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HEALTH STATUS AND DAMAGE CHARACTERISTICS OF *Canarium indicum* IN BOGOR GREEN SPACES

Sandy Andika[1], Tsarwan Thirafi Tsasy[1], Fachri Rafi Prayoga[1], Inggar Damayanti[1]*, Peniwidiyanti[2], Prima Anggoro[3]

[1]Departement of Forestry, Faculty of Agriculture, Universitas Lampung, Bandar Lampung 35145, Lampung, Indonesia
[2]Research Center for Ecology, The National Research and Innovation Agency, Bogor 16911, Jawa Barat, Indonesia
[3]Botani Tropika Indonesia Foundation (BOTANIKA), Bogor 16112, Jawa Barat, Indonesia

*Email: inggar.damayanti@fp.unila.ac.id

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ABSTRACT

Although Canarium indicum is widely planted as a shade and heritage tree in Bogor City, information regarding its health condition and damage characteristics in urban environments remains limited. Assessing tree health is essential for supporting sustainable urban forest management and maintaining the ecological functions of urban green spaces. This study aimed to evaluate the health condition of Canarium indicum L. growing in urban green spaces in Bogor City, Indonesia. Tree health was evaluated using a modified Forest Health Monitoring (FHM) approach by measuring diameter at breast height (DBH), basal area, damage location, damage type, and damage severity. Tree health status was quantified using the Damage Index (DI), Tree Level Index (TLI), and Plot Level Index (PLI). The results showed that most trees were classified as lightly damaged, accounting for 66.67%, 85.72%, and 84.62% of assessed trees in Ahmad Yani Urban Forest, Ahmad Yani Street, and Sudirman Street, respectively. PLI values ranged from 8.35 to 9.60 among study sites. Damage was primarily concentrated in the lower stem (22.22%), upper stem (18.52%), and root–stem transition zone (15.56%). These findings indicate that the observed defects were mainly associated with structural components and biological agents commonly found in mature urban trees. Despite the presence of various defects, the overall health condition of C. indicum trees remained generally favourable. The study demonstrates that the FHM approach provides useful information for evaluating urban tree health and can support monitoring and preventive management strategies to maintain the ecological and environmental functions of urban trees in Bogor City.

Keywords: *Forest Health Monitoring; Structural Vulnerability; Urban Green Spaces; Urban Trees*

INTRODUCTION

Urban trees provide a wide range of ecosystem services that contribute significantly to environmental quality and human wellbeing. In urban environments, trees regulate microclimates, reduce air pollution, intercept stormwater runoff, support biodiversity, and enhance landscape aesthetics (Escobedo *et al.*, 2011; *Miller et al.*, 2015). These ecological functions make urban trees essential components of green open spaces and sustainable urban development. However, the benefits provided by urban trees depend largely on their health and structural integrity. Trees experiencing physiological decline or structural damage may exhibit reduced ecosystem service provision and increased susceptibility to branch or whole-tree failure, particularly in areas with high human activity (Esperon-Rodriguez *et al.*, 2025).

Climate conditions are among the most important factors influencing urban tree health and stability. Increasing rainfall intensity, prolonged periods of high humidity, and more frequent extreme weather events can accelerate wood decay, weaken root anchorage, and increase the likelihood of structural failure (Jahani & Saffariha, 2021; Esperon-Rodriguez *et al.*, 2022). Furthermore, climate change is projected to increase environmental stress on urban forests globally, potentially reducing tree resilience and increasing management challenges in cities (Esperon-Rodriguez *et al.*, 2022). Consequently, regular tree health monitoring has become an essential component of urban forest management and disaster risk reduction strategies.

Bogor City is recognized as one of the wettest urban regions in Indonesia, with annual rainfall reaching 4,812.2 mm and relative humidity ranging from 77–87% throughout the year (BPS Bogor City, 2024; BPS Bogor City, 2025). These environmental conditions are favorable for tree growth but may also accelerate the development of structural defects and biological deterioration. In addition, Bogor City experiences intensive urban activities, as reflected by the large number of registered vehicles, which reached 742,444 units in 2025 (Korlantas Polri, 2025). Such conditions expose urban trees to various anthropogenic stressors, including soil compaction, air pollution, mechanical injury, and restricted rooting space, all of which may negatively affect tree vitality and structural stability (Kahirunnisa *et al.*, 2025).

One of the dominant tree species commonly planted in urban green spaces and roadside corridors in Bogor City is *Canarium indicum* L. This species is valued for its broad canopy, evergreen foliage, extensive root system, and ability to provide shade and environmental benefits in urban landscapes (Maudina & Medha, 2023). Many individuals of *C. indicum* growing along major roads in Bogor are mature trees that have been established for several decades (Akbar, 2019). While these characteristics contribute substantially to urban ecosystem services, large tree size and advanced age may increase susceptibility to structural deterioration caused by environmental stress, biological agents, and natural aging processes (Nabawiah *et al.*, 2025). Therefore, understanding the health condition of this species is important for supporting sustainable urban tree management.

Disaster records indicate that tree-fall incidents in Bogor City have increased in recent years. The Regional Disaster Management Agency (BPBD) recorded 170 tree-fall incidents in 2022, rising to 246 in 2023 (BPBD Bogor City, 2024). Such incidents may disrupt transportation systems, damage public infrastructure, and threaten public safety. Previous studies have evaluated urban tree health using visual assessments and Forest Health Monitoring (FHM) approaches in various urban environments (Sodikin, 2014; Safe'i *et al.*, 2023; Pratama & Putra, 2025). However, information regarding the health condition of mature *C. indicum* trees across different urban green-space typologies in Bogor City remains limited. Moreover, few studies have specifically examined dominant damage characteristics and their implications for structural vulnerability under the high-rainfall conditions characteristic of Bogor City.

Given the large size and mature age of many Canarium indicum individuals in Bogor City, the presence of structural defects and biological deterioration may increase the likelihood of branch or whole-tree failure during extreme weather events. Consequently, assessing tree health is important not only for maintaining ecosystem services but also for supporting preventive urban tree management and public safety. Tree health monitoring can provide early indications of deterioration that may require maintenance interventions before more serious structural problems develop.

Therefore, this study aimed to evaluate the health status of *C. indicum* trees across three urban green spaces in Bogor City using a modified Forest Health Monitoring (FHM) approach. Specifically, the study aims to (1) assess tree health status based on damage indicators, (2) identify dominant damage locations and damage types, and (3) discuss the implications of tree health conditions for urban green-space management and tree-failure risk mitigation. The findings are expected to provide scientific information to support evidence-based urban tree management strategies and to improve public safety and the sustainability of urban green spaces in Bogor City.

METHOD

Study Area

This study was conducted from January 7-17, 2025, at three urban green spaces in Bogor City, West Java, Indonesia: Ahmad Yani Urban Forest, Ahmad Yani Street, and Sudirman Street (Figures 1 and 2). These locations were purposively selected because they represent urban green spaces characterized by intensive public activity, the presence of mature *C. indicum* trees, and a relatively high risk of tree falls. Ahmad Yani Urban Forest represents an urban forest ecosystem, whereas Ahmad Yani Street and Sudirman Street are roadside green corridors subject to continuous anthropogenic disturbance.

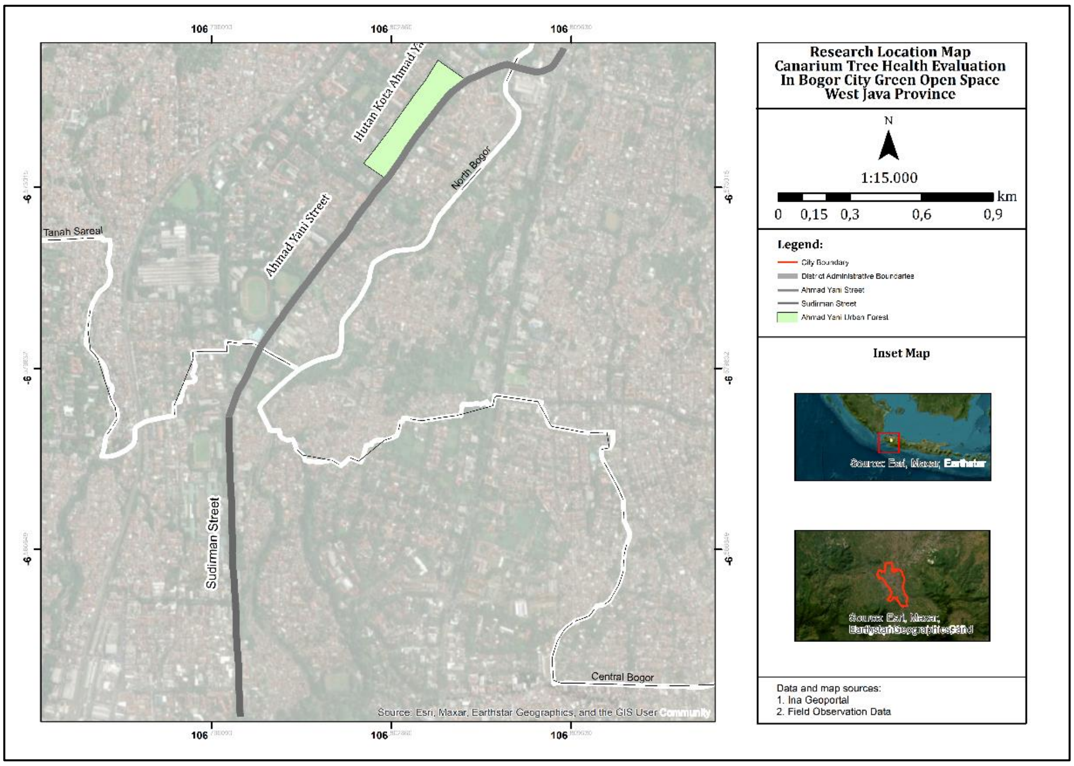


Figure 1. Research Location Map Showing the Three Study Sites in Bogor City, Indonesia

A B C

(A) Ahmad Yani Urban Forest, (B) Ahmad Yani Street, and (C) Sudirman Street.

Figure 2. Study locations of Canarium indicum in Bogor City

Tree Sampling and Data Collection

A total of 45 *C. indicum* trees were assessed across the three study locations. Trees were selected using purposive sampling based on the following criteria: (1) mature individuals growing within the study area, (2) accessible for visual assessment, and (3) exhibiting complete crown and stem structures suitable for FHM evaluation.

For each sampled tree, geographic coordinates, diameter at breast height (DBH), basal area, damage location, damage type, and damage severity were recorded. DBH was measured at 1.3 m above ground level using a diameter tape. For trees with buttresses, measurements were taken approximately 20 cm above the highest buttress following standard forestry measurement procedures. Field observations focused on identifying visible structural defects and vitality-related damage that could potentially affect tree health and stability.

Tree Health Assessment

Tree health assessment was conducted using a modified Forest Health Monitoring (FHM) approach developed by Mangold (1997) and adapted by Safe'i *et al.* (2023). Conventional FHM is commonly applied using cluster plots in forest ecosystems. However, because the present study was conducted in urban green spaces and roadside corridors, where establishing cluster plots was not feasible, the assessment was conducted at the individual-tree level.

Tree health evaluation was based on three damage attributes, namely damage location (Table 1), damage type (Table 2), and damage severity (Table 3). Following FHM procedures, a maximum of three dominant damages were recorded for each tree. Damage locations and damage types were classified according to the coding system proposed by Safe'i *et al.* (2023), while damage severity was estimated as the percentage of affected tissue or structure. All observed damages were documented photographically to support field observations and data verification.

Table 1. Tree Damage Location Codes Used in the FHM Assessment

Code	Tree Damage Location
0	No damage
01	Exposed roots and root collar (stump) (12 inches/ 30 cm) above ground surface
02	Roots and lower stem
03	Lower stem (lower half of the stem between the stump and the base of the live crown)
04	Lower and upper stem
05	Upper stem (upper half of the stem between the stump and the base of the live crown)
06	Stem within the live crown (crown stem)
07	Branches (> 2.54 cm in diameter at the point of attachment to the main stem or crown stem)
08	Shoots and new growth
09	Leaves

Source: Mangold (1997); Safe'i *et al.* (2023).

Table 2. Damage Type Classification Used in the FHM Assessment

Code	Damage Type
01	Cancer
02	Conk, fruiting body, and other indicators of decay
03	Open wound

Code	Damage Type
04	Resinosis or gummosis
05	Broken stem
06	Termite nest
07	Liana on stem
11	Broken stems or roots within 0.9 m (3 ft) of the trunk
12	Burl on the root or stem
13	Root damaged or dead root beyond 0.9 m (3 ft) from the trunk
20	Liana is on leave/crown or mistletoe infestation
21	Loss of dominant tip, dead tip
22	Broken or dead branches
23	Excessive branching (witches' broom)
24	Damaged leaf shoots or buds
25	Leaves discoloration
31	Other damaged

Source: Mangold (1997); Safe'i *et al.* (2023).

Table 3. Scoring System for Damage Location, Damage Type, and Severity Level Used in the Calculation of the Damage Index (DI)

Damage Location Code	Location Weight (x)	Damage Type Code	Damage Type Weight (y)	Damage Severity Level	Severity Weight (z)
0	-	11.05	2.0	1-19%	1.1
01, 02	2.0	01	1.9	20-29%	1.2
03, 04	1.8	02.06	1.7	30-39%	1.3
05	1.6	12	1.6	40-49%	1.4
06	1.2	03, 04, 13	1.5	50-59%	1.5
		21	1.3	60-69%	1.6
07, 08, 09	1.0	07, 20, 22, 23, 24, 25, 31	1.0	70-79%	1.7
				80-89%	1.8
				≥90%	1.9
				0%	-

Source: Mangold (1997); Safe'i *et al.* (2023).

Tree Size Characteristics

Tree size characteristics were evaluated using diameter at breast height (DBH) and basal area measurements. These parameters were included to describe tree structural attributes and size variation among study sites. Basal area was calculated using the following equation:

$$BA=\frac{1}{4}\times 3{,}14\times DBH^2$$

where BA is basal area (m²), and DBH is diameter at breast height (m). The resulting basal area values were analyzed descriptively to compare tree size characteristics among study locations. Larger basal area values indicate greater biomass accumulation and growth potential of individual trees (Mustikaningrum & Rosida, 2023; Laia *et al.*, 2026).

Tree Vitality Analysis

Tree health status was evaluated using the Damage Index (DI), Tree Level Index (TLI), and Plot Level Index (PLI). The distribution of damage locations and types was summarized using frequencies and percentages. Diameter at breast height (DBH) and basal area were analyzed using descriptive statistics and presented as mean values and graphical visualizations. The Damage Index for each observed damage was calculated as:

$$DI = x \times y \times z$$

where x represents the damage location weight, y represents the damage type weight, and z represents the damage severity weight (Mangold, 1997; Safe'i *et al.*, 2023). The Tree Level Index (TLI) was obtained by summing all damage index values recorded for an individual tree.

$$TLI=[DI_1]+[DI_2]+[DI_3]$$

The Plot Level Index (PLI) was calculated as the mean TLI across all sampled trees at each study location.

$$PLI=\frac{\sum \text{TLI within a plot}}{\sum \text{trees within the plot}}$$

Based on TLI values, tree health conditions were classified into four categories (Table 4): healthy, lightly damaged, moderately damaged, and severely damaged, following Ashari *et al.* (2025).

Table 4. Classification of Tree Health Based on TLI Values

Tree Health Classification	TLI Value
Healthy	0 - 5
Lightly Damaged	6 - 10
Moderately Damaged	11 - 15
Severely Damaged	>16

Source: Ashari *et al.*, 2025

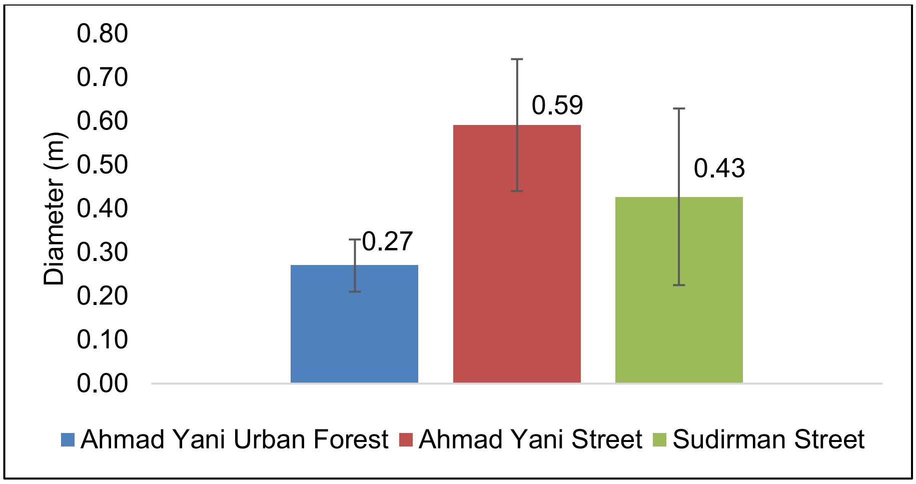
Higher TLI and PLI values indicate greater levels of tree damage and a decline in tree health. This classification is used as a basis for evaluating the potential risk of tree falls and formulating recommendations for disaster management and mitigation in Bogor City's green open spaces.

Because the study was designed as a descriptive tree health assessment using the Forest Health Monitoring approach, data were analyzed descriptively using means, frequencies, percentages, and graphical visualization. No inferential statistical tests were performed, and comparisons among locations should therefore be interpreted as descriptive patterns rather than statistically significant differences.

RESULTS and DISCUSSION,

Tree Size Characteristics

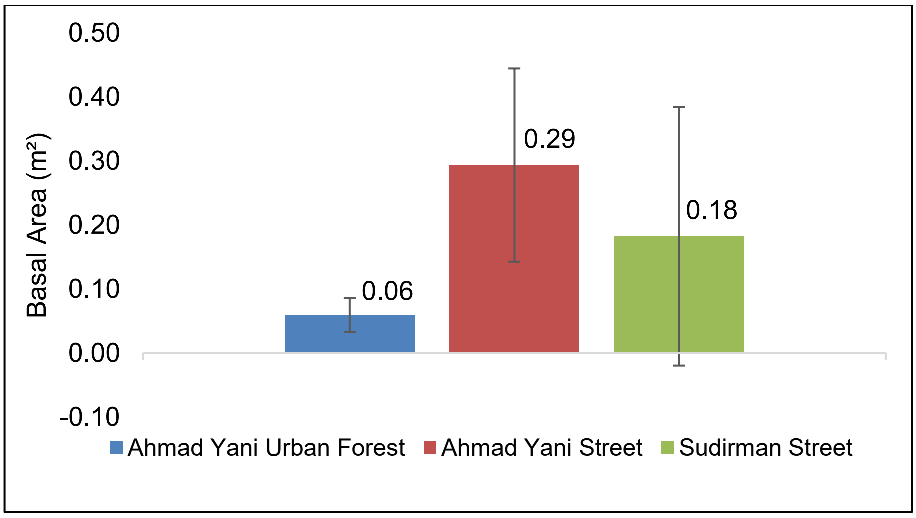
The size characteristic of *C. indicum* trees was evaluated using diameter at breast height (DBH) and basal area measurements. The highest mean DBH and basal area values were recorded along Ahmad Yani Street, followed by Sudirman Street and Ahmad Yani Urban Forest (Figure 2). The boxplot distributions further revealed that trees growing along Ahmad Yani Street not only exhibited the largest average size but also showed greater variability in diameter and basal area compared with the other study locations. In contrast, trees in Ahmad Yani Urban Forest displayed a narrower distribution, indicating a more homogeneous stand structure (Figure 3).



Error bars represent standard deviation (±SD)

Figure 2. Mean diameter at breast height (DBH) of C. indicum trees across the three study locations

The observed differences in tree size among locations may be attributed to variations in planting history, site conditions, management practices, and environmental factors influencing tree growth (Pretzsch *et al.*, 2017). According to Akbar (2019), many *C. indicum* trees along Ahmad Yani Street and Sudirman Street were established during the colonial period and are estimated to be several decades to more than a century old. The prolonged growth period of these mature trees likely contributed to their larger stem dimensions and greater basal area values (Harris *et al.*, 1992; Pretzsch *et al.*, 2017). This relationship is expected because basal area is directly derived from stem diameter and increases exponentially with diameter (Avery & Burkhart, 2015).



Error bars represent standard deviation (±SD)

Figure 3. Mean basal area of C. indicum trees across the three study locations

The wider distributions observed in Ahmad Yani Street and Sudirman Street suggest substantial variation in tree size among individuals, which may reflect differences in age, microsite conditions, and historical management practices. Conversely, the relatively narrow distribution in Ahmad Yani Urban Forest indicates a more uniform tree population. Larger diameters and basal areas are generally associated with greater biomass accumulation and carbon storage capacity, thereby enhancing ecosystem services such as carbon sequestration, shade provision, and microclimate regulation (Nowak *et al.*, 2002). Consequently, the mature *C. indicum* trees growing along Ahmad Yani Street are likely to contribute more substantially to urban ecosystem functions than those occurring in Ahmad Yani Urban Forest.

Although DBH and basal area do not directly represent tree health, they provide important information on tree size, structural development, and stand condition, which may influence damage accumulation and maintenance requirements in urban environments (Harris *et al.*, 2004; Gilman *et al.*, 2008). Larger and older trees generally experience longer exposure to environmental stressors and mechanical disturbances, increasing the likelihood of developing structural defects and multiple symptoms of damage over time (Nowak *et al.*, 2002; Roman *et al.*, 2014; Smiley et al., 2017).

Tree Health Status

A tree health assessment was conducted using the Tree Level Index (TLI), and the overall health condition of each location was represented by the Plot Level Index (PLI). The mean PLI values ranged from 8.35 to 9.60 (Table 5), with Ahmad Yani Urban Forest recording the highest value (9.60), followed by Ahmad Yani Street (8.46) and Sudirman Street (8.35). Although higher PLI values indicate greater damage, the differences among locations were relatively small, suggesting that the overall health of *C. indicum* was broadly similar across the study sites.

Table 5. Plot Level Index (PLI) Values of C. indicum Across the Study Locations

Location	PLI value
Ahmad Yani Urban Forest	9.60
Ahmad Yani Street	8.46
Sudirman Street	8.35

The distribution of TLI values further illustrates variation in tree health among individual trees (Figure 4). Ahmad Yani Urban Forest exhibited the highest mean TLI value, whereas Ahmad Yani Street and Sudirman Street showed slightly lower values. Despite these differences, substantial overlap among the boxplots indicates that the health conditions of individual trees were generally comparable among locations. The relatively narrow interquartile range observed in Ahmad Yani Urban Forest suggests a more homogeneous level of damage among trees. In contrast, Ahmad Yani Street displayed a wider distribution, indicating greater variability in individual tree health conditions. Variation in tree health within urban environments is often influenced by differences in site quality, environmental stressors, maintenance practices, and tree age (Nowak *et al.*, 2014; Pretzsch *et al.*, 2017).

An outlier was observed in Ahmad Yani Street, representing an individual tree with a substantially higher TLI value than the rest of the sampled population. This suggests the occurrence of localized damage or tree-specific stress factors that were not representative of the overall stand condition. Such variability is common in urban tree populations because individual trees are exposed to differing levels of mechanical disturbance, soil compaction, pollution, and pruning history (Roman & Scatena, 2011; Vogt *et al.*, 2015).

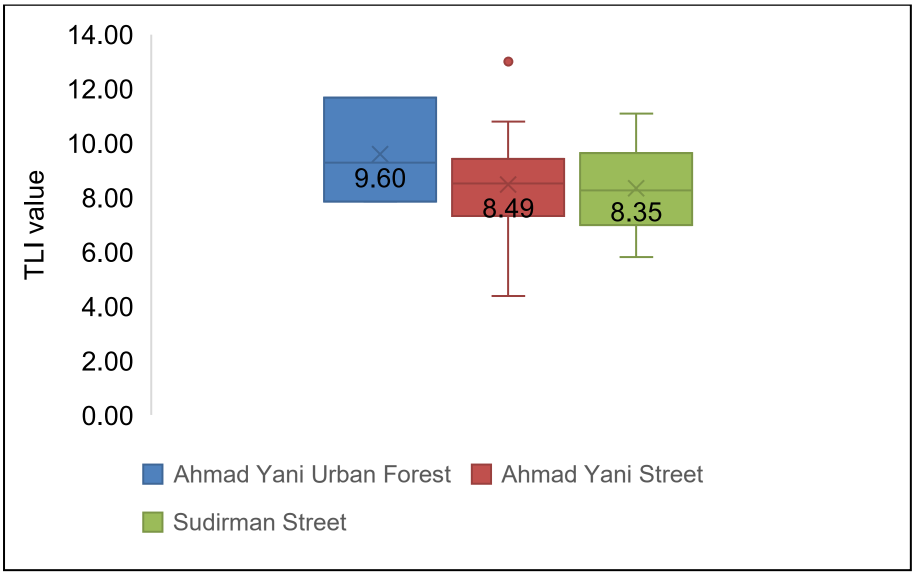


Figure 4. Boxplot Distribution of Tree Level Index (TLI) Values Among Study Locations.

The distribution of health categories (Figure 5) supports the patterns observed in the TLI boxplots. Lightly damaged trees dominated all study locations, accounting for 66.67% of trees in Ahmad Yani Urban Forest, 82.14% in Ahmad Yani Street, and 85.71% in Sudirman Street. Moderately damaged trees represented a smaller proportion of the population, ranging from 14.29% to 33.33%, while no severely damaged trees were recorded. Only Ahmad Yani Street contained a small proportion of healthy trees (3.57%). These findings indicate that most *C. indicum* individuals exhibited only minor defects and remained in generally acceptable condition. Similar patterns have been reported in urban tree health assessments, in which light damage categories frequently dominate among mature urban tree populations (Safe'i *et al.*, 2019).

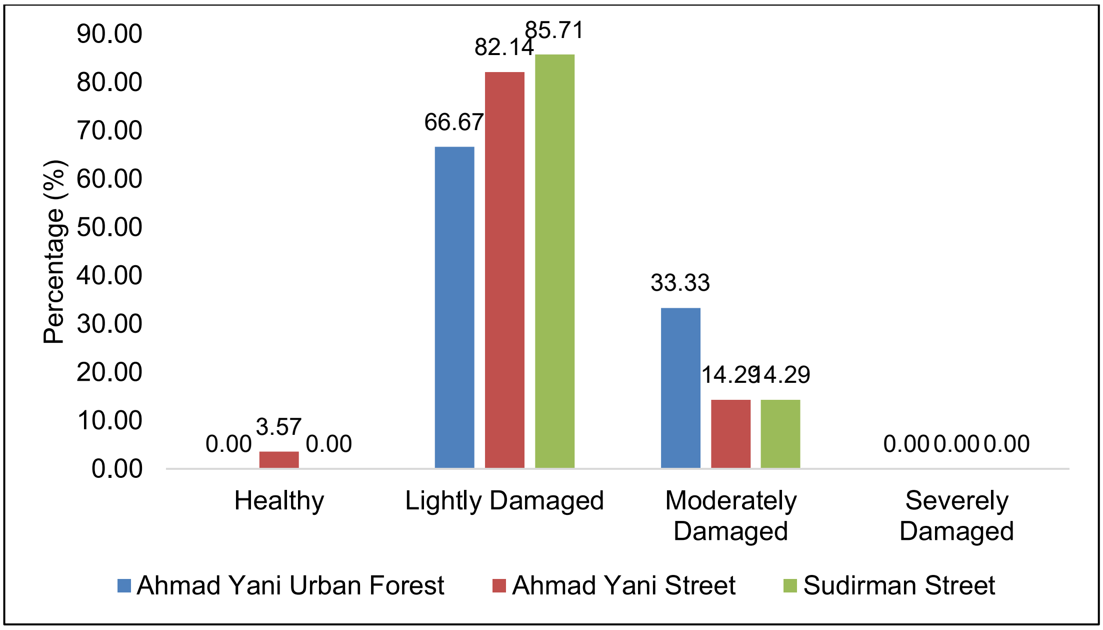


Figure 5. Distribution of Health Condition Categories of C. indicum in the Study Locations.

The higher mean TLI value observed in Ahmad Yani Urban Forest corresponds with the greater proportion of moderately damaged trees recorded at this location. Conversely, Ahmad Yani Street and Sudirman Street were characterized by lower mean TLI values and a higher proportion of individuals with light damage. Nevertheless, the relatively small differences in TLI values among locations and the predominance of lightly damaged trees indicate that the overall health status of *C. indicum* was relatively similar throughout the study area.

Bogor City is characterized by high annual rainfall and humidity, environmental conditions that may promote biological deterioration, fungal colonization, and the development of structural defects in urban trees (Jahani & Saffariha, 2021; Esperon-Rodriguez *et al.*, 2022; Shigo, 1991). Despite these conditions, most *C. indicum* individuals remained within the lightly damaged category, suggesting that the recorded damage was generally localized and had not substantially impaired overall tree condition. This pattern indicates that although environmental factors may favor the occurrence of certain defects, the severity of damage observed in the assessed trees remained relatively low. Considering that many *C. indicum* trees in Bogor are mature individuals that have persisted for several decades and, in some cases, since the colonial period (Akbar, 2019), these findings suggest that the species can maintain acceptable condition under urban environmental pressures. However, physiological responses and tree age were not directly measured in this study; therefore, the mechanisms underlying this condition cannot be confirmed and should be interpreted cautiously. The observed defects are more likely associated with natural aging processes and long-term environmental exposure than with severe physiological decline (Gilman et al., 2008).

Interestingly, locations with larger tree dimensions did not necessarily exhibit higher levels of damage. Although Ahmad Yani Street showed the largest diameter and basal area values, its TLI and PLI values were only slightly different from those recorded in the other locations. This finding suggests that tree size alone cannot be used as an indicator of health status, as larger trees do not necessarily exhibit greater damage. Therefore, structural attributes and health indicators should be evaluated together to provide a comprehensive assessment of urban tree condition (Pretzsch *et al.*, 2017; Nowak *et al.*, 2002).

Damage Location Characteristic

The distribution of damage locations recorded on *C. indicum* trees is presented in Table 3. A total of 135 damage occurrences were observed, with most defects concentrated in stem- and root-related components. The lower stem was the most frequently damaged part (22.22%), followed by the upper stem (18.52%), roots and lower stem (15.56%), and exposed roots and root collar (14.07%). Together, these four damage locations accounted for more than 70% of all recorded damage occurrences. This pattern indicates that structural defects were primarily concentrated in the tree's main supporting components. Similar findings have been reported in urban tree health assessments, where stem and root-related damage commonly accumulate due to long-term environmental exposure, mechanical injury, and aging processes (Shigo, 1991). Considering that many *C. indicum* trees in Bogor are mature individuals that have persisted for several decades (Akbar, 2019), the observed damage may reflect cumulative structural deterioration associated with age and prolonged exposure to urban conditions.

Table 6. Percentage of Damage Locations Recorded on C. indicum Trees

Code	Tree Damage Location	Frequency	Percentage (%)
0	No damage	0	0
01	Exposed roots and root collar	19	14.07
02	Roots and lower stem	21	15.56
03	Lower stem	30	22.22
04	Lower and upper stem	8	5.93
05	Upper stem	25	18.52
06	Crown stem	13	9.63

Code	Tree Damage Location	Frequency	Percentage (%)
07	Branches	10	7.41
08	Shoots and new growth	3	2.22
09	Leaves	6	4.44

The distribution of damage locations differed among the three study sites (Figure 6). Ahmad Yani Street exhibited the highest frequency of damage across almost all damage-location categories, particularly in the lower stem, upper stem, and root-related regions. In contrast, Ahmad Yani Urban Forest showed relatively few damage occurrences, while Sudirman Street displayed intermediate levels of damage. These differences may be related to varying environmental conditions and levels of anthropogenic disturbance among locations. Trees growing along roadsides are generally exposed to greater environmental stress, including soil compaction, limited rooting space, vehicle emissions, and maintenance activities, which can contribute to the development of structural defects (Smiley *et al.*, 2017; Pretzsch *et al.*, 2017). Nevertheless, stem-related damage remained the dominant damage location across all study sites, indicating a consistent pattern of structural deterioration in mature urban *C. indicum* trees.

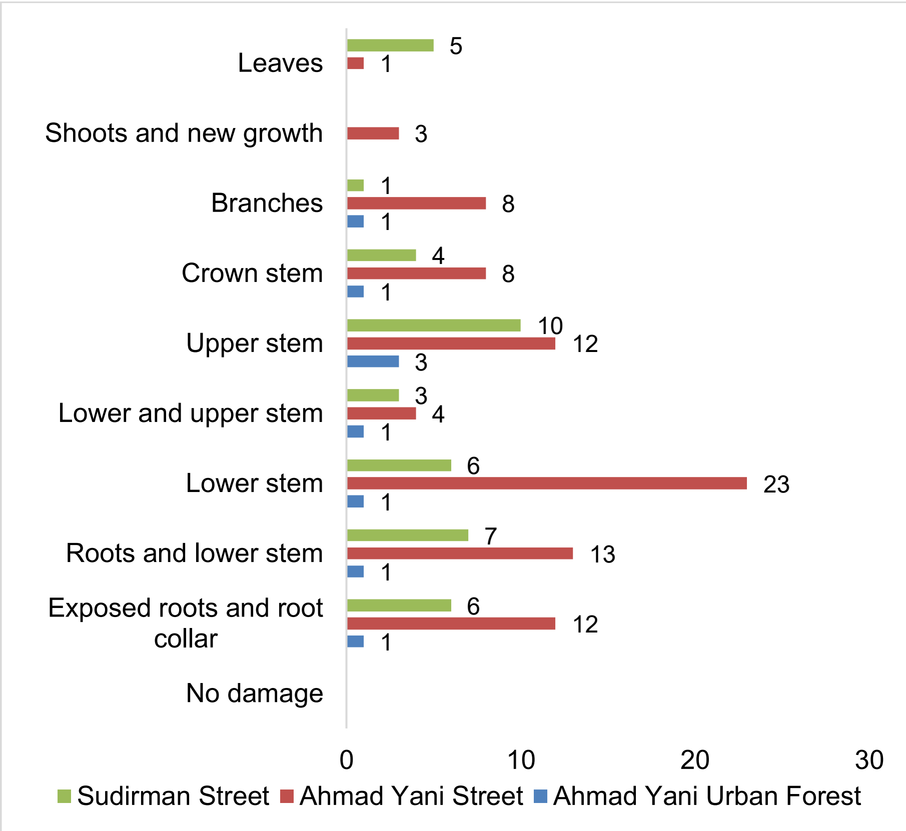


Figure 6. Distribution of Damage Locations of C. indicum Trees Across the Three Study Locations.

Damage Type Characteristic

The relative distribution of damage types recorded on *C. indicum* trees is presented in Figure 7. A total of 17 damage types were identified during the assessment, indicating that tree deterioration resulted from a combination of structural, biological, and physiological factors. The most frequently observed damage type was broken or dead branches (22.96%), followed by termite nests (13.33%), lianas on stems (13.33%), and burls on roots or stems (10.37%). In contrast, damage affecting roots, foliage, and shoot development occurred at relatively low frequencies. The dominance of branch-related damage suggests that deterioration was primarily concentrated in the crown structure rather than in actively growing tissues. This pattern is consistent with the results of the damage location analysis, which showed that damage was predominantly recorded in the stem and crown-associated components of the tree.

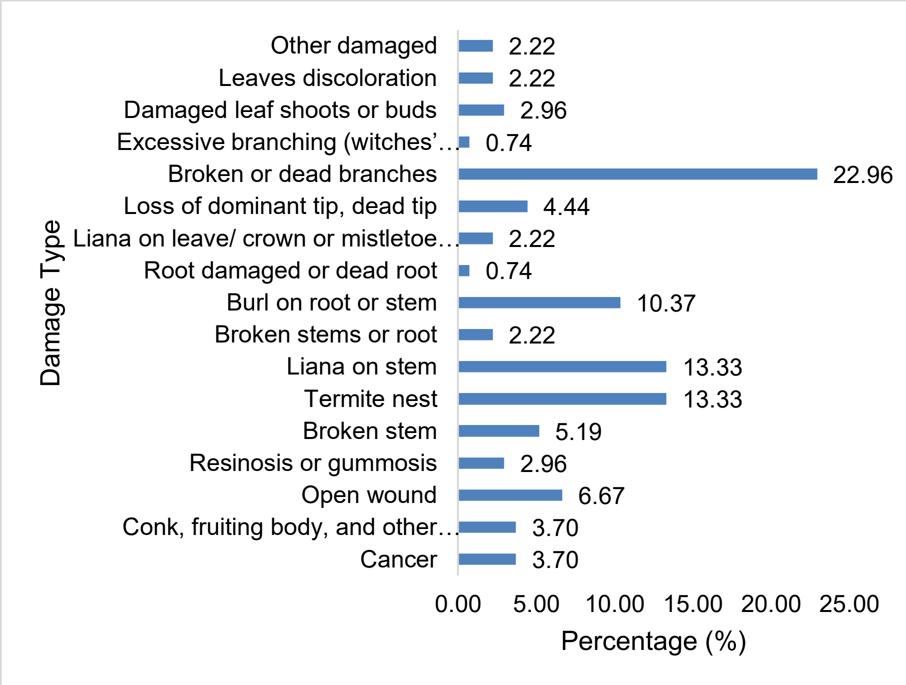


Figure 7. Percentage Distribution of Damage Types Recorded on C. indicum Trees in the Study Area.

Similar damage types have frequently been reported in mature urban trees regardless of species, particularly in environments characterized by high humidity and prolonged exposure to environmental stressors (Shigo, 1991; Harris et al., 2004). Therefore, the dominance of dead branches, termite nests, and liana infestation observed in this study is more likely associated with tree maturity and urban environmental conditions than with species-specific characteristics of *C. indicum*. In urban landscapes, trees are continuously exposed to mechanical disturbance, pruning, restricted rooting space, soil compaction, and climatic stresses that may gradually contribute to structural defects and biological deterioration (Nowak *et al*., 2002; Vogt et al., 2015).

The high occurrence of broken or dead branches may be associated with natural aging processes, branch senescence, mechanical stress, and prolonged exposure to urban environmental conditions. Branch mortality is commonly observed in mature urban trees as a consequence of self-pruning, canopy competition, storm events, and previous physical injuries (Gilman *et al*., 2008). Although dead branches do not necessarily indicate severe physiological decline, they represent an important structural concern because they can increase the likelihood of branch failure and reduce the aesthetic, ecological, and safety functions of urban trees. The prevalence of this type of damage suggests that canopy maintenance should be prioritized in the routine management of mature *C. indicum* trees in Bogor City.

Biological agents also contributed substantially to the observed damage pattern. The relatively high frequency of termite nests and stem-climbing lianas indicates ongoing interactions between trees and associated organisms within the urban ecosystem. Termites are commonly found in mature trees and often colonize decayed or weakened woody tissues. Their presence may therefore indicate pre-existing structural deterioration rather than serving as the primary cause of damage (Shigo, 1991). Similarly, lianas use trees as structural support and may persist for many years on mature individuals. While moderate liana presence is a natural ecological phenomenon, excessive growth can increase canopy loading, reduce light availability, and potentially accelerate branch breakage, particularly in urban trees exposed to additional environmental stresses (Putz, 1984). Consequently, the presence of termites and lianas may serve as useful visual indicators of trees that require closer inspection and maintenance.

Representative examples of damage observed during field assessment are shown in Figure 8. Common defects included stem burls, open wounds, stem decay, and termite infestation. These damage types illustrate the diversity of structural and biological disturbances affecting *C. indicum* trees in the study area. Open wounds and stem decay are particularly important because they can facilitate the entry of pathogens and wood-decaying organisms, potentially leading to progressive internal deterioration over time (Shigo, 1991; Smiley *et al.*, 2017). Meanwhile, the occurrence of burls may reflect long-term physiological responses to injury, environmental stress, or localized infections. The presence of these defects on mature trees suggests that much of the observed damage has developed gradually over extended periods rather than from recent disturbance events.

A B C D

(A) Burl on Stem, (B) Open Wound, (C) Stem Decay, and (D) Termite Infestation.

Figure 8. Examples of Common Damage Types Recorded on C. indicum Trees During the Field Assessment

Overall, the occurrence of branch mortality, termite infestation, stem wounds, and decay indicates that mature *C. indicum* trees in urban environments are exposed to a variety of structural and biological stressors. However, these findings should be interpreted alongside the TLI and PLI results, which showed that most trees remained in the lightly damaged category. This suggests that the majority of recorded defects were localized and generally of low severity, reflecting long-term environmental exposure and natural aging processes rather than severe health decline. Nevertheless, routine monitoring, selective pruning, liana control, and periodic inspection of trees exhibiting signs of decay remain necessary to prevent further deterioration and to maintain the ecological, aesthetic, and safety functions of urban trees.

Implications for Urban Tree Management

The health assessment of *C. indicum* trees in Bogor City showed that most individuals remained in the lightly damaged category despite exhibiting a range of structural and biological defects. The relatively low TLI and PLI values, together with the absence of severely damaged trees, indicate that the overall condition of the assessed trees was generally acceptable. However, the presence of defects in structurally important components, particularly the lower stem, upper stem, and root–stem transition zone, suggests deterioration in parts of the tree that play critical roles in mechanical support and stability. Although the observed damage was generally localized and of low severity, these findings highlight the importance of proactive management to prevent the gradual progression of defects and to maintain long-term tree health and structural integrity.

One of the primary management priorities identified in this study is the regular inspection and maintenance of crown structures. Broken or dead branches were the most frequently recorded damage type, representing nearly one-quarter of all observed defects. Branch mortality is a common characteristic of mature urban trees and is often associated with natural aging, environmental stress, and previous mechanical injuries (Gilman *et al.*, 2008). While dead branches do not necessarily indicate severe physiological decline, they may increase the likelihood of branch failure, particularly during periods of heavy rainfall and strong winds. In densely populated urban environments, falling branches can pose hazards to pedestrians, vehicles, and surrounding infrastructure. Consequently, routine pruning of dead, weakened, or hazardous branches should be incorporated into preventive maintenance programs to reduce potential hazards while maintaining canopy health, ecosystem functions, and aesthetic value (Smiley *et al*., 2017).

The relatively high occurrence of termite nests and liana infestation also suggests the need for periodic monitoring of biological agents associated with mature trees. Although termites often colonize previously weakened tissues rather than initiate damage directly, their presence may accelerate wood deterioration and compromise structural integrity over time (Shigo, 1991). Similarly, lianas are natural components of tropical ecosystems. However, excessive growth on urban trees can increase canopy loading, compete for light resources, and contribute to branch breakage, particularly in trees already affected by structural defects (Putz, 1984). The frequent occurrence of these biological agents in the assessed trees suggests that visual inspection programs should include routine evaluation of termite activity, decay symptoms, and liana development as part of long-term tree maintenance strategies.

The findings also highlight the ecological and cultural importance of conserving mature *C. indicum* trees within Bogor City's urban landscape. Trees along Ahmad Yani Street and Sudirman Street exhibited large diameters and basal areas, reflecting decades of growth and substantial biomass accumulation. Such mature trees provide numerous ecosystem services, including carbon sequestration, urban heat mitigation, microclimate regulation, air quality improvement, habitat provision, and aesthetic enhancement (Nowak *et al.*, 2002; McPherson *et al.*, 2016). In addition, many *C. indicum* individuals are believed to have been established during the colonial period and therefore represent valuable elements of the city's historical landscape (Akbar, 2019). Maintaining these trees is therefore important not only from an ecological perspective but also from a cultural and urban heritage standpoint.

Overall, the results suggest that intensive rehabilitation measures are not currently required for most *C. indicum* trees in Bogor City. Instead, preventive management strategies are likely to be the most appropriate approach. Periodic health assessments, selective pruning, monitoring of biological deterioration agents, protection of the rooting environment, and timely treatment of structural defects can help maintain tree vitality and reduce the likelihood of further deterioration. Such measures are consistent with sustainable urban forest management principles that seek to balance ecosystem service provision, biodiversity conservation, and public safety within urban environments (Konijnendijk *et al.*, 2013). It should be noted that the present study evaluated tree health indicators using the Forest Health Monitoring (FHM) approach and did not directly assess the probability of tree failure or tree risk. Therefore, the recommendations presented here should be interpreted as preventive management actions based on observed tree health conditions rather than as the outcomes of a formal tree risk assessment.

CONCLUSION and RECOMMENDATION

This study demonstrated that *C. indicum* trees in Bogor City generally remain in good health despite the presence of various structural and biological defects. Most trees were classified as lightly damaged, with damage primarily concentrated in the stem and root-related components. Broken or dead branches, termite nests, and liana infestations were the most common types of damage observed. The findings suggest that the recorded defects are largely associated with aging processes and long-term exposure to urban environmental conditions rather than severe tree decline. The study provides baseline information on the health status and damage characteristics of mature *C. indicum* trees in urban environments. It highlights the usefulness of the Forest Health Monitoring (FHM) approach for assessing urban tree health. Regular monitoring, preventive maintenance, and timely management interventions are recommended to maintain tree health, support public safety, and sustain the ecological benefits provided by mature urban trees in Bogor City.

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