# ABOVE GROUND BIOMASS AND CARBON SEQUESTRATION OF URBAN GREEN SPACES IN DANANG CITY, VIETNAM


## Abstract

Green space in cities is an essential component of the urban environment. Different forms of urban green spaces, with varying populations, plant communities, and roles, offer varying urban ecological advantages. Using the i-Tree Eco model, this study examined the structural characteristics of urban green trees and calculated the biomass storage capacity and carbon sequestrationin urban green spaces in Da Nang City. The results revealed a considerable diversity of species composition among 7,513 trees belonging to 42 species of 20 families studied in four types of green spaces, with *Terminalia catappa*, *Cyrtostachysrenda*, and *Roystonea regia* dominating. The average Shannon biodiversity index was 2.9, with the institution having the highest at 2.6 and the park having the lowest at 2.2. The total leaf biomass per hectare was 588.0 kg/ha, and the carbon sequestration rate was 2,845.30 kg/ha. *Ficus subpisocarpa* was the species with the highest value for these two advantages, and the park was the green space with the highest benefit in terms of biomass and carbon sequestration.



**Keywords:**i-Tree Eco, green spaces, biomass, carbonsequestration, dominant species, Danang, Vietnam.


## 1. Introduction

Climate change is defined as a shift in the climate through time caused by natural circumstances and human activity(Walther et al., 2002); (Constance et al., 2007). Global warming, sea level rise, and an increase in severe hydrometeorological occurrences are all symptoms of current climate change(Nguyễn Văn Thắng, 2016). Climate change is regarded as the greatest threat to human health(Patz et al., 2005) and a major challenge confronting humanity, with human activity being the primary cause, owing to the production of one of the main greenhouse gases causing climate change, carbon dioxide, by the combustion of fossil fuels such as coal, oil, and natural gas. As a result, limiting carbon emissions is the most crucial answer to climate change.

Planting trees is one of the top priorities for addressing the challenge of reducing carbon emissions. By sequestering carbon and lowering vehicular pollution, urban trees play a vital ecological role in cities(Kiran & Kinnary, 2015). By fixing carbon during photosynthesis and storing carbon in the form of biomass, urban trees operate as a carbon dioxide reservoir(Nowak et al., 2013). Planting trees, preserving and growing urban green spaces provides chances for enhanced carbon removal from the atmosphere(Niemelä et al., 2010); (Livesley et al., 2016), as well as a variety of additional co-benefits for city inhabitants, such as improved health, reduced pollution, and increased infrastructure life(Steenberg et al., 2023). Furthermore, trees in urban green spaces provide economic and social benefits such as energy savings, community inclusion, and outdoor leisure(Song et al., 2020).

There have been numerous studies in Vietnam to calculate biomass reserves and carbon buildup for trees, however the majority of the work is still done using traditional methods. The i-

Tree Eco model was used in this study to evaluate the structure and quantify the value of biomass and carbon accumulation of trees (Song et al., 2020)in four green spaces in Da Nang City, Vietnam, with the goal of assessing the current status of tree structure and species composition, as well as determining the biomass and carbon stocks of tree species in green spaces. The findings of the study are being utilized to track the city's carbon footprint.

## 2. Materials and Methods

The research was conducted in four green spaces totaling 68.93 acres in Da Nang City, Vietnam. For the field data collection, we used the standard plot size for an Eco analysis is a 0.1 acre circular plot with radius of 11.4 m (USDA Forest Service, 2021)A total of 134 circular (Table 1) were created with public parks (36 plots), residential green spaces (28 plots), educationalInstuitiongreen spaces (50 plots), and industrial green spaces (20 plots). Each plot has an area of 408.07m$^2$ as recommended by Nowak et al (Nowak et al., 2008).

**Table 1**. Characteristic sample plots of the four types of urban green spaces

| Four kind of urban greenspaces | Area of greenspaces (ha) | Number of sample plots | Locations |
|---|---|---|---|
| Public Park | 9.13 | 36 | 29/3 Park |
| Residential spaces | 7.71 | 28 | Nguyen_Duc_Trung Residence, Phu_Loc Residence, Hoa_Minh Residence. |
| Educational institutions | 20.83 | 50 | Le_Van_Tam primary school, University of Sport Danang, The University of Danang (Danang University of Science and Education, Danang University of Science and Technology |
| Industrial zone | 31.26 | 20 | Hoa_Khanh industrial zone |
| **Total** | **68.93** | **134** | |

During biomass estimate, a non-destructive sampling approach that does not affect plants was utilized, which requires the application of a generic or specialized correlation formula for a given type of vegetation (Rahmawaty et al., 2017). Calculations for biomass and carbon sequestrationbased on i-Tree Eco model.

The i-Tree Eco program (formerly known as UFORE, Urban Forest Effect Modeling) is intended to employ standardized field data from sample plots or full inventory, as well as climatic data. The biomass and carbon sequestration of trees atfour green spaces were calculated using local hourly visualization and air pollution for thorough characterization of urban green spaces structure and multi-ecosystem quantification (www.itreetools.org).

## 3. Results and Discussion

### *3.1. Plant community composition*

The study surveyed 7,513 trees from 42 different families, with 24.4% coverage in four types of green spaces: parks, institution, industrial, and residential areas, with three species predominating: *Terminalia catappa*, *Cyrtostachysrenda*, and *Roystonea regia*. Furthermore, several plant species, however few in number, are predominantly found in four green spaces, including *Samanea saman*, *Bauhinia variegata*, *Plumeria rubra*, *Lagerstroemia speciosa*, *Alstoniascholaris*, and *Peltophorumpterocarpum* (Table 2).

**Table2.**Plant species composition at 4 green spaces

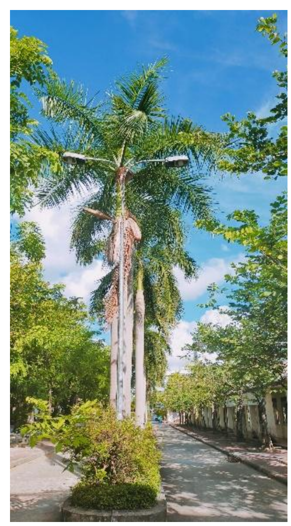
| **Species** | **Families** | **Park** | **Residential area** | **Industry** | **Institution** |
|---|---|---|---|---|---|
| *Acacia auriculiformis* | Fabaceae | ✓ | ✓ | ✓ | |
| *Alstoniascholaris* | Apocynaceae | ✓ | ✓ | ✓ | ✓ |
| *Areca catechu* | Arecaceae | ✓ | | | |
| *Artocarpus altilis* | Moraceae | | ✓ | | |
| *Artocarpus heterophyllus* | Moraceae | | ✓ | ✓ | |
| *Barringtonia acutangula* | Lecythidaceae | | ✓ | | ✓ |
| *Bauhinia variegata* | Fabaceae | ✓ | ✓ | ✓ | ✓ |
| *Casuarina equisetifolia* | Casuarinaceae | | | ✓ | |
| *Cassia fistula* | Fabaceae | | | | ✓ |
| *Ceiba pentandra* | Malvaceae | | ✓ | | |
| *Cinnamomum camphora* | Lauraceae | ✓ | | | |
| *Cocos nucifera* | Arecaceae | ✓ | | | ✓ |
| *Coccolobauvifera* | Polygonaceae | ✓ | | | |
| *Cyrtostachysrenda* | Arecaceae | ✓ | ✓ | ✓ | ✓ |
| *Chukrasiatabularis* | Meliaceae | | ✓ | | |
| *Dalbergia tonkinensis* | Fabaceae | ✓ | ✓ | | |
| *Delonix regia* | Fabaceae | ✓ | | ✓ | ✓ |
| *Dimocarpus longan* | Sapindaceae | ✓ | ✓ | | |
| *Dracontomelonduperreanum* | Anacardiaceae | ✓ | | | |
| *Erythrina fusca* | Fabaceae | | ✓ | | ✓ |
| *Ficus benjamina* | Moraceae | ✓ | | | |
| *Ficus elastica* | Moraceae | ✓ | | | ✓ |
| *Ficus racemosa* | Moraceae | ✓ | ✓ | | ✓ |

| | | | | | |
|---|---|---|---|---|---|
| *Ficus subpisocarpa* | *Ficus subpisocarpa* | √ | | | |
| *Ficus religiosa* | Moraceae | | √ | | |
| *Hopea odorata* | Dipterocarpaceae | √ | √ | | √ |
| *Khaya senegalensis* | Meliaceae | √ | | | √ |
| *Lagerstroemia speciosa* | Lythraceae | √ | √ | √ | √ |
| *Mangifera indica* | Anacardiaceae | | √ | | √ |
| *Manilkara zapota* | Sapotaceae | | | √ | |
| *Mimusopselengi* | Sapotaceae | | | √ | |
| *Peltophorumpterocarpum* | Fabaceae | √ | √ | √ | √ |
| *Plumeria rubra* | Apocynaceae | √ | √ | √ | √ |
| *Pinus kesiya* | Pinaceae | √ | | | |
| *Roystonea regia* | Arecaceae | √ | | | √ |
| *Samanea saman* | Fabaceae | √ | √ | √ | √ |
| *Salix babylonica* | Salicaceae | √ | | | |
| *Senna siamea* | Fabaceae | √ | | | √ |
| *Syzygiumsamarangense* | Myrtaceae | √ | √ | | |
| *Tamarindus indica* | Fabaceae | √ | √ | | |
| *Terminalia catappa* | Combretaceae | √ | √ | √ | √ |
| *Terminalia mantaly* | Combretaceae | √ | | | |



*(Terminalia catappa)*

*(Cyrtostachysrenda)*



*(Roystonea regia)*

**Figure1.** Three common species at 4 green spaces

The difference in the area of four types of green spaces has resulted in an uneven distribution of the plant system in terms of quantity and types, specifically, the industrial zone with an area of 31.26 hectares has 17 species with 2,399 trees (accounting for 31.93%), followed by the institution with an area of 20.83 ha has 22 species with2,109 trees (28.07%), the park with an area of 9.13 ha has 31 species with2,331trees (31.03%), and the residential zone with an area of 7.71 ha has 23 species with 674 trees (accounting for 8.97%).When the Shannon diversity index is compared among the green spaces, it is found that the total score of four green spaceswas at an average of 2.9, with the greatest being 2.6 for the institution and the lowest being 2.2 for the park. Industrial and residential zones have the same diversity index of 2.3 (Table 3).

**Table3.**Distribution of trees in four green spaces

| Green spaces | Area (ha) | Number of plant species | Number of trees | Quantity ratio (%) | Shannon index |
|---|---|---|---|---|---|
| Industrial zone | 31.26 | 17 | 2,399 | 31.93 | 2.3 |
| Institution | 20.83 | 22 | 2,109 | 28.07 | 2.6 |
| Park | 9.13 | 31 | 2,331 | 31.03 | 2.2 |
| Residential zone | 7.71 | 23 | 674 | 8.97 | 2.3 |
| Total | 68.93 | | 7,513 | | 2.9 |

*3.2. Tree trunk diameter distribution*

The distribution of trunk diameter (DBH) in the four green spaces was uneven, with DBH ranged from 7.6 to 15.2 cm accounting for 39.70%, followed by DBH from 0 - 7.6 cm (38.94%), DBH from 15.2 - 30.5 cm (20.73%), DBH from 30.5 - 45.7 cm (0.38%), and DBH greater than 45.5 cm (0.25%) (Figure 2).

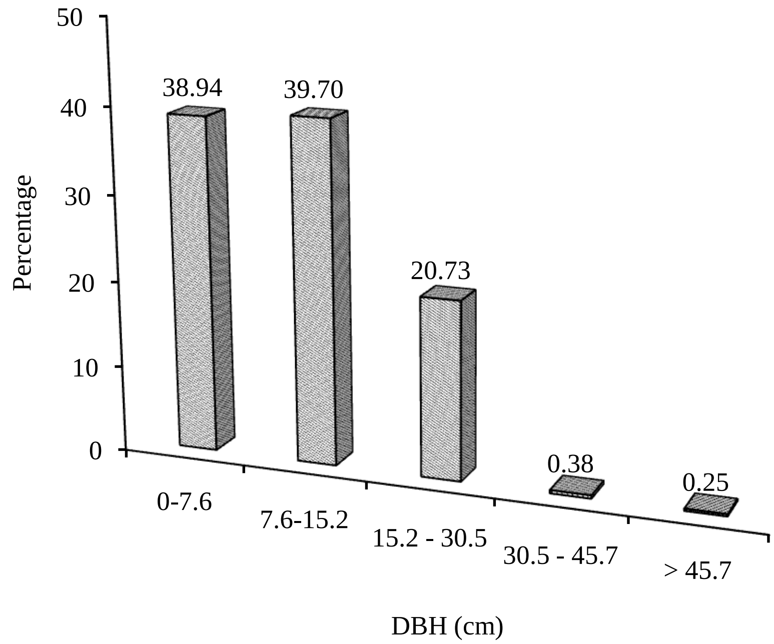



**Figure2.**The DBH distribution of trees in four green spaces

When the distribution of DBH among trees in the four green spaces was compared, it was discovered that, with the exception of the park, the trees in the other green spaces were generally in the young and growing phases. Trees in the park have the most complete trunk diameter distribution structure, though there was still a difference in the distribution ratio between DBHs, specifically: DBH from 0 - 7.6 cm accounted for 30.65%, 7.6 - 15.2 cm was 34.95%, 15.2 - 30.5 cm was 33.6%, 30.5 - 45.7 cm was 0.27%, and greater than 45.7 cm was 0.54%; followed by trees in the institute with DBH range from 0 - 7.6 cm accounting for 40.63%. Trees in residential and industrial areas exhibited a substantial difference in trunk diameter distribution between trees with BDH ranging from 0 to 7.2 cm and trees with DBH ranging from 15.2 to 30.5 cm (as shown in Figure 3).

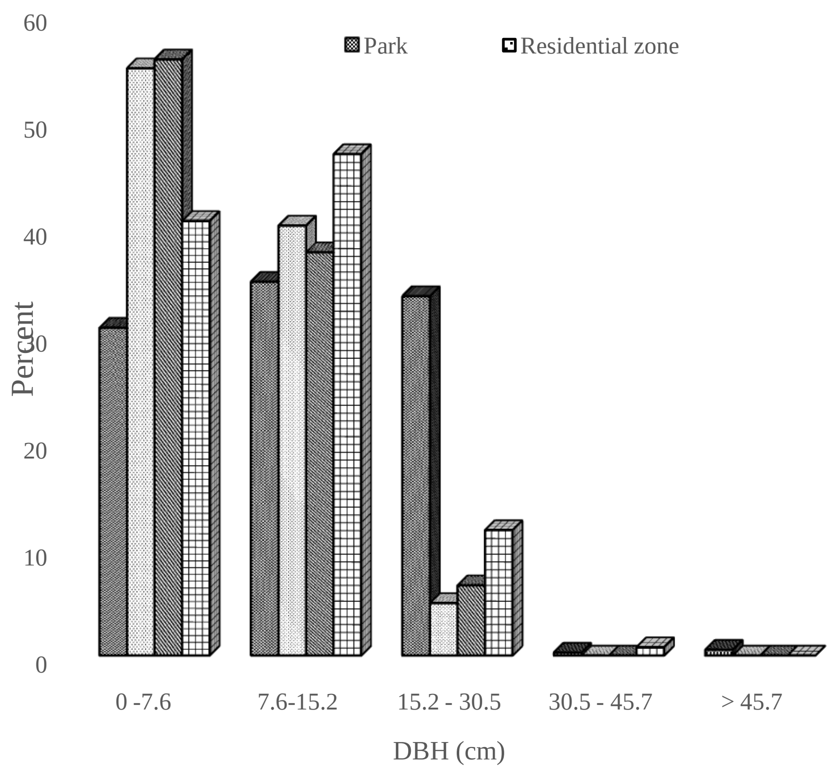



**Figure 3.** DBH distribution of trees in each green space

*Samanea saman* has the most constant trunk diameter distribution among the 10 prominent species in the study region, whereas the majority of the other dominant species had a DBH ranged from 0 to 30.5 cm (Figure 4).

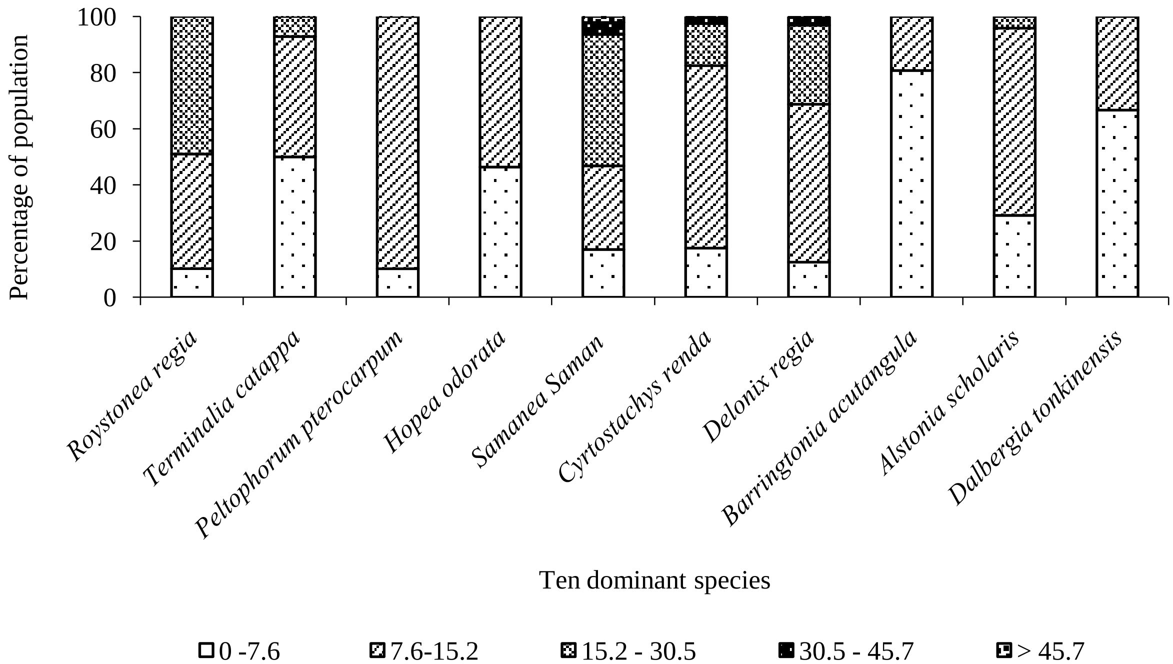



**Figure4.**Distribution of DBH of 10 dominant species in four green spaces

*3.3. Carbon storage and sequestration*

The overall tree density in the four green spaces was around 109.00 trees/ha, with the density in the park being the greatest at 255.30 trees/ha and the industrial zone being the lowest at 76.70 trees/ha. The four green spaces obtained a total biomass density of 588.00 kg/ha, with trees in the park reaching 1,643.70 kg/ha, followed by residential areas at 627.80 kg/ha, industrial zones at 432.30 kg/ha, and institutions at 344.10 kg/ha (Table 4).

**Table4.**Total biomass and carbon sequestrationof trees at four green spaces

| **Type of urban green space** | **Tree density (trees/ha)** | **Leaf biomass density (kg/ha)** | **Carbon storage (kg/ha)** | **Net carbon sequestration density (kg/yr/ha)** | **Gross carbon sequestration density (kg/yr/ha)** | **$CO_2$ equivalent (kg/yr/ha)** |
|---|---|---|---|---|---|---|
| Park | 255.30 | 1,643.70 | 13,421.40 | 2,587.90 | 2,682.91 | 9,838.23 |
| Residential | 87.40 | 627.80 | 639.60 | 221.11 | 225.45 | 826.73 |
| Industrial | 76.70 | 432.30 | 744.30 | 233.83 | 240.95 | 883.57 |
| Institution | 101.30 | 344.10 | 2,179.00 | 637.10 | 657.03 | 2,409.32 |
| Average | 109.00 | 588.00 | 2,845.30 | 666.08 | 688.40 | 2,524.35 |

The average carbon storage at four green spaces was 2,845.30 kg/ha, with the park having the most at 13,421.40 kg/ha and the residential having the lowest at 639.60 kg/ha. The densities of total net sequestration and carbon sequestration were 666.08 kg/year/ha and 688.40 kg/year/ha, respectively. The park had the highest net sequestration and carbon sequestration, at 2,587.90 kg/year/ha and 2,682.91 kg/year/ha, respectively; the institution had 637.10 kg/year/ha and 657.03 kg/year/ha, respectively; the industrial zone had 233.83 kg/ha/year and 240.95 kg/year/ha, respectively; and the residential area had 221.11 kg/year/ha and 225.45 kg/year/ha. The overall quantity of carbon dioxide equivalent was 2,524.35 kg/year/ha, with the park being the greenest space at 9,838.23 kg/year/ha and the residential area being the least at 826.73 kg/year/ha (Table 4).

**Table 5.**The top ten species have the highest levels of carbon storage and sequestration.

| No. | **Leaf biomass** | | | | **Carbon storage** | | | |
|---|---|---|---|---|---|---|---|---|
| | Species | Number of trees | Biomass (kg) | Average mass per tree (kg) | Species | Number of trees | Biomass (kg) | Average mass per tree (kg) |
| 1 | *Terminalia catappa* | 1,333 | 11,458 | 8.60 | *Roystonea regia* | 1,316 | 82,320 | 62.55 |
| 2 | *Roystonea regia* | 1,316 | 4,505 | 3.42 | *Samanea saman* | 430 | 24,620 | 57.26 |
| 3 | *Samanea saman* | 430 | 3,952 | 9.19 | *Ficus subpisocarpa* | 13 | 16,490 | 1,268.46 |
| 4 | *Dalbergia tonkinensis* | 123 | 2,729 | 22.19 | *Terminalia catappa* | 1,333 | 11,560 | 8.67 |
| 5 | *Lagerstroemia speciosa* | 373 | 1,899 | 5.09 | *Peltophorumpterocarpum* | 406 | 11,070 | 27.27 |
| 6 | *Delonix regia* | 323 | 1,836 | 5.68 | *Khaya senegalensis* | 107 | 9,650 | 90.19 |
| 7 | *Ficus subpisocarpa* | 13 | 1,570 | 120.77 | *Delonix regia* | 323 | 6,710 | 20.77 |
| 8 | *Peltophorumpterocarpum* | 406 | 1,513 | 3.73 | *Cocos nucifera* | 141 | 3,860 | 27.38 |
| 9 | *Hopea odorata* | 431 | 1,440 | 3.34 | *Ficus elastica* | 16 | 3,620 | 226.25 |
| 10 | *Dracontomelonduperreanum* | 163 | 914 | 5.61 | *Hopea odorata* | 431 | 3,500 | 8.12 |

The species with the greatest biomass value (11,458 kg) was *Terminalia catappa*, followed by *Roystonea regia* (4,505 kg) and *Samanea saman* (3,952 kg). However, when evaluating the average weight of a tree, *Ficus subpisocarpa* has the greatest biomass value (120.77 kg/tree).*Roystonearegi* was the species with the highest carbon storage value (82,320 kg), followed by *Samanea saman* (24,620 kg), *Ficus subpisocarpa* (16,490 kg). The highest average mass per tree belonged to *Ficus subpisocarpa* (1,268.46 kg/tree) (as shown in Table 5).

## 4. Conclusion

The study found a great diversity in species composition among 7,513 trees belonging to 42 species from 20 families surveyed in four green spaces, with the major species being *Terminalia catappa*, *Cyrtostachysrenda*, and *Roystonea regia*. The total Shannon biodiversity index was 2.9, with the institution area having the greatest at 2.6 and the park having the lowest at 2.2. The total biomass per hectare was 588.00 kg/ha, and the total carbon sequestration was 2,845.30 kg/ha. *Ficus subpisocarpa* was the species with the highest value for biomass and carbon sequestration, and the park was the green space with the highest value for these two advantages.

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