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Original Research Article

Assessment of Urban Afforestation Performance Using a Multiple-Criteria Floristic Inventory and Strengths, Weaknesses, Opportunities, and Threats Analysis

*Fernando Lima[1], Mohammad K. Najjar[2], Assed Haddad[2], Elaine Vazquez[*1]*

[1]Programa de Engenharia Urbana, Universidade Federal do Rio de Janeiro, Brazil.
e-mail: fernandoacylino@poli.ufrj.br, elaine@poli.ufrj.br

[2]Programa de Engenharia Ambiental, Universidade Federal do Rio de Janeiro, Brazil
e-mail: mnajjar@poli.ufrj.br, assed@poli.ufrj.br

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ABSTRACT

This exploratory study evaluated the structural and phytosanitary condition of green infrastructure in the Humaitá street, Rio de Janeiro, Brazil. Environmental and ecological attributes were analysed using a Multiple Criteria Urban Tree Inventory framework. Field survey data were collected via a route-based census to cataloging 53 tree individuals, recording biometrics, species adaptation, utility conflicts, and phytosanitary health. A numerical coding scale mapped attributes into an adapted evaluation framework inspired by Strengths, Weaknesses, Opportunities, and Threats principles. Results indicate that 54.7% of surveyed trees are mature autochthonous species exhibiting good crown structure, but significant management challenges exist, including 15 trees with hollow trunks and 16 trees in severe conflict with overhead utilities. Combining multi-criteria inventories with structured matrix evaluations provides a transparent decision-support tool for strategic urban tree management.

KEYWORDS

Green infrastructure, Urban Afforestation, Floristic inventory, SWOT analysis, Ecological value, Multiple criteria analysis.

INTRODUCTION

In the 21st century, humanity is facing unprecedented economic and social challenges caused mainly by recent climate change and the prospect of a progressive shortage of food and raw materials [1]. Cities across the globe consume approximately 75% of the worldwide primary energy and is responsible for more than 70% of CO_2 emissions [2]. The worldwide phenomenon of urbanization and rapid population growth exponentially increases the pressure both on cities themselves and on the system that supports life in them [3]. Urbanization modifies land use and cause severe transformation in the natural landscape, altering environmental processes and triggering socioenvironmental issues that hinder urban sustainable development, which is aggravated by climate change [4]. Thus, there is an urgency to adopt strategies and methodologies that contribute to mitigating the effects of accelerated urbanization [5]. In the middle of the 18th century, several architects and critics of urbanism

* Corresponding author

started a movement to combat the bad occupation of urban land. The most prominent forerunners of this movement are the industrialist Robert Owen, the sanitation specialist Benjamin Ward Richardson, the architect Camillo Sitte, and the socialist Ebenezer Howard, the latter the creator of the concept of garden cities. These authors offered suggestions to modify the city planning process that resulted in the development of urbanization models focused on the relationship between the city and green spaces [6].

The garden city concept addresses the duality between urban and rural ways of life. The theory formulated by Ebenezer Howard suggests that urban living should be planned to embrace both dimensions and, precisely, to avoid a strict polarization between these environments. In his view, the ideal solution lies in the creation of spaces where the advantages provided by the diversity of activities and urban amenities are combined with the healthful benefits of rural life [7]. The implementation of green infrastructure contributes to the mitigation of several urban environmental problems, as it provides sustainable alternatives that consume less energy, protect biodiversity and reduce pollution. Ecologically designed cities, with well-planned and easily accessible public green spaces, also provide a high quality of life for all social strata of the urban population [8]. The study of living organisms, the environment, and their reciprocal influences holds enormous potential for application to human affairs, since the natural interactions of the biosphere consist of biological and physical processes. Ecology can be regarded as the most effective instrument for integrating the natural and social sciences. Therefore, ecological research aimed at developing lasting solutions to critical environmental problems must consider natural processes in conjunction with the socioeconomic and cultural conditions of the areas under study [9].

Urban nature, also called green infrastructure, is recognized as an important structural element in the composition of barriers that act to mitigate the consequences caused by environmental extremes. Wooded spaces and land with natural drainage retain rainwater, help maintain ecological flows, support the preservation of urban fauna, and even prevent the formation of “heat islands” [10]. It is important to consider the contribution of the vegetal element to the urban composition. Green spaces have a great capacity to absorb solar radiation and, consequently, radiate less heat than other materials, since the foliage retains a significant portion of the energy sequestered by the photosynthesis process [11].

The urban environmental problem in Brazil can be summarized as a consequence of the disproportionate growth of monofunctional gray infrastructure, which prioritizes automobiles at the expense of green areas. One of the outcomes of the expansion of gray infrastructure is the increasing impermeabilization of urban soil, which leads to rapid and inadequate stormwater drainage and results in flooding and landslides that frequently occur during the rainy season. Soil impermeabilization also disrupts the natural flows of the biotope, generating another negative consequence: the progressive reduction of biodiversity and, consequently, the ecological decline of the urban environment. Moreover, environmental degradation is further intensified by the burning of fossil fuels by the dominant modes of transportation. This uncontrolled emission of greenhouse gases is responsible for numerous health problems and for the formation of urban heat islands. In this context, it can be stated that the processes capable of fostering sustainable urban development are subject to numerous counteracting forces, which compromise natural cycle flows and promote the ecological degradation of extensive urban areas [12]. Recently, in order to mitigate the effects of urban environmental deterioration, several National Policies aimed at environmental preservation and at regulating the urban metabolism of Brazilian cities have been implemented to an unprecedented extent. In this way, the new legislation has provided the actors responsible for environmental management with the necessary instruments to address problems related to the ecological degradation of the urban environment [13].

The new legislation gave the professionals and experts for environmental management the necessary instruments to combat the problems related to the ecological degradation of the urban environment. As an example of these actions, at the municipal level, in the city of Rio de

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Janeiro, the Master Plan for Sustainable Urban Development (PDDUS - 2011) [14], and the Master Plan for Urban Afforestation of the City of Rio de Janeiro (PDAU-Rio, 2015) stand out [15]. Although these regulatory measures have the potential to place Brazil at the forefront of sustainable planning in the 21st century, the current difficulty, however, lies in the fact that socio-economic-cultural problems tend to attract the largest share of public investments, and the ecological agenda ends always relegated to the last action plan [16]. Moreover, the current problems of large cities are driven by the rapid expansion of social demands. In fact, the depletion of environmental resources has fueled the increase in social exclusion and has brought about a functional crisis in Brazilian municipalities, marked by insecurity stemming from socioeconomic disparities. In addition to the setbacks described above, it has been observed that sustainable models of urban, housing, and environmental management planning exhibit contradictory tendencies. Thus, even when there is an intention to consolidate certain administrative practices of decentralization and participation, it is possible to discern misguided approaches that directly threaten the preservation of natural resources [12].

This study considers the use of the ecological principle as a guiding framework for the dynamics of planning and environmental research to be fundamental, since only in this way will it be possible to establish guidelines for the construction of ecologically viable urban environments, integrated with the endemic landscape, and endowed with properties that mitigate environmental extremes while providing comfort and well-being. However, achieving positive outcomes in environmental matters could be facilitated by raising public awareness of potential economic "gains" directly associated with the preservation of natural resources. The implementation or restoration of a given Green Infrastructure should therefore always be preceded by explanations regarding the economic potential of biophilic urbanism, with emphasis on its importance for improving quality of life and public health.

This study assesses the characteristics and observed condition of the urban tree population along the main street of the Humaitá neighborhood, Rio de Janeiro, Brazil. The assessment considers three main dimensions: tree identity, adaptation to the urban setting, and phytosanitary and structural conditions. A multi-attribute assessment framework is used to organize the inventory information, identify relevant condition indicators, and support the preliminary identification of management and inspection needs. Although urban trees may contribute to environmental regulation and outdoor comfort, the present study does not directly measure these effects; rather, it provides an inventory-based assessment that may inform future investigations of the environmental performance of urban green infrastructure. However, a limited body of academic literature addressing the management and governance of urban Green Infrastructure is observed. Within the context of a heterogeneous set of biotic and abiotic interactions, a narrowly defined objective could not be achieved without a holistic approach to ecological and urban factors. Accordingly, to diagnose the mechanisms responsible for generating environmental patterns in the Humaitá neighborhood, the study also prioritized an assessment of the overall condition of the Green Infrastructure. As a result, the scope of the research was expanded through the development of an ecological value database, which enabled the construction of a relational analysis model linking ecological factors to environmental comfort. In this sense, the main objective was complemented by evaluations of the overall condition of Green Infrastructure in comparison with its performance in mitigating environmental extremes.

The contribution of the present study is the development of a methodological framework to elaborate an inventory for the evaluation of the general condition of each tree individual to enable the Ecological Value analysis of the existing trees in the course of the measurements. Such knowledge can be used to support activities associated with the urban planning of cities to promote green spaces integrated into the urban fabric. The ambition herein is to analyze the behavior of the Green Infrastructure, through the evaluation of the environmental and ecological performance of the urban tree inventory by a Multiple Criteria Floristic Inventory. Urban tree inventories have progressively evolved from basic records of species identity,

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location, and biometric characteristics into more comprehensive systems designed to support urban forest monitoring, ecological assessment, and management decisions [17]. Traditional field-based inventories provide information on species composition, tree dimensions, and visible condition, thereby supporting the identification of local characteristics and management requirements [18]. Nevertheless, the collection and interpretation of these data can be resource-intensive, particularly when inventories cover extensive urban areas or require repeated assessments over time. Recent research has therefore explored the integration of field inventories with digital technologies [19], remote sensing [20], and automated data-processing methods [21], to improve the spatial coverage, efficiency, and consistency of urban vegetation monitoring. Gupta et al. [22] reviewed technology-supported methods for monitoring urban greenery and highlighted the potential of combining different sensing approaches to obtain information on vegetation health. Their analysis also emphasized the trade-offs between spatial and temporal resolution, monitoring costs, and the level of detail available from different assessment techniques. Similarly, Sharma et al. [23] examined the integration of remote sensing and the i-Tree Eco model for assessing urban forest structure and ecosystem services. Their review identified opportunities for combining field-based information with LiDAR and multispectral or hyperspectral data to improve the estimation of tree dimensions and ecosystem-service indicators. However, the authors also identified limitations concerning the assessment of crown condition and the need to better understand uncertainty when remotely derived measurements are compared with field observations.The purpose of the present study of Humaitá St. Green Infrastructure was to inventory and evaluate the aspects of Ecological Value of the existing trees. Due to the importance of urban afforestation, several researches have been developed, addressing aspects ranging from the Floristic survey to the mapping of species such as, for example, the research carried out by Freitas et al. (2015) [24], Kramer, Krupek (2012) [25], Romani et al. (2012) [26], Santos et al. (2015) [27] e Souza, Cintra (2007) [28].

Developments in automated species identification have also expanded the possibilities for urban tree inventories. Velasquez-Camacho et al. [29] investigated the use of citizen-science applications and street-level imagery for the taxonomic identification of urban trees. Their research demonstrated the potential of combining artificial intelligence, remote sensing, and ground-level imagery to support the assessment of urban forest biodiversity at different spatial scales. These approaches can improve the availability of species-related information, although field verification remains important when taxonomic identification is uncertain or when detailed individual-tree condition assessments are required. In addition to technological developments, recent research has placed increasing emphasis on the relationship between tree condition and the characteristics of the urban environment. Wang et al. [30], investigated 907 street trees across 136 roads in Hangzhou, China, assessed tree health using indicators related to growth performance, crown quality, and crown vigor. Their findings showed differences in tree condition among species and districts and identified associations between tree health and near-ground growing conditions, including tree-pit area, spacing, and soil conditions. This study reinforces the importance of considering both individual-tree characteristics and the physical conditions in which trees develop when evaluating urban afforestation.

Recent evidence from Brazil also demonstrates the relevance of integrated street-tree assessments. Morais et al. [31] examined species composition, tree health, infrastructure conflicts, spatial variation, and carbon storage in a medium-sized Brazilian city. By combining information on tree condition and urban infrastructure interactions with ecosystem-service indicators, their study illustrates the importance of evaluating street-tree populations through multiple complementary dimensions. Such research is particularly relevant to Brazilian cities, where urban trees frequently coexist with dense transport and utility networks and where local inventories can support more informed maintenance and planning decisions. A further development concerns the use of decision-support methods to translate inventory information into practical urban forestry strategies. Zhang and Ludwig [32] reviewed decision-support

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methods and tools for urban tree planting, identifying different approaches for species selection, the identification of suitable planting areas, spatial prioritization, and planting-layout optimization. Their review highlights the diversity of available methods and the importance of matching decision-support approaches to the objectives, spatial scale, and data available for each application. Although these methods provide valuable support for planning new urban-tree populations, the assessment and prioritization of existing trees also require approaches capable of organizing information about current tree condition, adaptation constraints, and management needs.

Taken together, recent studies demonstrate substantial progress in digital inventory development, automated species identification, remote-sensing applications, tree-health monitoring, ecosystem-service assessment, and decision-support methods. However, these approaches address different assessment objectives and often require specific technologies, datasets, or analytical procedures. Field-based inventories remain particularly relevant when the objective is to document the condition of individual trees and identify visible interactions between vegetation and the surrounding urban infrastructure. The integration of these observations into a clear and operational management-oriented synthesis is therefore an important complementary task. In this context, the present study adopts a multiple-criteria floristic inventory to organize information on three complementary dimensions of the surveyed tree population: identity, including species characteristics and ecological attributes; adaptation, including biometric characteristics and interactions with urban infrastructure; and phytosanitary condition, including observed structural damage and visible signs of biological disturbance. These dimensions are evaluated through attribute-specific classification criteria and organized using a spreadsheet-based data system. The resulting information is subsequently synthesized through a (Strengths, Weaknesses, Opportunities, and Threats) SWOT-inspired matrix to facilitate the interpretation of favorable conditions, deficiencies, and potential management concerns.

The reference methodology adopted in this study for the elaboration of the Floristic inventory was the "inventory for Management Plan", of the "Census" type, where all individuals of a predetermined biological spectrum are registered [33]. In this context, this process is best suited for small areas or sites with few arboreal individuals. The biological spectrum of the inventory included Microfanerophytes, Mesophanerophytes and Megaphanerophytes. The formulation of models for data analysis of this study was based on the methodology used in PDAU Rio (2015) [15] and created from the data obtained, after careful analysis of the object area in the Floristic Inventory stage. The registration of the arboreal individuals was carried out through the *in situ* identification of species and families, complemented by bibliographic research of individual aspects of occurrence, regionality, environmental risk, wood category, and leaf abscission [34].

The Ecological Value analyses, related to the Adaptation aspects, were concentrated on the measurement of the biometric data of height, circumference at breast height, canopy diameter, and age of the trees [35]. In the Adaptation attribute, the conflicts of each individual with urban networks, buildings, and vehicle traffic, among others, were also evaluated [36]. In the context of Plant Health, the fieldwork noted the traces of termite attacks and the presence of hemiparasites, in addition to diagnosing the phytopathology observed in the branches and trunks [35]. Relevant aspects of the research can be mentioned: the elaboration of an ecological value database, which allowed the creation of a relational analysis model between ecological and environmental comfort factors and the elaboration of an analytical criteria to identify problems that would simplify the management of the urban tree population inventory.

The methodological contribution of this research is the application of a structured field-inventory procedure that combines several individual-tree attributes and presents their results in a format intended to facilitate interpretation and management-oriented diagnosis. The spreadsheet supports the organization and graphical presentation of the inventory data, while the final synthesis matrix is manually compiled from the resulting assessments. This distinction

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is important because the classification of individual attributes and their presentation in the synthesis matrix do not constitute an independently validated prediction of tree failure or a quantitative measurement of ecosystem services. Accordingly, the present study contributes an applied assessment framework for the surveyed section of Humaitá Street, Rio de Janeiro, Brazil. The framework provides a structured description of the inventoried trees and highlights attributes that may require monitoring, maintenance, or further technical inspection by combining species identification, urban-adaptation characteristics, and visible phytosanitary conditions. Its application is intended to complement existing urban-tree inventory and management approaches, particularly in contexts where detailed field observations are available but a concise system for organizing and interpreting individual-tree information is needed.

Despite the progress in urban tree monitoring and decision-support methods, there remains a practical need for assessment procedures that organize field-observed information on individual trees into an interpretable structure connecting species characteristics, adaptation to the built environment, and phytosanitary conditions. The present study addresses this applied need through the following objectives: (1) to characterize the species composition and selected ecological attributes of the trees recorded within the defined Humaitá Street survey route; (2) to assess their biometric characteristics, adaptation to the urban environment, and observed phytosanitary conditions using predefined attribute-specific classifications; and (3) to synthesize the assessment results through a SWOT-inspired matrix to identify favorable conditions, deficiencies, and potential management priorities. The study is exploratory and site-specific: it does not directly quantify ecosystem services, microclimatic effects, thermal comfort, or the probability of tree failure.

MATERIALS AND METHODS

The methods adopted for the present study are divided into three main stages: choice of the object of study, the survey of field information and evaluation of the performance of the urban tree population by the SWOT method [37]. This study is divided into two distinct instances, the first focused on the collection of a multiplicity of data which would be compiled, contrasted and analyzed in the second stage of the study.

Choice of the object of study

The selection of an urban landscape study area should consider three possible scales: street, neighborhood, and city [38]. The present study opted for the evaluation of the Green Infrastructure of the main street of the Humaitá district, in Rio de Janeiro city, Brazil. The typical neighborhood characterization considers the existence of a structural and morphological unit necessary, with its social content and functions [38]. The morphological elements on the street scale are considered adequate for the study since they allow the evaluation of groups with common characteristics. In this sense, after compiling and crossing the data, it is possible to analyse the general state of afforestation [39]. The selected district is located in the south of the city and with a territorial area of 105.45ha [38], surrounded by the districts of Botafogo, Jardim Botânico, Lagoa, Alto da Boa Vista, Santa Teresa, and Copacabana, as presented in **Figure 1**.

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Figure 1. Location and delimitation of the Humaitá district [40].

The selection of the area occurred due to the particularities of Humaitá land use and the characteristics of its micro-ployment (the different widths of the street boxes, the variable dimensions of the sidewalks, and the absence or presence of afforestation are easily noticeable). The forest acts as the background of the district and limits the streets as its gradient rises up to the Corcovado hill [37]. The highlighted portion of the urban district of Humaitá consists of five distinct segments, as illustrated in **Figure 2**. The first segment is Humaitá St., an arterial street that cuts longitudinally through the neighborhood and it is the focus of the present research [38].

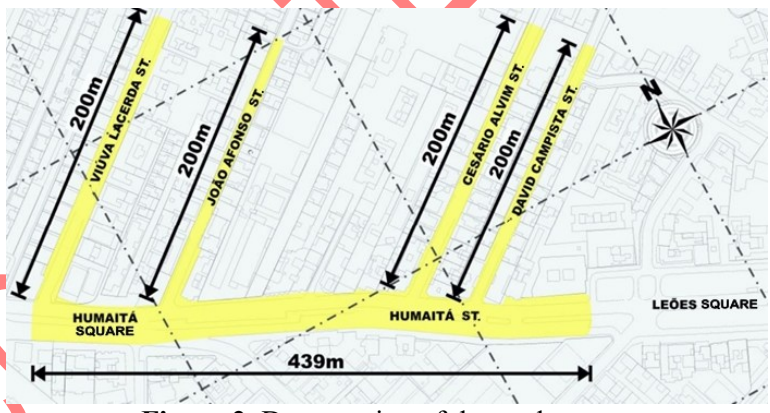


Figure 2. Demarcation of the study area.

The spatial boundary of the present study was defined by the selected survey route along Humaitá Street, in the Humaitá neighborhood of Rio de Janeiro, Brazil, rather than by the full extent of the street or the neighborhood. The field inventory covered the eligible tree individuals located along the northeast sidewalk and within the central median of the selected street segments. Trees located on the southwest sidewalk were excluded because this sidewalk was outside the main axis of the survey route adopted for the field measurements. The original study design also considered the lower solar incidence on this side of the street when defining the route in relation to the intended environmental measurements.

Within this predefined route and the adopted biological inclusion criteria, the survey was conducted as a census of the eligible tree individuals encountered in the selected area. Accordingly, the 53 recorded trees represent a census of the selected survey route, not a complete census of all trees along Humaitá Street, the entire Humaitá neighborhood, or the surrounding urban area. This distinction is important when interpreting the results: the

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inventory provides a detailed description of the selected route, but its findings should not be assumed to represent the excluded sidewalk or the wider neighborhood. The exclusion of the southwest sidewalk may also have influenced the species composition, tree-condition profile, and distribution of the observed attributes. Comparisons with the excluded side or with other urban areas would require additional inventories using a spatially comprehensive and explicitly defined sampling design.

Survey of field information

The first stage of the Inventory was the survey of existing trees in the measurement route. This process was carried out with the help of collaborators, using a 50m measuring tape and a 5m metal measuring tape. The mapping of the streets was necessary to record the exact location of the trees and the first instance of registration was the assignment of numbers to the individuals surveyed. The criterion used for the numbering was quite simple, with the trees on the southeast sidewalks of the transversal streets to Humaitá St. identified with even numbers, while the individuals on the northwest sidewalks were registered with odd numbers. Tree canopies and trunks were drawn to scale, according to field survey data [38]. In Humaitá St., the even numbering is assigned to the trees located on the northeast sidewalk and the odd-numbered to those located in the central bed [39].

Figure 3 and **Figure 4** present the two sectors of Humaitá Street included in the study, indicating the location of the measurement points and the identification of the surveyed trees according to the nomenclature provided alongside the site plan. This representation facilitates the spatial visualization of the sampling design and the distribution of the inventoried individuals within the study area.

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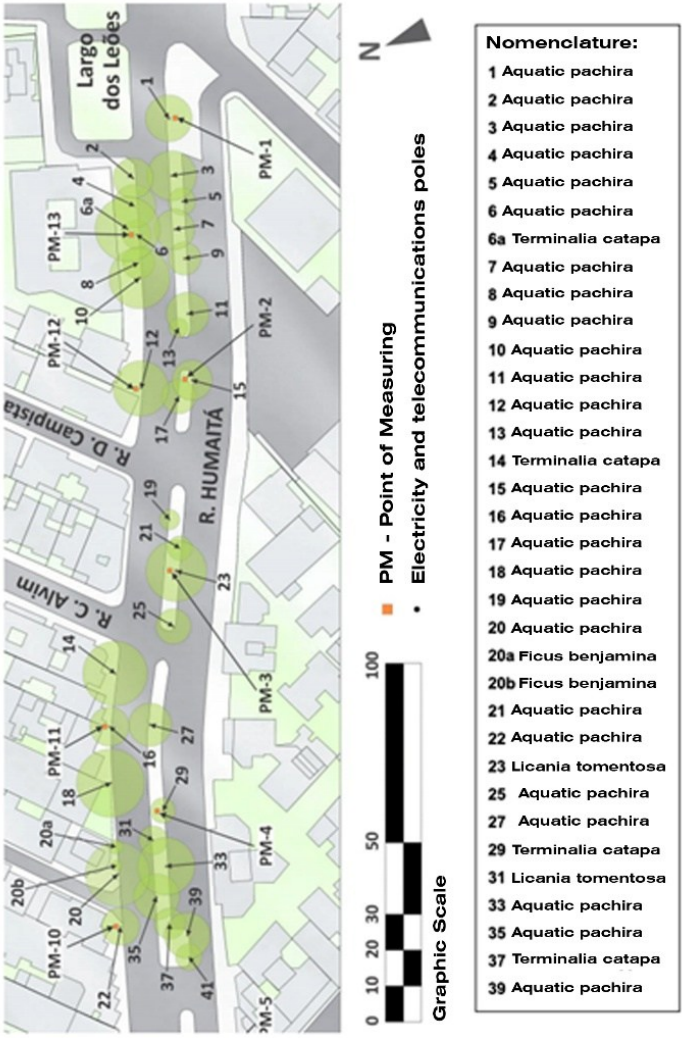


Figure 3. Sector 1 of the selected Humaitá Street survey route, showing the included tree locations and individual identification codes. The inventory covered the northeast sidewalk and central median; the southwest sidewalk was outside the survey boundary [39].

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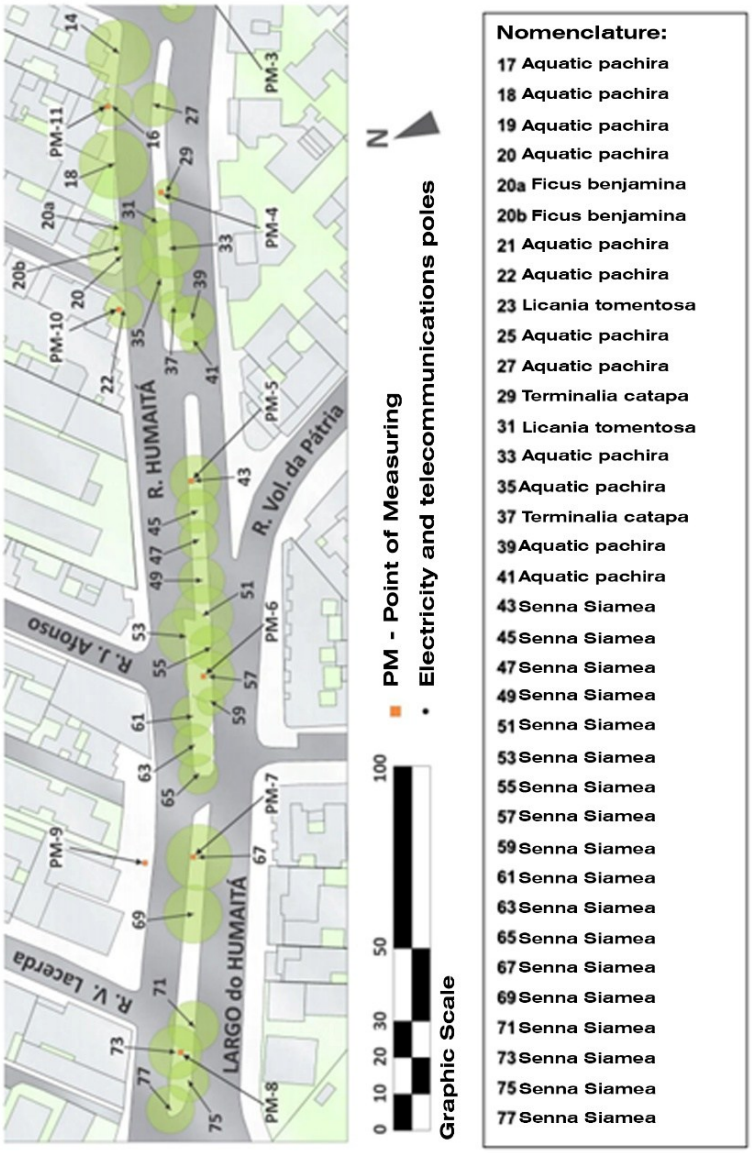


Figure 4. Sector 2 of the selected Humaitá Street survey route, showing the included tree locations and individual identification codes. The inventory covered the northeast sidewalk and central median; the southwest sidewalk was outside the survey boundary [39].

The field survey consisted of a census-type inventory of eligible tree individuals within the predefined survey route. The inclusion criteria were based on the spatial boundary of the route and the biological scope adopted for the inventory. The survey covered tree individuals located along the northeast sidewalk and in the central median of the selected Humaitá Street segments. Individuals belonging to the adopted biological spectrum (Microphanerophytes, Mesophanerophytes, and Megaphanerophytes) were included. In accordance with the criteria adopted in the original inventory, plants shorter than 1 m were excluded. Microphanerophytes were defined as woody plants exceeding 1 m in height and reaching up to 8 m, Mesophanerophytes as trees approximately 8–30 m in height, and Megaphanerophytes as trees exceeding 30 m [41]. Trees located on the southwest sidewalk were outside the predefined survey boundary and were therefore not included. Thus, the term census refers exclusively to the enumeration of eligible individuals within the selected route and does not imply complete coverage of all street trees.

The field procedure included the identification of tree species and botanical families, the recording of biometric attributes, the observation of interactions with the urban environment,

and the assessment of visible phytosanitary and structural conditions. Direct measurements were obtained using measuring tapes for trunk circumference at breast height and canopy diameter. Trunk or stipe inclination was assessed using the Leveling Tools application. Tree height was estimated by comparison with nearby constructed elements, such as utility poles and buildings, while tree age was estimated using the empirical circumference-based procedure described in the preceding section. Phytosanitary and structural attributes, including visible evidence of termite activity, hemiparasites, nutritional symptoms, trunk cavities, exposed heartwood, and branch condition, were recorded through field observation. The collected information was subsequently transferred to the inventory spreadsheets, organized by individual tree identification code, and processed according to the indicator definitions and classification criteria described in this study.

Tree Inventory and Characterization. During the field survey, the tree inventory system was organized into tables cataloged according to individual identification and ecological value. The inventory database was compiled by listing all surveyed trees in ascending numerical order based on their unique identification number. The records included the tree identification number, species name according to scientific nomenclature, and the corresponding botanical family.

To characterize the development, growth condition, and functional attributes of the surveyed individuals, additional biometric parameters were recorded, following the requirements related to the assessment of tree condition and ecological functions [41]. The biometric parameters included total tree height (m), circumference at breast height (CCH, m), (m), trunk inclination (θ, °), canopy diameter (DC, m), and estimated age (years) [42]. **Table 1** presents an identification example developed for Humaitá Street, illustrating the tree inventory system adopted in the Botanical Inventory.

Table 1. Example of the tree inventory identification table used for Humaitá Street, illustrating the botanical inventory system adopted in this study.

Floristic Inventory – Humaitá St.							
Identification, Biometrics, and Age							
Nº	Species	Family	height (m)	CCH (m)	θ (º)	DC (m)	Age (years)
01	*Aquatic Pachira* Aubl. Fritsch	Bombacaceae	8.0 to 12.0	2.50	Bob	13.0	45 to 50

For the interpretation of the inventory results, a distinction was made between mutually exclusive classifications and observations that could coexist within the same tree individual. Where an attribute was defined through a categorical classification, each tree was assigned to the corresponding condition category. In contrast, observations concerning interactions with different urban infrastructure elements and the presence of multiple phytosanitary conditions were considered separately, since more than one occurrence could be recorded for the same individual. Consequently, the frequencies of overlapping observations were not expected to sum to the total number of inventoried trees. Where an individual could not be assigned to a displayed category, this was identified separately rather than implicitly included in another class.

The formulation of a system for assessing the issues of development and adequacy of phenomena regulating the interactions of green infrastructures is a difficult task and the result is often insufficient or inconclusive. However, despite budgetary limitations and of various natures, the largest portion of the data obtained in the field surveys was carried out carefully, aiming to minimize the subjectivity of the measurements. In this context, it is important to

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emphasize that the data collection was based on the recommendations of the Brazilian standards for inventories of this nature [33].

According to Silva et al. (1979) [43], biometric parameters may be obtained through either direct or indirect measurement approaches. Direct measurements are conducted using the *determination method*, which involves the direct assessment of tree attributes in the field. In this study, the determination method was applied to measure trunk/stipe inclination, canopy diameter, and trunk and stipe circumference, generating the biometric data required for the characterization of the inventoried trees [42]. Tree canopy diameters were determined using a measuring tape, suitable for topographic surveys. However, due to different reasons, most of the canopies were deformed and the parameter used in their assessment was the largest diameter measured [42].

O instrumento ideal para a medição direta de diâmetros é a Suta, uma espécie de paquímetro de grandes dimensões, utilizada na dendrometria para a obtenção de medidas dos fustes e estipes. Contudo, por não dispor de uma Suta, o autor do presente estudo lançou mão de um método alternativo, que consistiu no emprego de uma trena para a medição das circunferências dos fustes das árvores na altura do peito. For the direct assessment of the trees and trunks Circumferences at Chest Height (CCH), again a measuring tape was used to measure the trunks perimeter at breast height. The measurement of the Circumference at Chest Height (CCH) is commonly adopted because it is an easy-to-assess feature, which offers reliable measurements at a relatively low cost (in this specific case, the same measuring tape that was used in the assessment of the canopy diameter). The “Chest Height” varies according to the dendrometry standards of each country, but the ideal measurement is between 1.20m and 1.30m [44]. In the method developed specifically for the field survey and for the data collection of the Floristic inventory step, it worked properly. The biometric characterization of the inventoried trees involved both direct and indirect measurement procedures. Direct measurements were used for trunk/stipe inclination, canopy diameter, and trunk circumference at breast height. Circumference and canopy diameter were measured using a measuring tape, while trunk/stipe inclination was assessed using the Leveling Tools® application. Although these procedures provided field-based measurements, the use of different instruments and the irregular morphology of some tree canopies may have introduced measurement variability.

Indirect estimation was used for total tree height and approximate age. Tree height was visually estimated by comparing individual trees with nearby constructed elements, such as utility poles and buildings. Approximate age was estimated using an empirical approach based on trunk circumference at breast height and assumed species-specific growth rates. Specifically, circumference values converted into centimetres were divided by factors of 1.5, 2, 3, 4, or 5, according to the growth-rate category attributed to each species. These procedures provided approximate biometric information for the exploratory assessment but should not be interpreted as equivalent to instrument-based height measurements or independently verified chronological ages.

The study did not include a formal calibration exercise against reference measurements, an independent reassessment of the same trees, or a statistical evaluation of inter-assessor agreement. Consequently, measurement uncertainty and observer-related variability could not be quantified. The resulting biometric values and condition classifications should therefore be interpreted as field-based estimates suitable for an initial characterization of the inventoried population, rather than as measurements with experimentally established accuracy or repeatability. The use of estimated height and age also introduces uncertainty into the classification of trees according to the biometric thresholds adopted in the assessment framework. Trees with estimated values close to a class boundary may be assigned to a different category if the measurement estimate changes. This limitation is particularly relevant to the height and age attributes, for which the assessment relied on visual comparison and empirical growth assumptions, respectively. Accordingly, the corresponding classifications are interpreted as indicative categories rather than precise determinations of tree development.

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Where the estimated value is close to a classification threshold, the assigned grade should be understood with caution and should not, by itself, determine a high-priority management intervention.

Ecological Value Assessment. The second individual registration worksheet was designed to evaluate aspects of ecological value, combining all notes referring to tree identities, association problems with the urban environment, and their current phytosanitary conditions.

Inspections were carried out to inventory and assess the Ecological Value aspects of the trees existing along the measurement route. Accordingly, the registration of arboreal individuals was conducted through in situ identification of species and families, complemented by a bibliographic review of individual aspects related to occurrence, regional distribution, environmental risk, timber category, and leaf abscission. Analyses of Ecological Value associated with Adaptation focused on the assessment of biometric data, including tree height, circumference at breast height (CBH), crown diameter, and age. Within the Adaptation attribute, conflicts between each individual and urban infrastructure, such as utility networks, buildings, and vehicular traffic, were also evaluated. In terms of Phytosanitary conditions, fieldwork recorded evidence of termite attacks and the presence of hemiparasites, in addition to diagnosing phytopathologies observed in branches and trunks.

The assessment of phytosanitary and structural attributes was based on field observations of visible characteristics, including trunk and branch conditions, exposed heartwood, cavities, dead branches, nutritional symptoms, termite traces, and hemiparasite occurrence. Although the grading criteria were defined in the assessment tables, the interpretation of some visual conditions necessarily involved observer judgment. In particular, the distinction between minor and major heartwood exposure and the classification of nutritional condition as adequate, partially deficient, or deficient may be influenced by the visibility and extent of the observed symptoms. No independent expert validation, repeat scoring, or inter-assessor agreement analysis was conducted for these attributes. Therefore, these classifications represent observational assessments made during the field inventory and should be interpreted accordingly.

The method of evaluating arboreal individuals used in the present research is inspired by the attributes discriminated for the field collection, suggested by Thurman [45] and Silva Filho et al [43]. Thus, as suggested by Silva Filho et al [43], the creation of a relational database to systematize the evaluation urban floristic inventory of this study was defined by the field survey of multiple criteria items such as Location, Identity, Biometric Dimensioning, Biological Aspects, Surrounding Situations and Interferences [43]. The attributes considered for the relational analyses of the present study were organized following the considerations of Silva Filho et al [43], but their distribution by categories was grouped according to the individual aspects of Identity, Adaptation, and Plant Health.

These categories have been graduated to allow the assessment of the general state of the urban tree population inventory. Additionally, it is important to emphasize that this grading system occurs in descending order, distributed by levels that are staggered from the “Optimum” to the “Critical” point. The assessment was based on a rating scale comprising six classes: Optimum (O), Good (G), Normal (N), Bad (B), Weak (W), and Critical (C). The overall condition of each tree was classified into categories according to the physical condition of the individual.

Finally, it is possible to develop an individual tree inventory table integrating all records related to tree identity, issues arising from interactions with the urban environment, and current phytosanitary conditions. This integrated approach enables a comprehensive assessment of each tree within the urban context. **Table 2** presents an example of ecological valence applied to Humaitá Street.

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Table 2. Example of Ecological Value Assessment of *Pachira aquatica* Aubl. Fritsch – Humaitá Street.

Floristic Inventory – Ecological Valence Table - Humaitá St.								
Identity, Adaptation and Phytosanitary Characteristics								
Species			**(O)**	**(G)**	**(N)**	**(W)**	**(B)**	**(C)**
Identity		Occurrence	x					
		Regional Distribution			x			
		Environmental Risk						
		Wood Category				x		
		Leaf Shedding	x					
Adaptation	Conflicts	Root Collar				x		
		Pruning		x				
		Electrical Lines						
		Gas / Water / Sewer Utilities						
		Telecommunications						
		Other Conflicts					x	
		Height	x					
		Age	x					
		Stem Lean		x				
Phytosanitary Condition	Aspects	Termites						
		Hemiparasite						
		Nutritional Status		x				
	Branches	Cleanliness	x					
		Exposed Heartwood						
		Dead Branches						
	Trunk & Stipe Condition	Cleanliness	x					
		Exposed Heartwood						
		Cavities / Secretions						

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The Identity, Adaptation, and Phytosanitary categories evaluated in the floristic inventory were detailed in **Table 3**, **Table 4**, and **Table 5**, respectively.

Table 3. Identity - Ecological Value Category Grading

Identity	
Occurrence	Autochthonous – Native species, coming from Brazilian biomes (OPTIMUM).
	Exotic - Species not native to Brazilian biomes (BAD).
Regionality	Regional - Native species, from the Atlantic Forest (GOOD).
	Compatible – Exotic species, with forest formation compatible with the Atlantic Forest (NORMAL).

	Incompatible - Exotic species, incompatible with the formation of Tropical Rainforest Semideciduous Ombrophylous Dense Atlantic Forest (WEAK).
Environmental Risk	Invasive Species – These are organisms introduced outside their natural range that threaten ecosystems and habitats, putting the survival of native species at risk (CRITICAL).
	Exotic poisonous species – Offer potential risk to urban population and fauna (CRITICAL).
Wood Category	This is an important attribute because it classifies the woods into 4 categories according to their density and demand. In the study, it was used as a resilience parameter. C-1 (OPTIMUM), C-2 (GOOD), C-3 (NORMAL), and C-4 (WEAK).
Leaf Fall	Perennial – Trees with perennial, perennial foliage (OPTIMUM).
	Semideciduous - Trees that show partial loss of foliage at a certain time of year (NORMAL).
	Deciduous or Deciduous – Trees that have a total loss of foliage at a certain time of year (WEAK).

Table 4. Adaptation - Ecological Value Category Grading

Adaptation	
Roots	Adequate dimensions and the tour preserved (GOOD).
	Inadequate dimensions, but roots are contained and the walkway is preserved (WEAK).
	Inadequate dimensions, with root leakage and destroyed walkway (BAD).
Pruning	Requires crop pruning to straighten the canopy and remove dead branches (NORMAL).
	Needs urgent removall of dead branches and to mitigate conflict with aerial networks (WEAK).
Conflicts	Mains (CRITICAL).
	Gas, Water, and Sewage Networks (CRITICAL).
	Telecommunications Network (CRITICAL).
	Conflicts with Buildings, Public Lighting networks, Traffic Lights, etc. (BAD).
Height	Greater than 15.00 m (OPTIMUM).
	Greater than 10.00 and up to 15.00 m (GOOD).
	Up to 10.00m (NORMAL).
Age	Age greater than 25 years (OPTIMUM).
	Age greater than 15 years and less than or equal to 25 years (GOOD).
	Age less than or equal to 15 years (NORMAL).
Inclination	Inclination angle from 0° (inclusive) to less than 7.5º (GOOD).
	Inclination angle from 7.5º to15º (inclusive) (WEAK).
	Inclination angle greater than 15º (BAD).

Table 5. Phytosanitary - Ecological Value Category Grading

Phytosanitary

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Aspects - Termite	Detection of traces of termite or borer attacks (CRITICAL).
Aspects - Hemiparasite	Struthantus flexicaulis Juss parasitism detection, the mistletoe. Infected individuals should receive cultural treatment (BAD).
Aspects - Nutrition	Adequate nutrition (GOOD).
	Partial visual symptoms of nutritional deficiency (WEAK).
	Pronounced visual symptoms of nutritional deficiency (BAD).
Branches	Unimpaired whole branches (OPTIMUM)
	Branches with small exposures of heartwood (WEAK).
	Branches with large heartwood exposures (BAD).
	Dry or dead branches (CRITICAL).
Trunk and Palm Stipe	Unimpaired whole trunks (OPTIMUM).
	Minor heartwood exposure (WEAK).
	Major heartwood exposure (BAD)
	Hollow and with shoot secretion (CRITICAL)

All quantitative indicators were classified using non-overlapping intervals with explicitly defined boundary values, to ensure consistency in the assignment of condition classes. Classification was based on the individual measurement recorded for each tree rather than on an assumed midpoint of an estimated range. When a measurement was available only as an interval crossing two or more classification thresholds, the corresponding category was considered undetermined unless the original field records allowed the precise value to be recovered. No arbitrary assignment to the higher or lower category was made. This procedure was adopted to avoid introducing classification bias and to ensure that the results could be reproduced using the same measurement criteria.

Urban tree population performance assessment

The third and final phase of the methodology focused on the analysis and evaluation of the overall condition of the urban tree population along Humaitá Street. The inventory data were examined using a condition-assessment framework inspired by the relational logic of SWOT analysis and adapted to the characteristics of urban green infrastructure. The purpose of this adaptation was to organize the multiple attributes recorded for each tree into a concise assessment structure that could support the interpretation of the tree population and the identification of management priorities. Unlike a conventional SWOT analysis, which distinguishes internal strengths and weaknesses from external opportunities and threats, the framework used in this study does not claim to establish a formal internal–external classification of all indicators. Instead, it organizes the observed tree attributes according to six condition grades: Optimum, Good, Normal, Weak, Bad, and Critical. These grades represent the assessed condition of individual attributes and are used to distinguish favorable conditions from deficiencies and potentially serious risks.

The framework therefore combines the systematic classification of inventory observations with a SWOT-inspired presentation of positive and negative aspects. The six-grade scale was adopted to represent a wider range of tree conditions than a simple binary classification of satisfactory and unsatisfactory attributes. The Optimum, Good, and Normal grades represent different levels of favorable or acceptable conditions, whereas Weak, Bad, and Critical identify increasingly serious deficiencies. In particular, the Critical grade was included to distinguish conditions that may involve substantial structural, phytosanitary, or public-safety risks and therefore require priority assessment or intervention. The Optimum grade represents the

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opposite end of the condition scale and identifies attributes that generally require preservation rather than corrective intervention.

The numerical values assigned to the six grades are classification codes used to support data organization and spreadsheet processing. They should not be interpreted as indicator weights, normalized importance coefficients, or thresholds for allocating indicators to the four conventional SWOT quadrants. No formal internal–external factor allocation or quantitative quadrant-assignment procedure was performed in this study. Accordingly, the framework is described as a SWOT-inspired condition-assessment approach rather than as a conventional quantitative SWOT analysis.

The SWOT method objectively relates the aspects described in a matrix, facilitating its apprehension and analysis. In the context of the Floristic Inventory, evaluating the field observations would, in principle, occur according to the SWOTs analysis parameters (strength, weakness, and threat) to perceive and manage Opportunities or vulnerabilities. However, as highlighted by Silva Filho et al (2002) [43], the analysis of biotic elements is complex and, as the qualitative validation of its attributes should embrace all levels of weakness. Therefore, the initial planning of valuing the inventory data with the degrees described above should also contemplate situations of imminent risk of life, hence the insertion of the parameter "CRITICAL". Thus, to maintain the original balance of the SWOT matrix, the classification "OPTIMUM" was also included in the present research, following the suggestion of [46].

Within the context of the Floristic Inventory, field observations were initially intended to be evaluated using four condition classes: Good, Bad, Normal, and Weak, aligned with the SWOT framework to assess strengths, weaknesses, opportunities, and threats. However, as noted by Silva Filho et al. (2002) [43], the assessment of biotic elements is inherently complex, and a qualitative evaluation should encompass the full spectrum of condition levels.

For this reason, the original four-category classification was expanded to include an additional class, *Critical*, allowing the identification of individuals presenting severe deterioration and an imminent risk of failure. Furthermore, following the recommendation of Silva Filho et al. (2002) [43], the category *Optimum* was incorporated into the assessment system adopted in this study. The inclusion of these two extreme categories was intended to preserve the balance of the SWOT-based evaluation framework by establishing opposite ends of the condition scale.

The *Optimum* category represents individuals in optimal condition, requiring little or no management intervention. In such cases, the tree is considered healthy, stable, and functioning adequately within the urban ecosystem. Conversely, the *Critical* category identifies trees exhibiting critical structural, physiological, or sanitary deficiencies, where the risk of failure is imminent and may result in significant damage to the urban forest and potential hazards to public safety. Under these circumstances, immediate management actions by public authorities are recommended. Management priorities were established through the interpretation of the individual attribute classifications rather than through a single aggregated numerical score. Particular attention was given to attributes classified as Critical, especially those associated with environmental risk, conflicts with urban infrastructure, dead branches, and hollow trunks. These conditions were considered priority concerns because of their potential implications for public safety and tree stability. Trees presenting multiple negative classifications, particularly when one or more attributes were classified as Critical, were identified as requiring closer technical assessment and, where appropriate, urgent corrective intervention. Favorable classifications in other attributes did not offset or eliminate the management implications of a Critical condition. This procedure allowed the assessment to preserve the multidimensional characteristics of each tree while supporting the identification of individuals requiring different levels of management attention. **Figure 5** presents the conceptual organization adopted in this study for the SWOT-inspired condition-assessment framework. The figure illustrates the use of the six condition grades to distinguish favorable attributes from deficiencies and critical conditions. It should be interpreted as a schematic representation of the adapted assessment

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logic, rather than as a quantitative decision model defining formal thresholds for assigning indicators to the conventional SWOT quadrants.

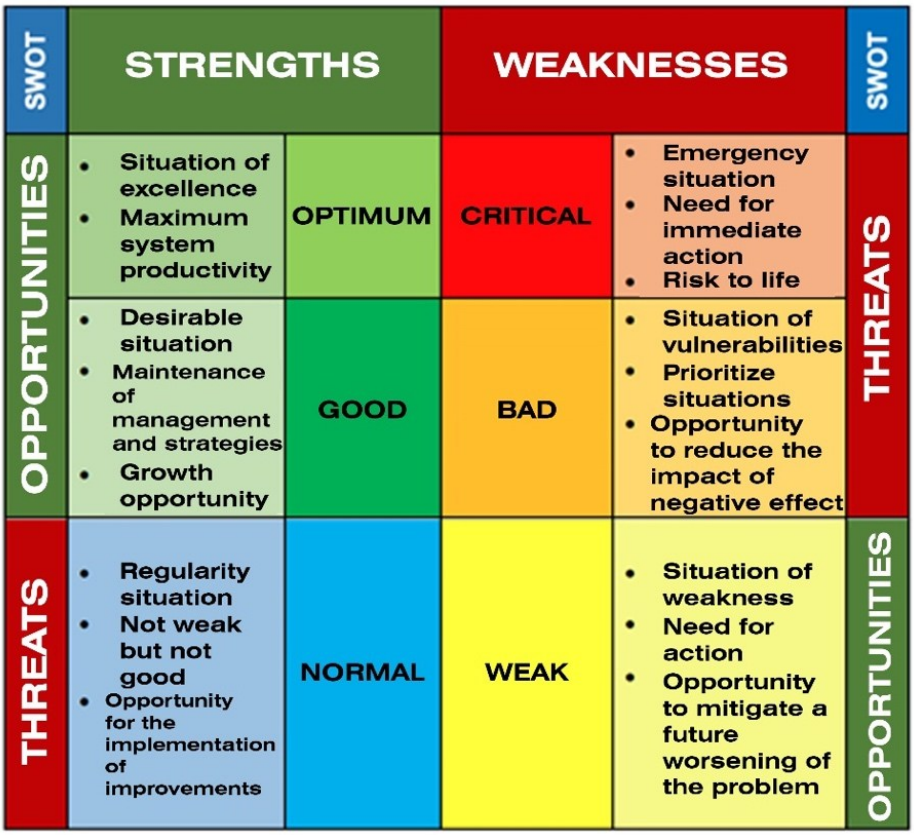


Figure 5. Conceptual structure of the SWOT-inspired six-grade condition-assessment framework adopted in this study.

The tree assessment methodology adopted in this study was based on the field inventory attributes proposed by Thurman [45], as reported by Silva Filho et al. (2002) [43]. To support the systematic evaluation of urban floristic inventories, Silva Filho et al. (2002) [43] developed a relational database structure in which field surveys encompass six main categories: Location, Identification, Biometric Measurements, Biological Characteristics, Surrounding Conditions, and Interferences.

Following this framework, the attributes considered in the present study were selected and adapted according to the recommendations of Silva Filho et al. (2002) [43]. However, for the purposes of the relational analyses performed herein, these attributes were reorganized into three broader categories reflecting the individual characteristics of each tree: Identity, Adaptation, and Phytosanitary Condition. This classification facilitated a more integrated assessment of species characteristics, environmental suitability, and overall tree health within the urban landscape.

Numerical scores were assigned to the six qualitative assessment classes adopted in this study to support the organization and analysis of the field inventory data in Microsoft Excel 2013®. These scores were used to encode the classification of each evaluated attribute according to its corresponding condition level: Optimum (O) = +3, Good (G) = +2, Normal (N) = +1, Weak (W) = −1, Bad (B) = −2, and Critical (C) = −3. The numerical values represent class scores and should not be interpreted as indicator weights. In other words, they express the qualitative assessment assigned to a specific attribute rather than the relative importance of that attribute in relation to the others. **Table 6**, **Table 7**, and **Table 8** present the numerical scores assigned to the attributes of Identity, Adaptation, and Phytosanitary Condition, respectively. The scores were used to support data coding, classification, and the organization

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of the results within the adapted SWOT framework. No normalized indicator weights or single weighted composite score for the overall condition of each tree were calculated in this study.
For the Environmental Risk attribute, the Critical classification was assigned a score of −3 to each of the two risk conditions considered in the assessment: invasive species and exotic poisonous species. Therefore, the notation previously presented as "−3 × 2 = −6" represents the addition of two separate Critical risk-condition scores, rather than the application of an indicator weight. When both conditions are identified, their combined contribution to the environmental-risk record is expressed as (−3) + (−3) = −6. This notation does not represent a weighting coefficient or a weighted composite score for the tree.
The condition grades provide a practical basis for interpreting management needs. Attributes classified as Optimum generally indicate conditions to be preserved, with routine monitoring as appropriate. Good and Normal conditions indicate satisfactory or acceptable situations in which preventive maintenance and periodic monitoring may be sufficient. Weak conditions identify deficiencies that should be monitored and addressed through corrective maintenance when required. Bad conditions indicate more pronounced problems that warrant priority technical assessment and appropriate intervention. Critical conditions identify potentially severe structural, phytosanitary, or environmental risks and therefore require urgent inspection and management action by the responsible authorities. These management implications are interpreted in relation to the specific attribute assessed; a favorable grade in one attribute does not cancel or compensate for a serious deficiency in another attribute of the same tree.

Table 6. Numerical scoring system assigned to Identity attributes for data entry and analysis in Microsoft Excel 2013®.

IDENTITY ASPECTS		Ratings and Scores					
		(O) +3	**(G) +2**	**(N) +1**	**(W) -1**	**(B) -2**	**(C) -3**
OCCURRENCE	Native	3					
	Exotic					-2	
REGIONAL SUITABILITY	Regional		2				
	Compatible			1			
	Other				-1		
Environmental Risk							(-3) + (-3)=-6
WOOD STRENGTH CLASS	Class C-1	3					
	Class C-2		2				
	Class C-3			1			
	Class C-4				-1		
LEAF PERSISTENCE	Evergreen	3					
	Semi-deciduous			1			
	Deciduous				-1		

Table 7. Numerical scoring system assigned to Adaptation attributes for data entry and analysis in Microsoft Excel 2013®.

ADAPTATION ASPECTS		Ratings and Scores					
		(O) +3	**(G) +2**	**(N) +1**	**(W) -1**	**(B) -2**	**(C) -3**
ROOT FLARE	Correct		2				

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	Incorrect				-1		
	Poor					-2	
PRUNING	Good		2				
	Normal			1			
	Weak				-1		
CONFLICTS	Electrical						-3
	Water / Gas / Sewer						-3
	Telecommunications						-3
	Others					-2	
HEIGHT	Greater than 15.00 m	3					
	Between 10.00 and 15.00 m		2				
	Between 5.00 and 10.00 m			1			
AGE	Age > 25 years	3					
	Age between 15 and 25 years		2				
	Age > 10 years			1			
INCLINATION	Vertical		2				
	Inclination < 7.5°				-1		
	Inclination From 7.5° to 15°					-2	
	Inclination > 15°					-2	

Table 8. Numerical scoring system assigned to Phytosanitary Condition attributes for data entry and analysis in Microsoft Excel 2013®.

PHYTOSANITARY ASPECTS		**Ratings and Scores**					
		(O) +3	**(G) +2**	**(N) +1**	**(W) -1**	**(B) -2**	**(C) -3**
BIOLOGICAL AGENTS	Hemiparasitic Plant					-2	
	Termites						-3
NUTRITIONAL STATUS	Well-nourished		2				
	Partial visual symptoms of nutritional deficiency				-1		
	Pronounced visual symptoms of nutritional deficiency					-2	
BRANCHES	Healthy	3					
	Minor Heartwood Exposure				-1		
	Major Heartwood Exposure					-2	
	Hazard						-3
TRUNK / STEM	Healthy	3					
	Minor Heartwood Exposure				-1		
	Major Heartwood Exposure					-2	
	Hazard						-3

The numerical scores assigned to the assessment classes were used as coding values for the individual attributes recorded in the floristic inventory. Each observation was first classified according to the corresponding criteria presented in **Table 3**, **Table 4**, and **Table 5** and subsequently associated with its respective numerical score in **Table 6**, **Table 7**, and **Table 8**. The resulting classifications were organized into the three assessment dimensions: Identity, Adaptation, and Phytosanitary Condition. The scores enabled the systematic identification and

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visualization of positive and negative conditions within the adapted SWOT framework. However, the scores were not multiplied by indicator-specific weights, normalized, or aggregated into a single numerical value representing the overall condition of each tree. Accordingly, the assessment retained the individual classification of each attribute, allowing favorable characteristics and serious deficiencies to be identified simultaneously.

Missing and non-applicable observations were distinguished from assessed conditions. An attribute recorded as absent following field inspection was interpreted according to its corresponding assessment criterion and was not treated as missing data. For example, the absence of visible termite activity represented an observed condition, rather than an unrecorded observation. When an attribute could not be assessed or the corresponding information was unavailable, it was not assigned an artificial numerical score and was not automatically classified as Optimum, Good, or any other condition level. Similarly, indicators that were not applicable to a particular tree were not assigned a score. These cases were kept distinct from observations indicating the absence of a problem. Since no overall composite score was calculated, missing and non-applicable observations did not require numerical imputation or adjustment of a weighted aggregation formula.

To illustrate the interpretation of the scoring system, consider a hypothetical tree presenting both favorable characteristics and serious defects. The tree may be classified as Optimum for species occurrence (native species, +3), Optimum for leaf persistence (evergreen, +3), and Optimum for height (greater than 15 m, +3). These attributes indicate favorable characteristics related to its ecological identity and development. However, the same individual may also present a Critical condition associated with a conflict with the electricity network (−3) and a Critical phytosanitary condition associated with a hollow trunk (−3).

In this example, the tree retains its favorable classifications for identity and development, while simultaneously receiving Critical classifications for the electricity-network conflict and trunk condition. These results are not combined into a single numerical score. Instead, the individual assessment preserves the complete condition profile of the tree, making it possible to identify both its ecological value and its management requirements. Despite the favorable characteristics, the presence of Critical conditions indicates the need for priority technical inspection and appropriate corrective intervention. This approach prevents favorable attributes from numerically compensating for serious structural or safety-related defects and supports management decisions based on the nature and severity of the identified problems.

RESULTS AND DISCUSSION

The collected data was carried out with considerable detail. Although the correct identification of species hardly occurs without the help of botanists or other experts in this type of floristic survey, the identification of species in the inventory of this research was accomplished with the help of specific literature mentioned by Lorenzi, H. [47], which provides guidance on the identification and cultivation of native Brazilian tree species in its first edition. Lorenzi, H. [48] presents the second edition of the same manual, while Lorenzi, H. [49] provides its third edition, updated in 2009. Lorenzi et al [50] address the identification and characteristics of exotic timber, ornamental, and aromatic trees cultivated in Brazil. Lorenzi et al. [51] focus on the identification and cultivation of Brazilian and exotic palm species. Finally,, Gonçalves et al [52] provide an illustrated reference on vascular plant morphology, covering plant organography and morphological terminology.

The registration of the trees was divided by street, and the planning adopted was to gather information regarding the location of the plant element and the dimensions of its Trunk, Height, Inclination, and Phytosanitary Conditions. Other aspects were also raised to assess the adaptation of each individual to the “pressures” exerted by the urbanized environment [42].

In this work, the results of Humaíta St. will be presented in detail, the greater length of Humaitá St. forced the division of the floor plan into two sectors. The sectioning of Humaitá

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St. is illustrated in **Figure 6**. The division took place at the time of the existing return on the central bed, approximately in the middle of the block comprised of Cesário Alvim St. and João Afonso St.



Figure 6. Sectorization of Humaitá Street.

The floristic inventory of the Humaitá Street recorded the existence of 53 arboreal individuals, representing five distinct species. The inventory covered the northeast sidewalk and the central median; trees on the southwest sidewalk were outside the defined survey route and were therefore excluded. **Table 9** summarizes the species composition and the number of individuals recorded in the surveyed area.

Table 9. List of tree species and quantities found on Humaitá St.

Humaitá St. - Species and Quantities			
Species	**Botanical Family**	**common name**	**The amount**
Pachira aquatica Aubl. Fritsch	Bombacaceae	Munguba , Wild Cacu , Mamorama	27
Terminalia catappa L. Fritsch	Combretaceae	Almond tree	4
Ficus benjamina L.	Moraceae	Fig tree benjamina	2
Licania tomentosa (Benth) Fritsch	Chrysobalanaceae	Hi	2
Senna siamea HS Irwin & R.C.Barneby	Fabaceae Caesalpinioideae	Cassia-do- Sion	18
	Total		**53**

Following the identification and mapping of the species recorded in the floristic inventory, biometrics measurement of the arboreal individuals and estimated ages were compiled for the inventoried individuals. **Table 10** presents selected examples of the individual-tree records , including tree identification, scientific name, biometric parameters, and estimated age. It is intended to illustrate the structure and type of information recorded for each tree; it does not reproduce the complete dataset of all 53 inventoried individuals.

Table 10. Identification, Biometrics, and Age of the trees on Humaitá St.

Floristic Inventory – Humaitá St.
Identification, Biometrics, and Age

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Species	Family	height (m)	CCH (m)	θ (º)	DC (m)	Age (years)
Pachira Aquatica Aubl. Fritsch	Bombacaceae	8.00 to 12.00	2.50	Bob	13.00	45 to 50
Terminalia catappa L. Fritsch	Combretaceae	16.00 to 18.00	1.50	10th S	18.00	30 to 35
Ficus benjamina L.	Moraceae	4.00 to 6.00	0.45	10th E	4.00	5 to 10
Licania tomentosa (Benth.) Fritsch	Chrysobalanace	14.00 to 16.00	2.95	14.00 to 16.00	17.00	95 to 100
Senna siamea HS Irwin & R.C.Barneby	Fabaceae Caesalpinioideae	16.00 to 18.00	1.60	10th S	14.00	50 to 55

The numerical scores presented in **Table 6**, **Table 7**, and **Table 8** were used to represent the condition classes assigned to individual inventory attributes. In the results, the assessment is presented through the frequency and distribution of these classifications, rather than through a single aggregated score for each tree. Accordingly, the results describe the number of individuals associated with each condition level and identify the attributes requiring management attention. The adapted SWOT matrix consolidates these findings by organizing favorable conditions and identified weaknesses or threats into the corresponding assessment categories. It should therefore be interpreted as a structured qualitative and attribute-based synthesis of the inventory results, rather than as the output of a weighted numerical aggregation model.

Humaitá St. analysis and results of the street-tree inventory

The first stage of the analysis of the **street-tree inventory** encompassed the afforestation Identity aspects. In that sense, these assessments complement the identity analyses carried out for each inventory-identified species. Below, in the street-tree inventory Identity chart, the bar labels indicate the numbers of individuals with the characteristics or problems related to each analyzed attribute. However, as this is an analysis-generalized aspect of Identity, despite having been (53) individuals inventoried; the item “Environmental Risk” will include just the number of trees found with the specific aspects of that attribute. The aspects of occurrence, ecological compatibility, environmental risk, wood category, and leaf fall were also considered as Identity characteristics. The list of Identity aspects of tree population along Humaitá Street is presented in **Figure 7**.

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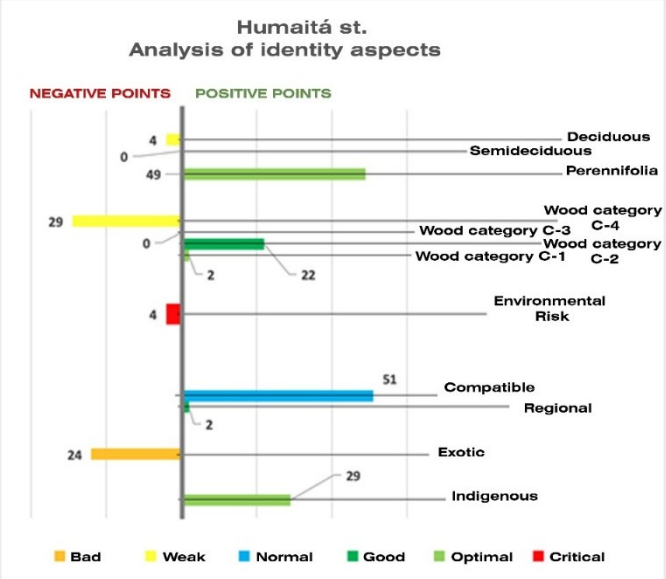


Figure 7. Humaitá St. - aspects of the identity graph.

The Occurrence aspect was the first item of the Humaitá St. trees identity attributes evaluated. In this category, (29) autochthonous and (24) exotic trees divided the total of (53) individuals. However, only (2) individuals are regional, whilst the others come from biomes compatible with the Atlantic Forest dense ombrophilous rainforest class. The SWOT evaluation of this attribute points to a positive result, with most of the autochthonous individuals compatible with the Biogeocenosis of Rio de Janeiro city. The presence of 24 exotic trees would be this vulnerability item. The third item indicates the presence of (4) trees that offer Environmental Risk. The investigation of which trees are specifically classified in this category can be carried out by consulting the individual species files, which contain a description of all the characteristics of the Identity factor.

However, the quickest and most appropriate query of a specific attribute of the street-tree inventory should be performed using the database in Microsoft Excel ©, where it is possible to obtain a list of individuals who present the analyzed aspect, as presented in **Figure 8**.

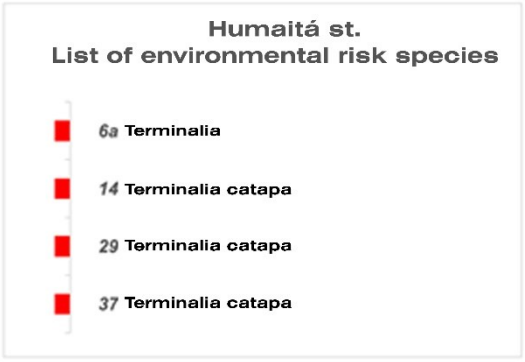


Figure 8. List of individuals from Humaitá St. with Environmental Risk conditions.

The second attribute of identity aspects relates to the category of wood of arboreal individuals. This reference was used as an indexing factor for the density, durability, and economic value of each tree. In this way, it is possible to estimate which individuals are most resistant to weather and pest attacks. Humaitá St. results by categories of wood registered (2) trees in categories C-1, 22, and (29) individuals at C-2 and C-4, respectively. No trees were registered in category C3. The SWOT result for this attribute indicates the existence of (29)

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trees with low-quality wood as a weakness, which can mean the possible fall of branches in storms or susceptibility to pest attacks. The fourth and last identity aspect was related to tree leaf abscission. In that context, the existence of (49) perennial trees and (4) deciduous was inventoried. In this particular SWOT assessment, most individuals were classified with the Optimum concept.

The assessment of adaptation considered characteristics associated with tree growth, development, and interactions with the urban environment, represented by the attributes Height, Age, and Inclination. The identified conflicts were separated into specific categories, being broken down according to the problems caused by the collars, pruning, and by the Electricity, Water, Sewage, Gas, and Telecommunications networks. Other minor conflicts, with pedestrians, buildings, urban signage, etc., were grouped into a single item. **Figure 9** presents the results of the Adaptation assessment, covering tree development and growth, root-collar condition, pruning requirements, and conflicts with urban infrastructure. Regarding tree height, the figure indicates that 29 individuals were taller than 15.00 m, 13 were between 10.00 and 15.00 m, and 11 were between 5.00 and 10.00 m. Regarding age, 39 trees were estimated to be older than 25 years, 11 were classified in the category greater than 15 and up to 25 years, and 3 were classified in the category greater than 10 and up to 15 years. Trees estimated to be 10 years old or younger were considered separately according to the additional age classification criterion defined in the Methodology.

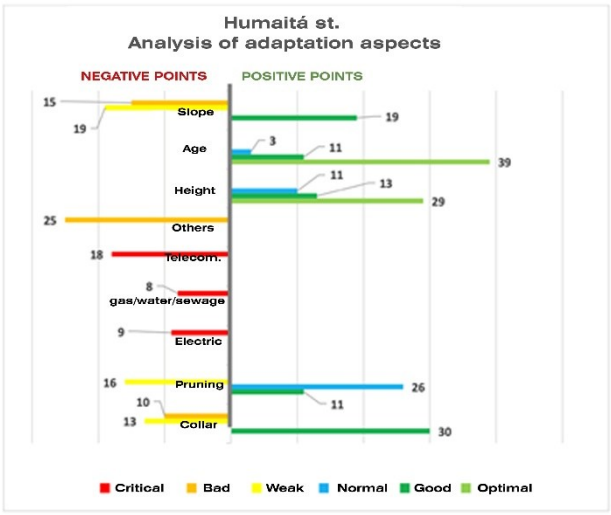


Figure 9. Graph of aspects of Adaptation of Humaitá St.

These height and age distributions should be interpreted as approximate classifications because the corresponding measurements were obtained through visual height estimation and empirical age estimation, respectively. Consequently, trees with estimated values close to the classification boundaries may be assigned to adjacent categories if more precise measurements become available. The observed distributions therefore provide an indicative description of the development characteristics of the inventoried population and should not be interpreted as precise measurements of tree height or chronological age. The results indicate that most trees were mature and belonged to the two taller height classes. Nevertheless, the inclination results identify a relevant structural concern, as 19 individuals were classified in the weak category and 15 in the bad category. These conditions may increase vulnerability to adverse weather and indicate the need for appropriate monitoring and management. The height and age distributions, on the other hand, suggest that a substantial proportion of the inventoried population consists of established trees that contribute to the urban green infrastructure and its associated environmental and biophilic functions. Regarding root-collar condition, **Figure 9** records 30 trees in good condition, 10 in the weak category, and 13 in the bad category. The

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pruning assessment identifies 11 trees in good condition, 26 requiring routine pruning, and 16 classified in the weak category, indicating a need for more urgent pruning intervention. These results highlight the importance of appropriate root-collar maintenance and pruning practices to reduce conflicts with pedestrian infrastructure and minimize the risk associated with defective or poorly managed branches.

Conflicts with urban infrastructure and equipment require particular attention because they may affect public safety, tree development, and the functionality of the surrounding urban space. **Figure 9** identifies 18 trees in conflict with the telecommunications network, 8 in conflict with water, sewage, or gas networks, 9 in conflict with the electricity network, and 25 presenting other types of conflicts, including interactions with pedestrians, buildings, urban signage, and other urban elements. These values represent the occurrences recorded for each type of conflict and should not be interpreted as mutually exclusive groups of trees, since a single individual may present more than one type of conflict. Consequently, the sum of these occurrences may exceed the total number of inventoried trees. The results demonstrate the need for coordinated management measures addressing both the physical condition of the trees and their interactions with the surrounding urban infrastructure.

Phytosanitary analysis was based on the assessment of damage caused by biotic and abiotic agents that directly affected the health, vigor, and structural integrity of the trees. Thus, the analysis of plant health aspects was designed to verify the presence of pests, parasites, and structural damage that could compromise the integrity of individuals. The items were separated by specific categories, determined by disturbances caused by external agents, and by structural problems detected either in the tree branches or in their trunks. The first group indicated the presence of Termites, Hemiparasites, and Nutrition Aspects. In the second block, trunk and branch impairments were related. The phytosanitary classifications presented in **Figure 10** are based on visual field observations and the grading criteria described in the methodology. Since no independent reassessment or inter-assessor agreement analysis was conducted, the distinction between minor and major damage, as well as the interpretation of nutritional symptoms, may be subject to observer-related variability. Nevertheless, the recorded observations provide an initial indication of the types and frequency of visible conditions requiring further technical attention. In particular, observations such as hollow trunks, dead branches, and evidence of termite activity should be regarded as indicators warranting detailed inspection rather than as independently validated determinations of tree failure probability.

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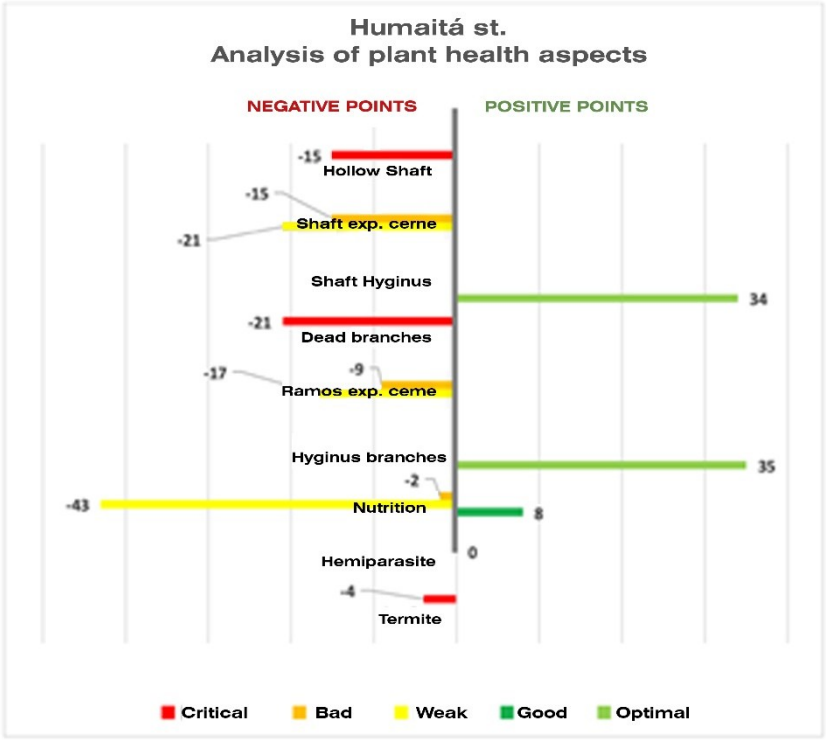


Figure 10. Phytosanity Aspects of Humaitá St.

Figure 10 summarizes the phytosanitary condition of the inventoried trees, considering biological agents, nutritional status, and structural damage to branches and trunks. Regarding biological agents, termite attacks were identified in 4 trees, while no individuals presenting hemiparasites were recorded. The nutritional assessment indicated that 8 trees were classified as well-nourished, 43 as partial visual symptoms of nutritional deficiency, and 2 as pronounced visual symptoms of nutritional deficiency.

The structural assessment identified 35 trees with branches without visible structural deterioration, 17 with minor heartwood exposure, and 9 with major heartwood exposure. In addition, 21 trees were recorded as presenting dead branches, representing a relevant phytosanitary and safety concern. Regarding trunk condition, 34 trees were classified as having trunks without visible structural deterioration, 21 presented minor heartwood exposure, 15 presented major heartwood exposure, and 15 were identified as having hollow trunks. The presence of hollow trunks and exposed heartwood indicates structural deterioration that may compromise tree stability, particularly under adverse weather conditions, and therefore requires appropriate technical assessment and management intervention.

It is important to distinguish between the recorded phytosanitary conditions and mutually exclusive classifications. Some structural problems may coexist in the same tree; for example, an individual may have dead branches and a trunk with exposed heartwood or a cavity. Accordingly, the frequencies of these observations should not necessarily be added together to obtain the number of affected individuals. The results emphasize the need for regular phytosanitary monitoring, appropriate pruning, and targeted intervention for trees presenting serious structural deterioration.

The SWOT analysis graph of the Phytosanitary Aspects highlights the presence of (34 to 35) healthy individuals as Optimal points. However, several problems are in the negative points range, the most serious being the (21) trees with dead branches and the (15) individuals with hollow trunks. Again, the visualization of trees with more serious problems can be done through a quick query to the database. The production of a specific analysis list for individuals with problems can encompass two or more items, as shown below in **Figure 11**. In this list, prepared in a similar way to the one created to identify and locate by numbering the trees with Environmental Risk characteristics, the individuals who presented problems with Termites,

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Dead Branches, and Hollow Trunks are displayed. The chosen items are highlighted in the Plant Health SWOT chart with red color and graded as 'Critical', hence an indication that they represent a serious risk to the population and demand immediate corrective action. However, in the list in **Figure 11**, the colors of each item were differentiated and labeled so that their identification was possible.

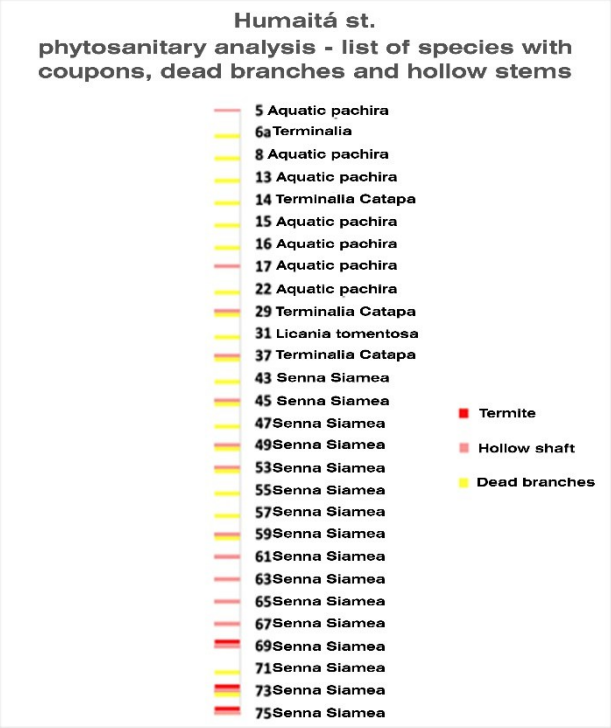


Figure 11. List of phytosanitary aspects, with the identification of trees with Termite, Dead Branches, and Hollow Trunks.

The individual assessment also enabled the identification of trees presenting combinations of unfavorable conditions. As illustrated in **Figure 11**, the individuals numbered 5, 29, 37, 45, 49, 53, 59, 69, 73, and 75 were identified as presenting particularly serious phytosanitary conditions. These trees were selected based on the presence of multiple negative attributes, including conditions classified as Critical. Their identification was not based on a single aggregated numerical score, but on the combined interpretation of the individual attribute classifications. This procedure allowed trees with serious structural or phytosanitary deficiencies to be distinguished from individuals presenting predominantly favorable characteristics, even when the latter also exhibited isolated weaknesses. The resulting list provides a practical basis for prioritizing technical inspection, monitoring, and corrective management interventions.

Strengths, Weaknesses, Opportunities, and Threats Analysis of Humaitá St.

The results of Humaitá Street punctual analysis eventually composed an accurate diagnosis of the street-tree inventory general state. As long as the purpose of this study was analyzing the neighborhood scale of a Green Infrastructure, it was necessary to summarize the results of the evaluations and analysis of the problems encountered. In this context, the organization of the data was carried out with the transposition of the results and analysis to an adapted SWOT matrix. Thus, the performance evaluation method used in the PDAU-Rio (2015) inspired the adaptations to the SWOT original tool and the development of the system adopted for the global analysis of the scenarios found.

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The Excel database supported the automated organization and processing of the inventory records, including the generation of spreadsheets, graphs, and attribute-specific lists that were updated when the underlying data were modified. The final summary matrix, however, was not generated automatically by the database. It was manually compiled by consulting the spreadsheet outputs and transferring the relevant attribute grades and their corresponding counts or percentages into the matrix. Therefore, two distinct stages should be distinguished: (i) automated data processing and graphical presentation through the Excel database; and (ii) manual synthesis and interpretation of the results in the final condition-assessment matrix. The matrix should consequently be understood as a manually prepared summary of the inventory findings, informed by the automated outputs, rather than as an automatically calculated SWOT result. **Table 11** presents the classification of the evaluated attributes according to the six condition levels adopted in this study: Optimum, Good, Normal, Weak, Bad, and Critical. The matrix provides a synthesized representation of the ecological value assessment, bringing together information on tree identity, adaptation to the urban environment, and phytosanitary condition. The results include both attributes describing the condition of individual trees and observations that may coexist within the same individual. Therefore, the frequencies of overlapping observations should be interpreted as attribute-specific occurrences rather than as mutually exclusive groups of trees.

Table 11. Summary matrix of the six-grade tree-condition assessment for Humaitá Street, organized using a SWOT-inspired structure

SWOT	Strengths		Weaknesses	SWOT
Opportunities	• 92% perennials • 54% Indigenous • 73.5% age > 25 years • 54.72% height > 15,0 m • Unimpaired Trunks = 17 trees • Unimpaired branches = 27 trees	Optimum	Critical • Environmental risk: 4 trees • Telecom Conflict = 18 trees • Gas/Water/sewage • Conflict = 8 trees • Electric conflict = 9 trees • Hollow Trunks = 15 trees • Dead branches = 9 trees • Termite = 4 trees	Threats
	• 4% regional • Collar = 30 trees • 41.5% wooden Cat. C-2 • Tilt < 7.5% = 19 trees • 21% age 15 to 25 years • 20.75% height 10,0m to 15,0m • Pruning = 14 trees • Proper nutrition = 8 trees	Good	Bad • 46% exotic • Inclination > 15° = 15 trees • Other conflicts = 25 trees • Collar = 13 trees • Trunk h. wood exp. =21 trees • Branches h. wood exp. = 17 trees	
Threats	• 96% compatible • 24.53% height less than 10,0m • Pruning = 26 trees	Normal	Weak • 8% deciduous trees • 54.7% of trees in wood category C-4 • Inclination 7.5°–15°= 19 trees • Pruning = 13 trees • Collar = 13 trees • Trunk h. wood exp. =15 trees • Branches h. wood exp. = 9 trees	Opportunities

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Table 11 presents a consolidated SWOT-based interpretation of the inventory results, organizing the evaluated attributes according to their respective condition classes. The entries summarize the occurrence of favorable and unfavorable characteristics identified during the field assessment. They do not represent indicator weights or the results of a mathematical aggregation of individual tree scores. Since the matrix consolidates different attributes, its entries should be interpreted according to the specific characteristic being reported. The presence of an individual in a favorable category for one attribute does not preclude its simultaneous classification in an unfavorable or Critical category for another attribute. Therefore, the matrix supports the identification of management priorities by highlighting the nature and severity of the conditions observed, rather than by ranking all trees through a single composite numerical value.

The summary of the Humaitá Street evaluations presented in the adapted assessment matrix provides an overview of the main characteristics and condition indicators recorded in the inventoried tree population. Most of the trees were mature and evergreen. The attribute-specific results showed that 35 trees were recorded as having healthy branches and 34 as having healthy trunks. These observations refer to separate components of the trees and do not establish the overall health condition of each individual, since different defects may coexist on the same tree. The assessment also identified several adverse conditions, including infrastructure conflicts, trunk and branch defects, and the presence of termites. These findings indicate the need for differentiated management and further inspection of the affected individuals. The assessment identified four trees classified under the environmental-risk indicator, as well as individuals presenting phytosanitary or structural observations requiring attention. These records should be interpreted as indicators for management consideration rather than as a validated diagnosis of imminent tree failure. In particular, the observation of termites, trunk cavities, exposed heartwood, dead branches, or conflicts with urban infrastructure does not, by itself, establish the probability or timing of tree failure. Such conditions may justify a more detailed inspection by a qualified arboricultural professional, who can consider the severity, location, extent, and interaction of the observed defects. Accordingly, the inventory provides preliminary information to support the identification of trees requiring follow-up, rather than a definitive assessment of their mechanical stability or failure risk.

The adapted SWOT matrix provides an integrated overview of the ecological value and management conditions of the Humaitá Street tree population. The assessment indicates that the inventoried green infrastructure has relevant positive characteristics, including a substantial proportion of mature and perennial trees. At the same time, the results reveal weaknesses and threats associated with infrastructure conflicts, inadequate root-collar conditions, pruning requirements, nutritional deficiencies, and structural damage to branches and trunks. These findings indicate that the maintenance of the existing tree population requires a differentiated management strategy, prioritizing individuals presenting serious phytosanitary or structural problems while also addressing recurring conflicts between trees and urban infrastructure. Rather than relying on a single general indicator of tree health, the proposed assessment considers the individual attributes separately, allowing management priorities to be established according to the nature and severity of the observed conditions.

To clarify how the condition-assessment results inform management decisions, **Table 12** summarizes the general interpretation and management implications associated with each of the six grades. These implications are indicative and should be applied in accordance with the specific attribute and the technical assessment of each tree.

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Table 12. Interpretation of the six condition grades and their corresponding management implications.

Condition grade	Interpretation	Management implication
Optimum (+3)	Attribute in optimal condition	Preserve the existing condition; routine monitoring as appropriate.
Good (+2)	Favorable attribute condition	Maintain the current condition; preventive maintenance where necessary.
Normal (+1)	Acceptable or standard condition	Continue routine maintenance and periodic monitoring.
Weak (−1)	Noticeable deficiency or vulnerability	Monitor the attribute and undertake corrective maintenance when required.
Bad (−2)	Pronounced deficiency or problem	Prioritize technical assessment and appropriate corrective intervention.
Critical (−3)	Severe condition or potentially serious risk	Urgent technical inspection and priority management action.

The field inventory identified phytosanitary and structural conditions in several trees along Humaitá Street, with the type and frequency of observations varying among the inventoried species. Approximately 30% of the inventoried Senna siamea individuals were recorded with the phytosanitary or structural conditions considered in this assessment. This observation indicates that these individuals warrant attention, but it does not establish that the species as a whole is poorly adapted to the urban environment. In some Pachira aquatica individuals, dead branches were among the recorded conditions. Although the attribute results provide a basis for comparing the observations recorded for the inventoried species, they should not be interpreted as a definitive ranking of species health or long-term adaptation, particularly in the absence of a longitudinal assessment.

It is important to note that Humaitá St. has a “boulevard” typology, has a southeast-northwest orientation, which allows the penetration of the trade winds, and is lushly adorned with trees on both sidewalks and in the central bed. Despite its large configuration, except for the areas of the tree collars, the remaining soil is completely waterproofed. The streets are paved with asphalt and the sidewalks have alternate paving solutions, sometimes they are cemented, sometimes covered with Portuguese mosaic. The street heavy vehicle traffic is also another striking feature, classifying Humaitá St. as an unfavorable environment for the biotic element. In this way, the maintenance of the current afforestation is of extreme importance for the conservation of the biophilic aspects of the neighborhood. These adverse conditions highlight the street necessity to receive more attention from the public authorities, as its trees is mostly composed of species in the process of decay, and the succession planning should already be in the drafting stage.

The added value of the proposed framework lies not in replacing the conventional floristic inventory or in introducing a new formal SWOT algorithm, but in structuring the inventory information so that different dimensions of tree condition can be examined together. The Identity, Adaptation, and Phytosanitary Condition categories provide a common assessment structure for attributes related to species characteristics, interactions with the urban environment, and tree health. The six-grade classification preserves distinctions between different levels of favorable conditions and deficiencies, while the spreadsheet-generated graphs and attribute-specific lists facilitate the identification and location of relevant observations. In addition, the individual tree records allow more than one deficiency to be considered for the same tree. This is particularly useful when identifying individuals presenting multiple serious phytosanitary problems, as illustrated by the critical-tree list in **Figure 11**. The final summary matrix complements the individual inventory records by presenting the

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distribution of the assessed conditions at the street scale. Thus, the framework connects individual tree observations with a consolidated diagnosis of the urban tree population and provides a practical basis for identifying attributes and individuals that require further inspection, monitoring, or management intervention.

Limitations and uncertainty of the assessment

The findings of this study should be interpreted in light of several methodological limitations. First, although the inventory covered the identified tree population within the selected study area, the reliability of individual measurements was not assessed through a formal calibration procedure or independent validation. Tree heights were visually estimated by comparison with nearby constructed elements, while approximate ages were derived from trunk circumference and empirical species growth-rate assumptions. These procedures introduce uncertainty, particularly when estimated values are close to the thresholds used to define the assessment categories.

Second, some structural and phytosanitary attributes were classified through visual field observations. Although predefined grading criteria were used, the distinction between different levels of heartwood exposure, nutritional condition, and other visible symptoms may involve observer judgment. The study did not include repeat scoring, independent expert assessment, or statistical evaluation of inter-assessor agreement. Therefore, the consistency and reproducibility of these classifications have not been empirically established.

Third, the study did not conduct a formal sensitivity analysis to quantify the effects of alternative measurement values or classification thresholds on the distribution of the condition grades and the resulting management priorities. In particular, uncertainty in estimated height and age may affect the classification of individual trees located near the adopted thresholds. Similarly, alternative interpretations of visual condition indicators could influence the number of trees assigned to specific grades. Accordingly, the reported classifications should be understood as indicative results from an exploratory field assessment rather than as validated diagnostic determinations.

The numerical codes assigned to the six condition grades were used to organize and visualize the inventory information and were not combined through a weighted aggregation procedure. Thus, the study did not establish a composite score for ranking individual trees, nor did it assess sensitivity to alternative indicator weights or numerical score spacing. Management priorities were interpreted from the presence and severity of specific observed deficiencies, particularly those associated with structural deterioration, dead branches, hollow trunks, and conflicts with urban infrastructure. These observations identify conditions that warrant attention but do not replace detailed arboricultural inspection or a formal tree-risk assessment.

Future studies should incorporate calibrated height-measurement procedures, independently verified age information where available, standardized visual assessment protocols, and repeat evaluations by multiple trained assessors. Inter-assessor agreement could then be quantified, and sensitivity analyses could be performed by varying measurement values and classification thresholds to determine whether individual tree classifications and management priorities remain stable. Such procedures would strengthen the reproducibility and reliability of the framework and support its application to other urban tree populations.

CONCLUSIONS

Urban green infrastructure is widely considered an important component of sustainable urban environments because of its potential contributions to ecological quality, urban well-being, and environmental regulation. However, the present study focused specifically on the inventory and condition assessment of the existing tree population along a section of Humaitá Street, Rio de Janeiro, Brazil. Its findings therefore concern the recorded characteristics and

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condition indicators of the inventoried trees and do not constitute a direct measurement of cooling effects, thermal comfort, or the mitigation of climatic extremes. Urban nature, also called green infrastructure, is recognized as an important structural element in the composition of barriers that act to mitigate the consequences caused by environmental extremes. Wooded spaces and land with natural drainage retain rainwater, help maintain ecological flows, support the preservation of urban fauna and even prevent the formation of "heat islands". Therefore, the creation, in the same proportion as the city expands, of green spaces integrated into the urban fabric is considered the most ecologically adequate solution to sustain the quality of life, in addition to providing the population with access to spaces that afford a beneficial coexistence with nature.

The best way to study a biological system is to extend the investigation beyond the study of individual species. Ideally, the scope of the research should encompass the relationships and interactions between living organisms and the abiotic environment. In a specific sphere, such as the Humaitá street, the afforestation beneficially interacts with the physical environment for the production of biotic structures and, in this context, the biomass accumulated through carbon sequestration from the atmosphere directly contributes to the maintenance of natural flows of energy, while simultaneously acting on the cycling of inorganic matter

The proposed analyses for the evaluation of the state of Humaitá Green Infrastructure were based on the concept of Ecological Value. The ultimate purpose of the present floristic inventory was the elaboration of a tool to facilitate the study of tree species performance, on a neighborhood scale, with the largest tolerance to the urban environment inconsistencies.

The complex assessment of the ability of plant organisms to adapt to numerous urban threats recommended the organization of the analysis into specific ecological value categories, establishing parameters for evaluating the inventoried tree individuals. The system developed for the present research was based on the integration of approaches reported in the literature on floristic inventories and urban afforestation management. The diversity of land-use patterns, the limitations imposed by the urban fabric, and the presence of infrastructure networks create challenging conditions for urban vegetation and influence the composition and performance of the tree population. According to the floristic inventory presented in **Table 9**, the 53 inventoried individuals comprised five species: *Pachira aquatica* (27 individuals), *Senna siamea* (18), *Terminalia catappa* (4), *Ficus benjamina* (2), and *Licania tomentosa* (2). Thus, *Pachira aquatica* was the most frequently recorded species, followed by *Senna siamea*. These results provide a clearer description of the floristic composition of Humaitá Street and establish a consistent basis for interpreting the species-level findings.

The investigations of the Humaitá Street's Green Infrastructure provided an exploratory assessment of the observed characteristics and condition of the inventoried tree population. The ecological value attributes evaluated in this study covered three main dimensions: Identity, Adaptation, and Phytosanitary Condition. The database developed in Microsoft Excel 2013® facilitated the organization of the field records, the generation of graphical summaries, and the identification of individual trees presenting relevant deficiencies. The six-grade classification framework provided a structured means of interpreting the inventory observations and identifying conditions that may require preservation, monitoring, corrective maintenance, or further technical inspection. However, because the study did not include formal measurement calibration, independent validation, inter-assessor agreement testing, or sensitivity analysis, the results should be regarded as an exploratory diagnosis rather than as evidence of a validated or universally applicable assessment model.

The use of the SWOT method, which permeated all analytical instances of the present study, was inspired by the analogous process used in the PDAU-Rio. However, the adaptation of the SWOT matrix to encompass the various characteristics and particularities of the urban tree inventory was the most relevant point for the Ecological Value data evaluation. The addition of Multiple Criteria aspects to construct the relational analysis guidelines complemented the present study, facilitating the assembly of graphics for the evaluation and grading of the aspects

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of identity, adaptation, and phytosanitary conditions. In this sense, due to its characteristics of reading and data disposition, the adapted SWOT system developed specifically for this dissertation study was certainly its most significant contribution. Another interesting aspect, promoted by the present research, was the generation of a faithful sampling of a specific plant community, which could serve as a basis for future investigations in the same object area or even as a method to be adopted for the analysis of other plant communities, provided that its main purpose is the detailed assessment of afforestation and the analysis of the undesirable effects of environmental variations.

The evaluation of Humaitá St. afforestation correlated to the urban environment and its ecological aspects were factors of great importance for the understanding of the current processes of quality-of-life degradation in large Brazilian cities. Therefore, in the same proportion that problems faced by Green Infrastructures expand, the understanding and rapid assessment of the urban vegetation mosaic conditions is crucial for its maintenance. The main contribution of the present study was the development and application of an integrated procedure for organizing and interpreting multiple attributes of an urban tree inventory. By combining field observations, a six-grade condition classification, spreadsheet-based data processing, and a consolidated summary matrix, the approach facilitated the identification of relevant characteristics and potential management concerns within the studied street-tree population. The procedure offers an initial decision-support structure for organizing inventory information, although its measurement accuracy, repeatability, and sensitivity to alternative classification thresholds remain to be established through further validation.

The proposed framework provides an organized basis for documenting tree characteristics and observed condition indicators that may be useful to professionals and public authorities involved in urban tree management. By making the recorded attributes and potential maintenance needs more readily identifiable, the approach may support the planning of subsequent inspections and management activities. Nevertheless, the present study did not quantify maintenance-cost reductions, changes in ecosystem performance, improvements in thermal comfort, or the mitigation of environmental extremes. These outcomes should therefore be regarded as potential motivations for improved urban-tree management and as subjects for future investigation, rather than as effects demonstrated by the present inventory.

To fulfill the main objective of this research, the sample design and the projected method generated some unexpected and spontaneous ramifications that ended up proving imperative and enriching for the development of the work. Thus, the purposed questions were substantially expanded, mainly due to the facilities offered by the data compilation system.

The data organization and attribute-based assessment enabled the characteristics and observed condition of the inventoried trees to be presented in a structured manner. By combining information on tree identity, adaptation to the urban setting, and phytosanitary and structural observations, the proposed framework offers a practical way to organize field-inventory information and identify conditions that may require further management attention. The present application demonstrates the feasibility of using this framework to structure and summarize a site-specific tree inventory; however, it does not constitute an independent validation of its accuracy, predictive performance, or effectiveness in improving environmental conditions. Its application to other urban contexts would require consideration of local conditions and further evaluation.

Among other factors, the prioritization of the SWOT system and its adaptation by the authors of the research for the marking of the stage of evaluation and diagnosis of the inventoried data, was based on the fact this system is a reasonably successful organizational instrument and because it was already being used in the marking of the propositions of the PDAU-Rio - Master Plan for Urban afforestation of Rio de Janeiro. Thus, it can be stated that its adoption further occurred because it was a well-known management tool already being handled by the teams responsible for the management of urban afforestation in the city.

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The adaptations made to the SWOT matrix were carried out to expand the objective criteria to generate analyzes based on facts and not on individual assumptions, along with the intention of reinforcing the implementation of a method focused on obtaining scientifically measurable data.

In these circumstances, the parameters adopted for the creation of the items of the ecological value table were carefully chosen so that their acquisition and subsequent evaluation were carried out scientifically, focusing on minimizing the margin of error in obtaining and transposing the data to the quadrants of the adapted SWOT Matrix.

Thus, it is important to emphasize that this analytical model was created to be used as an auxiliary tool for the management and planning of urban areas. Therefore, despite the mechanisms carefully developed to mitigate the weaknesses and inaccuracies of the model, many other relevant analytical factors were left out simply because they would demand greater availability of the field team, burden the costs of the survey and delay the analyzes, which would also result in reckless delay in decision-making.

Currently, in the state of Rio de Janeiro, the municipality of Niterói has a digital georeferencing platform, SIGeo (https://www.sigeo.niteroi.rj.gov.br/). However, despite presenting a careful census-type inventory of the municipality urban trees, with biometrics and phytosanitary data, the portal does not have an evaluation system to highlight the most relevant management needs and, thus, the performance of the teams responsible for urban arborization maintenance is impaired. Thereupon, a hypothetical adoption by the Municipality Administration of Niterói city of the evaluation system would positively accelerate management decisions, reduce the burden of maintenance costs, and mitigate environmental calamities.

The findings are specific to the surveyed tree population along Humaitá Street and should not be directly generalized to other urban areas without further assessment. Application to other locations would require adaptation to local species composition, environmental conditions, urban infrastructure, and management requirements. Future research should prioritize the validation of biometric estimates, standardized assessment protocols, independent scoring by trained assessors, and sensitivity analysis of classification thresholds. These steps would help determine the robustness and transferability of the proposed exploratory framework and support its future development as a more reproducible tool for urban tree management.

The interpretation of the phytosanitary and structural observations also requires caution. The presence of termites, trunk cavities, exposed heartwood, dead branches, or conflicts with telecommunications, electricity, water, sewage, or other urban infrastructure was recorded as an attribute of the inventoried trees. These observations can indicate conditions that deserve monitoring or further technical examination, but they do not independently establish imminent tree failure or quantify the probability of failure. The study did not include a dedicated arboricultural risk assessment based on detailed evaluation of defect severity, likelihood of failure, likelihood of impact, and potential consequences. Therefore, references to management priorities should be understood as preliminary indications for follow-up inspection, not as definitive recommendations for tree removal or as confirmation of an immediate hazard. Further research should extend the present inventory by incorporating direct and repeated measurements of microclimatic variables, such as air and surface temperatures, relative humidity, and other indicators relevant to outdoor thermal comfort. Such measurements, preferably collected across different seasons and under comparable environmental conditions, would be necessary to evaluate whether and to what extent the inventoried green infrastructure contributes to local cooling and the mitigation of climatic extremes. In parallel, independent arboricultural inspections and repeated assessments would help validate the interpretation of the observed phytosanitary and structural conditions. These complementary investigations would allow future applications of the framework to move beyond inventory-based diagnosis and examine environmental performance and tree-risk conditions using specific and independently assessed evidence.

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