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# Screening Tree Species for Carbon Storage Potential through Urban Tree Inventory in Planted Vegetation

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## Abstract

Urban tree inventory is a great tool for gathering data that can be used by different end users. This study attempted to chart the species diversity in planted areas and measure their tree diameter at breast height to screen them for the carbon storage potential. A total of 2860 trees belonging to 36 species were recorded in the planted vegetation in parks and avenue plantation. The dominant species were *Azadirachta indicia* (25.5%), *Conocarpus erectus* (19.2%), *Ficus* spp. (15.5%), *Tabebuia rosea* (9.2%), *Peitophorum pterocarpum* (9.0%) and the remaining represents (21.6%) of the tree identified in this study. It was found that the highest contribution of carbon sequestration ($CO_2$ equivalent) is dominated by the *Ficus* spp. (30.3%) with a total of 3399.3 $tCO_2eq$, followed by *Azadirachta indicia* (25.4%) with a total of 2845.2 $tCO_2eq$ and *Conocarpus erectus* (20.4%) with a total of 2286 $tCO_2eq$. The entire area has the capability to sequester around 11,213.3 $tCO_2eq$ and on average of 3.9 ± 0.1 $tCO_2eq$. In accordance with the findings, it is imperative for the preservation of a sustainable environment to have vegetation that has the capacity to store carbon. The study suggests, there is potential to increase carbon sequestration in urban cities through plantation programs on existing and new land uses and along roads.

## Keywords

Tree Inventory, Urban Vegetation, Carbon Storage, Carbon Sequestration, Screening

## 1. Introduction

Urban tree inventories are a method of gathering data, and the data are used by city planners, researchers as well as other end users (Östberg, 2013). City planners are interested in data about trees that are relevant to city beautification, while researchers are interested in data on the ecosystem service, they provide in the city ecosystem. The other diverse end users use it for a wide range of applications. A wide range of purposes includes, charting the diversity of urban trees (Sjöman et al., 2012; Raupp et al., 2006), modelling local climate (Nowak et al., 2006; Dimoudi & Nikolopoulou, 2003; Nowak et al., 2001; Yokohari et al., 2001), reducing urban heat island effects (King & Davis, 2007). Urban tree inventories are also used to assist with choosing species able to capture particles (Sæbø et al., 2012; Gallagher et al., 2011; McPherson et al., 1997; Sæbø & Mortensen, 1996), for finding key places in the urban environment where trees contribute most in reducing energy costs, air pollution and decreasing runoff from storm water (McPherson et al., 1997). In general, urban trees have ecological, economic, and social values, which can be quantified through an urban tree inventory (Klobucar et al., 2020; Mcpherson et al., 2016).

Muscat city administration invests substantially to plant and maintain vegetation cover in the city on parks and avenue plantations. As a decision-making tool, a tree inventory contains information such as tree species, health status, size, risk level, and location, which provide benchmark information for urban greenery planning and management (Morgenroth & Östberg, 2017). The parameters selected for a tree inventory are important and should be sufficient to make informed and planned decision-making (Miller et al., 2015). City authorities in Muscat might normally go with crucial consideration of tree attributes such as fast growing, maximum size, life span, low maintenance, etc. to choose species at the same time to survive in extreme climatic conditions. However, the choice of species may not be supported by other benefits such as ecological values. Considering such benefits, this study aims to investigate the diversity of urban trees in planted vegetation such as parks and avenues in the capital city of Muscat, Oman. Second, the study uses a commonly collected tree attribute namely diameter at breast height (DBH) to screen the identified species for their carbon storage potential. To maximize the contribution of urban greening to carbon storage and climate change mitigation, it is vital to identify and promote species with these qualities (Soulé et al., 2021). Evidence shows that plantation and management of urban green spaces may store more carbon than nearby suburban or rural areas. According to Tang et al. (2016), densely planted urban tree cover can have a higher carbon density and rate of carbon accumulation than natural tree cover. Therefore, the purpose of this study is to screen tree species in planted vegetation in parks and avenue plantations in Muscat city for their carbon sequestration potential. Planting authorities in Oman may find this study useful, as an input for future plantation programs.

## 2. Materials and Method

### 2.1. Study Site

The capital city of the Sultanate of Oman is Muscat, which is located at

58˚32'43.02"E and 23˚36'51.58"N. It is classified as a hot arid climate (BWh) environment based on Köppen climate nomenclature (Al-Rasbi & Gadi, 2021). Rainfall in the country is often less than 100 mm per year, well below the global average of 1123 mm (Al-Ghafri et al., 2014). The observed annual mean air temperature (˚C) and rainfall (mm) levels as of 2016-2019 in the study area are 28.6˚C and 86.0 mm respectively (CAA, 2020). The city of Muscat is home to a number of parks and gardens, in addition to having trees lining its roads and streets. The Directorate General of Landscaping and Public Parks, which falls under the purview of the Muscat Municipality, is in charge of maintaining all different types of vegetation. This research was done in Muscat city covering different parks and roads distributed across the city with a total of 100 plots and 41 transects distributed in different locations (**Figure 1**).

## 2.2. Sampling

To more accurately reflect the urban vegetation under review, stratified sampling was employed (Zhang et al., 2015; Bijalwan et al., 2010). The fieldwork for the survey started on December 1, 2020 and lasted for a full four months, finishing on March 28, 2021. A 30 m by 30 m plot was set up in each of the parks used for the samples. The exact coordinates of each plot were determined using a Global Positioning System (GPS-Garmin −62s) to within three meters. The GPS coordinates were used to determine the focal point, and a plot was drawn in the surrounding area. For roadside plantation, a systematic sampling using line transect was conducted (Adeyemi, 2016; Fan et al., 2007) and tree trunks were measured every 100 m with 50 m intervals in every 1 km transact.

## 2.3. Tree Species Inventory and Carbon Storage Potential

During the fieldwork, the scientific names of various tree species were documented. Diameter at breast height (DBH) is a biometric feature (Getnet & Negash, 2021), that is generally measured 1.30 meters off the ground (Ali et al., 2020; Miah et al., 2020). At this height above the ground, a measuring tape was utilized to get the value of the circumference at breast height (CBH) of each tree. When there was more than one stem with a height of fewer than 1.30 meters, separate measurements were collected for each of the stems (Yilma & Derero, 2020). In addition, small saplings were included by measuring the circumference at base height (also known as CBH), at 10 centimeters above the ground. Then, the diameter of the trunk was calculated by using the following equation (Snehlata et al., 2021).

$$D = \frac{C}{\pi} \quad (1)$$

where $D$ = Diameter, $C$ = Circumference, $\pi$ = pi = 3.14.

To determine the biomass and, hence, the amounts of carbon stored above and below ground in trees, non-destructive allometric approach was used. Site- or species-specific allometric equations are preferred because they yield more

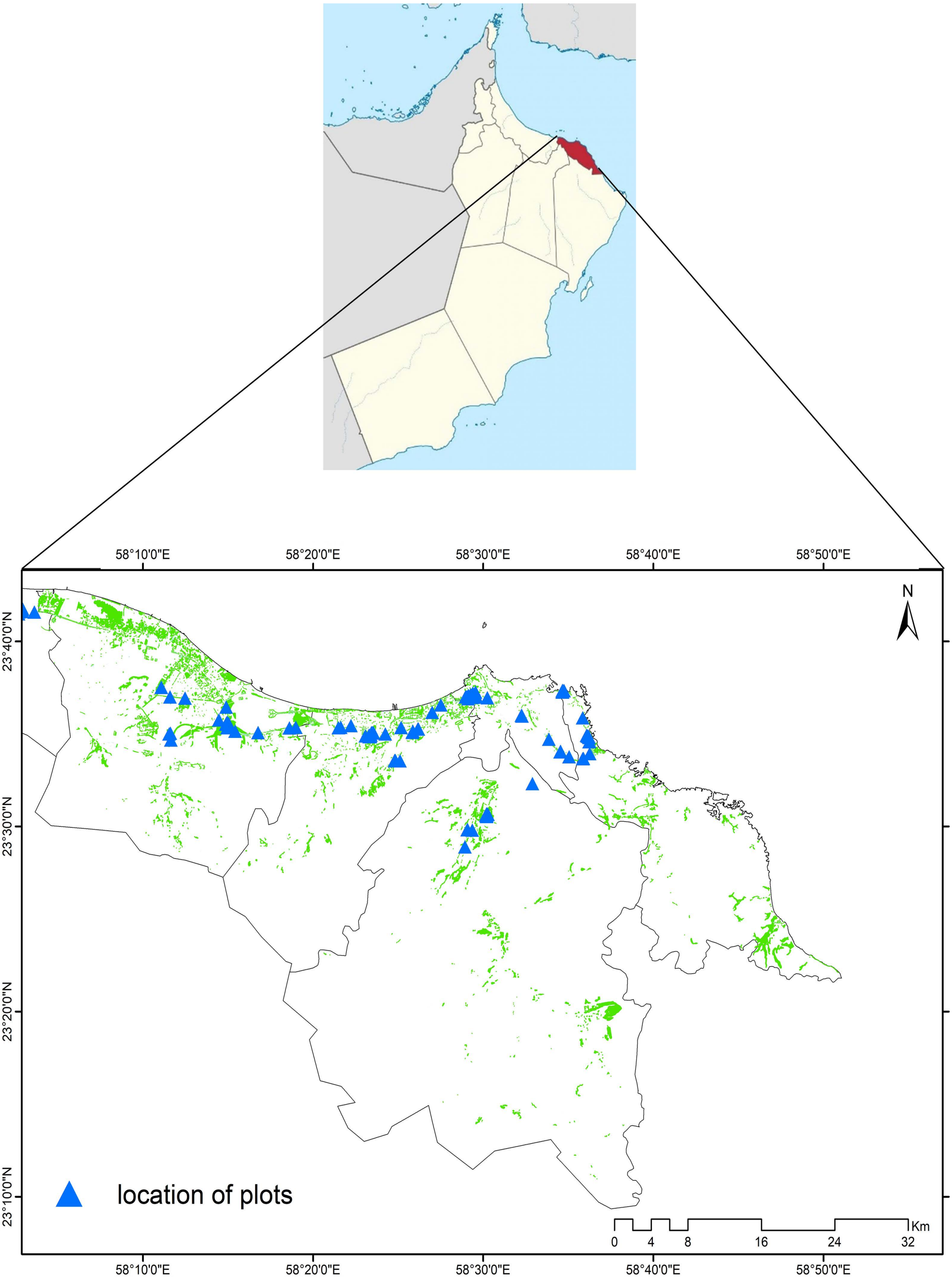


**Figure 1.** Sampling location in the study area.

accurate estimates of biomass and carbon. When such specialized equations are unavailable, however, general ones are often substituted (Ekoungoulou et al., 2018). Since species-specific biomass equations are not available, generic biomass equations are used from different models (Brown, 1997; Cairns et al., 1997; Yao et al., 2015; Snehlata et al., 2021).

$$AGB = 42.69 - 12.800(DBH) + 1.242 \times (DBH)^2 \quad (2)$$

$$BGB = \exp\left[-1.0587 + 0.8836 \times \ln(AGB)\right] \quad (3)$$

$$AGB = 0.182 \times D^{2.487} \quad (4)$$

$$BGB = AGB \times 0.24 \quad (5)$$

Since forest trees often have a higher biomass than trees planted in urban environments, these allometric equations are typically developed from forest trees. As urban trees have different surroundings in terms of space, light and nutrients that natural forest, variation in biomass is multiplied by a conversion factor of 0.8 (Dangulla et al., 2021; Lahoti et al., 2020). Tree carbon storage capacity was evaluated using biomass values and a carbon default value of 0.50 (Mngadi et al., 2021; Shen et al., 2020). Afterwards, in order to produce $CO_2$ equivalent ($CO_2$eq), the amount of carbon present was multiplied by 3.67, the ratio of the molecular weight of carbon dioxide to the atomic weight of carbon (Amiri et al., 2020).

$$CO_2eq = 0.5 \times Biomass \times 3.67 \times 0.001 \quad (6)$$

where; 0.001 = factor for converting $CO_2$eq from kg to tonne.

The following chart illustrates the methodology used in this study (**Figure 2**).

## 3. Results and Discussion

### 3.1. Tree Inventory

A total of 2860 trees belonging to 36 species were recorded at this sampling area. *Azadirachta indica* (25.5%), *Conocarpus erectus* (19.2%), *Ficus* spp. [*Ficus benjamina*, *Ficus religiosa*, *Ficus benghalensis*, *Ficus macrocarpa*, *Ficus elastica*, *Ficus nitida*] (15.5%), *Tabebuia rosea* (9.2%), *Peitophorum pterocarpum* (9.0%) were the dominant species among the sampling sites (**Figure 3**). The DBH categories ranging from <50.0 cm, 50.0 - 99.9 cm, 100.0 - 149.9 cm, 150.0 - 199.9, and >200.0 cm each accounted for 74.0, 22.8, 2.9, 0.2, and 0.1 percent of the total, respectively (**Figure 4**), with total number of trees falling in each category as 2118, 651, 83, 6 and 2 respectively. The mean DBH of all sampled trees was 40.8 cm, while maximum value was 233.4 cm. However, the maximum mean DBH values recorded were 54.6 cm, 57.4 cm, 44.6 cm, 43.8 cm, 51.5 cm, 42.5 cm, 41.9 cm and 40.8 cm for *Ficus* spp., *Triadica sebifera*, *Albizia lebbeck*, *Azadirachta indica*, *Syzygium cumini*, *Peltophorum pterocarpum*, *Conocarpus erectus*, and *Casuarina equisetifolia* respectively (**Figure 5**). **Table 1** shows the percentage of DBH classes in parks and roadside.

In general, mean DBH of the trees that were measured ranged from 3.2 to 57.4

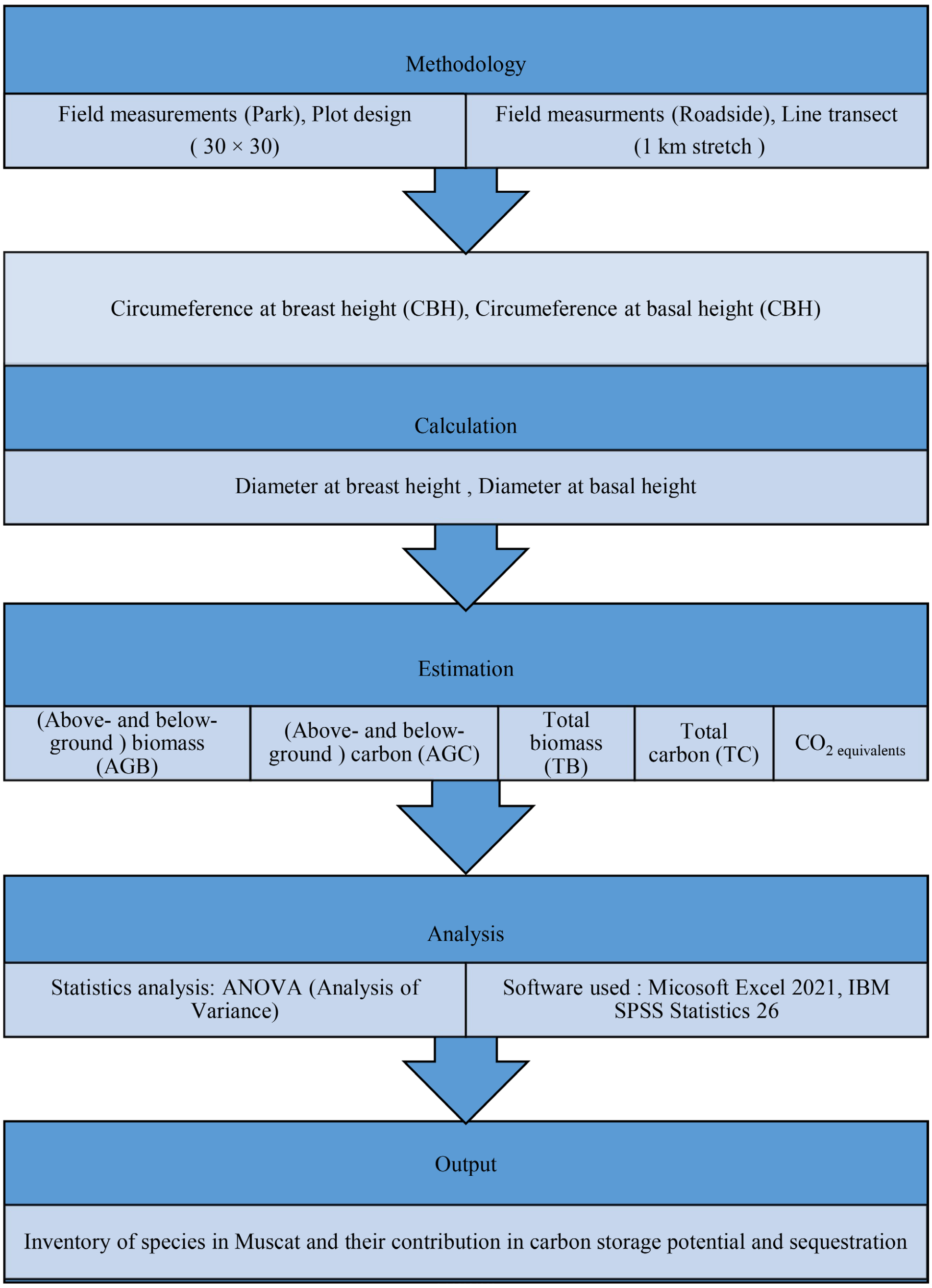


**Figure 2.** Methodology of the study.

cm, which was a smaller than the DBH range of trees (11.0 to 77.1 cm) that was found in the urban regions of Delhi, India (Snehlata et al., 2021); and in Pakistan (11.93 - 50.96 cm) (Zubair et al., 2022). Sharma et al. (2020) found a maximum of 298.7 cm at Amity University campus, India. Such differences are attributable to the fact that climatic circumstances vary from place to place, in addition to the relative abundance of mature and young trees.

## 3.2. Carbon Storage and Sequestration

The most dominant species in terms of carbon sequestration potential are *Ficus*

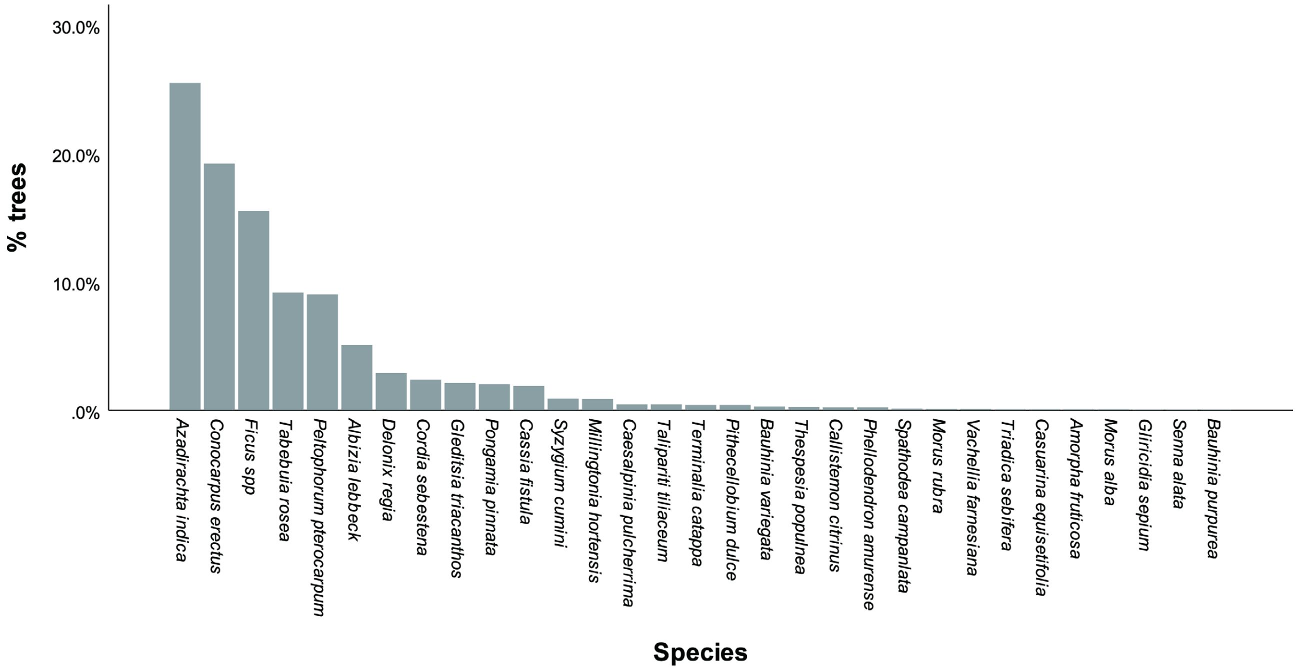


Figure 3. Percentage of different species in the study area.

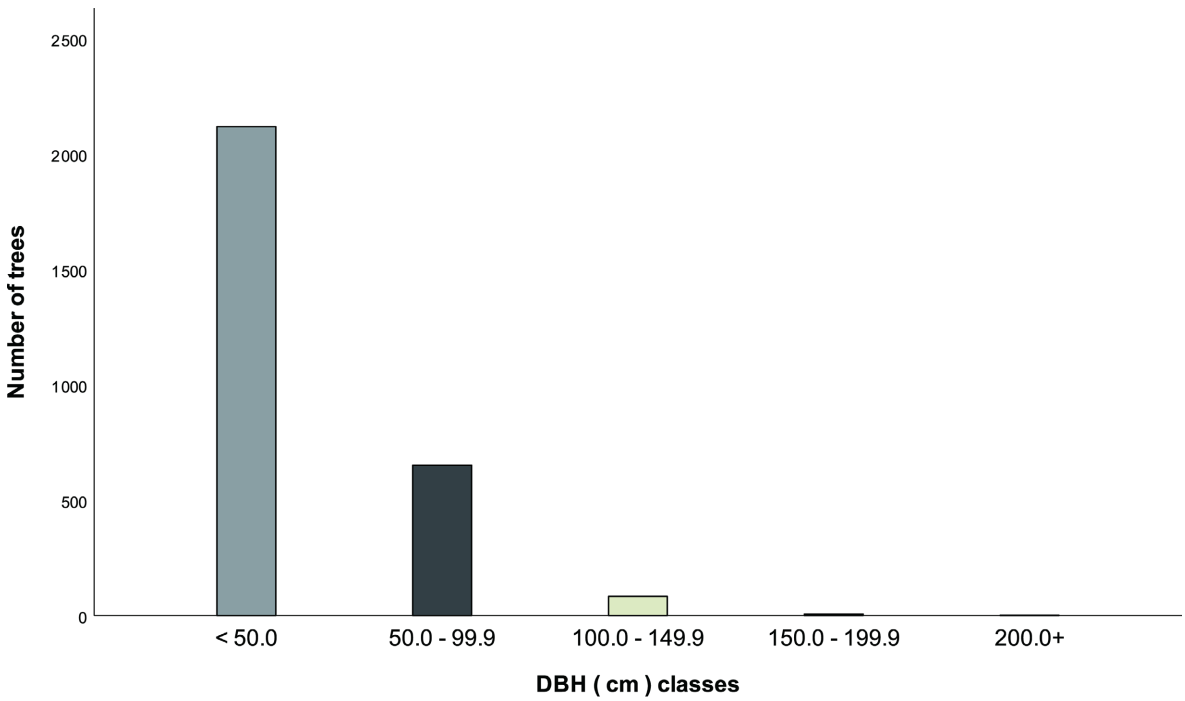


Figure 4. Distribution of trees in different DBH classes.

spp., *Azadirachta indica* and *Conocarpus erectus* with a total of 3399.3 $tCO_2eq$, 2845.2 $tCO_2eq$, 2286.9 $tCO_2eq$, which represents 76.1% of the carbon sequestered by trees in the study area. The next set of species *Albizia lebbeck, Tabebuia rosea*, *Syzygium cumini*, *Pongamia pinnata*, *Delonix regia* contributed by 13.3%, and the remaining 22 species only by 3.0% (Table 2). However, the total number of trees that belong to the same species can have a significant impact on this

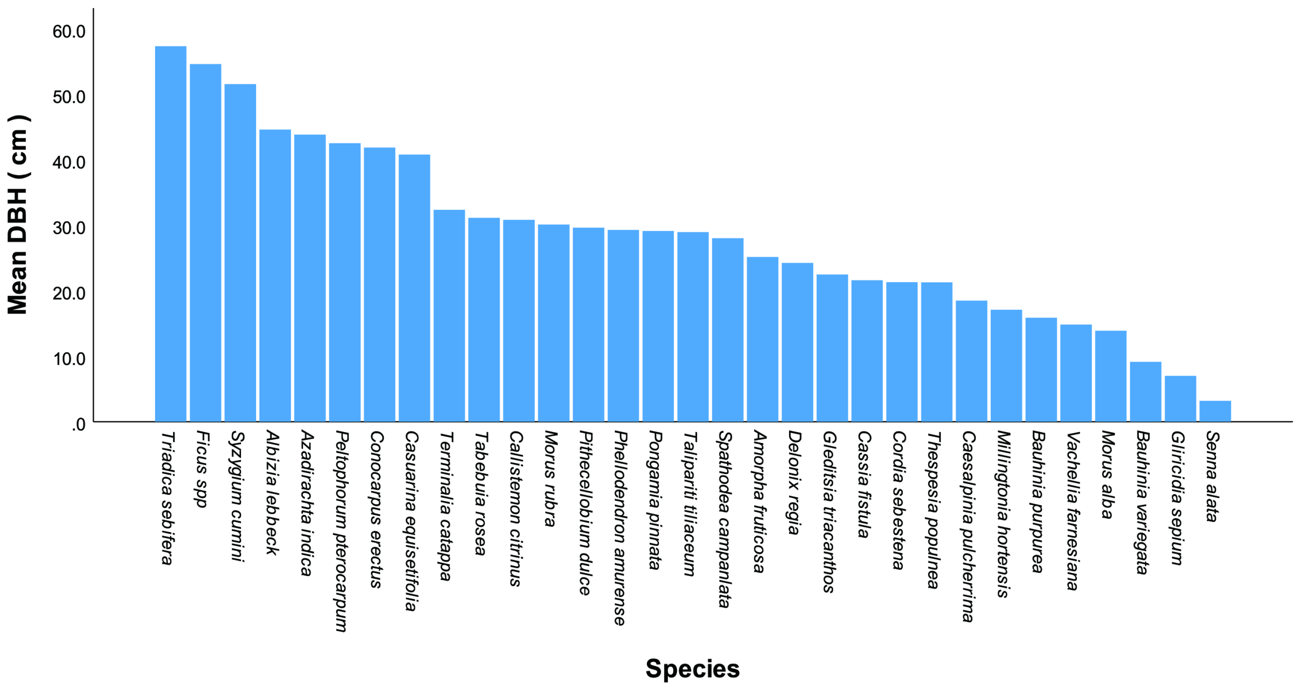


**Figure 5.** Mean DBH of species across sampling plots/transects.

**Table 1.** Number of trees and percentage of DBH classes in parks and roadside.

| DBH (cm) classes | Park (No. of trees) | Percentage (%) | Roadside (No. of trees) | Percentage (%) |
|---|---|---|---|---|
| <50.0 | 1346 | 82.5 | 772 | 62.8 |
| 50.0 - 99.9 | 252 | 15.5 | 399 | 32.5 |
| 100.0 - 149.9 | 27 | 1.7 | 56 | 4.6 |
| 150.0 - 199.9 | 4 | 0.2 | 2 | 0.2 |
| ≤200.0 | 2 | 0.1 | 0 | 0.0 |
| Total | 1631 | 100.0 | 1229 | 100.0 |

**Table 2.** Carbon sequestration potential by different species ($tCO_2eq$).

| Species | Statistic | $CO_2eq$ (tonne) |
|---|---|---|
| *Ficus* spp. | Mean | 7.7 ± 0.6 |
| | Total | 3399.28 |
| *Albizia lebbeck* | Mean | 4.6 ± 0.40 |
| | Total | 663.72 |
| *Azadirachta indica* | Mean | 3.9 ± 0.1 |
| | Total | 2845.19 |
| *Peltophorum pterocarpum* | Mean | 3.3 ± 0.16 |
| | Total | 847.23 |
| *Delonix regia* | Mean | 1.4 ± 0.2 |

**Continued**

| | | |
|---|---|---|
| | Total | 114.67 |
| *Conocarpus erectus* | Mean | 4.2 ± 0.2 |
| | Total | 2286.93 |
| *Syzygium cumini* | Mean | 5.5 ± 1.0 |
| | Total | 143.21 |
| *Tabebuia rosea* | Mean | 1.7 ± 0.1 |
| | Total | 449.45 |
| *Pongamia pinnata* | Mean | 2.0 ± 0.4 |
| | Total | 118.20 |

**Table 3.** Most dominant species in terms of carbon sequestration potential.

| Species | No. of trees | Mean (DBH) cm | (%) $CO_2$eq (tonne) Sequestration |
|---|---|---|---|
| *Ficus* spp. | 444 | 54.6 | 30.3% |
| *Azadirachta indica* | 729 | 43.8 | 25.4% |
| *Conocarpus erectus* | 549 | 41.8 | 20.4% |
| *Peltophorum pterocarpum* | 258 | 42.5 | 7.6% |
| *Albizia lebbeck* | 145 | 44.6 | 5.9% |
| *Tabebuia rosea* | 262 | 31.1 | 4.0% |
| *Syzygium cumini* | 26 | 51.5 | 1.3% |
| *Pongamia pinnata* | 58 | 29.1 | 1.1% |
| *Delonix regia* | 83 | 24.2 | 1.0% |

percentage contribution. In addition to that, the age of trees and other factors that affect the growth of the tree could influence the total biomass. **Table 3** shows the contribution of the dominant species. Research on similar species done in Pakistan by Ajani and Shams (2016), found that *Azadirachta indica* can store 662.3 kg C, and *Conocarpus erectus* 192.7 kg C and in India by Sharma et al. (2020), estimated that *Ficus benjamina* can sequester 30.53 tons of carbon. These studies measure less number of trees compared to this work. In contrast, a study in Nigeria conducted by Eneji et al. (2014), found that *Azadirachta indica* can store 5448.8 kg C, and *Albizia lebbeck* 1040.4 kg C.

The total carbon storage which represents above-ground carbon and below-ground carbon varied among the locations of sampling with a significant difference ($P \leq 0.05$), ranging between 1425.9 tonne and 1632.6 tonne for Parks and roadside respectively. The total amount of $CO_2$ equivalent ($CO_2$eq) sequestered by the trees in the parks is about 5227.6 tonne, with an average of 3.2 ± 0.1 tonne per tree. In contrast, plantation along roadside has the capability to sequester 5985.7 tonne with an average of 4.9 ± 0.2 tonne per tree (**Figure 6**). It

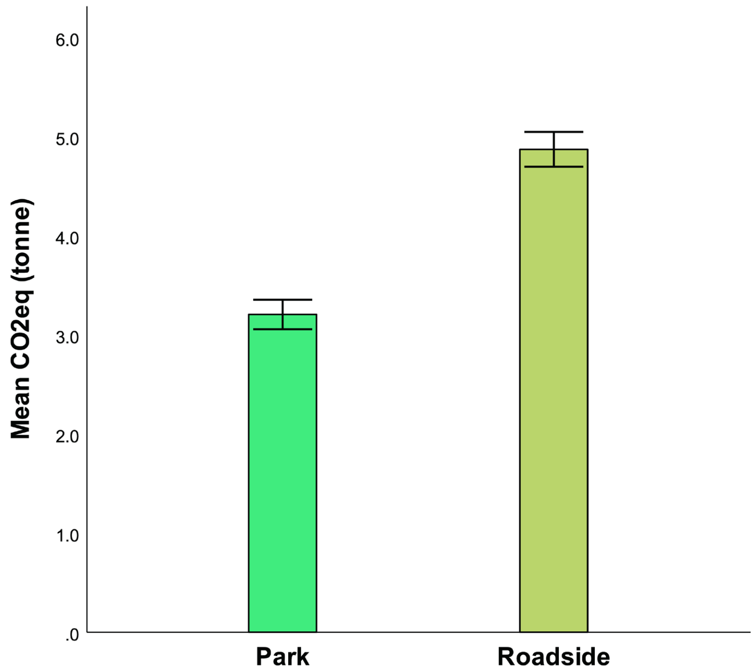


Figure 6. Mean carbon sequestration ($CO_2eq$) in park and roadside plantation. Error bars represent ± one standard error of the mean.

seems that roadside plantation is sequestering more $CO_2eq$ during their life span up until this study. In general, all parks and roadside plantation covered in this study have the capability to sequester 11,213.3 $tCO_2eq$ with an average of 3.9 ± 0.1 tonne per tree. A study conducted by Amoatey and Sulaiman (2019), estimated that urban green spaces in Muscat can sequester around 11,100 $tCO_2$/ha. Another study with similar objective to measure carbon storage in the same city but in the aquatic ecosystem (a piece of mangrove site within the city), found that it has the capability to sequester around 9512 $tCO_2eq$ (Al-Nadabi & Sulaiman, 2021).

## 4. Conclusion

The study measured substantial number of trees in the planted vegetation both in parks and avenue planation to take stock of the species and their DBH attribute to derive their carbon storage and sequestration potential. The study identified 36 different tree species planted and maintained by the city authorities. The DBH ranges from <50.0 cm to >200.0 cm and the DBH < 50.0 cm accounted for 74.0 percent of the total trees. Climatic condition in general and the management of the planted trees at the local level are the key factors for the difference within the species in the study site and similar studies done elsewhere. Out of the 36 species, 97 percent of carbon storage contribution comes from nine species, which clearly indicates that these species are preferred by the planting authorities. The choice of species for avenue plantation reveals that the higher biomass trees as the key requirement compared to the parks where other tree attributes are considered for plantation. The study concludes that conducting and maintaining a tree inventory is important before launching any project related to plantation in the city. Carbon sequestration is just one functional attribute from this study and why it needs to be considered for species selection in urban plantation for greater benefits.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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