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Tree Risk Assessment in the College of Forestry and Natural Resources, University of the Philippines, Los Baños, Laguna

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Abstract. Trees are essential components of campus landscapes, providing ecological, aesthetic, and microclimatic benefits; however, when located near infrastructure and areas of high human activity, trees pose potential risks when structural defects are present. This study assessed tree-related risks within 10 meters of the academic buildings at the College of Forestry and Natural Resources, University of the Philippines, Los Baños. The study determined the species composition and structural characteristics of trees, evaluated their risk levels using the International Society of Arboriculture (ISA) Basic Tree Risk Assessment framework supported by sonic tree tomography, and mapped the spatial distribution of tree risks to guide mitigation strategies. A total of 116 trees representing 23 families were inventoried and assessed. The families Meliaceae, Fabaceae, and Moraceae were the most dominant across the study area. Diversity analysis indicated relatively high species diversity (H' = 3.741) but moderate evenness, indicating the dominance of several species within the landscape. There were 66 trees classified as moderate risk, 27 as low risk, 22 as high risk, and one as extreme risk, with common defects included codominant stems, weak branch attachments, broken branches, hanging limbs, trunk decay, leaning stems, root plate lifting, and root cavities. Statistical analysis revealed weak but significant positive correlations between tree risk level and structural variables, including DBH ($r_s = 0.270$, $p = 0.003$), TH ($r_s = 0.212$, $p = 0.022$), and crown spread ($r_s = 0.264$, $p = 0.004$). Sonic tree tomography of ten selected high-risk trees revealed varying levels of internal decay. Spatial mapping identified clusters of moderate to extreme-risk trees near areas of frequent human activity. Targeted mitigation strategies were proposed, ranging from routine monitoring to immediate interventions, such as tree removal, to enhance campus safety and support sustainable tree management.

Keywords: *Tree failure, sonic tree tomography, defects, decay, mitigation*

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Introduction

Trees play a significant role in the environment by providing ecological, aesthetic, and microclimatic benefits. However, trees can pose risk in developed areas where they grow close to buildings, roads, and areas with high human activity (Li et al., 2022). Risk refers to the probability that a tree-related hazard will cause damage or losses to potential targets. Hazards may arise from structural defects in the trunk, branches, or root system, which can compromise tree stability (Klein et al., 2019). When a tree fails, nearby targets, such as people, buildings, vehicles, or infrastructure, may be injured or damaged (Smiley et al., 2012). As outlined in the International Society of Arboriculture (ISA) manual, trees with significant defects, evidence of internal decay, and exposure to external loads such as wind or gravity are at higher risk of failure, particularly during extreme weather events. Tree risk assessment is significant on campuses, especially concerning trees near academic institutions, as it helps identify potential risks and prevent accidents that could result in injury, property damage, or even legal liabilities.

University campuses are areas with high human activity and frequent pedestrian movement. Assessing trees within a defined proximity, such as within a 10-meter distance within each campus academic building, and conducting a tree risk assessment is essential to safeguard the environment and preserve the aesthetics. The ISA Basic Tree Risk Assessment systematically evaluates the tree’s likelihood of failure, potential impact, and consequences using descriptive categories (Purcell, 2012; Dunster et al., 2013). While sonic tomography provides non-destructive internal detection, its combined application with spatial mapping remains underexplored (Allison et al., 2020). Integrating ISA risk assessment, sonic tomography, and spatial analysis can improve the accuracy of site-specific risk prioritization by identifying spatial patterns of tree risks relative to buildings and human activity zones. (Allison et al., 2020).

The College of Forestry and Natural Resources, University of the Philippines Los Baños, Laguna, is situated within the biodiverse Mt. Makiling Forest Reserve (Magcale-Macandog et al., 2023). The presence of mature trees in this area enhances the campus landscape but may also present potential hazards if structural defects are present. This study aimed to determine the species composition and structural characteristics of trees within 10 meters of CFNR academic buildings, evaluate tree risk level using ISA assessment criteria and sonic tomography, and map the distribution of tree risk relative to building proximity and zones of high human activity.

Methodology

Study Area

The study was carried out within 10 meters of each building in CFNR. These buildings are the Florencio Tamesis Hall, Emmanuel Bello Hall, Calixto Mabesa Hall, and Gregorio Zamuco Hall, as well as the CFNR Biotechnology laboratory, insectary, forest nursery, and the old basketry building (Figure 1). Tree risk assessment was performed in these areas due to regular use by students, faculty, and staff, along with the presence of infrastructure that could be impacted in the event of tree failure.

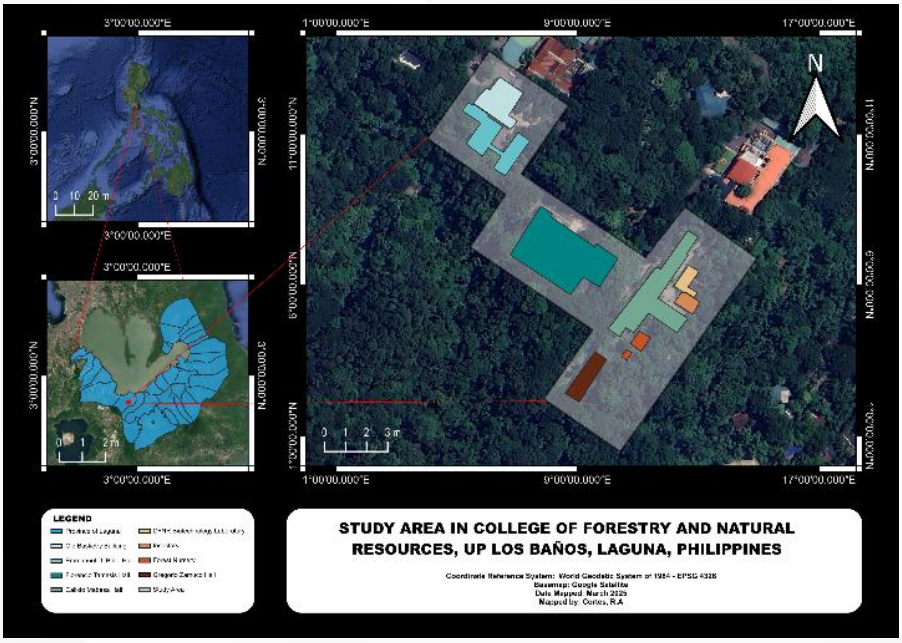

Figure 1. Study Area Map Presenting the Location of the Buildings in CFNR, UPLB

Tree Inventory

Tree inventory establishes a framework for documenting tree assessments and keeping records of tree inspections (Roloff, 2016). All trees greater than 10 cm within the 10-meter buffer from the edge of the buildings were included in the survey. For each tree, the following parameters were established: common name, scientific name, family name, tree classification (native or exotic), diameter at breast height (cm), tree height (m), coordinates, tree defects, overall tree health, and overall tree risk rating. Tree height (TH) was obtained using a Haga altimeter, while diameter at breast height (DBH) was measured 1.3 meters above ground level with a diameter tape. The crown spread of each tree was determined by measuring the distance from the base of the tree to the outermost edge of the crown along the four cardinal directions (north, south, east, and west). These measurements were averaged to approximate the crown spread diameter, providing a representative estimate of the canopy extent. The coordinates of each tree were recorded using a GPS device.

ISA Basic Tree Risk Assessment

ISA Basic Tree Risk Assessment involves conducting a thorough 360-degree inspection of a tree and facilitates the collection of information specifically related to the risk. The form comprises the following sections: tree identification (e.g., DBH, height, crown diameter), target information (e.g., house, people near tree), site factors, tree health and species profile, load factors (e.g., dynamic load), tree defects and conditions affecting the likelihood of failure, categorization of risk, and mitigation options and further recommendations to complete the assessment.

Risk Categorization

The ISA Basic Tree Risk Assessment form included a chart that linked the initial data collected to the risk categorization process. There are two components for tree risk: (1) the likelihood of tree failure, which is further divided into the likelihood of failure and the likelihood of impact, and (2) the consequences of failure. Decisions were also made using Matrix 1 (Likelihood matrix) and Matrix 2 (Risk rating matrix) (Table 1). Matrix 1 assessed trees based on Likelihood of Failure and Likelihood of Impact, categorizing results as Unlikely, Somewhat likely, Likely, or Very likely. The resulting classification from Matrix 1 was then combined with the failure consequences, which were categorized as Negligible, Minor, Significant, or Severe. One category was selected and applied in Matrix 2 to determine the overall risk rating of each tree. Each tree within the 10-meter buffer zone was assessed using these parameters and categorized as low, moderate, high, or extreme risk. This followed the ISA standards in determining the overall risk rating.

Table 1.
Components of Risk Categorization Using the International Society of Arboriculture (ISA) Basic Tree Risk Assessment Form (2017)

Likelihood			Consequences	
Failure	**Impact**			
Improbable – Unlikely to fail in normal or extreme weather	**Very low** – Minimal chance of impact; target is rarely occupied or protected	**Failure & Impact** *(from Matrix 1)*	**Negligible** – personal injury is unlikely, low-value property damage, or disruptions that can be replaced or repaired	**Risk Rating** *(from Matrix 2)*
Possible – May fail in extreme weather but unlikely in normal weather	**Low** – Slight chance of impact; target may have partial protection		**Minor** – minor personal injury, low-to-moderate value property damage, or small disruption of activities	
Probable – Failure is expected under normal weather conditions	**Medium** – Impact is possible but not expected; target is frequently occupied		**Significant** – personal injury is likely, moderate- to high-value property damage, or considerable disruption of activities	
Imminent – Failure has begun or is more likely to occur in near future, requiring immediate action	**High** – Impact is likely; target is constant and unprotected		**Severe** – One or more people could be injured or killed, high-value property damage, or major disruption of activities	

Matrix 1. Likelihood Matrix

Likelihood of Failure	Likelihood of Impact			
	Very low	**Low**	**Medium**	**High**
Imminent	Unlikely	Somewhat likely	Likely	Very likely
Probable	Unlikely	Unlikely	Somewhat likely	Likely
Possible	Unlikely	Unlikely	Unlikely	Somewhat likely
Improbable	Unlikely	Unlikely	Unlikely	Unlikely

Matrix 2. Risk Rating Matrix

Likelihood of failure and impact	Consequences of failure			
	Negligible	**Minor**	**Significant**	**Severe**
Very likely	Low	Moderate	High	Extreme
Likely	Low	Moderate	High	High
Somewhat likely	Low	Low	Moderate	Moderate
Unlikely	Low	Low	Low	Low

Targets

Targets around CFNR included buildings, walkways, parking areas, driveways, vehicles, and people, all of which were exposed to varying degrees of vulnerability to tree failure (Smiley et al., 2012). These targets were classified as either static (e.g., buildings and driveways) or mobile (e.g., vehicles and people).

The likelihood of target impact depended on the level of occupancy within the target zone, which was categorized as constant, frequent, occasional, or rare. This classification was used to assess and categorize the probability that a target would be impacted by a failing tree (Table 1).

Sonic Tree Tomography

The Sonic tree tomograph is an advanced non-destructive instrument designed to assess the internal decay. Tree tomography measurements were taken from the top 10 high-risk trees observed to be decayed during the tree inventory. These trees were evaluated not only on observable defects but also on their location within high-use target zones and corresponding occupancy levels. Specifically, the selected trees were situated in areas with frequent use and consistent occupancy, such as parking lots with regularly present vehicles, thereby increasing the likelihood and consequence of impact (Smiley et al., 2012). The specific unit used to obtain data was the ARBOTOM®, and the sensors were positioned on visibly affected areas to determine the extent of internal deterioration (Rinn, 2012).

The output of the tree tomograph was further analyzed using ImageJ software. ImageJ is a scientific image analysis program that supports various image formats and measures area, shape, and intensity, which are useful for data analysis (Schneider et al., 2012). ImageJ was used to determine the proportions of damaged areas within the trunks of the top 10 high-risk trees. The software enabled the quantification of internal decay and structural weaknesses by processing cross-sectional images, allowing for precise measurement of affected areas. The process involved adding a 2D image of each selected tree into the software, and the scale was set by measuring a reference length in centimeters. A polygon was then selected to measure the area of each color present in the image. Different colors represented areas of decay. The measured area of decay was divided by the whole area to calculate the percentage of decay.

Tree Mapping

Quantum Geographic Information System, or QGIS, was used to map and visualize tree distribution in relation to the infrastructure. Distribution and thematic maps were generated, serving as the basis for formulating tree risk mitigation strategies.

Statistical Treatment

Spearman's rank correlation coefficient (r_s) was used to assess the direction (direct or indirect) and strength of association of the risk level (ordinal) with DBH and TH (quantitative variables). Ecological parameters such as the Shannon-Wiener diversity index (H'), species richness, and evenness were used to quantify species diversity (Konopiński, 2020). To classify and interpret the diversity levels based on H' values, Fernando's Biodiversity Scale (1998) was applied, providing categorical benchmarks for ecological interpretation (Sarmiento and Mercado, 2019).

Fernando's Biodiversity Scale (1998)

Relative Values	Shannon (H') Index	Evenness (E)
Very high	3.5 and above	0.75-1.00
High	3.0-3.49	0.50-0.74
Moderate	2.5-2.99	0.25-0.49
Low	2.0-2.45	0.15-0.24
Very low	1.9 and below	0.05-0.14

The chi-square (χ^2) test was used to assess the association between categorical variables, particularly between tree conditions and associated risk categories. This test evaluates whether observed frequency distributions differ significantly from expected frequencies under the assumption of independence (McHugh, 2013).

All statistical analyses, including correlation and diversity indices, were performed using PAST (Paleontological Statistics Software). The chi-square test was conducted using JAMOVI statistical software.

Results and Discussion

Tree Species Distribution

The tree inventory conducted within 10 meters around CFNR academic buildings recorded a total of 116 individual trees from 23 families. The Meliaceae family was identified as the most dominant, with 32 individuals, followed by the Fabaceae and Moraceae families, with 17 and 12 individuals, respectively. Aside from these dominant families, a diverse array of tree families was inventoried (Figure 2). The predominance of these families reflected their ecological adaptability and frequent use in institutional landscapes.

The Meliaceae family is widely distributed across tropical and subtropical regions. Most species under Meliaceae offer benefits, such as shade, and tolerance to varied soil conditions, making them suitable for campus environments (Noorliyana Ramlee et al., 2023). However, certain structural concerns were observed among several individuals, particularly those located near potential targets such as buildings, walkways, and parking areas. For instance, *Swietenia macrophylla* was observed to be prone to developing weak branch unions, often resulting from improper pruning or the presence of codominant stems, which may increase the likelihood of structural failure during severe weather events. These structural vulnerabilities, combined with the proximity of trees to high-activity areas, contributed to the relatively higher recorded risk levels in locations dominated by this family (Sudrajat et al., 2021).

The Fabaceae family was recognizable by its flowers and, especially, by its distinctive fruits. This contributes to the aesthetic appeal of the campus landscapes. Their adaptability to a wide range of soil textures and moisture regimes further explained their spatial prevalence on campus. Many species within the Fabaceae family possessed expansive canopies; for instance, *Pterocarpus indicus* provided substantial shade due to its broad crown, which helped reduce the Urban Heat Island (UHI) effect (Ihsan and Dian, 2020; Tu, 2021). Despite these benefits, *P. indicus* presented structural concerns, including weak or overextended branches and dead branches still attached to the main trunk. Under strong wind conditions, these branches could snap or be detached, as wind forces acting on them generated high bending stress, thereby posing potential risks to nearby infrastructure and people (Helmanto et al., 2022).

Similarly, the Moraceae family, which includes genera such as *Ficus* and *Artocarpus*, was commonly observed in campus landscapes because of its environmental and aesthetic benefits. Many species in this family were effective at trapping airborne pollutants due to their dense canopies and were frequently used in landscape design for their attractive foliage and distinctive trunk forms. In addition, these trees supported urban wildlife by providing fruits that served as food resources (Muhammad et al., 2021; Mulyani et al., 2021; Gilman et al., 2019). However, as observed in the Meliaceae and Fabaceae families, several trees in the Moraceae family exhibited structural defects, such as weak branches and codominant stems, making them more susceptible to branch breakage in strong winds.

Aside from the dominant families, Meliaceae, Fabaceae, and Moraceae, a diverse range of other tree families was also recorded. The distribution of these families and their corresponding numbers of individuals was summarized in the tree distribution-per-family graph (Figure 2).

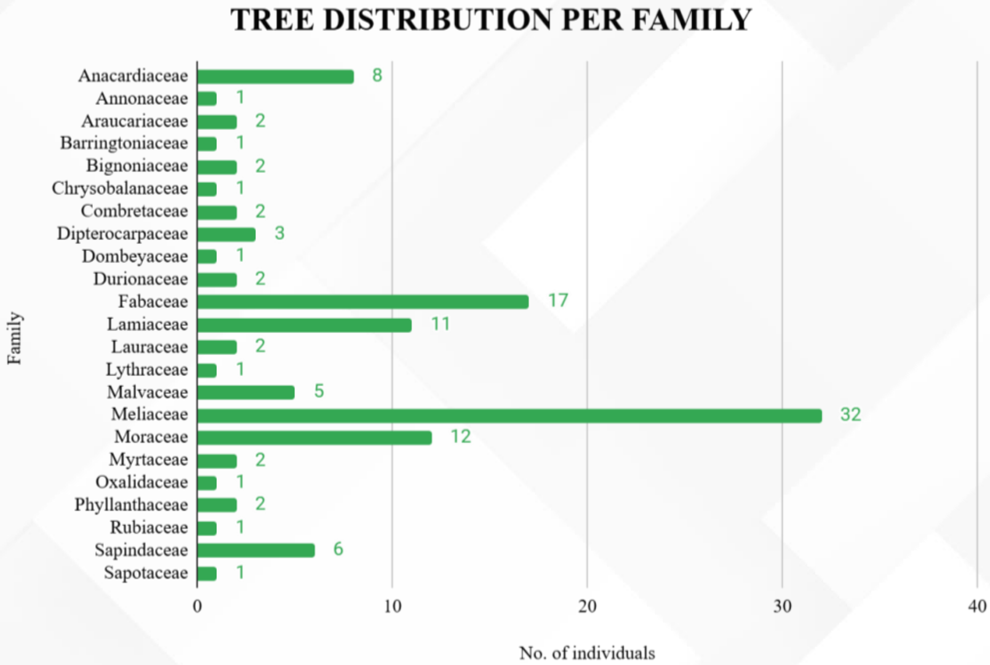

Figure 2. Summary of the Tree Distribution per Family with its Corresponding Number of Trees

The distribution map showed diverse species throughout the area, with denser clusters near the Calixto Mabesa Hall and the Florencio Tamesis Hall (Figure 3). The proximity of these concentrations to academic structures was recognized as a contributing factor to increased risk of damage in the event of tree failure, particularly during extreme weather events or typhoons (Suchocka et al., 2022).

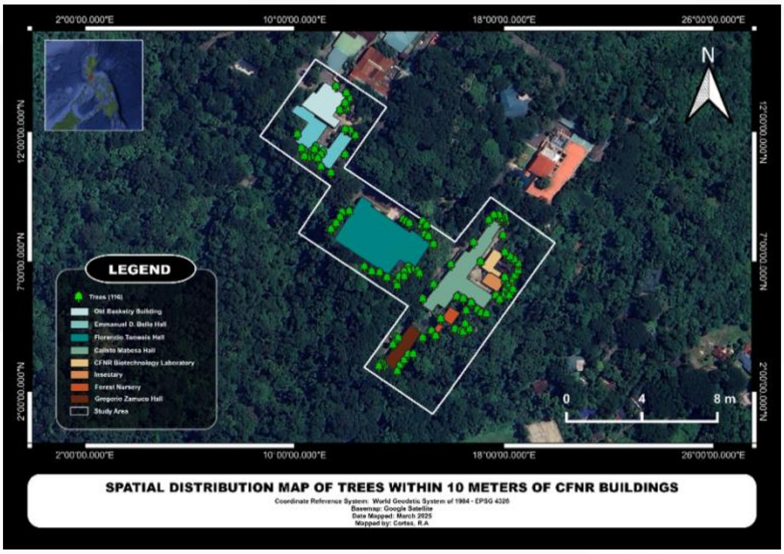

Figure 3. Distribution Map of the Overall Identified Trees Within 10 Meters of CFNR Academic Buildings

Tree Species Diversity and Evenness

Tree diversity across the CFNR academic buildings: C. Mabesa, E. Bello, F. Tamesis, and G. Zamora halls, were assessed using the Shannon Diversity Index (H') and evenness (E) (Table 2).

Table 2.
Summary of Tree Species Diversity Indices Within 10 Meters of CFNR Academic Buildings

	C. Mabesa Hall	E. Bello Hall	F. Tamesis Hall	G. Zamuco Hall	TOTAL
Individuals	46	26	28	16	116
Shannon (H')	3.493	2.395	2.564	1.767	3.741
Evenness (E)	0.913	0.784	0.812	0.731	0.691

C. Mabesa Hall exhibited the highest species diversity, with a Shannon index (H') of 3.493 and an evenness (E) value of 0.913 from 46 individuals. The high Shannon index indicated a relatively large number of species with a balanced distribution of individuals among species. The high evenness value indicated that most species in this area were represented by similar numbers of individuals, indicating minimal dominance by any single species (Magurran, 2004). Such patterns typically reflected a more heterogeneous and stable tree community.

In comparison, E. Bello Hall recorded H' of 2.395 and E of 0.784 with 26 individuals. While the diversity index remains moderate, the slightly lower evenness suggested a greater level of species dominance within the tree population. This implied that a few species accounted for a larger proportion of the total individuals, thereby reducing overall diversity compared with areas where species were more evenly distributed (Magurran, 2004).

Similarly, F. Tamesis Hall showed moderate diversity with H' of 2.564 and E of 0.812 from 28 individuals. These values suggested a reasonably diverse tree assemblage, although the slightly lower evenness compared with C. Mabesa Hall indicated that some species were more dominant than others. Nevertheless, the diversity level still reflected a balanced species composition (Magurran, 2004).

In contrast, G. Zamora Hall exhibited the lowest diversity with H' of 1.767 and evenness of 0.731, based on 16 individuals. A low Shannon index indicated fewer species or stronger dominance of certain species within this location. The lower evenness value showed that the distribution of individuals among species was less balanced, with some species occurring more frequently than others (Magurran, 2004).

When all areas were combined, the overall Shannon index was 3.741, signifying a relatively high level of species diversity across the study sites. However, the overall evenness value of 0.691 demonstrated that, at the landscape level, some species were more dominant than others. This pattern was common in managed areas where certain species were preferentially planted and were better adapted to local environmental conditions (Threlfall et al., 2016). Furthermore, the completeness of the tree inventory was influenced by accessibility constraints arising from physical barriers and safety considerations.

Tree Classification

The classification of trees into native and exotic species was important for assessing tree risks on campus because it helped determine each species' adaptability, structural stability, and pest and disease resistance. This classification served as a guide for developing appropriate tree risk mitigation strategies, particularly when trees posed potential risks to people and infrastructure within the campus.

A total of 116 trees were inventoried, of which 71 (61.7%) were classified as native, while 45 (38.3%) were exotic species (Figure 4). Both native and exotic species demonstrated ecological value within the campus landscape. Native trees provide greater ecosystem services, exhibiting varying degrees of adaptability and ecological resilience, and supporting local wildlife that may not be fully provided by exotic species alone (Aguiar et al., 2014).

In contrast, exotic trees were introduced species that often exhibited faster growth rates, making them suitable for newly developed landscapes. Some exotic species also demonstrated greater tolerance to artificial conditions and harsh urban environments. Both native and exotic trees contributed to mitigating the Urban Heat Island (UHI) effect by providing shade and cooling surfaces in built environments (Susilowati et al., 2021). In terms of tree management and risk implications, both native and exotic trees may pose potential risks if they are poorly maintained or planted in locations that do not meet their ecological or structural requirements (Fransen, 2023).

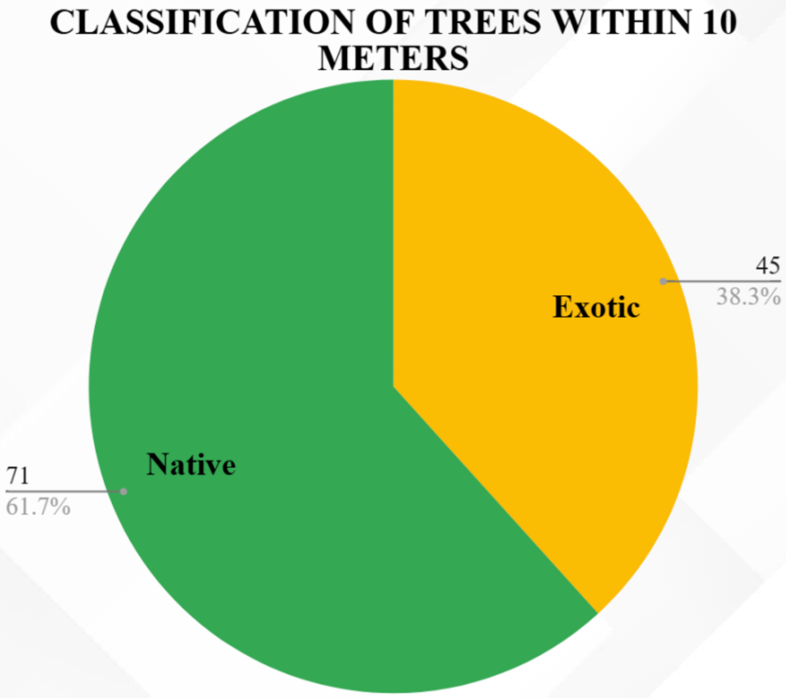

Figure 4. Tree Classifications Within 10 Meters of Each Academic Building.

Risk Categorization

All trees within 10 meters of each academic building were categorized into four risk levels: low, moderate, high, and extreme. The assessment of tree risk within the CFNR academic buildings revealed a notable presence of moderate to extreme-risk trees, particularly concentrated around areas with high pedestrian activity, such as C. Mabesa Hall and F. Tamesis Hall. C. Mabesa Hall recorded the highest number of high-risk trees (12 individuals) (Table 3). This finding highlighted the need for targeted monitoring and mitigation measures in this area, where potential structural failure could affect nearby people and infrastructure.

F. Tamesis Hall was identified as having one extreme-risk tree (Table 3), which was *Samanea saman*. The tree was observed leaning toward the building, resulting in structural damage to portions of the roof and walls. Additionally, the root plate was uplifted, and conks were present at the base of the tree, indicating internal decay and structural instability.

Table 3.
Summary of Risk Category of Trees Within 10 meters in Each Academic Building

Site	Extreme	High	Moderate	Low
C. Mabesa Hall		12	22	12
E. Bello Hall		4	16	6
F. Tamesis Hall	1	5	20	2
G. Zamuco Hall		1	8	7
TOTAL	**1**	**22**	**66**	**27**

The spatial distribution map of tree risk levels across the campus showed a concentration of low to extreme-risk trees within 10 meters of each CFNR academic building (Figure 5).

Figure 5. Risk Rating Map of the Assessed Trees within 10 meters of CFNR Academic Buildings. Data indicated the distribution of low (green), moderate (yellow), high (orange), and extreme (red) risk trees across the CFNR academic buildings

The overall distribution of tree risk categories by family showed that the Meliaceae family had the highest number of moderate-risk trees (20), along with 8 low-risk and 4 high-risk trees (Figure 6). This observation supported previous findings that certain species within this family, particularly *S. macrophylla*, were prone to structural defects. These defects are often driven by light-responsive growth patterns and the structural mechanics of branch unions; without consistent arboricultural intervention, such trees are at elevated risk of failure, particularly under typhoon conditions (Gilman, 2012; Krisnawati et al., 2011).

Similarly, the Fabaceae family recorded four high-risk trees, nine moderate-risk trees, and one extreme-risk tree (Figure 6). Species within this family exhibited a range of growth forms, and several developed broad crowns, such as *Millettia pinnata* and *Pterocarpus indicus*. These showed clear evidence of pre-existing branch-related defects, including codominant stems and previous branch failures. These structural weaknesses significantly increase their susceptibility to failure in strong winds (Klein et al., 2019). Furthermore, their proximity to high-occupancy zones creates a high potential for target strikes, transforming these biological defects into urgent hazards for both academic structures and campus pedestrians (Ellison, 2005; James et al., 2014).

The Lamiaceae family had three high-risk trees, while the Moraceae family had three high-risk trees and six moderate-risk trees (Figure 6). Trees within these families were observed to exhibit unbalanced canopies, branch failures, or poor structural form, often resulting from previous storm damage, improper pruning practices, or internal decay caused by biotic agents (James et al., 2014).

Other families that contained at least one high-risk tree included Anacardiaceae, Barringtoniaceae, Chrysobalanaceae, Combretaceae, Durionaceae, Dipterocarpaceae, Lauraceae, and Sapindaceae (Figure 6). In many cases, tree risk appeared to be associated with site-specific factors, including previous branch failures due to weak branch attachments during typhoons, improper pruning history, or inadequate maintenance (Klein et al., 2019). For example, a *Barringtonia asiatica* tree near a building exhibited a leaning trunk, weak branch attachments, hanging branches, and root disturbance, likely resulting from past typhoons in the area. Given its location near a frequently used building and pedestrian walkway, the tree was classified as high risk due to the potential hazard it posed to people and nearby infrastructure.

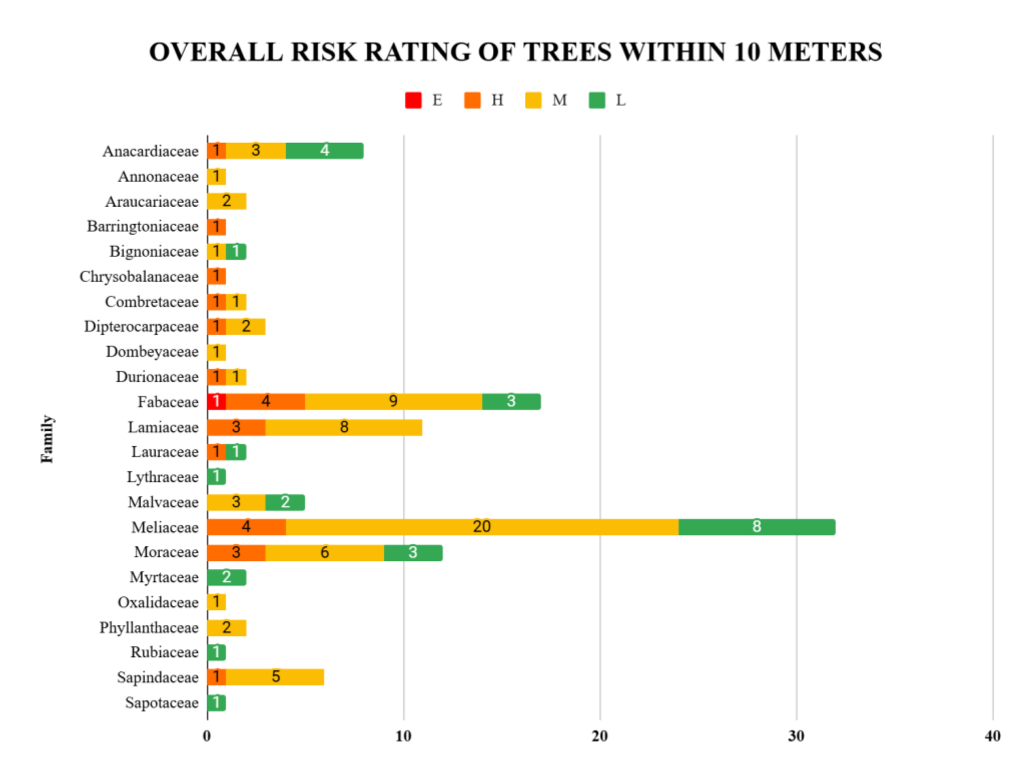

Figure 6. Overall Risk Rating of the Identified Trees within 10 meters of CFNR Academic Buildings.

Correlation of Risk Level with DBH, TH, and Crown Spread

The relationship between tree risk levels and selected tree variables, diameter at breast height (DBH), tree height (TH), and crown spread, was analyzed using Spearman's rank correlation (r_s) (Table 4). The results indicated statistically significant but weak positive correlations between tree risk level and all measured variables. These findings suggested that increases in DBH, tree height, and crown spread were generally associated with a slight increase in the likelihood of higher tree risk levels.

Table 4.
Relationship of Risk Level with DBH, TH, and Crown Spread

	r_s	p-value
Risk level vs DBH	0.270	0.003
Risk level vs TH	0.212	0.022
Risk level vs Crown Spread	0.264	0.004

The correlation between DBH and tree risk level yielded a Spearman's rho of 0.270 (p = 0.003), indicating a weak but statistically significant positive relationship. This result suggested that tree risk levels tended to increase with DBH. Larger diameter trees often represented older individuals that may have accumulated structural defects over time, including decay, cavities, or large dead branches. In several observed cases, trees with greater DBH also exhibited broader crowns, which may increase the potential consequences of failure due to the greater canopy mass and extent (Hernandez et al., 2020).

Similarly, tree height showed a weak positive correlation with tree risk level, with r_s value of 0.212 and a p-value of 0.022. Taller trees were generally more exposed to environmental stresses such as strong winds and severe weather events. Trees that extended above surrounding vegetation experienced greater wind loading, which may increase the likelihood of structural failure, particularly when combined with other defects such as poor trunk taper, internal decay, leaning stems, or compromised root systems (Dahle et al., 2017).

A comparable relationship was observed between crown spread and tree risk level, with r_s of 0.264 and a p-value of 0.004, highlighting the potential role of crown morphometrics in tree structural stability. Trees with larger crown spreads intercepted greater wind forces, which may increase mechanical stress on the trunk and root system during storm events. In addition, expansive crowns contributed to greater overall tree mass, potentially amplifying the consequences if structural failure occurred (Cantiani and Chiavetta, 2015).

Association Between Tree Classification and Risk Levels Across DBH, Tree Height, and Crown Spread

The association analysis indicated that tree classification (native versus exotic) was significantly related to tree risk levels across all structural attributes examined (DBH, TH, crown spread) (Table 5). The analysis revealed that risk distribution among trees influenced by both species' origin and structural growth characteristics.

Table 5.
Tree Classification vs Risk Levels in terms of DBH, TH, and Crown Spread

Structural Variable	X^2	df	N	p-value
DBH	142	3	4221	<0.0001
TH	86.9	3	1837	<0.0001
Crown Spread	241	3	8489	<0.0001

For DBH, the distribution of risk levels differed significantly between native and exotic species ($p < 0.0001$; $N = 4221$). This implied that tree size played an important role in shaping risk patterns between native and exotic species. As DBH increased, trees generally experienced greater mechanical loads and structural stresses due to increased biomass and canopy weight (Hernandez et al., 2020). This was particularly relevant for species with rapid radial growth or those that developed large stems within relatively short periods. Differences in growth rate and wood density between native and exotic species likely influenced the distribution of risk levels across diameter classes. Fast-growing exotic species, for instance, may have attained larger diameters more rapidly but may have exhibited lower structural strength than slower-growing native species, thereby affecting stability outcomes (Hernandez et al., 2020).

In terms of tree height ($p < 0.0001$; N = 1837), the significant relationship suggested that vertical development influenced risk classification differently between native and exotic trees. Taller trees were generally more exposed to wind loading and mechanical stress, especially in open or urban environments (Dahle et al., 2017). Variations in growth architecture between species groups, such as differences in crown form, tapering, and branch distribution, likely contributed to differences in structural stability. Native species may have exhibited more structurally adaptive forms due to long-term ecological adaptation, whereas some exotic species may not have been equally adapted to local typhoon-prone conditions (Hernandez et al., 2020).

The strongest association was observed for crown spread ($p < 0.0001$; N = 8489), indicating that canopy architecture played a major role in determining the distribution of risk. Trees with wider crown spreads experienced greater wind resistance and increased leverage forces on branches and stems, which elevated the likelihood of structural failure. This was particularly critical in tropical environments, which are frequently affected by strong wind events such as typhoons (Moore, 2014). Species with broad, umbrella-like crowns were more vulnerable to branch failure and uprooting, especially when structural defects or inadequate maintenance were present (Cantiani and Chiavetta, 2015).

From a management perspective, the observed differences in risk distribution may also have reflected historical silvicultural and maintenance practices. Urban and institutional landscapes often favored certain exotic species for aesthetic value, shade provision, or rapid growth, sometimes without long-term structural pruning strategies (Slik et al., 2024). In contrast, native species may have grown under more natural conditions yet still experienced variable maintenance intensity across locations. The presence or absence of pruning, crown reduction, and hazard mitigation interventions likely contributed to the observed differences in risk levels between species groups (Hassan et al., 2023).

Crown and Branch Defects

Codominant branches were observed, particularly in *Artocarpus heterophyllus* located near F. Tamesis and G. Zamuco Hall (Figure 7). These formed when branches of equal diameter emerged from the same point on the trunk, creating structurally weak unions that could split under load (Helliwell, 2004). Their occurrence was likely related to crown architecture, as the analysis showed that crown spread had the strongest association with tree risk levels. Trees with broader crowns experienced greater wind resistance and leverage forces on branch unions, increasing the likelihood of structural weaknesses developing within the canopy (Moore, 2014). Larger DBH may have further intensified these stresses by supporting heavier crowns and larger branches (Hernandez et al., 2020). The formation of codominant stems was also often linked to the absence of early structural pruning or unfavorable environmental conditions (Gilman & Grabosky, 2006).

Broken branches and hangers referred to damaged branches that remained lodged within the crown, often due to storms. *Acacia mangium* (Figure 7) found in the CFNR Biotechnology Laboratory exhibited broken branches and hangers. These defects posed a potential risk because they could detach and fall unexpectedly during storms, thereby increasing the risk to pedestrians (James et al., 2014).

Previous branch failures were also evident in *S. macrophylla* (Figure 7), which commonly resulted from strong winds, heavy rainfall, and improper pruning practices. The species commonly developed multiple vertical stems that formed weak branch attachments, making them prone to structural failure (Bakewell-Stone, 2023). The risk of such failures increased in trees with large crown spread, where expanded canopy surfaces created greater aerial drag and bending forces on branches and stems (Cantiani and Chiavetta, 2015).

Dead twigs were small in diameter and were commonly associated with declining vascular function. This condition also resulted from damage at the points of attachment, which reduced the structural integrity of the branch. Weak attachments were frequently characterized by narrow branch unions, often due to poor crown management, resulting in structural instability and an increased risk of limb failure during extreme weather events. In trees with larger crown spreads, the added canopy weight and wind exposure further increased stress on these weakened attachments, elevating the likelihood of limb failure during extreme weather events (Helliwell, 2004; Hernandez et al., 2020).

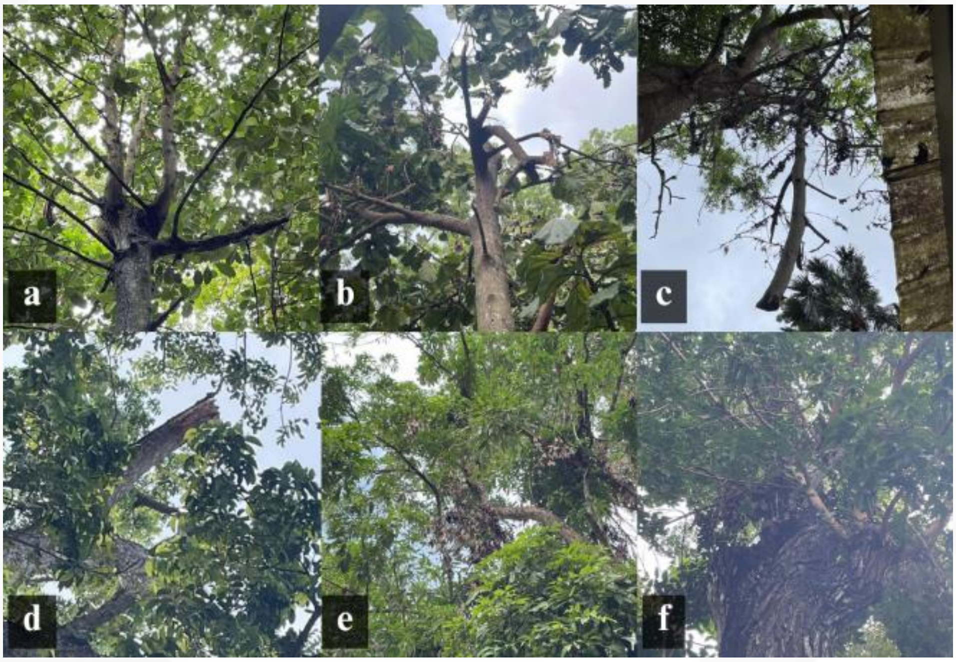

Figure 7. Common Tree Defects Observed in Crown and Branches of the Identified Trees: (a) codominant branches, (b) broken branches, (c) hanger, (d) previous branch failure, (e) dead twigs, (f) weak attachments

Trunk Defects

Gummosis was observed on the trunks of some of the inspected trees, including *Buchanania arborescens* (Figure 8). Gummosis was characterized by sap exudation, typically indicating environmental stress or pathogen infection (Aloi et al., 2021). The occurrence of such trunk defects has been associated with tree size and structural development, as the analysis showed that DBH and tree height were significantly related to tree risk levels. Larger and taller trees often experience greater physiological stress due to increased biomass, mechanical loading, and exposure to environmental stressors, which could predispose them to trunk injuries and pathogen invasion (Hernandez et al., 2020). Cankers, on the other hand, were lesions primarily caused by fungi or bacteria. Once established, these cankers often failed to compartmentalize, thereby compromising the structural integrity of the trunk (Castro-Medina et al., 2014). In certain cases, *Nephelium lappaceum* (Figure 8), cankers were observed to affect nearly half of the trunk, indicating a progression of the infection.

Conks were fruiting bodies of wood-decaying fungi, observed in *Ficus Septica*, and *Koordersiodendron pinnatum* found within the C. Mabesa hall, (Figure 8). The presence of conks indicated ongoing internal wood decay, which typically progressed through entry points such as trunk or branch wounds (Gauthier et al., 2015). In humid tropical environments like the Philippines, high moisture levels in wood promoted the enzymatic activity of decay fungi, accelerating the degradation of structural tissues (Ata, 2025). This process gradually reduced the wood's flexural stiffness, increasing the susceptibility of trees to structural failure during high-velocity winds associated with typhoons (Fraver et al., 2018). The occurrence of fungal fruiting bodies was often associated with mature trees of larger DBH, where decay organisms had greater opportunity to colonize internal tissues over time (Suchocka et al., 2022). These conditions indicated reduced wood strength and highlighted the need for further diagnostic assessment using advanced tools such as sonic tree tomography.

Leaning trees were also documented in several species, including *Terminalia microcarpa* (Figure 8), found in CFNR Biotechnology laboratory and *S. saman* leaning against the building of Florencio Tamesis Hall, which caused damage to the structure's roof and wall (Figure 8). These defects indicated significant structural instability. Tree height may have contributed to this condition, as taller trees were more exposed to wind forces that increased bending stress and the likelihood of tilting or displacement. Combined with large stem diameters and canopy weight, these factors could weaken root anchorage and increase susceptibility to leaning, particularly following severe weather events (Ogle, 2021).

Figure 8. Common Tree Defects Observed in The Trunk of the Identified Trees: (a) gummosis, (b) canker, (c) conks, (d) leaning

Roots or Root Collar Defects

Root plate lifting was observed in some species, such as the *Bauhinia malabarica*, found beside the nursery in C. Mabesa Hall (Figure 9). Root plate lifting is frequently attributed to pavement over roots or by excessively compacted soils with insufficient drainage. Both of which are known to intensify the problem and must be carefully noted, as both directly compromise root function and stability (Shi et al., 2023).

Another common observed defect in roots was the root cavity, found in species such as *Gmelina arborea* near the Florencio Tamesis Hall. Root cavities form around tree roots, often due to storm damage, animal or insect excavation, or mechanical injury. This defect may come from a small opening that may enlarge over time, allowing fungi and other microorganisms to invade the wood, which can lead to decay (Roloff, 2016; Gilman, 2020).

Figure 9. Commonly Observed Roots or Root Collar Defects: (a) root plate lifting, (b) root cavity

Sonic Tree Tomography

The tomographic assessment of ten selected high-risk trees around CFNR academic buildings revealed varying levels of internal condition, which are classified into five condition categories: Green (sound wood), Yellow (slightly decayed), Orange (moderately decayed), Red (severely decayed), and Purple (hollow or missing) (Figure 10).

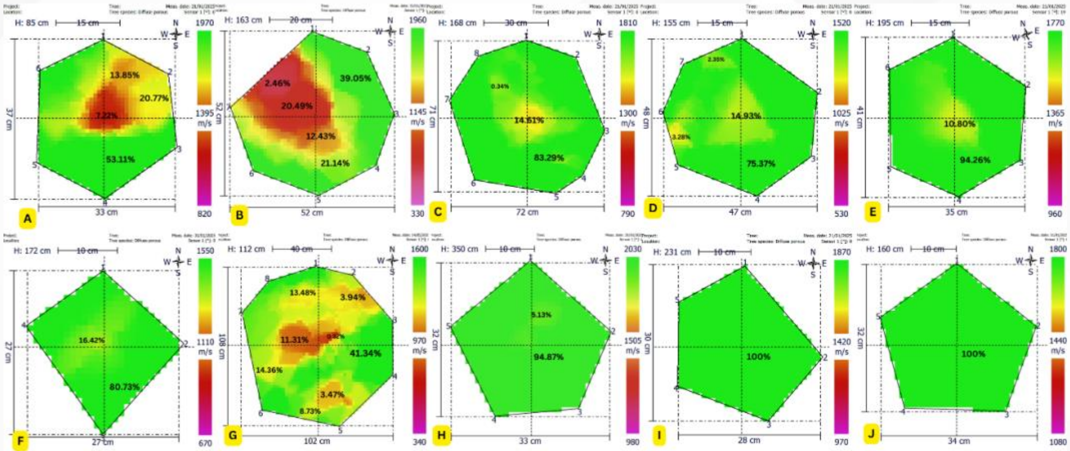

Figure 10. Result of the Selected Top ten High-Risk Trees Using Sonic Tree Tomography: (A) Avocado, (B) Tabon-tabon, (C) Botong, (D) Dapdap palong, (E) Himbabao, (F) Rambutan, (G) Gmelina, (H) Kalumpit, (I) Fiddle leaf, (J) Balinghasai

Fiddle leaf (*Ficus lyrata*) and Balinghasai (*Buchanania arborescens*) (Table 6) both exhibited 100% sound wood, indicating that no advanced decay or hollowing was detected despite their visible trunk defects, such as gummosis and sap ooze. This is largely due to the biological phenomenon of CODIT (Compartmentalization of Decay in Trees), in which trees create barriers that isolate damaged or infected tissue, effectively preventing decay from spreading further internally (Negishi & Kanno, 2022; Brazee et al., 2011).

Similarly, Kalumpit (*Terminalia microcarpa*) and Botong (*Barringtonia asiatica*) showed over 94% sound wood, with only minor signs of early decay (Yellow) (Table 6). Slight decay typically indicates early-wood degradation associated with minor injuries or environmental stress. In the case of *T. microcarpa*, which was observed leaning against a nearby building, localized trunk damage corresponded with the areas of early decay. Tree height may have contributed to this condition, as taller trees experienced greater wind exposure and bending stress, increasing the likelihood of trunk injuries that could initiate early decay if left unmanaged (Slik et al., 2024).

High proportions of sound wood were also recorded in Rambutan (*Nephelium lappaceum*) (80.73%), Himbabao (*Broussonetia luzonica*) (83.29%), and Dapdap palong (*Erythrina crista-galli*) (75.37%), with slightly decayed portions and no indication of moderate to severe decay (Table 6). *N. lappaceum*, canker formation accompanied by galls, attributed to abnormal proliferation of wood tissue typically induced by bacterial or pathogenic infestation, resulting in 16.42% of slightly decayed areas located on the western side of the trunk. *B. luzonica* exhibited a leaning trunk, along with a small root cavity, leading to 14.95% slightly decayed wood in the central trunk region. Additionally, *E. crista-galli* was found to have 20.56% slightly decayed wood on the western portion of the trunk. This deterioration is likely associated with the leaning trunk against the roof of a nearby storage facility, where minor structural damage has been inspected. Both trees have evidence of structural deformation, potentially due to poor root systems or load factors such as strong wind (Ogle, 2021).

Tabon-tabon (*Atuna racemosa*), Avocado (*Persea americana*), and Gmelina (*Gmelina arborea*) exhibited moderate to severe decay. *A. racemosa* had the lowest percentage of sound wood at 39.05%, with decay distributed across multiple classes and 2.46% hollow wood located in the northwest section of the trunk. A visible trunk split was observed, likely caused by prolonged mechanical stress or environmental loading. *P. americana* showed 53.11% sound wood, while the remaining 46.89% exhibited varying levels of decay, including 7.22% severely decayed wood concentrated in the northeastern portion of the trunk. The presence of a trunk cavity and the tree's leaning orientation toward the parking area further elevated its classification to high risk, as both internal decay and external mechanical loading likely contributed to structural weakening. In *G. arborea*, a root cavity contributed to 11.31% moderately decayed wood in the northwest and 0.32% severely decayed wood in the northeast, with additional slightly decayed areas recorded in multiple sections of the trunk. Only 41.34% of the wood remained sound (Table 6). These patterns indicated substantial internal deterioration, which may have been exacerbated by the structural demands imposed by larger DBH and tree height, increasing the likelihood of decay progression and structural instability over time (Terho, 2009).

Table 6.
Result of the Sonic Tree Tomograph of Ten Selected High-Risk Trees

Common name	Scientific name	DBH (cm)	TH (m)	Crown Spread (sqm)	Percentage of area (%)				
					Green	Yellow	Orange	Red	Purple
Tabon-tabon	*Atuna racemosa*	24.30	22.20	44.77	39.05	21.14	12.43	20.49	2.46
Avocado	*Persea americana*	34	10	57.41	53.11	20.77	13.85	7.22	-
Gmelina	*Gmelina arborea*	94	27.50	155.04	41.34	36.56	18.72	0.32	-
Himbabao	*Broussonetia luzonica*	78	14	34.47	83.29	14.95	-	-	-
Dapdap palong	*Erythrina crista-galli*	46	13	58.49	75.37	20.56	-	-	-
Botong	*Barringtonia asiatica*	39	25	89.50	94.26	10.80	-	-	-
Rambutan	*Nephelium lappaceum*	21	17	43.01	80.73	16.42	-	-	-

Kalumpit	*Terminalia microcarpa*	31.70	9.50	15.55	94.87	5.13	-	-	-
Balinghasai	*Buchanania arborescens*	34.20	16.50	70.36	100	-	-	-	-
Fiddle leaf	*Ficus lyrata*	22.60	8.40	106.14	100	-	-	-	-

Risk Mitigation

Low-risk trees

A total of 27 trees were classified as low risk, exhibiting minimal structural defects and no significant internal decay. Defects such as weak attachments, and unbalanced crown were particularly observed in species such as *Heritiera littoralis* (Figure 11). *H. littoralis* found in the C. Mabesa Hall, within 1.5 meters of a target zone (Figure 11). Despite the trees' current low-risk status, it is recommended to conduct annual inspections to detect early signs of defects such as developing cracks, leaning, or fungal activity, which may indicate potential structural damage over time. Pruning is also utilized to remove dead branches (Smiley et al., 2017).

Figure 11. *Heritiera littoralis* Classified as Low-Risk with Observed Defects

Moderate-risk trees

In the moderate-risk category, preventive interventions were prioritized. *Milletia pinnata*, for instance, located in E. Bello Hall, and *Artocarpus heterophyllus,* located in C. Mabesa Hall, exhibited defects such as dead twigs, codominant branches, and previous branch failure (Figure 12). Management actions at this risk level included reducing or removing dead twigs and broken branches to minimize potential hazards. The installation of support cables was also recommended to stabilize limbs with codominant branches and reduce the likelihood of structural failure. Non-invasive textile-based cables were preferred because they avoided drilling into the wood. Regular inspections of tree condition, cable tension, and placement were necessary to ensure proper function and prevent additional damage. Furthermore, early structural pruning was recommended for juvenile trees to prevent the future development of codominant stems (Rust, 2016; ANSI, 2016).

Figure 12. *Millettia pinnata* and *Artocarpus heterophyllus* exhibiting Common Tree Defects

High-risk trees

Trees classified under the high-risk level exhibited severe structural defects, including extensive decay, trunk lean, root instability, cavities, and trunk splits. A total of ten representative trees were documented (Figure 13).

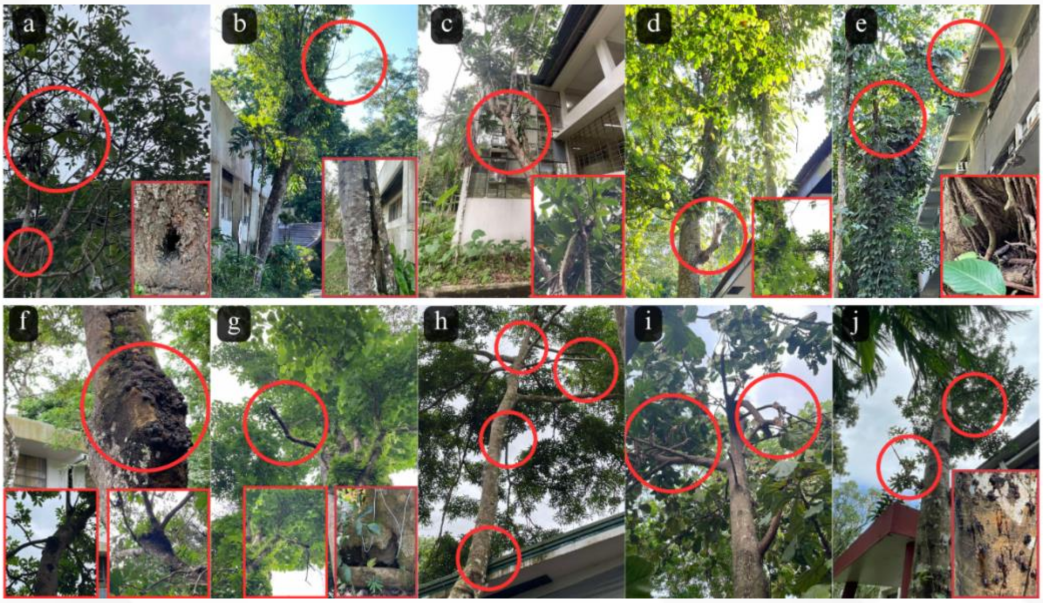

Figure 13. Ten Selected High-Risk Trees with Common Tree Defects: (a) *Persea americana*, (b) *Atuna racemosa*, (c) *Barringtonia asiatica*, (d) *Erythrina crista-galli*, (e) *Broussonetia luzonica*, (f) *Nephelium lappaceum*, (g) *Gmelina arborea*, (h) *Terminalia microcarpa*, (i) *Ficus lyrata*, (j) *Buchanania arborescens*

High-risk trees posed an immediate hazard, particularly when located near critical infrastructure where the likelihood of property damage or injury was greater. The ten trees classified as high risk and subjected to sonic tree tomography were situated near high-value targets, such as buildings, walkways, driveways, and parking areas, with frequent human activity. Tree defects and site conditions associated with potential failure were evaluated to determine the level of risk posed by each tree. In all ten cases, defective components, including the crown, branches, trunk, and roots, were located within the target zones and areas of high occupancy. Consequently, regular re-evaluation, annual monitoring, and emergency pruning were recommended as necessary management measures to significantly reduce the likelihood of tree failure (Smiley et al., 2012; Pradipta et al., 2018).

Among the ten selected high-risk trees, *E. crista-galli* in the insectary exhibited weak attachments, previous branch failures, and overgrown vines, all of which increased branch loading and the likelihood of failure (Figure 13). Regular pruning and vine removal were therefore recommended to reduce structural stress and mitigate potential hazards. Similarly, *P. americana* at C. Mabesa Hall and *F. lyrata* at E. Bello Hall both exhibited codominant branching, which created structurally weak unions susceptible to splitting. For these trees, reduction cuts were recommended to correct crown imbalance and reduce the risk of branch failure. Reduction cuts shortened extended branches by pruning back to a lateral branch with a diameter of at least one-third that of the removed branch, thereby maintaining structural stability while reducing mechanical stress on the canopy (Wiseman et al., 2020). *T. microcarpa*, also located at C. Mabesa Hall, exhibited broken branches and a leaning trunk that extended toward the building (Figure 10), indicating the need for immediate pruning interventions. Branches measuring approximately one to three inches in diameter were recommended for removal using a pole pruner or pole saw. Proper drop-cut techniques were advised, in which the first cut was made one-third to one-half through the limb, followed by a second cut positioned two to six inches farther from the initial cut. This method helped prevent bark stripping and minimized additional damage to the trunk during pruning operations (Wilson, 2024; Stone, 2023).

Trunk defects were observed in *N. lappaceum* near E. Bello Hall and in *B. arborescens* near F. Tamesis Hall, both of which exhibited symptoms such as cankers and gummosis. In such cases, identifying the causal agent, whether fungal or bacterial, was essential, particularly when the infection was still in its early stages. Sanitation of infected tissues and disinfection of pruning tools were recommended to prevent further spread of the disease (Murray, 2020). Additionally, trees could compartmentalize the affected area when the damage remained localized, thereby limiting the internal progression of infection (Nelson & Hudler, 2007).

Other species, such as *G. arborea, B. luzonica*, and *B. asiatica,* showed advanced decay, root cavities, and leaning trunks, which compromised their structural stability. Management of leaning trees and trunk splits in large individuals involved installing bracing systems at branch unions, with multiple support rods positioned below the attachment points to redistribute mechanical stress and enhance stabilization. The base of the bracing system was securely anchored into the ground, with careful consideration to avoid damage to the root system. Regular inspections and adjustments of the supports were conducted to ensure continued effectiveness and to prevent unintended injury to the tree (Rust, 2016). In terms of root cavities, it is necessary to conduct periodic monitoring on the root system, along with the provision of adequate rooting space, soil mulching, proper irrigation, and canopy pruning to reduce wind load by lowering the tree's center of mass (He et al., 2024; Watson et al., 2014). Furthermore, *A. racemosa* exhibited a visible trunk split and a leaning stem, indicating the need for urgent inspection and bracing intervention. When mitigation measures were no longer sufficient to address structural defects, tree removal was recommended (Rust, 2016).

Extreme-risk tree

S. saman, located on the left side of F. Tamesis Hall, had already failed and exhibited partial root plate uplift, with approximately half of its root system displaced (Figure 14).

Figure 14. Tree Failure Located in Florencio Tamesis Hall Showing Uplifted Roots and Structural Damage

The tree had already failed, with approximately half of its root system uplifted and the crown impacting the building roof, resulting in structural damage. Immediate attention was required, and the surrounding area was promptly restricted using temporary fencing and warning signage to minimize exposure to potential targets.

Selective removal of severely damaged parts, or complete tree removal, was recommended. This approach was typically carried out in consultation with the property owner and a certified arborist (Till & Prager, 2025; Cox, 2009). The removal process began with reduction cuts and drop cuts on large branches to minimize the risk of uncontrolled branch failure during trunk removal. Subsequently, trunk removal was performed using the undercut-and-backcut technique, commonly referred to as the drop-cut method.

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