Inventorying and proposing solutions for street tree management in Thu Duc city, Ho Chi Minh City

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ABSTRACT

Tree inventory plays an essential role in the urban landscape master plan. It serves as the foundation for data acquisition that supports the planning strategy and decisions relating to the community's interests, particularly in recently established cities like Thu Duc city. This research was carried out from October 2021 to December 2022 in this city and aimed to inventory to gather qualified information for managing the city's street trees. The study used an inventory form of street trees including criteria such as name, family, diameter at breast height (DBH), total height, and indicators of vitality and distance from trees to infrastructure. By this form, 287 streets were surveyed. The total number of investigated trees was 31.023 trees belonging to 65 species and 24 flora families, of which the species with a high percentage (from 10% or more) were *Dipterocarpus alatus*, *Hopea odorata*, *Peltophorum pterocarpum*, and *Lagerstroemia speciosa*. The most numerous plant family was Fabaceae. These trees typically had a height of less than 10 m, with a DBH of less than 20 cm. Many streets did not guarantee the distance between trees and infrastructure, particularly the distance to the electrical systems. The survey also showed that the majority of trees were healthy and grow healthily. From the current situation of Thu Duc city street trees, three solutions must be prioritized in order to improve street trees in this city.

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I. Introduction

Since the nineteenth century, street trees have become an important component of the urban landscape, playing many ecological and socio-economic roles (Caneva et al., 2020). They are an integral part of urban ecosystems, improving environmental quality by providing ecological benefits (Dover, 2015). Street trees significantly reduce air pollution by removing pollutants such as SO_2, NO_x, CO, and O_3 through their leaf stomata and by capturing dust on their leaf surfaces (Smith, 1984). Additionally, street trees contribute to reducing the urban heat island effect and have a clear role in improving the microclimate (Chang et al., 2007). "Greening the city" is a crucial issue on the agendas of major cities around the world, and trees are an important aspect of it (Braverman, 2008). Urban tree planting initiatives are being actively promoted as a planning tool for urban areas to adapt to and mitigate climate change, enhance urban sustainability, and improve health and well-being (Salmond et al., 2016).

From a landscape architecture perspective, street trees are one of the most important components of urban green space, playing an important role in street aesthetics (Li et al., 2011). The first impression of a city often comes from its streetscape (Jacobs, 1993). Over the centuries, street trees have remained enduring features of urban landscapes (Merse et al., 2008). However, data on species diversity of street trees, the criteria for species selection, and regulations on tree planting and maintenance are still limited (Caneva et al., 2020).

However, data on the species diversity of street trees, the criteria for species selection, and regulations on tree planting and maintenance are still limited (Caneva et al., 2020). For street trees, the design and selection of species reinforce the identity and distinctiveness of a city. Species diversity contributes to improving the aesthetics and health of trees in urban areas (Ware, 1994; Jim, 1999; Thaiutsa et al., 2008). Besides suitability to local climatic conditions, factors such as size and aesthetic value should be considered when selecting species (Caneva et al., 2020). In urban environments, trees are adversely affected by atmospheric pollutants, poor drainage, harsh soil conditions, mechanical impact, and limited growth space due to high and low ambient temperatures (Ware, 1994; Jim, 1999; Thaiutsa et al., 2008). Design and species selection depend on urban-specific characteristics such as land use (commercial land, residential land, etc.), street specifications (size, width, length), and the location of trees (sidewalks, medians) (Li et al., 2011). Successful street tree planting can only be achieved if multiple criteria are met (Pauleit, 2003).

Cities around the world have issued regulations for the selection of species, technical parameters to be ensured when planting and maintaining street trees, planting location, and the distance between trees and road edges, intersections, fire hydrants, and manholes. Some examples include the Street Tree Manual issued by SDOT in 2013, the Design Standards for Street Trees published by TDPRLC (2007), the Street Tree Planting Standards published by NYC Parks (2016), the Regulation of Street Trees: Maintenance Of Street Trees And Sidewalks issued by TFM (2022), and Street Trees promulgated by City of Tulare, California (CTCCO, 2008). In Vietnam, standards and specifications for street trees are stipulated by MOC (2005) of the Ministry of Construction on guiding the management of urban green trees, GOV (2010) of the government on urban green tree management, the national standard (MOST, 2012) on planning green trees for public use in

urban areas - design standards; GOV (2005) detailing and guiding the implementation of a number of articles of the Electricity Law on safety protection of high-voltage grid works.

In Ho Chi Minh City, regulations governing the selection of plant species are outlined in PCHCMC (2013) by the People's Committee, which provides a list of encouraged and restricted trees and prohibits certain types of planting. Thu Duc city was recently established in 2021 according to the Resolution SCNA (2020) of the National Assembly Standing Committee, and is currently focused on improving the quality of its "green-clean-beautiful" street landscape. However, there is currently no inventory of street trees in the city. This study aims to assess the current situation of street trees in Thu Duc city in relation to government regulations, specifically in terms of species composition and compliance with specifications. The findings of this study will contribute to the development of a database for the management and research of urban trees.

2. Materials and Methods

This research utilized a standard urban tree inventory form from the urban forestry discipline, which included various technical parameters of the road (such as length, road width, sidewalk width, and the presence or absence of a separator), plant species information (including botanical name, flora family, total height, diameter at breast height - DBH, and planting location with other components like intersections, fire hydrants, manholes, and electricity), and vitality. Certain pieces of information were selected for this inventory, such as tree height and DBH, for specific reasons. Total tree height is one of the most important tree attributes in forest inventory (Jurjević et al., 2020). This indicator is usually used to calculate individual trees, it directly affects the calculation of other attributes (Wang et al., 2019). The DBH is a widely-used forestry management measurement that has been utilized since the 19th century to estimate wood volume, identify trees, and measure tree growth (Magarik, 2020) without cutting down the trees (Chaudhuri, 2016).

The gathered information was evaluated and compared to the guidelines on species composition, height, and regulation on location and planting distance specified in the government's legal documents (listed and discussed in section 3.1).

The data was collected via field survey methods like observing, recording information, taking photos, and collecting samples according to Klein and Klein's method (1970) for unidentified species. Tape measures and clinometers were also used to collect street width, total tree height, DBH, and other parameters.

To identify the species' botanical names, samples, photos, and descriptions of trees were compared morphologically with species in some books like "An Illustrated Flora of Vietnam" by Pham (2000) and "500 Useful Plants in Landscape Design" by Dinh (2021). This study was also updated with the latest scientific name according to the website http://www.worldfloraonline.org/. The collected data were synthesized in Microsoft Excel 2015 and then analyzed, evaluated, and compared to (MOC, 2005) and (PCHCMC, 2013).

3. Results and Discussion

3.1. Inventory of street trees

Streets in the investigation areas

The inventory was conducted on 287 streets in 3 old districts of Thu Duc city (district 2, district 9 and Thu Duc district). There are only 24 streets

with separator in width from 1 - 8 m. These are streets that are already available or qualified for tree planting. The width of the streets ranges from 3 m to 60 - 70 m (Mai Chi Tho street, Pham Van Dong street and Hanoi highway). The sidewalk width is mostly 3 - 5 m.

Number of trees and number of species

The study investigated 31,023 trees belonging to 65 different species, as shown in Table 1. Some species, including Dipterocarpus alatus, Hopea odorata, Peltophorum pterocarpum, and Lagerstroemia speciosa, accounts for 10% or more of the total trees. Additionally, some species constituts 3 - 7% of the total trees, such as Mimusops elengi, Khaya senegalensis, Pterocarpus macrocarpus, Pterocarpus indicus, Delonix regia, Cassia fistula, and Tamarindus indica. On the other hand, some species, mostly fruit trees like Syzygium samarangense, Dimocarpus longan, Chrysophyllum cainito, and Cocos nucifera, are available in small number. Despite the variety of street tree species in Thu Duc city, there are also several species on the list of trees banned from planting and restricted from planting under Decision 52/2013/QD-UBND of the People's Committee. For example, Ficus racemosa roots damage the infrastructure, and ripe figs falling on the street can lead to unhygienic conditions. Terminalia captappa, which has 648 trees, is vulnerable to pests and diseases. Alstonia scholaris has easily broken branches and smelly flowers that cause discomfort to the citizens. Khaya senegalensis, with its protruding roots on the ground, can damage sidewalks and the street surface and pose a danger to pedestrians. Additionally, fruit trees like Dimocarpus longan, Mangifera indica, Cocos nucifera, and Chrysophyllum cainito, when ripe, can attract children to climb dangerously or fall, leading to hazardous conditions for people. Acacia auriculiformis has branches that pose a risk to pedestrians, and Hura crepitans is forbidden to plant because of its toxic seeds and latex. Therefore, it is essential to take timely action to eliminate these restricted and banned species from the streets to ensure aesthetic appeal and safety for citizens.

Table 1. Number of trees and species investigated in the streets of Thu Duc city

No.	Names	Family	Quantity	Percentage (%)
1	*Dracontomelon duperreanum* Pierre	Anacardiaceae	7	0.02
2	*Mangifera indica* L.	Anacardiaceae	32	0.10
3	*Monoon longifolium* (Sonn.) B.Xue & R.M.K.Saunders	Annonaceae	119	0.38
4	*Alstonia scholaris* (L.) R.Br.	Apocynaceae	32	0.10
5	*Holarrhena pubescens* Wall. & G.Don Wall. ex G.Don	Apocynaceae	1	0.00
6	*Kopsia arborea* Blume	Apocynaceae	9	0.03
7	*Plumeria rubra* L.	Apocynaceae	9	0.03
8	*Plumeria obtusa* L.	Apocynacesae	289	0.93
9	*Araucaria columnaris* Hook.	Araucariaceae	4	0.01
10	*Adonidia merrillii* (Becc.) Becc.	Arecaceae	329	1.06
11	*Archontophoenix alexandrae* (F.Muell.) H.Wendl. & Drude	Arecaceae	3	0.01
12	*Cocos nucifera* L.	Arecaceae	1	0.00
13	*Elaeis guineensis* Jacq.	Arecaceae	143	0.46
14	*Roystonea regia* O.F.Cook	Arecaceae	103	0.33
15	*Spathodea campanulata* P. Beauv.	Bignoniaceae	17	0.05
16	*Tabebuia rosea* (Bertol.) Bertero ex A.DC.	Bignoniaceae	585	1.89
17	*Tecoma stans* (L.) Kunth	Bignoniaceae	5	0.02
18	*Bucida molineti* (M.Gomez) Alwan & Stace	Combretaceae	420	1.35
19	*Terminalia captappa* L.	Combretaceae	352	1.13
20	*Terminalia chebula* Retz.	Combretaceae	180	0.58
21	*Dipterocarpus alatus* Roxb. & G.Don	Dipterocarpaceae	4,513	14.55
22	*Hopea odorata* Roxb	Dipterocarpaceae	4,279	13.79
23	*Diospyros decandra* Lour	Ebenaceae	2	0.01
24	*Hura crepitans* L.	Euphorbiaceae	3	0.01
25	*Acacia auriculiformis* A.Cunn. ex Benth.	Fabaceae	4	0.01
26	*Acacia mangium* Willd.	Fabaceae	1	0.00
27	*Afzelia xylocarpa* (Kurz) Craib	Fabaceae	42	0.14
28	*Bauhinia purpurea* L.	Fabaceae	509	1.64
29	*Bauhinia variegata* L.	Fabaceae	9	0.03
30	*Cassia fistula* L.	Fabaceae	981	3.16
31	*Dalbergia oliveri* Gamble ex Prain	Fabaceae	38	0.12
32	*Delonix regia* (Bojer ex Hook.) Raf.	Fabaceae	932	3.00

Table 1. Number of trees and species investigated in the streets of Thu Duc city (cont.)

33	*Erythrina fusca* Lour.	Fabaceae	26	0.08
34	*Erythrophleum fordii* Oliv.	Fabaceae	7	0.02
35	*Peltophorum pterocarpum* (DC.) Backer ex K.Heyne	Fabaceae	3,586	11.56
36	*Pterocarpus indicus* Willd.	Fabaceae	1,662	5.36
37	*Pterocarpus macrocarpus* Kurz	Fabaceae	970	3.13
38	*Samanea saman* (Jacq.) Merr.	Fabaceae	421	1.36
39	*Tamarindus indica* L.	Fabaceae	1,047	3.37
40	*Tectona grandis* L.f.	Lamiaceae	508	1.64
41	*Cinnamomum camphora* (L.) J.Presl	Lauraceae	78	0.25
42	*Barringtonia acutangular* (L.) Gaertn.	Lecythidaceae	507	1.63
43	*Couroupita guianensis* Aubl.	Lecythidaceae	24	0.08
44	*Lagerstroemia calyculata* Kurz	Lythraceae	7	0.02
45	*Lagerstroemia reginae* Roxb.	Lythraceae	490	1.58
46	*Lagerstroemia speciosa* (L.) Pers.	Lythraceae	3,952	12.74
47	*Michelia alba* DC.	Magnoliaceae	8	0.03
48	*Ceiba pentandra* (L.) Gaertn.	Malvaceae	10	0.03
49	*Azadirachta indica* A.Juss.	Meliaceae	3	0.01
50	*Chukrasia tabularis* A.Juss	Meliaceae	572	1.84
51	*Khaya senegalensis* A.Juss.	Meliaceae	1,002	3.23
52	*Artocarpus altilis* (Parkinson ex F.A.Zorn) Fosberg	Moraceae	149	0.48
53	*Artocarpus heterophyllus* Lam.	Moraceae	8	0.03
54	*Ficus benjamina* L.	Moraceae	29	0.09
55	*Ficus microcarpa* L.f.	Moraceae	76	0.24
56	*Ficus racemosa* L.	Moraceae	18	0.06
57	*Ficus religiosa* L.	Moraceae	15	0.05
58	*Ficus rumphii* Blume	Moraceae	8	0.03
59	*Muntingia calabura* L.	Muntingiaceae	7	0.02
60	*Syzygium cumini* (L.) Skeels	Myrtacea	1	0.00
61	*Syzygium samarangense* (Blume) Merr & L.M.Perry	Myrtaceae	2	0.01
62	*Averrhoa carambola* L.	Oxalidaceae	6	0.02
63	*Dimocarpus longan* Lour.	Sapindaceae	1	0.00
64	*Chrysophyllum cainito* L.	Sapotaceae	2	0.01
65	*Mimusops elengi* L.	Sapotaceae	1,868	6.02
			31,023	100.00

Number of families

65 species of trees investigated belong to 24 flora families, in which Fabaceae accounted for the majority in both the number of species (15 species, 23%) and the number of trees (10,340 trees, nearly 35%). This can be explained by the fact that Fabaceae is a family with many beautiful flowering trees that can be grown in the street. In addition, Fabaceae is the third largest family of flowering flora after Asteraceae and Orchidaceae (Judd et al., 2002), Fabaceae is also a large plant family in Vietnam with about 600 species (Nguyen, 2003). Some other families also are considered noteworthy such as Moraceae (7 species), Apocynaceae, and Arecaceae (5 species of each), the remaining families account for 1 - 3 species of each (Figure 1). The family Dipterocarpaceae had only 2 species but in very large number (7,265 trees, ranked second after Fabaceae). Two other families, Lythraceae and Meliaceae, had only 3 species per family, but the number of trees was also considerable (4,117 trees and 1,577 trees).

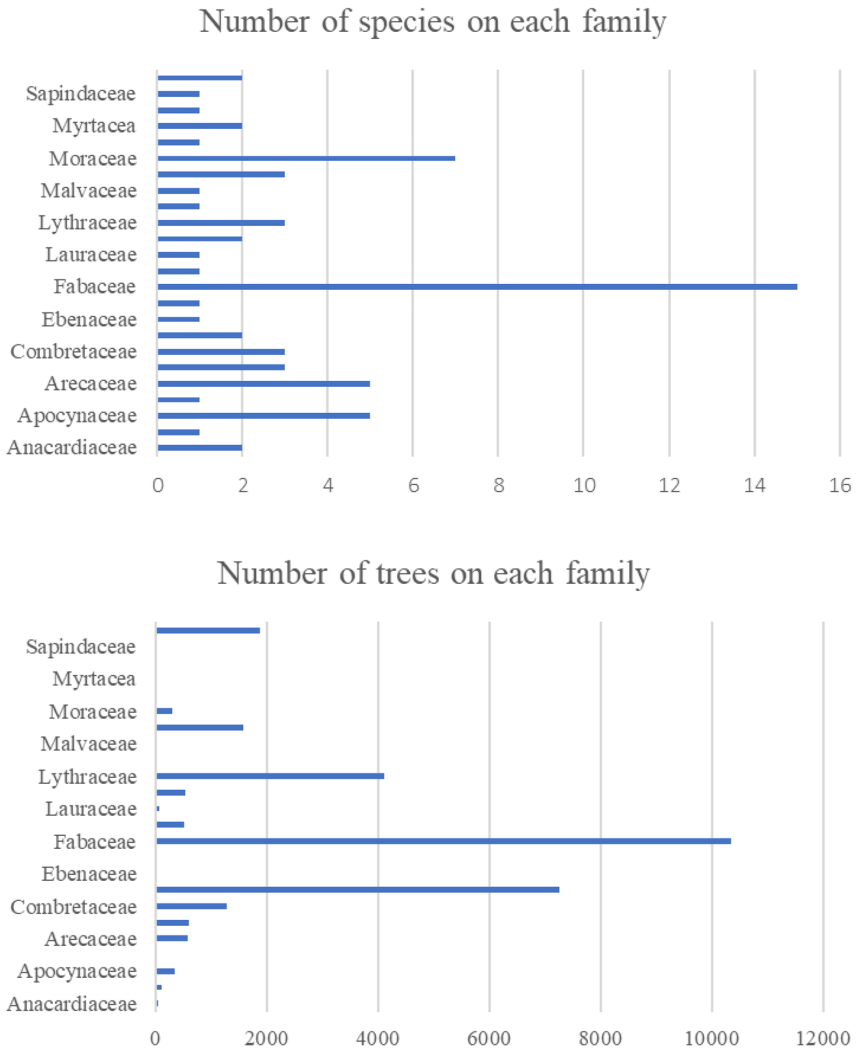

Figure 1. Tree families.

Total height of trees

The inventory showed that most of the street shade trees in Thu Duc city had a total height of less than 10 m (74%). According to the classification of (MOC, 2005), there are type 1 trees. The proportion of type 2 ones (total height from 10 m to 15 m) accounts for 24% and type 3 ones (trees with a total height greater than 15 m) accounts for only about 2% (Figure 2). According to Table 1, 42 species (accounting for 65%) at maturity are type 3. There are some reasons for this situation, such as recently planted trees, trees height is limited because of entangled with power lines or to limit falls, broken branches due to weather. Regarding 587 trees on type 3, the majority is Dipterocarpus alatus Roxb. & G. Doni and Hopea odorata Roxb with the number of 167 and 249 plants, respectively.

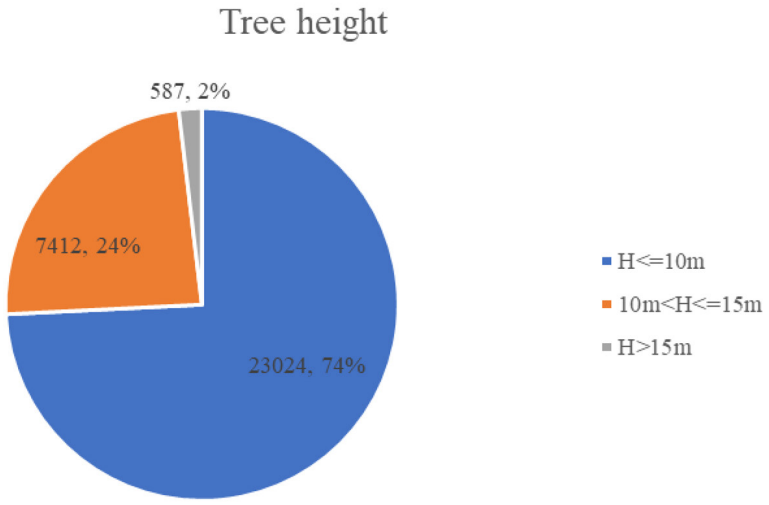

Figure 2. Tree height class according to Ministry of Construction (2005).

Diameter at breast height (DBH)

In this inventory, 56% of street trees in Thu Duc city had a DBH of less than 20 cm, 43% of trees had DBH between 20 and 50 cm, and only 1% (corresponding to 264 trees) was found to have DBH greater than 50 cm (Figure 3) in which the main species were Samanea saman, Khaya senegalensis and Delonix regia. These were species that grow and develop quite rapidly, easily reaching bigger diameters than other common street tree species. Species with a large number of trees such as Dipterocarpus alatus, Hopea odorata, Peltophorum pterocarpum, and Lagerstroemia speciosa were mostly at DBH mainly distributed in less than 20 cm class and 20 cm 50 cm class.

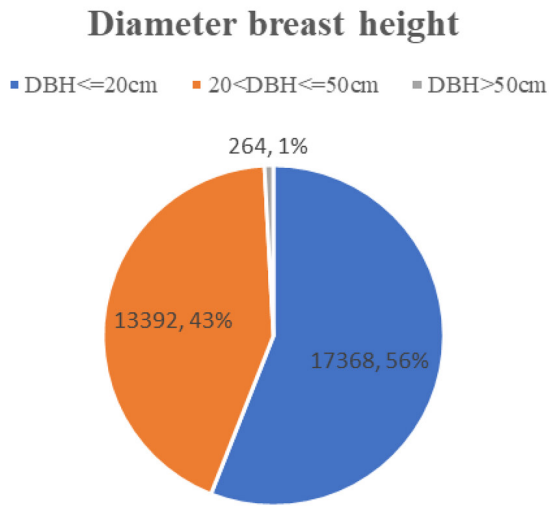

Figure 3. Diameter at breast height class according to Ministry of Construction (2005).

Distance of trees to infrastructure

As can be seen in the Table 2, there are 17/287 streets with street trees that have not to meet the stipulation of Circular No. 20/2009/TT-BXD of the Ministry of Construction amending and supplementing MOC (2005) the distance from trees to the manhole is from 1 m to 2 m, but the ones are on Nguyen Hoang street (district 2) and some streets such as Dinh Phong Phu, Man Thien, 3rd Avenue, No. 10, No. 13, etc (district 9) with tree distance to the manhole less than 1 m.

According to the above regulation, there are 30/287 streets with trees planted illegally, which is less than 1 m from light such as Thong Nhat, Hiep Binh, Ngo Chi Quoc streets (Thu Duc district), Nguyen Van Huong, Xuan Thuy, Nguyen Hoang, Vu Tong Phan, etc (district 2) and some streets in district 9 such as Dinh Phong Phu, Duong Dinh Hoi, etc. Compared with the regulations on the distance between street trees and intersections, it was found that there are 18/287 streets with tree planting distances and intersections less than 5 - 8 m, namely streets B, D, Tam Chau (Thu Duc district) and streets 442, No. 10, No. 14 (district 9), etc.

Regarding the distance from the trees to the fire hydrant, there are 11/287 streets with a distance from the tree to the fire hydrant less than 2 - 3 m, such as No. 71-TML, No. 103-TML, No. 57-CL, etc (district 2) and No. 12, B (Thu Duc district). Trees planted along the electricity must ensure safety according to the provisions of GOV (2005) detailing and guiding the implementation of the Electricity Law on safety protection of high-voltage. However, the study found up to 104/287 streets which have trees that did not meet this regulation (Figure 4). This is an issue that Thu Duc needs to pay attention to improve the safety of urban people and ensure a good development environment for street trees.

Table 2. Distance from street trees to infrastructure

Distance to infrastructure	G	P
Distance of trees to manholes	270	17
Distance of trees to street lights	257	30
Distance of trees to intersections	269	18
Distance of trees to fire hydrants	276	11
Distance of trees to electricity	183	104

Figure 4. The unsafety of trees and electricity at Chu Manh Trinh and Cong Ly streets.

Tree vitality

Healthy trees provide a variety of advantages for the urban environment (Wargo, 2002). Nevertheless, several environmental pressures might have an impact on urban trees' vitality like pests and biotic diseases (Dobbertin, 2005; Percival, 2005). Street trees in Thu Duc city are evaluated in terms of vitality according to the following 4 classes. There are Class A - Good (trees without decay or rots at the trunk and full foliage/crown, no pests, and diseases); Class B - Fair (full foliage/crown, show signs of pests and diseases but are not significant to growth, unbalanced canopy, percentage of parasites and pet or diseases, rot less than 10%); Class C - Moderate (significantly less vitality, yellow/decay leaves, damaged by pests and diseases, poorly crown, percentage of parasitic and pet or diseases from 10 to 30%); and Class D - Poor, need to replace other trees (dead or nearly dead). As shown in Figure 5, 80% of street trees in Thu Duc city are classified A, and 19% ones in class B. However, there had 1% (432 trees) in classes C and D. These are trees that need to be monitored closely or replaced immediately.

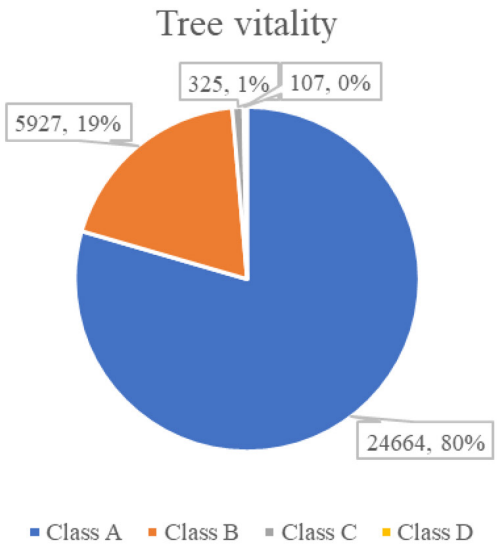

Figure 5. Tree vitality class.

3.2. Solutions for street tree management in Thu Duc city

To improve the street trees in Thu Duc city, the research proposes three main solutions based on legal documents, which are issued by the government related to urban trees and the current tree situation.

Firstly, it is important to choose accurate and suitable species. As shown in Table 1, many species do not comply with street tree regulations and must be replaced to ensure a beautiful and safe streetscape. Future street planning must also follow this solution. Suitable species that can be considered include *Chukrasia tabularis* A.Juss., *Diospyros martabanica* C.B.Clarke, *Anisoptera costata* Korth., *Terminalia chebula* Retz., *Dipterocarpus alatus* Roxb. ex G.Don, *Hopea odorata* Roxb, *Pterocarpus macrocarpus* Kurz, *Swietenia macrophylla* King, *Cinnamomum camphora* (L.) J.Presl, and *Dalbergia oliveri* Gamble ex Prain, among others.

Secondly, it is necessary to renovate existing street trees. This involves replacing dead or nearly dead trees, monitoring and closely caring for them, removing trees that do not comply with regulations, ensuring proper distance from infrastructure, and trimming to ensure safety and aesthetics.

Thirdly, in planning and designing trees for new streets, it is important to follow general regulations and also choose a different form of tree planting for each street depending on its length to create a unique landscape aesthetic and promote environmental efficiency.

4. Conclusions

The study surveyed 287 streets in Thu Duc city, counting 31,023 trees of 65 species and 24 flora families. The most prevalent family was Fabaceae, and the most abundant species were *Dipterocarpus alatus*, *Hopea odorata*, *Peltophorum pterocarpum*, and *Lagerstroemia speciosa*. However, some trees are currently

prohibited or restricted from being planted and should be replaced as soon as possible. The trees on the streets are generally less than 10 meters tall and have a diameter at breast height of less than 20 cm. Unfortunately, many trees are not properly distanced from infrastructure, including electricity/power line, presenting safety hazards. Despite this, most trees exhibit good vitality and growth. To improve the street trees in Thu Duc city, three solutions must be prioritized: selecting appropriate species, providing timely maintenance, care, and replacement of trees, and enhancing the planning and design of new streets.

Conflict of interest

The authors declare that they have no conflict of interest in this article.

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