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Applying GIS to Manage the Current Status of Tree Pests and Diseases in Urban Environment (Da Nang, Socialist Republic of Vietnam)

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Abstract. In urban environments, landscape plants play a crucial role. Greenery provides a fresh and vibrant atmosphere, reducing the monotony of rigid concrete structures. Planting trees and greenery in urban areas helps improve the quality of the environment by reducing air pollution, noise, and the urban heat island effect. This, in turn, improves air quality, as well as the physical and mental well-being of urban residents. This study aims to understand the status of pests and diseases affecting landscape plants and propose measures to manage, mitigate, and enhance their resilience in urban environments, with the further application of GIS technologies to develop a data system that will help manage landscape plants quickly and most efficiently. The study utilizes morphological comparison methods to classify plants and identify pests and diseases on landscape plants. In addition, GIS technology is applied for digitizing the collected data using Mapinfo Professional 15 software. The study has collected data on over 500 managed landscape plants along the major roads of Hai Chau District, Da Nang, resulting in the identification of 27 plant species and 12 types of pests and diseases affecting them. In general, the current status of landscape plants in the study area is favorable, pest and disease infestation is minimal. Only a few trees have been found to be leaning or at risk of falling, suggesting their removal and replacement with new trees. Based on the collected data, the authors have created a digitized greenery map of the study area.

Keywords: urban environment, GIS technology, Da Nang, landscape plants, pests, diseases

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Научная статья

Применение геоинформационных систем для управления текущим статусом вредителей и болезней деревьев в городской среде (Дананг, Социалистическая Республика Вьетнам)

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Аннотация. В городских условиях ландшафтные растения играют решающую роль. Зелень создает свежую и яркую атмосферу, уменьшая монотонность бетонных конструкций. Посадка деревьев и кустарников в городских районах способствует улучшению качества окружающей среды за счет снижения уровней загрязнения воздуха, шума и эффекта острова тепла. Это, в свою очередь, улучшает качество воздуха, а также физическое и психологическое благополучие жителей. Настоящее исследование направлено на изучение вредителей и болезней, влияющих на ландшафтные растения, и предложение мер по уходу за пораженными растениями, повышению их устойчивости в городских условиях с дальнейшим применением ГИС-технологий для создания системы данных, которая поможет эффективно управлять растениями. Используются методы морфологического сравнения для классификации растений и выявления вредителей и болезней. Кроме того, технология ГИС применяется для оцифровки собранных данных с помощью программного обеспечения Mapinfo Professional 15. В ходе исследования получена информация о более чем 500 управляемых ландшафтных растениях вдоль основных дорог района Хай Чау г. Дананг, в результате чего было идентифицировано 27 видов растений и 12 типов вредителей и болезней. В целом современное состояние ландшафтных растений на территории исследования благоприятное, пораженность вредителями и болезнями минимальна. Обнаружено лишь несколько наклоненных деревьев, которые могут упасть, что позволяет предложить их удаление и замену новыми экземплярами. По итогам работы создана оцифрованная карта озеленения анализируемой территории.

Ключевые слова: городская среда, ГИС-технологии, Дананг, ландшафтные растения, вредители, болезни

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Introduction

As urban areas continue to develop, the urban greenery system becomes increasingly important. Green plants are integral to architectural structures and are vital in climate regulation, environmental protection, and addressing ecological issues. The development of urban greenery can be likened to constructing “green lungs” for the city, helping regulate air quality in the face of increasing environmental pollution. The urban greenery system also serves as a focal point for residents’ recreational, leisure, and cultural activities.

Currently, countries are interested in applying GIS software in various fields. However, there is still limited research on the application of GIS in managing the current status of landscape plants, with only a few related studies available. For example, in Russia, GIS has been applied in such studies as “Application of GIS technologies in Monitoring and Assessing the Condition of Agricultural Land in the Kazakh Sector of the Caspian Sea” [14]; and “Landscape Zoning of the Sea of Azov Using Elements of GIS Technologies” [3]. In Germany, GIS technology has been utilized in the topics like “GIS in Landscape Planning” [24]. There is also a research project in India on “Applications of GIS in Plant Taxonomy, Species Distribution and Ecology” [29]. In the United States, GIS is used in tree management. Several tree management software programs have been developed, such as CANOPY (urban forest management planning, tree risk management policy, natural area restoration, consultation, tree conservation regulations, urban forest program auditing, tree inventory, GIS mapping) and SILVIBASE (tree inventory, inventory auditing, and reporting) [1]. In terms of research on the current status of landscape plants, there are several studies by scientists such as O.N. Ezhov [9], K. Tubby [30], and K.M. Vail [31]. Additionally, the study “Effectiveness of Poisonous Plants in The Fight with Pests and Diseases of Field and Garden Crops” by T.L. Chapalda explores the role of toxic plants in pest and disease control [4].

In recent years, the city of Da Nang has changed its urban landscape, particularly in its urban greenery system, which exhibits diversity in plant species. However, the urban environment is not optimal for plant growth, exacerbated by pollution and dust, leading to the proliferation of various pests and diseases in landscape plants. Meanwhile, there is a lack of comprehensive research on the current status of pests and diseases affecting urban plants in Vietnam. In 2016, a study titled “Applying Remote Sensing and GIS to Research and Evaluate the Current Status of Urban Greenery in Cau Giay District” [1] has been carried out and other related studies included into a research project in Hue in 2006 [12]. In Ho Chi Minh City, in 2008, Dr. C.D. Ly led a research project titled "Building an Information System for Managing Street Trees and Parks in Ho Chi Minh City" [17]. In Da Nang there has also been a study titled "Applying GIS to Manage Shade Trees on Some Streets in Hai Chau District, Da Nang City" [25]. However, there has been limited attention regarding the current status of landscape plants, particularly the study of pests and diseases affecting them. Only a few studies have been carried out, such as "Composition and Basic Biological Characteristics of Ornamental Plant Pests of the Genus Ficus in Xuan Mai Area" [22], "Preventing Pests and Diseases of Ornamental Plants" [19] and "Current Status and Development Solutions Shade Trees for Street System in Thanh Hoa City" [10]. As for the landscape plants in the city of Da Nang, no specific research studies have been conducted thus far. Therefore, the current one aims to collect data to understand the occurrence of pests and diseases on urban plants in the city of Da Nang and propose methods to enhance the resilience of these plants in the urban environment. This will be achieved by applying GIS technology for data digitization, to support urban greenery management authorities.

Research Objects and Methods

Da Nang is located in a tropical monsoon climate zone, with high air temperatures (on average, 25 °C) and minimal fluctuations. There are 2 distinct seasons: the dry season from January to September and the rainy season from October to December. Occasionally, there are brief periods of intense cold, but they are not prolonged. The average air humidity is 83.4 %. Da Nang is a city with a rare diversity of landscapes and ecological environments, with landscapes changing from mountainous areas to deltas to coastal area regions. However, compared to 1997, the urban area of Da Nang has expanded about 4 times. This has led to an increasing narrowing of the urban tree area, along with the effects of urbanization on the living conditions of landscape trees such as changes in temperature, dust, noise, and the narrowing of the growing space for trees. The research has been conducted on landscape plants along several major roads in Hai Chau District, Da Nang, including Cao Thang, Thanh Son, Thanh Hai, Thanh Thuy, and Ly Tu Trong, totaling more than 500 trees. These landscape plants all grow under the environmental and climatic conditions of the city of Da Nang.

Firstly, a survey has been conducted in the study area, selecting roads with many landscape plants. The survey has aimed to determine the current health status of the trees, specifically identifying pests and diseases. A digital map has been established to monitor, manage, and implement remedial and care measures for the trees under study.

The comparative morphological method has been utilized for plant classification [2, 7]. This method relies on the external characteristics of the plant's nutritional and reproductive organs. In classification, the study of reproductive organs is essential because its characteristics are closely related to the genetic code and are less influenced by environmental conditions. Comparing these characteristics and morphological features in classification is known as morphological comparison. Accordingly, plant classification is based on the morphological features of leaves, branches, flowers, bark, and stems, as described in the book "Ornamental Plants and Flowers of Vietnam" by T. Hop [11, 21].

The identification of pests and diseases affecting landscape plants based on their morphological characteristics is described in the book “Preventing Pests and Diseases of Ornamental Plants” [19], and the book “Preventing Pests and Diseases on Some Popular Flower Species” [8]. After obtaining the necessary data (pest samples, images of leaves damaged by pests, images of diseases on trees, etc.) the types of pests have been identified [6, 18]. Methods to improve plant resistance have been based on the studies by T. Hop [11, 21] and T.V. Mao et al. [19]. The method for determining the social status of trees according to the International Union of Forest Research Organizations (IUFRO) is based on the judicial and regulatory acts of the Russian Federation, specifically the Decree of the Russian Federal Forestry Agency dated 10.11.2011 no. 472 (as amended on 15.03.2018) “On the Approval of Methodological Recommendations for the Conduct of State Forest Inventory”.

GIS technology digitizes the collected data using Mapinfo Professional 15 software. The sequence of steps for establishing the database is as follows (Fig. 1) [15, 16].

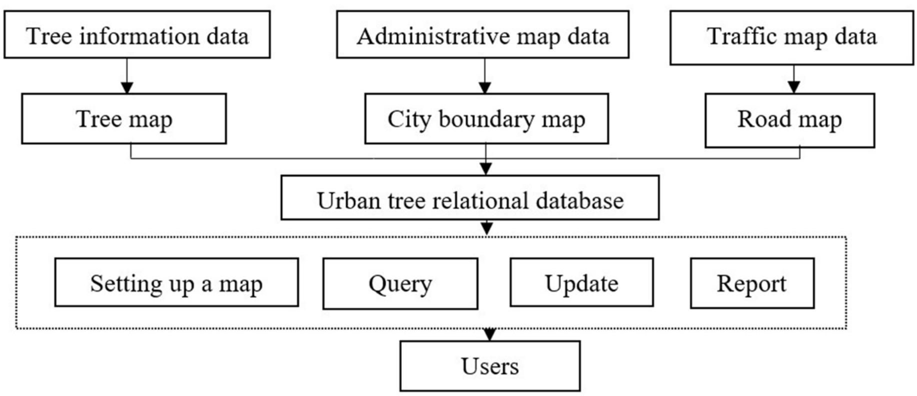

Fig. 1. The diagram of the database setup steps

After obtaining the green tree information database, the data has been collected on the administrative map, city boundaries, transportation, and road network maps. With the administrative and transportation maps, as well as green tree data in possession, the map has been georeferenced. Subsequently, the boundary map and transportation map have been created. Based on the obtained tree database, the next step has been to establish a tree map (Fig. 2).

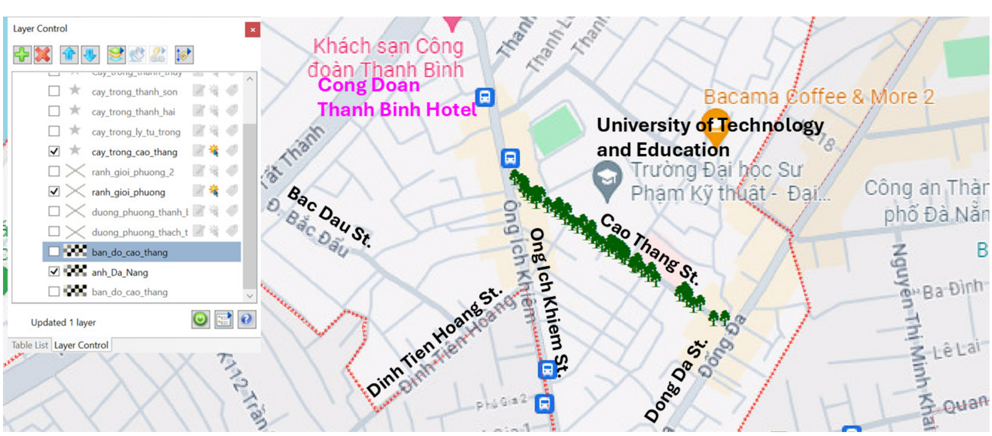

Fig. 2. Digitizing the information on the crop on Cao Thang Street

After digitization, the tree will be displayed on the screen when the mouse is moved to its location (Fig. 3).

Fig. 3. Tree information on the tree displayed on the screen

After successful digitization, all the databases of coordinates, tree names, and tree statuses, such as pests, diseases, diameter (D), and height (H), are displayed by the software (Table 1). This helps the managers easily understand the crop's location and current status. And then it is also possible to update and change the data.

Table 1

An exapmle of the digitized tree data

No.	X coordinates	Y coordinates	Scientific name of the plant	Current status of pests and diseases on trees	Pests causing diseases in plants	D	H
1	108.21219700	16.07746900	*Terminalia catappa* L.	Leaves are eaten by worms and turn yellow	*Arna pseudoconspersa* Strand	25.30	6
2	108.21225400	16.07742300	*Terminalia catappa* L.	Leaves are eaten by worms and turn yellow	*Arna pseudoconspersa* Strand	21.70	9
3	108.21231000	16.07738900	*Terminalia catappa* L.	Leaves are eaten by worms, turn yellow and have leaf spots	*Arna pseudoconspersa* Strand	20.00	10
…	…	…	…	…	…	…	…

After obtaining the dataset, calculations of the Average Diameter (AD), Average Height (AH), and the frequency of disease occurrence at each location are carried out via Python 3.13.0 software. With the help of Python software, statistical analysis (correlation analysis, logistic regression model, chi-squared test) is performed to examine the relationship between the presence of the disease and the tree location, as well as the diameter and height of the tree.

Correlation Analysis. Correlation analysis is a method of measuring the degree of correspondence between the orders of 2 random variables [13]. It helps to indicate the relationship between the occurrence of pests and the location of the crop [28].

Chi-Squared Test. The chi-squared test is a non-parametric statistical method used to analyze categorical data and assess the relationship between variables. In this case, it is used to determine the statistical significance between the disease and the height and diameter of the tree [5, 26].

Logistic Regression Model. Logistic regression models are used to study the effects of predictor variables on classification outcomes, especially binary outcomes [23]. Logistic regression models have been effectively used to predict the occurrence of diseases and tree characteristics in various forest ecosystems. Studies have shown a relationship between tree bark beetle outbreaks and factors such as tree size, tree density, and topography [27]. The relationship between tree height-diameter and growth patterns has been modeled using logistic regression [20]. This study uses the logistic regression model to determine the relationship between the diameter, height, and the likelihood of tree disease infestation.

Results and Discussion

The List of the Planted Trees in the Study Area. Firstly, before commencing the process of digitizing the landscape tree map, it has been essential to obtain data on these trees. Consequently, an investigation and data collection regarding the current status of landscape trees in the study area have been performed. Based on the results of the survey conducted along Cao Thang, Ly Tu Trong, Thanh Hai, Thanh Son, and Thanh Thuy Streets, a general observation has been made that the landscape trees in the city undergo regular pruning before the rainy season to mitigate the occurrence of falling or breaking incidents. As a result, these trees exhibit an average height ranging from 5 to 10 m, with an average diameter of 20 to 25 cm. The classification of the trees along the streets above is presented in Table 2.

Table 2

The list of the trees planted in the study area

Order	Family	Genus	Species	Average diameter (AD, m)	Average height (AH, m)
Magnoliales	Magnoliaceae	*Magnolia*	*Magnolia × alba* (DC.) Figlar	17.0	6.8
Caryophyllales	Nyctaginaceae	*Bougainvillea*	*Bougainvillea glabra* Choisy	10.7	5.0
Ericales	Lecythidaceae	*Barringtonia*	*Barringtonia acutangula* (L.) Gaertn.	22.4	5.4
	Sapotaceae	*Mimusops*	*Mimusops elengi* L.	18.7	5.0
Rosales	Moraceae	*Artocarpus*	*Artocarpus altilis* (Parkinson) Fosberg	26.9	6.7
			Artocarpus heterophyllus Lam.	8.0	3.5
		Ficus	*Ficus racemosa* L.	24.1	4.8
			Ficus bengalensis L.	33.2	5.7
Fabales	Fabaceae	*Peltophorum*	*Peltophorum pterocarpum* (DC.) K. Heyne	28.0	7.5
		Erythrina	*Erythrina fusca* Lour.	24.5	5.0
		Cassia	*Cassia fistula* L.	22.8	9.3
		Pterocarpus	*Pterocarpus macrocarpus* Kurz	15.1	6.5

End of Table 2

Order	Family	Genus	Species	Average diameter (AD, m)	Average height (AH, m)
Fabales	Fabaceae	*Tamarindus*	*Tamarindus indica* L.	24.4	7.1
		Samanea	*Samanea saman* (Jacq.) Merr.	27.8	8.0
	Leguminosae	*Phanera*	*Phanera purpurea* (L.) Benth.	27.8	7.0
Myrtales	Combretaceae	*Terminalia*	*Terminalia catappa* L.	23.2	6.7
			Terminalia mantaly H.Perrier	20.4	5.2
	Lythraceae	*Lagerstroemia*	*Lagerstroemia speciosa* (L.) Pers.	23.7	5.1
Sapindales	Anacardiaceae	*Mangifera*	*Mangifera indica* Linnaeus	16.4	5.0
	Meliaceae	*Chukrasia*	*Chukrasia tabularis* M.Roem	24.4	5.8
		Khaya	*Khaya senegalensis* (Desr.) A. Juss.	23.4	5.7
Oxalidales	Oxalidaceae	*Averrhoa*	*Averrhoa carambola* L.	10.1	3.1
Gentianales	Apocynaceae	*Alstonia*	*Alstonia scholaris* L. R. Br.	26.0	6.4
		Thevetia	*Thevetia peruviana* (Pers.) K. Schum.	2.3	2.0
Lamiales	Bignoniaceae	*Spathodea*	*Spathodea campanulata* P. Beauv.	11.8	7.0
Arecales	Arecaceae	*Chrysalidocarpus*	*Chrysalidocarpus lutescens* H. Wendl	10.1	5.2
		Washingtonia	*Washingtonia filifera* (Lind.) H. Wendl	25.7	9.0

Thus, after conducting the surveys along Cao Thang, Thanh Son, Thanh Hai, Thanh Thuy, and Ly Tu Trong Streets, a catalog of 27 tree species has been compiled, totaling over 500 trees. The most commonly encountered species are *Peltophorum pterocarpum* (40 %), *Terminalia catappa* (20 %), and *Chukrasia tabularis* (10 %). The least frequently encountered ones are *Thevetia peruviana* (0.04 %), *Washingtonia filifera* (0.04 %), and *Artocarpus heterophyllus* (0.04 %).

The Catalog of Pests and Diseases in the Study Area. Once the catalog of landscape trees has been compiled, the next step has been to create a database on the pest and disease status of the trees. Following the investigation, a database has been gathered of pests and diseases affecting each tree along Cao Thang, Ly Tu Trong, Thanh Hai, Thanh Son, and Thanh Thuy Streets (Table 3). The trees have been sequentially numbered to correspond their respective locations, facilitating the process of constructing the green tree data map.

Table 3

The catalog of pests and diseases in the study area

Tree location	Scientific name of the plant	Pests causing diseases in plants
Thanh Thuy: 1, 2, 4, 5, 7, 11, 16, 18–20, 22, 26, 32–34, 36, 40, 41, 43, 44, 47, 53, 54, 57, 60, 77, 78, 85, 87, 99, 100, 105, 106, 110–113, 117, 122, 123, 128, 129, 131–133, 138, 139, 144, 145, 146, 148, 149, 151. Thanh Hai: 3, 4, 12, 14, 15, 16, 21–23, 29, 30, 34, 37, 43, 44, 46, 49, 51, 52 Thanh Son: 58, 79, 80, 82, 85, 86 Cao Thang: 26, 37, 44, 47 Ly Tu Trong: 1–7, 10–12, 15, 17–20, 23, 24, 28, 42, 43, 77, 88–100, 104–106.	*Peltophorum pterocarpum* (DC.) K. Heyne	*Pericyma cruegeri* Butler
Thanh Thuy: 3,10, 28, 82, 142	*Ficus racemosa* L.	*Gynaikothrips uzeli* Zimmerman
Thanh Hai: 6 Thanh Son: 8, 10	*Ficus bengalensis* L.	*Ocinara varians* Walker
Thanh Thuy: 8, 9, 37, 38, 46, 61, 62, 80, 81, 89, 90, 124, 125, 136, 137 Thanh Hai: 7–9, 31, 32, 41, 47, 48 Thanh Son: 9, 50, 64, 65, 74 Cao Thang: 11, 21, 24, 43 Ly Tu Trong: 40, 41, 44, 45, 69, 82, 83, 112	*Barringtonia acutangula* (L.) Gaertn.	*Pestalotia sp*
Thanh Thuy: 12, 50–52, 75, 76, 79, 91, 104, 115, 116, 140, 141, 147 Thanh Hai: 5, 6, 17, 18, 20, 25, 35, 36, 45 Thanh Son: 1,3, 4, 6, 11–13, 41–43, 51, 52, 62, 73 Cao Thang: 1–5, 9, 10, 19, 25, 31, 34, 36, 42 Ly Tu Trong: 8, 9, 37–39, 60–62, 70, 71, 80, 109, 110, 111	*Terminalia catappa* L.	*Arna pseudoconspersa* Strand
Thanh Thuy: 13, 48, 71, 94, 95 Thanh Hai: 10, 11 Thanh Son: 29 Cao Thang: 28 Ly Tu Trong: 48	*Chrysalido carpuslutescens* H. Wendl	*Dasichira mendosa* Hubner
Thanh Thuy: 14, 21, 64–66, 86, 97, 98, 118, 119 Thanh Sơn: 57, 77, 78, 83 Cao Thang 7, 8 Ly Tu Trong: 76	*Terminalia mantaly* H.Perrier	*Thosea sinensis* Walker
Thanh Thuy: 49, 70 Thanh Hai: 13, 24, 53 Thanh Son: 2, 5, 7, 17, 20, 22–25, 30–32, 37–40, 47, 49, 53–56, 59, 63, 67, 68, 71, 72, 76 Cao Thang: 13, 14, 15, 17, 22, 23, 27, 29, 39, 40, 41, 45 Ly Tu Trong: 49–51, 56–59, 66, 68, 72–75, 78, 81, 85	*Chukrasia tabularis* M.Roem	*Plocaederus obesus* Gahan
Thanh Thuy: 58, 59, 88, 96, 107, 127 Thanh Hai: 42 Thanh Son: 61, 70, 75, 84 Cao Thang: 18, 20 Ly Tu Trong: 79	*Alstonia scholaris* L. R. Br.	*Josephiella microcarpae* Beardsley & Rasplus

End of Table 3

Tree location	Scientific name of the plant	Pests causing diseases in plants
Ly Tu Trong: 25–27, 29, 31–34, 97–99, 101, 103	*Magnolia × alba* (DC.) Figlar	*Phyllosticta yugokwa* Saw.
Thanh Son: 69	*Thevetia peruviana* (Pers.) K. Schum	*Euploea core amymone* Godart
Thanh Thuy: 143 Thanh Son: 26	*Mangifera indica* Linnaeus	*Planococcus citri* Risso

After investigating the street pest status, 12 types of pests have been identified, *Pericyma cruegeri* being the largest, accounting for 40 %. Among more than 500 trees, 90 % have been found to have pests and diseases, but the rate of pests and diseases on trees is not high.

The results of the investigation in Table 1 and the results of the disease survey have been used to determine the social status of trees according to the IUFRO classification, as presented in Table 4.

Table 4

The social status of trees according to the IUFRO classification

<table>
<tr><th>Species</th><th>Height</th><th>Viability</th><th>Growth Trend</th></tr>
<tr><td>Magnolia × alba (DC.) Figlar</td><td>Upper canopy</td><td>Class 2</td><td>Stable</td></tr>
<tr><td>Bougainvillea glabra Choisy</td><td rowspan="3">Middle canopy</td><td>Class 1</td><td>Ascending</td></tr>
<tr><td>Barringtonia acutangula (L.) Gaertn.</td><td rowspan="2">Class 2</td><td rowspan="2">Stable</td></tr>
<tr><td>Mimusops elengi L.</td></tr>
<tr><td>Artocarpus altilis (Parkinson) Fosberg</td><td rowspan="4">Upper canopy</td><td>Class 1</td><td>Ascending</td></tr>
<tr><td>Artocarpus heterophyllus Lam.</td><td>Class 2</td><td>Stable</td></tr>
<tr><td>Ficus racemosa L.</td><td>Class 1</td><td>Ascending</td></tr>
<tr><td>Ficus bengalensis L.</td><td rowspan="6">Class 2</td><td rowspan="6">Stable</td></tr>
<tr><td>Peltophorum pterocarpum (DC.) K. Heyne</td><td rowspan="4">Middle canopy</td></tr>
<tr><td>Erythrina fusca Lour.</td></tr>
<tr><td>Cassia fistula L.</td></tr>
<tr><td>Pterocarpus macrocarpus Kurz</td></tr>
<tr><td>Tamarindus indica L.</td><td rowspan="2">Upper canopy</td></tr>
<tr><td>Samanea saman (Jacq.) Merr.</td><td>Class 1</td><td>Ascending</td></tr>
<tr><td>Phanera purpurea (L.) Benth.</td><td>Middle canopy</td><td rowspan="9">Class 2</td><td rowspan="9">Stable</td></tr>
<tr><td>Terminalia catappa L.</td><td>Upper canopy</td></tr>
<tr><td>Terminalia mantaly H.Perrier</td><td rowspan="2">Middle canopy</td></tr>
<tr><td>Lagerstroemia speciosa (L.) Pers.</td></tr>
<tr><td>Mangifera indica Linnaeus</td><td rowspan="3">Upper canopy</td></tr>
<tr><td>Chukrasia tabularis M.Roem</td></tr>
<tr><td>Khaya senegalensis (Desr.) A. Juss.</td></tr>
<tr><td>Averrhoa carambola L.</td><td>Middle canopy</td></tr>
<tr><td>Alstonia scholaris L. R. Br.</td><td>Upper canopy</td></tr>
<tr><td>Thevetia peruviana (Pers.) K. Schum.</td><td>Lower canopy</td><td>Class 1</td><td>Ascending</td></tr>
<tr><td>Spathodea campanulata P. Beauv.</td><td rowspan="3">Middle canopy</td><td>Class 2</td><td>Stable</td></tr>
<tr><td>Chrysalidocarpus lutescens H. Wendl</td><td>Class 1</td><td>Ascending</td></tr>
<tr><td>Washingtonia filifera (Lind.) H. Wendl</td><td>Class 2</td><td>Stable</td></tr>
</table>

Each living tree has been evaluated using the modified IUFRO classification based on tree height, viability, and growth trend. Each of the described characteristics has been assessed independently. The results show that the landscape trees in the study area are mostly middle canopy, with the ability to survive in class 2 (standard tree) and the growth trend is stable (growth is consistent). Some species that are well adapted to the urban environment are in a good state of development (class 1), especially *Bougainvillea glabra* Choisy, which is a very typical species in the landscape of the city of Da Nang (this species blooms year-round, creating diverse colorful patches in the city landscape).

However, certain trees like *Lagerstroemia speciosa* exhibit stunted growth, with leaves mostly fallen and branches broken, resulting in a loss of urban aesthetics, such as trees numbered 14, 15, 16, and 36 along Thanh Son Street. Therefore, these trees should be uprooted and replanted with trees that can withstand Da Nang's weather conditions. Many trees lean towards the road, and branches can break when the wind is strong, causing safety issues for road users. Large branches like those of trees 10, 25, 36, and 85 along the Ly Tu Trong Street need to be cut down.

Digitizing the Landscape Tree Map. According to the above steps, the tree map of the roads has been digitized as follows: Cao Thang, Thanh Hai, Thanh Son, Thanh Thuy, Ly Tu Trong (Fig. 4).

a *b* *c* *d* *e*

Fig. 4. The landscape trees on:
a – Cao Thang Street; *b* –Thanh Hai Street;
c – Thanh Son Street; *d* – Thanh Thuy Street;
e – Ly Tu Trong Street

After that, the digital map of landscape trees of Hai Chau District, Da Nang has been created with Mapinfo Professional 15 and Python 3.13.0 software (Fig. 5). The software can quickly support tree management. In future, during the query process, it will be possible to add, remove and change tree data directly via the software.

Fig. 5. The digital map of landscape trees in Hai Chau District, Da Nang

The Results of Analysis of the Relationship between Pests and Tree Location. Statistical analysis of the collected data has been conducted to examine the relationship between the presence of the disease and the location of the trees. Initially, the frequency of disease occurrence at each location has been calculated using Python 3.13.0 software. The results are presented in Table 5.

Table 5

The frequency of disease occurrence at each location

Location	Disease Occurence Frequency
Cao Thang	0.765957
Ly Tu Trong	0.735294
Thanh Hai	0.698413
Thanh Son	0.976744
Thanh Thuy	0.836601

According to the results, Thanh Son Street is at the top with a frequency of 0.976744, and Thanh Hai Street is at the bottom with a frequency of 0.698413. Thanh Thuy, Cao Thang and Ly Tu Trong Streets are at the 2nd, 3rd and 4th places, respectively. Based on this table, correlation analysis and chi-squared test have been performed to determine statistical significance. The calculations resulted in a chi-squared value of 26.664303833569036 and a p-value of 2.3239746880920638e-05. As the results show, a p-value less than 0.05 is observed, indicating a statistically significant relationship between the tree location and the disease status. Thus, it can be concluded that the location is a factor influencing the disease status.

Another hypothesis is proposed: whether the height and diameter of the trees are related to the disease status. To investigate this hypothesis, correlation analysis and logistic regression have been performed. The results of the correlation analysis between pests and height and diameter show a correlation value between pests and diameter of 0.10309905001739862 and a correlation value between pests and height of 0.06347175723006228.

The correlation coefficient between pests and diameter of 0.1031 indicates a weak positive correlation, meaning that as the tree diameter increases, the likelihood of pest infestation also tends to increase, but this relationship is very weak and only shows a slight trend. The correlation coefficient between pests and height of 0.0635 demonstrates a very weak correlation, indicating almost no clear relationship between tree height and pest infestation. Thus, tree height does not significantly influence the occurrence of pests.

Next, a logistic regression model has been used to determine the relationship between the diameter, height, and the likelihood of tree infestation. The results are shown in Table 6.

Table 6

The relationship between the D, H and the susceptibility of plants to pests and diseases

Optimization terminated successfully.
Current function value: 0.474250
Iterations 6

Logit regression results

Dep. variable: Pests and diseases presence	*No. observations*: 480
Model: Logit	*Df Residuals*: 477
Method: MLE	*Df Model*: 2
Date: Mon, 16 Sep 2024	*Pseudo R-squ.*: 0.03532
Time: 10:11:35	*Log-Likelihood*: –227.64
Converged: True	*LL-Null:* –235.98
Covariance Type: Non-robust	*LLR p-value*: 0.0002399

	coef	std err	z	P>|z|	[0.025	0.975]
const	0.0531	0.435	0.122	0.903	–0.799	0.905
D	0.0547	0.015	3.667	0.000	0.025	0.084
H	0.0268	0.057	0.472	0.637	–0.085	0.138

The model shown in Table 6 can be explained as follows:

Dependent variable: Pests and diseases presence.

Number of observations: 480.

Pseudo R-squared: 0.03532, meaning the model explains approximately 3.5 % of the variation in the data.

Log-Likelihood: –227.64, compared to LL-Null (model with no independent variables) of – 235.98.

LLR p-value: 0.0002399, indicating that the model is statistically significant overall ($p < 0.05$).

The results for each variable:

Constant (const):

Coefficient: 0.0531, with a p-value = 0.903. This indicates that the constant is not statistically significant ($p > 0.05$), suggesting it may not significantly impact the prediction outcomes.

Variable D (Tree Diameter):

Coefficient: 0.0547, with a p-value = 0.000, statistically significant ($p < 0.05$), indicating that as tree diameter increases, the probability of tree pests also increases. 95 % Confidence Interval: [0.025, 0.084], indicating that the effect of D on the probability of pests is positive and significant.

Variable H (Tree Height):

Coefficient: 0.0268, p-value = 0.637, not statistically significant ($p > 0.05$), meaning that tree height does not significantly affect the probability of pest infestation in this dataset. 95 % Confidence Interval: [–0.085, 0.138], indicating that the effect of tree height is not clear.

From this, it can be concluded that the tree diameter (D) significantly influences the probability of tree infestation (as the tree diameter increases, the likelihood of pest infestation also increases). The tree height (H) does not have a clear relationship with the occurrence of pests and diseases in this dataset. In reality, Da Nang is a city prone to storms and typhoons, so landscape trees in the city are often pruned and controlled for height. This practice has influenced the analysis of the relationship between tree height and pest infestation in this study.

Methods to Improve Plant Resistance. Watering: Provide enough water for landscape plants, depending on the species and their requirements. However, avoid overwatering to prevent waterlogging and harm to the plant.

Fertilization: Use organic or chemical fertilizer to provide necessary nutrients for plants. Depending on the plant type and requirements, follow fertilizer application instructions to avoid over- or under-nutrition.

Pruning: Perform pruning to maintain the shape and size of landscape plants. Remove damaged branches, unnecessary saplings and buds to encourage growth and create a more beautiful tree shape.

Weed Control*:* Remove unwanted weeds and grass from the base of landscape plants. Weeds can compete with plants for water and nutrients, so keep the area around plants clean.

Pest Inspection and Treatment: Monitor landscape crops to detect early signs of pests and other problems. If an infestation is detected, appropriate treatment, such as using pesticides or natural control methods, should be taken to stop the spread and protect the tree's health.

Organize and Clean the Surrounding Area: Keep the area around landscape plants clean and tidy. Remove fallen leaves, dry twigs and other unnecessary materials to prevent the accumulation of insects and diseases.

Protect Plants from Adverse Weather: In case of adverse weather, such as heat, rain, storms, or cold, protect plants by using tarpaulins, firewood, or glass screens.

Monitor and Manage Soil Quality: Check pH, aeration and nutrient concentration to ensure good soil quality for landscape plants. Adjust soil quality by adding organic fertilizer or amendments depending on the test results.

Plant Storm-Resilient Plants: Especially for areas prone to storms like Da Nang, it is recommended to plant trees that are resilient and can withstand storms well such as *Dipterocarpus alatus* Roxb. ex G.Don, *Hopea odorata* Roxb., *Sindora siamensis* Teijsm. ex Miq., etc.

Prepare Planting Holes Thoroughly: In particular, to improve the tree's resistance, it is recommended to invest in tree planting holes and focus on changing the following:

You should replace sandy soil with loam or sandy loam to avoid uprooting plants;

Tree planting holes must comply with "National Standard TCVN 9257:2012 on Greenery Planning for Public Utilities in Urban Areas – Design Standards. Construction Publishing House. 2021". The size of the tree planting space is specified as follows: row trees on the sidewalk; square-shaped open holes: minimum 1.2 × 1.2 m; circle with a minimum diameter of 1.2 m. This ensures space for the tree's roots to grow. Meanwhile, most tree planting holes in the investigation area do not meet standards, so trees often tilt and fall.

When planting trees, the pit's depth should be greater than the root ball's height. If the tree has a root ball, it should be removed before planting, and fertilizers should be added below it to facilitate root growth. The tree's root base should be placed lower than the ground surface to enhance wind resistance.

Due to the hot and sunny weather in Da Nang, urban tree planting tends to prioritize immediate shade by planting tall and mature trees. However, this practice can have drawbacks. When transplanting tall trees, the roots must be pruned, which alters the root system and prevents deep root penetration. Therefore, it is recommended that young trees be planted to avoid disturbing the taproot and facilitate deep root development, preventing uprooting during storms. When the tree is young, you must carefully support it so it grows straight and does not tilt. Monitor and promptly remove any trees that show signs of leaning and replace them with new ones.

Conclusion

After investigating Cao Thang, Thanh Hai, Thanh Thuy, Thanh Son, and Ly Tu Trong Streets, over 500 trees have been selected for the study organized into a list of 27 tree species. Among them, the most common trees are *Peltophorum pterocarpum*, *Terminalia catappa*, *Barringtonia acutangula*, and *Chukrasia tabularis*; the least common trees are *Averrhoa carambola*, *Mangifera indica*, *Artocarpus heterophyllus*, *Chrysalidocarpus lutescens*, and *Thevetia peruviana*. A pest investigation of the trees has been conducted. Most landscape trees in the study area have common pests and diseases, for example, *Peltophorum pterocarpum* are infested with *Pericyma cruegeri*. All the data on the current status of landscape plants have been built on GIS maps through Mapinfo 15 software, supporting managers in understanding the current status of each plant and updating changes in the following years. The statistical analysis results indicate that the position and diameter of the tree have an impact on the presence of pests and diseases, while the effect of tree height is not clear.

The findings on the soil and light conditions in the study area show that such trees as *Peltophorum pterocarpum*, *Terminalia catappa*, *Terminalia mantaly*, *Chukrasia tabularis*, *Alstonia scholaris*, *Mimusops elengi*, etc., are thriving and adapting well. However, some trees demonstrate stunted growth, leaf shedding, branch breakage, and aesthetic issues in urban areas. Trees leaning towards the road pose a safety hazard to traffic participants, especially during strong winds. Therefore, these trees need to be removed and replaced with more climate-adaptive species suitable for the climate of Da Nang. To improve tree resilience, attention should be given to tree hygiene, tree care, proper tree planting, and planting trees when they are young.

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