Different trees were selected from the Botanical Garden of Faculty of Science, Damietta University, New Damietta City, which is located in the Northern Part of Egypt (31°26'22" N, 31°40'59"3E) (Fig .1).



Fig. 1. Map of the study area (Damietta University in the New Damietta "Red Rectangle").

2.2 Biological data and the non-destructive method of biomass estimation

Tree selection on the campus was carried out in 2023; they are cultivated trees. Species identification was conducted by a taxonomist, with the focus solely on trees—shrubs and herbs were not included in the survey. Measurements were taken for trees with a girth at breast height (GBH) of 30 cm or more, measured at 1.55 meters above the ground. Tree height (TH) was recorded using a clinometer or altimeter, while GBH was measured with a standard measuring tape.

Above-ground biomass (AGB) and below-ground biomass (BGB) were estimated using field measurements of diameter at breast height (DBH), applying allometric equations [21]. These equations are suitable for dry climates receiving less than 1500 mm of annual rainfall, making them appropriate for conditions in Egypt, where annual rainfall typically ranges from 100 to 175 mm.

$$AGB = 34.4703 - 8.0671D + 0.6589D^2 \quad (\text{Eq. 1})$$

where D is the DBH (cm).

$$BGB = AGB \times (15/100) \quad (\text{Eq. 2})$$

Total Biomass (TB) of individual trees is the sum of their above- and below-ground biomasses, respectively, given by the following equation:

$$\text{Total Biomass} = \text{AGB} + \text{BGB} \quad (\text{Eq. 3})$$

Carbon Content Generally, for any plant species, is estimated as 50% of its biomass:

$$\text{Carbon Content} = 0.5 \times \text{Total Biomass} \quad (\text{Eq. 4})$$

CO₂ equivalent is then calculated using the below given equation:

$$\text{CO}_2 (\text{eq.}) = (\text{Carbon content} \times 44)/12$$

3 RESULTS & DISCUSSION

A total of 323 trees were recorded on the campus, representing seven species: *Ficus benjamina*, *Platanus orientalis*, *Danae racemosa*, *Citrus sinensis*, *Eucalyptus globulus*, *Gardenia thunbergia*, and *Rhus angustifolia*.

Ficus benjamin was the most prevalent species, accounting for 77 trees (approximately 24% of the total). This species is characterized by a dense, expansive canopy and its adaptability to a wide range of environmental conditions. It requires minimal water, nutrients, and maintenance, and is tolerant of shaded areas, making it a popular choice for urban landscaping [22]. However, it also has an aggressive root system capable of damaging pavements and infrastructure (Sharma et al., 2021).

The second and third most common species were *Platanus orientalis* and *Danae racemosa*, with 65 (20%) and 49 (15%) individuals, respectively. Both species are well adapted to arid conditions, are resilient by nature, and can survive in areas affected by high levels of air pollution [23].

Eucalyptus globulus and, and *Citrus sinensis* were represented by 37 trees each (11.5%), while *Gardenia thunbergia* and *Rhus angustifolia* accounted for 30 (9.3%) and 28 (8.7%) trees, respectively (Fig. 2).

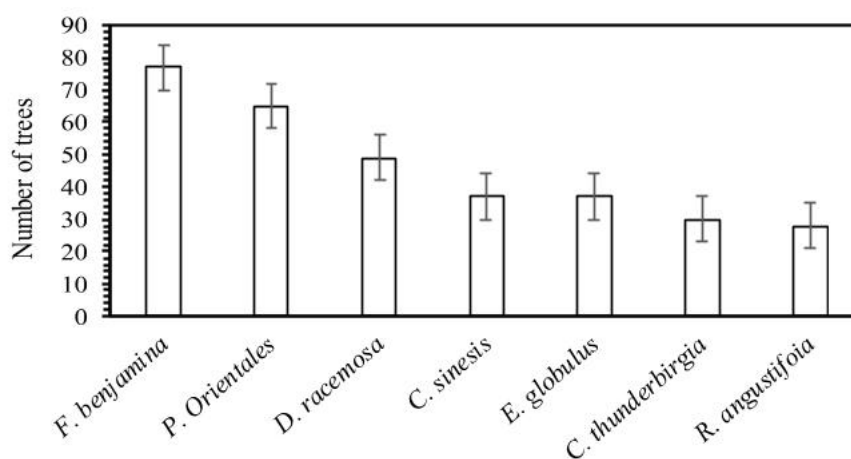


Fig. 2 Number of trees from different species within the campus

Table 1 presents the estimates of total biomass (TB), above-ground biomass (AGB), below-ground biomass (BGB), total carbon content, and carbon sequestration (expressed as CO₂ equivalents) for the recorded tree species.

The total carbon content—calculated as 50% of the total biomass (kg/tree)—ranged from 492.45 kg for *R. angustifolia* to 8,326.74 kg for *Ficus benjamina*. The cumulative AGB, BGB, TB, and total carbon for all trees on campus amounted to 30,799 kg, 4,784 kg, 35,583 kg, and 19,199 kg, respectively (Table 1). The total amount of CO₂ sequestered by all trees was estimated at 68.14 metric tons. On average, each tree contributed approximately 211 kg (0.21 tons) of carbon sequestration (Table 1).

Notably, *F. benjamina* exhibited the highest carbon sequestration capacity among the species, accounting for 29.11 tons of CO₂ (Table 1; Fig. 3). On a per-tree basis, this species sequesters approximately 378 kg of CO₂ annually (0.378 tons tree⁻¹ year⁻¹).

Table 1 Total Biomass and Carbon Sequestration of the selected trees

Species	AGB (Kg)	BGB (Kg)	TB (kg)	Carbon (kg)	CO ₂ EQ (kg)	CO ₂ EQ. (Tons)
<i>Ficus benjamina</i>	12,987.5	2022.87	14,762.23	8326.74	29,109.97	29,11
<i>Platanus orientails</i>	9768.96	1328.97	9878.11	5467.94	18,971.44	18.97
<i>Danae racemosa</i>	3274.72	491.21	3765.92	1882.96	7005.25	7.05
<i>Citrus sinensis</i>	2430.46	364.57	2795.03	1397.51	5124.21	5.12
<i>Eucalyptus globulus</i>	1525.29	247.28	1772.57	878.25	3344.11	3.34
<i>Gardenia thunderbirgia</i>	1311.96	196.89	1508.85	753.17	2898.81	2.89
<i>Rhus angustifoli</i>	873.16	132.31	1005.47	492.45	1773.64	1.77
TOTAL	30,799	4784	35,583	19,199	68138	68.14

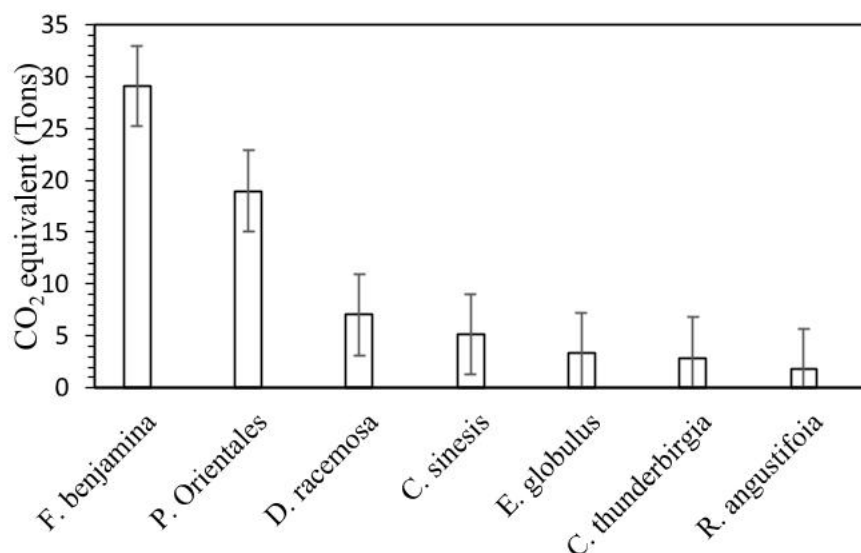


Fig. 3 Annual CO₂ sequestered by different tree species in the campus.

The carbon sequestration potential of the tree species followed the order: *Ficus benjamina* > *Platanus orientalis* > *Danae racemosa* > *Citrus sinensi* > *Eucalyptus globulus* > *Gardenia thunbergia* > *Rhus angustifolia*. This pattern suggests that trees with larger girth at breast height (GBH) tend to store more carbon than those with smaller GBH values (Table 1). These findings align with previous studies by De Villiers et al. (2014) in New Zealand, Sahu et al. (2020) and Sharma et al. (2021) in India, and Cox (2012) in the United States, which reported that large-canopy species such as *Ficus benghalensis* are among the most efficient at sequestering carbon (Table 2).

Table 2 Comparative study of the CO₂ stored by trees across the world.

Country	No. of trees	CO ₂ sequestration (Tons)	Reference
India	2345	1694.5	[13]
India	1997	139.86	[25]
India	12723	9261.34	[6]
USA	798	154	[24]
New Zealand	4139	5809	[23]
Egypt	323	68.14	This study

As shown in Table 2, Cox [24] reported that 798 trees at California State University sequestered approximately 154 tons of CO₂ annually. At a university campus in New Zealand, 4,139 trees were estimated to capture 5,809 tons of CO₂ per year [23]. In a similar study conducted at Pune University, India, they found that 1,997 trees stored about 1,694.5 tons of carbon [25]. More recently, it was found that carbon sequestration by 12,723 and 2,345 trees, amounting to 9,261.34 and 1,694.5 tons of CO₂ per year, respectively [6, 13].

A statistically significant positive correlation was observed between girth at breast height (GBH) and carbon sequestration ($r = 0.91$, $p < 0.05$; data not shown), indicating that trees with greater trunk girth tend to store more carbon. This finding aligns with Sahu et al. [6], who also reported a significant relationship between diameter at breast height (DBH) and carbon storage in an Indian university setting. Similar conclusions were drawn [13], reinforcing that trees with robust lateral and vertical growth characteristics have higher carbon sequestration potential. Consequently, selecting species with substantial biomass accumulation potential is advisable for afforestation in polluted and arid urban environments [15, 16].

4 Conclusions

Vegetation responds to environmental stressors—such as pollution, extreme heat, and drought—by increasing photosynthetic activity and storing more carbon in its biomass. In other words, trees are indispensable in the global carbon cycle, serving as both active carbon sinks and long-term storage reservoirs. This biological response plays a vital role in mitigating atmospheric CO₂ levels, thereby helping to reduce the intensity of heatwaves and slowing the progression of climate change. Effective integration of forest-based strategies such as carbon markets and carbon taxes, as well as land-use planning is essential to enhance their role in climate change mitigation.

The findings of this study suggest that species with large GBH, particularly *Ficus benjamina*, are highly efficient in carbon sequestration. Such species should be strategically incorporated into urban greening programs to enhance carbon capture. Their widespread use could contribute to national carbon credit systems and support carbon trading mechanisms. Moreover, this research provides a valuable reference point for future green planning initiatives on campus and contributes to the establishment of long-term carbon sink monitoring frameworks. As centers of innovation and knowledge, universities are uniquely positioned to lead climate action by integrating sustainability education, promoting behavioral change among students, and engaging communities in environmentally responsible practices—fostering the development of sustainable cities and communities.

Author contribution

All authors contributed to the conception and design of the study. AM, and DE.—Material preparation, data collection, conducted data analysis and analysis were performed. OE, and IH—supervised the work and drafted the first manuscript. All authors read and approved the final manuscript.

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Declarations

The authors declare no competing interests

R E F E R E N C E S

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