

TREE HEALTH ASSESSMENT IN AN INSTITUTIONAL GREEN SPACE: INAOE CASE STUDY

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ABSTRACT

Knowledge of the health condition of urban trees is fundamental for making decisions regarding management and resource allocation. The objective of this study was to determine the current health status of the trees at the National Institute of Astrophysics, Optics, and Electronics (INAOE) in San Andres Cholula, Mexico. Five health indicators previously used in urban forests were assessed. The structure and diversity indicator indicated the existence of 2210 trees, mostly (58.8 %) of small size (< 20 cm average diameter at breast height), 20 botanical families, and 32 tree species. The crown condition and its variables indicated high foliage transparency (> 40 %) in some of its species and low percentages of dieback. Live crown ratio and crown density were moderate in eight and six species, respectively. The tree damage indicator showed the existence of 44 damaging agents in 956 trees (43.3 % of the total), highlighting the ball moss (*Tillandsia recurvata*), the felt fungus of evergreen ash (*Septobasidium* sp.) associated with an armored scale, the same fungus also affecting white cedar (*Hesperocyparis lusitanica*) in association with another scale (a new record), and two bark beetles, *Hylesinus aztecus* in evergreen ash, and *Phloeinus* sp. in white cedar. Regarding the mortality indicator, 75 trees (3.3 %) were recorded. Finally, the soil condition indicated that the pH was close to neutral, with electrical conductivity values above 2 dS m⁻¹ and a low beneficial mycoflora population. All these factors, together with the imbalance in tree diversity, high planting density, compacted soils, and the presence of risky trees, are negatively affecting the health of INAOE's tree community.

Key words: health indicators, plant diversity, crown condition, damage, soil.

INTRODUCTION

The importance of maintaining the environmental quality and health of forest ecosystems and urban forests is increasing due to the rapid development of urban centers (McDonnell and Kendal, 2018). In this context, and as part of the New Urban Agenda 2030, the United Nations, in its Sustainable Development Goal (ODS) 11, highlights the importance of green spaces to improve living standards and human health, foster social cohesion and inclusion, and ensure the sustainable development of cities. Therefore, some countries were committed to increasing the area of green, accessible, safe, and high-quality spaces (Borelli *et al.*, 2018). Given this commitment,

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increasing and/or maintaining the world's forested area is an unprecedented challenge. However, meeting current demands in an equitable manner is not easy. In European cities, for example, the green area per capita distribution varies by country, from 4 m² in Macedonia and southern Italy to 200 m² in Belgium and Austria (Fuller and Gaston, 2009). In Mexico City, 7.54 m² are reported (SEDEMA, 2017), so achieving an acceptable surface of green area per individual requires substantial economic resources, better urban planning (Peckham *et al.*, 2013), and greater environmental education. Urban trees provide shade, remove pollutants from the atmosphere, capture carbon, reduce noise, and beautify the city, as well as contribute to improving the physical and psychological health of citizens. Their presence alone can increase property values by 9–27 %, depending on their location and health condition (Conway *et al.*, 2010; Turner-Skoff and Cavender, 2019). The inclusion of healthy wooded areas is becoming increasingly important in urban development plans (Abebe and Megento, 2017). However, the current health condition of urban green areas must be studied in order to implement timely management strategies to mitigate precarious tree health conditions (Guerra-Hernández *et al.*, 2021) and reduce possible tree risk situations (Macías-Muro *et al.*, 2022). In this sense, different studies on the health assessment of urban trees using health indicators have been carried out in various parts of the world, including Mexico (Zaragoza-Hernández *et al.*, 2015; Saavedra-Romero *et al.*, 2021). Not enough attention has been given to the institutional green areas, which are distinct from other types of green spaces. It is the responsibility of the authorities to offer quality green areas to students, teachers, and employees. Unfortunately, due to a lack of budget and vision, this is becoming increasingly difficult. Therefore, the objective of this study was to determine the current health condition of the trees belonging to the National Institute of Astrophysics, Optics, and Electronics (INAOE), as a prior step to making decisions regarding management, resource allocation, and congruence with the objectives of the New Urban Agenda 2030.

MATERIALS AND METHODS

Study area

The study was conducted in the green areas of INAOE at Santa Maria Tonantzintla, located in the municipality of San Andres Cholula in the state of Puebla, Mexico (19° 01' 53" N and 98° 18' 55" W), from January 27 to September 23, 2022. According to the points generated through the UTM Geo Map and Google Earth 2022 platforms, the institute has an area of approximately 7.5 ha and a general parking space of 0.53 ha (Figure 1).

Inventory and sampling

All standing trees (living and dead) between the buildings with a diameter at breast height (DBH) of more than 7.5 cm (Saavedra-Romero *et al.*, 2016) were inventoried. A sampling was conducted using three 1000 m² circular plots (radius = 17.84 m) in the

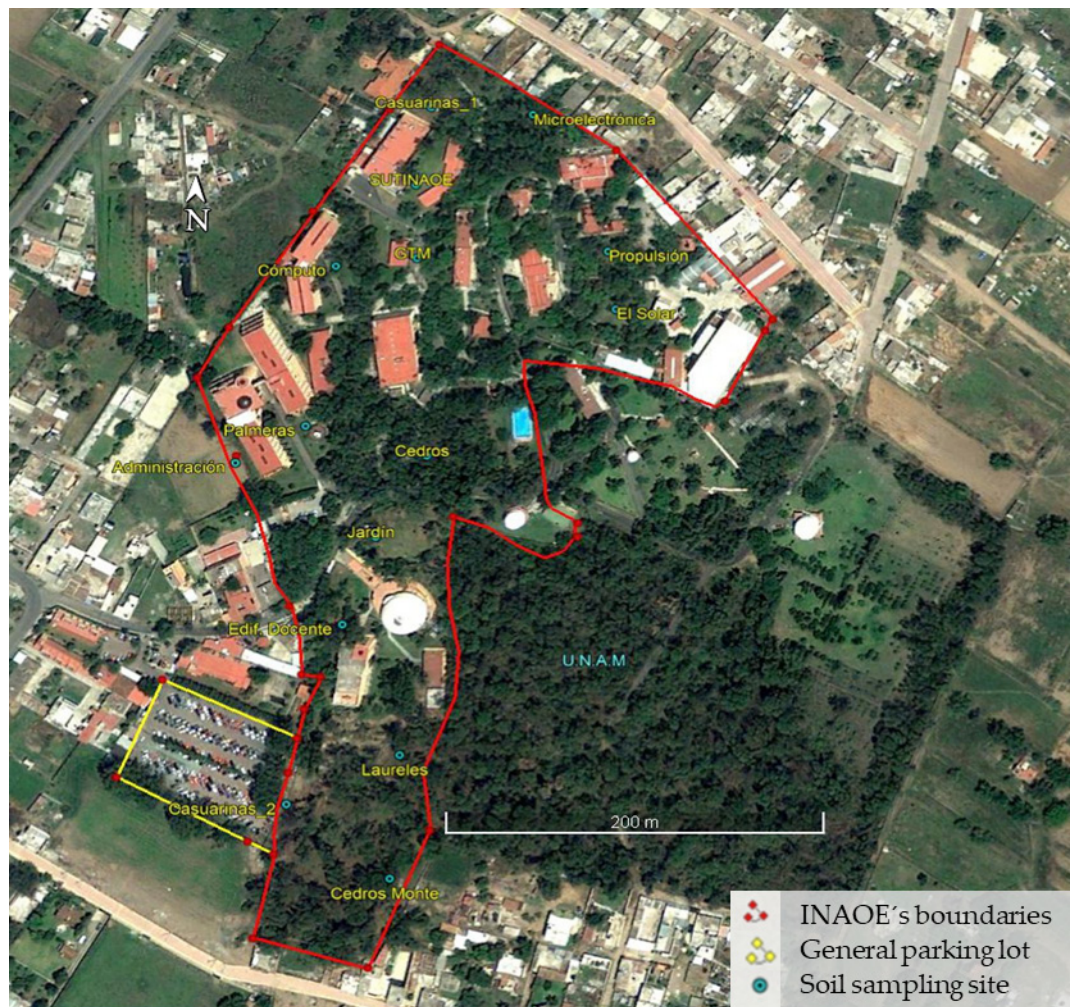


Figure 1. Polygon of the National Institute of Astrophysics, Optics, and Electronics (INAOE) in Santa Maria Tonantzintla, Puebla, Mexico, through UTM Geo-Map and Google Earth 2022 platforms.

“El Monte” portion (based on its topography, similar to a natural forest), located on the southern side (Casuarinas 2, Laureles, and Cedros Monte) (Figure 1).

Health condition assessment

The assessment was performed by recording five health indicators previously used in natural forests (Randolph, 2018) and adapted by Saavedra-Romero *et al.* (2016, 2019b, 2020, 2021) for urban green areas in Mexico City. Additionally, a tree risk assessment was carried out for potential damage to property and human lives (Saavedra-Romero *et al.*, 2019a). The assessment description of each indicator is briefly described below.

Tree diversity and structure

Each tree was taxonomically identified. The DBH (calculated at a height of 1.3 m from the base of the tree) was measured using a Hagl of caliper, and the overall tree height was recorded using a Haga altimeter. These data were used to create frequency histograms.

Crown condition

Four absolute crown variables were assessed visually to estimate the amount, condition, and distribution of biomass in the crown of each tree at 5 % intervals (Randolph, 2015): a) live crown ratio (Lcr), b) crown density (CDen), c) foliage transparency (Ftra), and d) crown dieback (CDie). The results were expressed as average values per species.

Damage agents

Two damaging agents per live tree were recorded. In the case of epiphytic plants, the level of severity was recorded using the Hawksworth (1977) six-class system. Samples with symptoms and signs were collected and processed at the Forest Pathology Laboratory of the Postgraduate College in the municipality of Texcoco, State of Mexico, Mexico.

Soil condition

A fractionated auger was used to collect 33 composite soil samples at a depth of 15 cm in 5 cm increments. The laboratory analyses performed were: bulk density (BD) and porous space (PS), pH (soil:water ratio, 1:2.5), electrical conductivity (EC), and associated mycoflora. Fifteen areas of the INAOE were sampled (Figure 1).

Mortality

Previous studies suggest that trees, regardless of age, die as a result of the impact of different additive and interactive stressors (Hilbert *et al.*, 2019). Dead trees were identified and, when possible, the probable reason was determined.

Tree risk assessment

The components included in the protocol were: a) probability of tree fall; b) probability of impacting a target based on area use; and c) size of the affected part (Saavedra-Romero *et al.*, 2019a). In addition, associated structural damage was identified to obtain a final risk rating.

Data analysis

A data matrix was created using Excel and InfoStat software (version 2020) for statistical analysis. Descriptive and parametric statistics were used. Tukey's test ($\alpha = 0.05$) was used to determine differences. The horizontal analysis for the soil condition indicator was performed with the average of the three sampling depths (0–5, 5–10, and 10–15 cm).

RESULTS AND DISCUSSION

Tree structure and diversity

From the inventory, a record of 2210 trees was obtained. The results for DBH and total height (m) show that, although there are specimens of considerable size, most of the trees are small, with an average diameter of 23 cm and an average height of 11 m (Figure 2). According to Richards (1983), urban green areas with a balanced and acceptable population distribution should have the following DBH categories: a) 40 % of the population with diameters < 20 cm; b) 30 % of the trees with diameters between 20 and 40 cm; c) 20 % from 40 to 60 cm; and d) 10 % greater than 60 cm. Based on this criterion, most of the trees in the INAOE are young, with diameters less than 20 cm (58.5 %), and will eventually replace mature, ill, and dead trees; 30.6 % had diameters

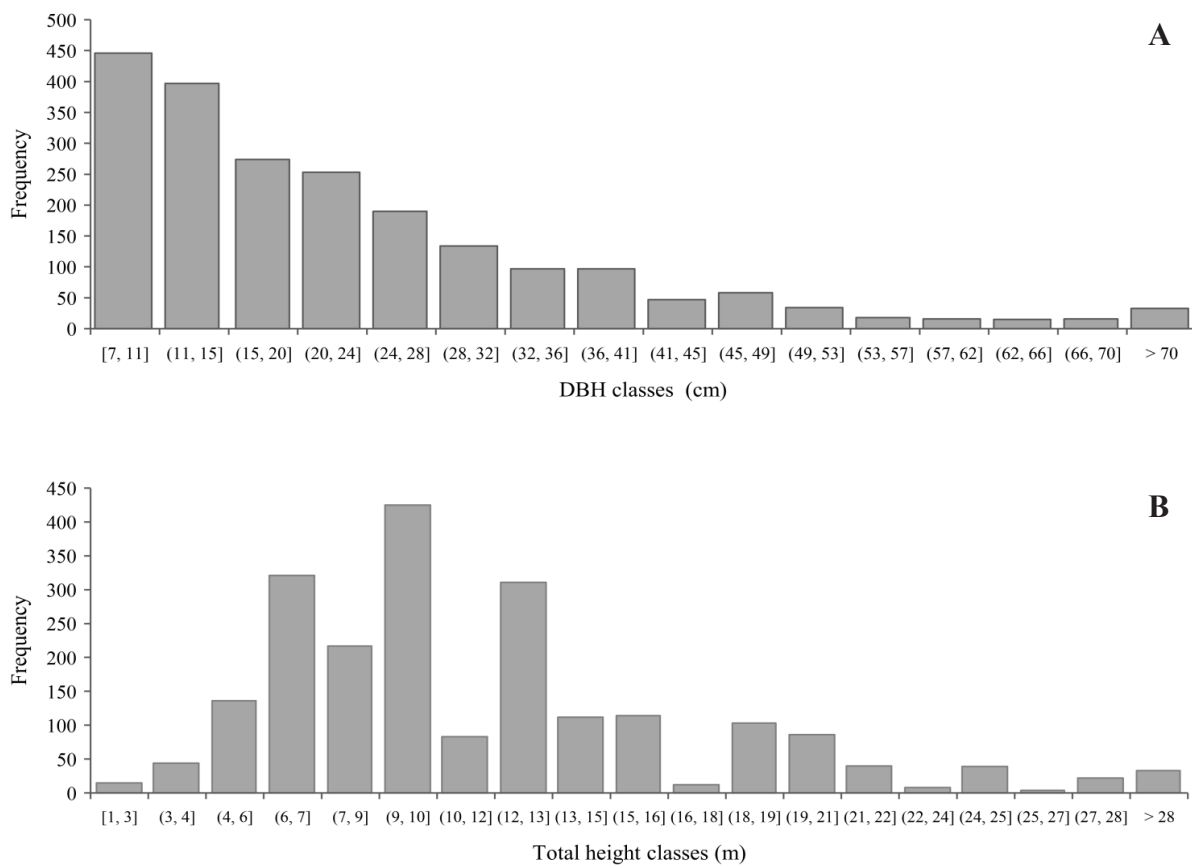


Figure 2. Frequency histograms for the 2210 trees evaluated at the INAOE in Santa Maria Tonantzintla, Puebla, Mexico. A: frequencies by diameter at breast height (DBH); B: frequencies by total height (m).

between 20 and 40 cm; 7.7 % between 40 and 60 cm; and finally, 3.1 % had values greater than 60 cm in diameter. It is advised not to plant any additional trees and to prioritize care for the young ones.

In terms of diversity, 20 botanical families of trees and two families of monocotyledons (Arecaceae and Asparagaceae) were identified. The most frequent families were Cupressaceae, Myrtaceae, Bignoniaceae, Oleaceae, and Casuarinaceae, among others, whose values were less than 7 %. Species richness was 32, with White cedar (*Hesperocyparis lusitanica* (Mill.) Bartel, synonym of *Cupressus lusitanica*), Red gum (*Eucalyptus camaldulensis* Dehnh.), Australian oak (*Casuarina equisetifolia* L.), Blue jacaranda (*Jacaranda mimosifolia* D. Don), and Evergreen ash (*Fraxinus uhdei* (Wenz.) Lingelsh) the most frequently occurring species (Figure 3). Two palm species were also recorded, Canary Island palm (*Phoenix canariensis* H. Wildpret) and Mexican fan palm (*Washingtonia robusta* H. Wendl).

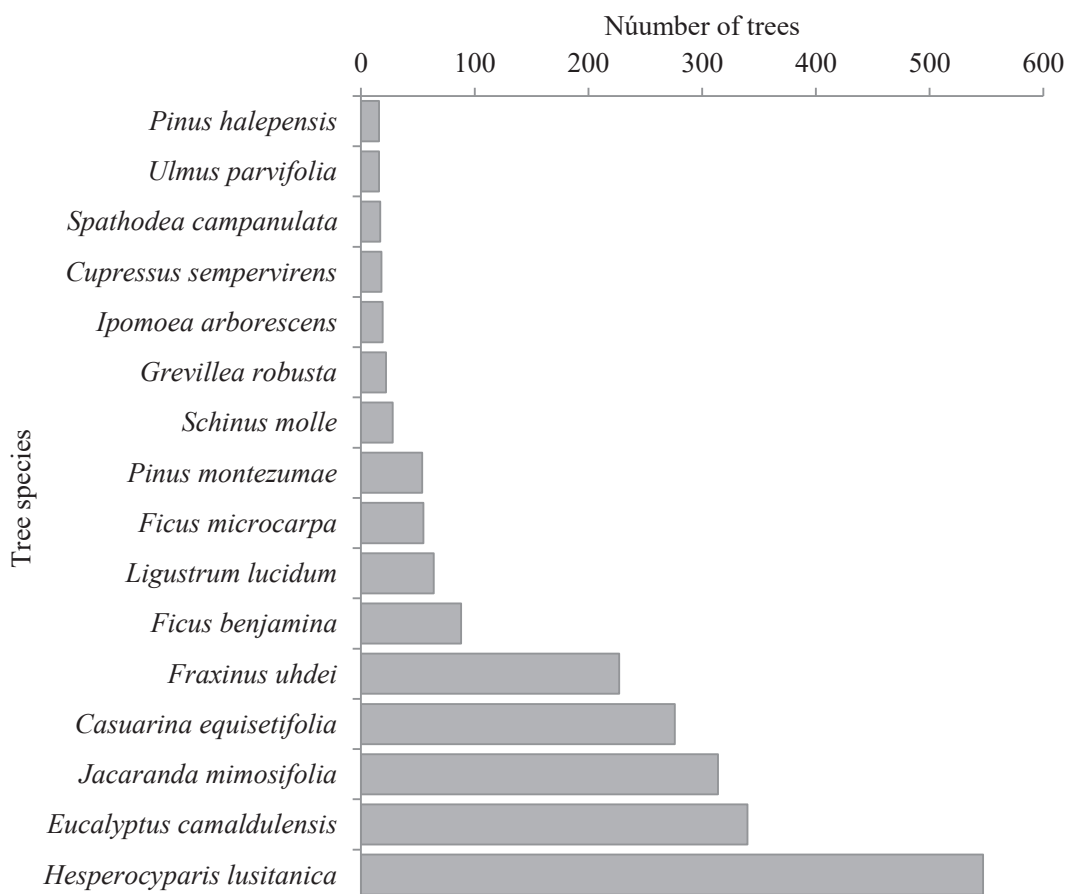


Figure 3. Main tree species identified in the green areas of INAOE in Santa María Tonantzintla, Puebla, Mexico (only 16 species are included).

For the diversity and stability of the tree community, maximum allowable percentages were proposed by species, genus, and family, which should not exceed 10, 20, and 30 %, respectively. The objective of this rule is to maximize the protection and conservation of urban forests against potential outbreaks of exotic and/or native pests and diseases (Calaza, 2021; Kendal *et al.*, 2014; Saavedra-Romero *et al.*, 2019a, 2019b). At INAOE, five species that do not meet the aforementioned standard (*Hesperocyparis lusitanica*, *Eucalyptus camaldulensis*, *Jacaranda mimosifolia*, *Casuarina equisetifolia*, and *Fraxinus uhdei*) present frequencies higher than 10 %. By genus, *Cupressus* exceeded 25 % of the tree population, and by family, none reached the established 30 % limit, so it is suggested not to increase the number of species mentioned and focus management activities on the existing ones.

Crown condition

In recent decades, comprehensive methods have been developed to assess, monitor, and detect early stress problems that impact the health of natural and urban forests (Alvarado-Rosales and Saavedra-Romero, 2021). The visual evaluation of the tree crown condition is one of the research lines of greatest interest because, through it, it is possible to distinguish symptoms of early and advanced stress, manifested by the amount of foliage present on the tree and by the way it is distributed along the trunk (Pontius and Hallet, 2014). At INAOE, during the dry season months (January to April), measurements of live crown ratio (Lcr), crown density (CDen), foliage transparency (FTra), and crown dieback (CDie) were recorded for tree species showing full leaf expansion only (for *Fraxinus uhdei* and *Jacaranda mimosifolia*, we waited until the rainy season). The percentages of Lcr were higher in *Cupressus sempervirens* and lower in *Eucalyptus camaldulensis* (Figure 4).

However, according to Saavedra-Romero *et al.* (2016), values above 30 % represent an adequate health condition. High foliage transparency (> 40 %) and low dieback rates were observed in some species. At least eight species had a moderate live crown ratio (31 to 50 %), and six had a poor to moderate crown density (< 40 %). According to different studies, the crown condition indicator displays a number of benefits, including its ability to detect symptoms of early stress and symptoms of imminent death. Therefore, all of its variables can be used to assess tree health.

Symptoms of early stress

Decreased photosynthetic efficiency is an initial symptom of loss of health (depending on species and season). However, this precedes, in many cases, the loss of foliage (increased transparency) (Pontius and Hallet, 2014). In the INAOE, species such as *Hesperocyparis lusitanica*, *Ligustrum lucidum*, *Eucalyptus camaldulensis*, and *Pinus montezumae* showed moderate transparencies, with values between 21 and 40 % (Figure 4), while *Pinus halepensis*, *Jacaranda mimosifolia*, and *Fraxinus uhdei* showed severe transparencies (> 40 %). While foliage loss may be caused by tree phenology, physiology, or both, it may also be caused by chronic stress; the latter is of particular importance.

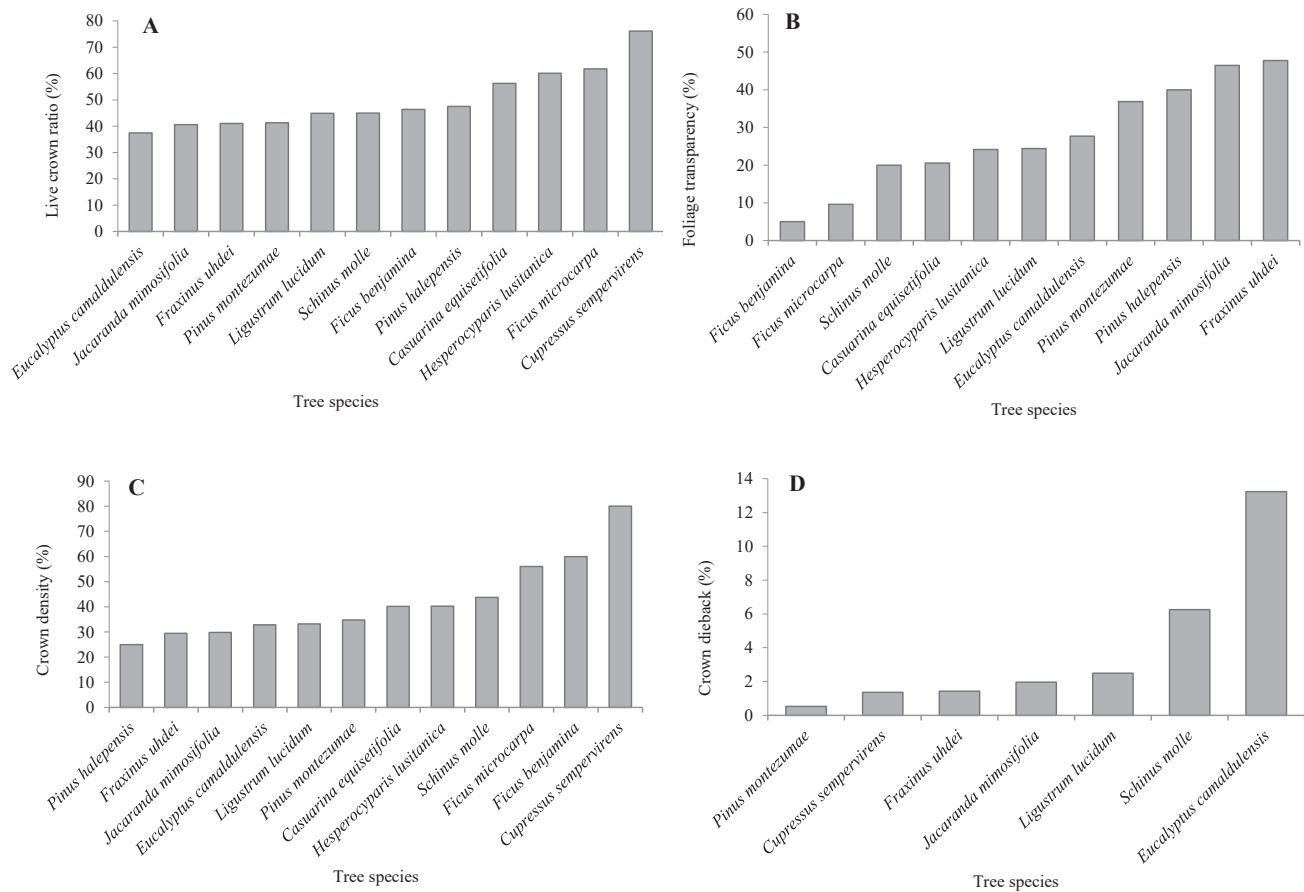


Figure 4. Average percentages of crown variables by tree species registered in the INAOE in Santa María Tonantzintla, Puebla, Mexico. A: live crown ratio; B: crown density; C: foliage transparency; D: crown dieback.

Symptoms of moderate stress

When predicting survival, crown dieback has been shown to be one of the most important variables (Morin *et al.*, 2015). In response to moderate stress, dieback is evidenced by the appearance of clusters of bare branches and twigs (without foliage), starting at the terminal part of a branch and progressing towards the trunk (Randolph, 2023). The death of these fine twigs can be categorized as a measure of recent health impact (that the death of these tissues has occurred in recent years). In this regard, in the INAOE, dieback showed low averages; only *Schinus molle* and *Eucalyptus camaldulensis* showed percentages in the light category (6 to 20 %) (Alvarado-Rosales *et al.*, 2021). However, other species such as *Fraxinus uhdei* and *Jacaranda mimosifolia*, whose twig dieback is increased by ball moss (*Tillandsia recurvata*) infestation, should not be overlooked.

Symptoms of decline

Among the final and obvious symptoms of tree health loss is the progressive crown reduction (crown shrinkage). In general, lower branches are first lost in several species due to shading, competition, or other damaging agents, until tufts of live foliage remain only in the upper part of the crown. In the green areas of the INAOE, at least eight species showed Lcr values in the moderate category (between 31 and 50 %). Four species were found in the adequate category (> 50 %) (Figure 4).

Healthy trees

Typically, trees with dense foliage (i.e., closed canopies) are associated with high growth rates, while small canopies and sparse foliage are related to a declining state (Randolph, 2018). The crown density variable, which is interpreted as the amount of foliage, branches, twigs, flowers, and fruits present in the crown, ranged from poor to moderate (0 to 40 %) in six species. The rest presented values above 50 % (adequate category); however, it was not possible to identify any individual in the optimum category. In summary, within a species, high values of crown density and low values of transparency and dieback are associated with healthy trees (Randolph, 2015). For INAOE trees, attention should be paid to trees showing the symptoms of decline described above at the time of maximum leaf expansion, depending on the species.

Damage agents

In the green areas of the INAOE, 44 damaging agents were identified in 956 trees (43.3% of the inventoried trees). Based on incidence, the ball moss or paxtle (*Tillandsia recurvata*) stood out with 37.23 %, followed by the felt fungus of evergreen ash (*Septobasidium* sp.) (6.17 %), bark beetle of evergreen ash (*Hylesinus aztecus*) (5.12 %), psyllid of red gum (*Glycaspis brimblecombei*) (5.12 %), black fungus of white cedar (*Septobasidium* sp.) (2.09 %), and the bark beetle of white cedar (*Phloesinus* sp.) (1.98 %) (Figure 5). By tree species, *Hesperocyparis lusitanica*, *Fraxinus uhdei*, and *Jacaranda mimosifolia* showed the highest populations of *T. recurvata*, with average severity levels of 2.6, 3.09, and 3.14 (on a Hawksworth rating system of 1 to 6), respectively, which could be an indicator that these species and the prevailing climatic conditions favor its development.

In white cedar, trunk cracks were prominent, making evident the prolonged periods of drought that have encouraged this damage. Finally, although bromeliads are reported as indicators of good growing conditions by providing enormous ecosystem benefits (Ladino *et al.*, 2019), their high populations cause branches, particularly those of *Jacaranda mimosifolia*, to bear excessive weight, turning these individuals into risk trees. By green area (Figure 1), the trees in the Enrique Chavira Building had the highest populations of ball moss, with an average severity of 3.77, followed by El Solar with 3.11 and to a lesser degree, the Optics Building, with a value of 1.

Regarding the presence of insects, two bark beetles were identified: *Phloesinus* sp., classified as secondary and affecting 19 white cedars, and *Hylesinus aztecus* on 35 ash trees. The presence of these insects is of concern, as attacks have been reported only

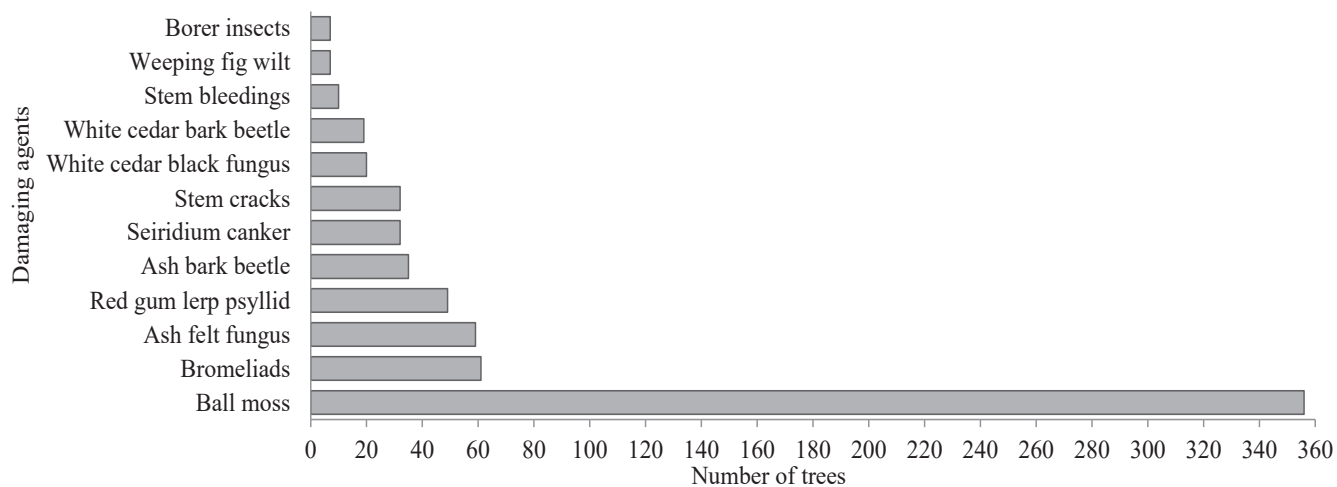


Figure 5. Damaging agents with greater representation in the green areas of the INAOE in Santa María Tonantzintla, Puebla, Mexico. Twelve damaging agents affecting $n \geq 7$ trees are shown.

on mature trees with large diameters. Unfortunately, in the INAOE, both insects are killing young trees that are perceived to be stressed, mainly due to high temperatures and a lack of soil moisture, factors that coexist with outbreaks of these type of insects, which have modified their growth patterns and larval development, causing the death of different woody species in different regions (Allen *et al.*, 2010; Bentz *et al.*, 2010).

Other agents that are causing damage are the felt fungus of ash and the black fungus of white cedar, both belonging to the genus *Septobasidium*. The first causes large tumors and the death of branches above the point of infection. Similar symptoms were reported by Galindo (1968) in the State of Mexico, Querétaro, Michoacán and Mexico City, who identified it as *Septobasidium curtisii* (Berk & Desm) Boed. & Stein, associated with two scales, *Melanaspis nigropunctata* and *Situlaspis* sp. A similar relationship is reported in Korea between *Septobasidium* spp., *Schisandra chinensis* (Turcz) Baill, and the scale *Pseudaulacaspis cockerelli* Cooley (Choi *et al.*, 2016).

Regarding the black fungus of white cedar, it was observed that its growth is restricted to the lower branches of the crown, where shade and moisture conditions are higher. Once its development begins, the hymenium is beige in color, and when infections are old, it dehydrates and detaches in small black lamellae. Affected twigs have a brown coloration and die towards the tip. This fungus is also associated with a scale insect; however, there are few studies on its identity. Worldwide, *S. cupressi* Couch, *S. crustaceum* Couch, and *S. mexicanum* Sydow are reported on cedar (Gómez and Henk, 2004), but they are not reported associated with any scale. For INAOE, although the same fungal genus was identified in both hosts, the identity of the fungal and scale species is still unknown.

Based on this information, it is recommended that management activities be implemented to reduce ball moss populations by hand and by spraying sodium bicarbonate solutions. Removing and burning trees attacked by bark beetles. Finally, pruning of infected branches, with tumors and those killed by the evergreen ash felt fungus and white cedar black fungus.

Mortality

Tree mortality is a natural and essential process in all healthy forest ecosystems; however, changes in mortality rates require careful examination to identify possible causes. A high percentage of tree mortality may indicate that forest stands are over-mature (Ambrose *et al.*, 2022), that there are problems with pests and diseases, or the effect of climate change. It is vital to identify the factors that influence tree death, their frequency, and the volume of timber they are affecting. This can help managers target resources needed for remediation activities and improve the condition of remnant trees, a practice that should certainly be contemplated in periodic management plans (Hilbert *et al.*, 2019).

In the INAOE, the number of dead trees in its green areas was 3.3 %; that is, 75 trees were found in this condition. The genus *Cupressus* presented the highest number of dead individuals, followed by *Eucalyptus* and, to a lesser degree, *Fraxinus*. Regarding cedars, the main cause of death was bark stripping and prolonged periods of drought. As for the eucalyptus trees, most of them were large and old. It is suggested to remove and burn dead trees, particularly those attacked by bark beetles, in order to avoid dispersion to adjacent areas and to avoid the risk of falling due to weak structure.

Tree risk identification

All wooded areas, including institutional areas, require a program to detect trees at risk. A tree at risk is defined as those trees with an unstable structure and located at a short distance from impacting human lives and material assets, such as cars, and infrastructure, such as buildings, telephone, electricity, and drinking water lines. Twenty-one trees were identified with the aforementioned defects. Among them are *Pinus montezumae* (8), *E. camaldulensis* (5), *Erythrina coralloides* (3), *Fraxinus udhei* (1), *Schinus molle* (3), and *Buddleja cordata* (1).

The areas that require priority attention due to the presence of these trees are the internal parking lot (in front of the central garden), the garden next to the guardhouse, the Enrique Chavira Building, as well as the general parking lot, where white cedar and eucalyptus trees are of considerable size. In this sense, it is essential to implement management actions for the removal of these specimens, or part of them, in order to reduce the risk to students, teachers, and administrative personnel, as well as to the infrastructure.

Soil condition

Soil, as a substrate, is the most important component influencing plant survival and vitality. Trees require a constant, sufficient, and adequate supply of non-compacted

soil, with excellent oxygen diffusion, good moisture retention, and drainage, among other properties. For most vegetated areas, such properties determine which plants and animals (macro- and microfauna) can live on or in the soil (Francini *et al.*, 2018). Based on the properties evaluated in the INAOE soils, the average values for each one and the confidence intervals at 95 % are shown. The average pH was 6.54, with a confidence interval of 6.02 to 6.85 (Table 1).

Table 1. Descriptive statistics and confidence intervals (95 %) for the properties evaluated in the INAOE soils.

| Variable | Depth (cm) | Mean | S.E. | L.L. | U.L. |
|--|------------|-------|------|-------|-------|
| pH | 5 | 6.42 | 0.22 | 5.95 | 6.89 |
| | 10 | 6.41 | 0.29 | 6.00 | 6.83 |
| | 15 | 6.45 | 0.25 | 5.92 | 6.98 |
| Electrical conductivity (EC) (dS m ⁻¹) | 5 | 3.35 | 0.41 | 2.47 | 4.22 |
| | 10 | 2.25 | 0.41 | 1.38 | 3.12 |
| | 15 | 1.80 | 0.28 | 1.19 | 2.40 |
| Bulk density (BA) (g cm ⁻³) | 5 | 1.15 | 0.07 | 0.99 | 1.31 |
| | 10 | 1.39 | 0.06 | 1.27 | 1.51 |
| | 15 | 1.38 | 0.05 | 1.26 | 1.49 |
| Porous space (PS) (%) | 5 | 56.70 | 2.32 | 51.83 | 61.57 |
| | 10 | 47.77 | 1.69 | 44.21 | 51.32 |
| | 15 | 47.79 | 1.64 | 44.13 | 51.46 |

S.E: standard error; L.I: lower limit; U.L: upper limit of the confidence interval.

Indirectly, soil reaction influences plant growth through its effect on ionic solubility and microbial activity. A satisfactory pH range for the growth of many plants ranges from 5.5 to 8.3. Other “acid soil loving” species do well at pH between 4.0 and 6.5. For the tree species identified in the study area, adequate development at the pH obtained is reported, but they can tolerate even alkaline soils (7.5 to 8.2) (Samson *et al.*, 2017). Regarding electrical conductivity, the average was 2.46 dS m⁻¹ (Table 1). However, eight areas presented conductivities > 2.0, which could restrict the growth of sensitive species (Pallardy, 2008). Bulk density averaged 1.3 g cm⁻³ (Table 1), and at least six sections of the INAOE had even higher densities. According to Hillel *et al.* (2004), bulk density values that can restrict root development vary according to soil texture, from 1.4 g cm⁻³ in clay soils to 1.7 g cm⁻³ in sandy soils. The pore space was greater than 50 %, which favors root penetration and a greater diversity of micro and macrofauna, fungi, bacteria, and ascomycetes (Goswami *et al.*, 2020).

Finally, regarding soil-associated mycoflora, based on morphological characters (Barnett and Hunter, 1998; Leslie and Summerell, 2006), the filamentous fungi *Aspergillus* spp., *Fusarium* spp., *Penicillium* spp., *Alternaria* sp., *Cladosporium* sp., *Paecilomyces* sp., *Trichoderma* sp., and *Mucor* sp. were identified, the first three with more than one morphotype (variable colony color and shape). During the dry season, populations ranged from 2000 to 9 642 000 cfu g⁻¹ (colony forming units per gram of soil), while in the rainy season, populations ranged from 2000 to 7 210 000 cfu g⁻¹ soil. It is worth mentioning that, despite the expectation of finding higher populations during the rainfall season, this did not occur, possibly due to the xerophytic character of some genera such as *Aspergillus* (Piontelli, 2014). Finally, although fungal populations were high for some genera, low numbers of beneficial fungal propagules, such as *Trichoderma* and *Paecilomyces*, were evident.

The characterization of INAOE soils will help us to plan and execute activities aimed at improving their condition, including decompaction in areas such as the Propulsion Laboratory, El Solar, SUTINAOE, Casuarinas 1, the Computer Building, and GTM (Figure 1). For this purpose, the incorporation of compost, mulch, and beneficial microorganisms is strongly recommended. It is worth mentioning that the Institute continuously obtains organic waste from grass and tree pruning, which could be used to produce its own compost.

Within cities, tree species composition is variable among different land uses (Knapp *et al.*, 2009), but perhaps institutional green areas should have the highest quality in terms of health. They should also have greater biological diversity and excellent soil quality, but this is far from reality, so the authorities must strive to preserve and manage their green infrastructure with the few resources that are annually allocated to them. Exceptional cases include some private institutions that allocate resources to increase and preserve their forested areas. Finally, it is important to mention that there are protected natural places around the world that, due to their biological and usage qualities, are protected by the government and their inhabitants. The green areas of INAOE, a renowned institution in the field of astronomical sciences, deserve to be preserved and improved in order to contribute to the comfort and development of the activities of its staff, to reduce pollution and the impact of climate change on the environment.

CONCLUSIONS

Based on different health indicators, the following points can be highlighted about the tree stock at the National Institute of Astrophysics, Optics, and Electronics: (a) there are 32 tree species and 20 families; (b) most of the tree stock is young (40 %, with diameter at breast height < 20 cm) and at high planting densities; (c) there are early stress symptoms in *Pinus halepensis*, *Jacaranda mimosifolia*, and *Fraxinus uhdei* (higher transparencies), moderate in *Schinus molle* and *Eucalyptus camaldulensis* (low dieback percentages), and adequate health in seven species (high live crown ratio and crown

density); (d) tree mortality was low (3.3 %); e) presence of two bark beetles, *Hylesinus aztecus* on evergreen ash (from which no previous reports exist on small diameter trees) and *Phloeosinus* sp. on white cedar; f) there is presence of *Tillandsia recurvata* on jacaranda; g) there is presence of *Septobasidium* sp. on evergreen ash and white cedar; h) soils are compact and poor in beneficial mycoflora; and i) 21 trees are considered a risk to property and human lives. These aspects should be considered in any future management program in the study area.

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