Nakhara: Journal of Environmental Design and Planning (2025)
Volume 24(3), Article 524
DOI: https://doi.org/10.54028/NJ202524524
Article Type: Research Article

Contextualizing Tree Defects and Risks in an Urban Tropical Campus, Chulalongkorn University, Thailand

Sirintra Vanno

Department of Landscape Architecture, Faculty of Architecture, Chulalongkorn University, Thailand

E-mail: Sirintra.v@chula.ac.th

Received 2025-10-20; Revised 2025-11-10; Accepted 2025-11-17

ABSTRACT

Tree failure poses a risk to property and people; however, there is limited data on tropical tree risk assessment, hindering effective risk management. Chulalongkorn University (CU) is an urban tropical forest campus in the heart of Bangkok, Thailand. The campus provides essential cultural, social, and ecological services but is subject to structural failure due to extreme weather and climate change that can cause severe consequences for property and public safety. This study aimed to carry out a tree risk assessment at CU using a form based on that of the International Society of Arboriculture (ISA). Altogether, 4,255 trees representing 256 species were identified, stressing the need for location of structural defects using adapted risk assessment forms identifying three levels of tree risk urgency management: immediate and critical, urgent, and non-urgent. The most common defects were observed in trunks and bark, branches, and roots. High-risk species included *Casuarina equisetifolia, Pterocarpus indicus,* and *Albizia saman*. Introduced tropical tree species demonstrated higher defect rates than native species. These findings emphasized the importance of tree assessments in tropical cities, where management practices and environmental conditions differ from temperate regions. Assessment will contribute to a safer urban public green space, well-planned management, and resilient urban tropical forestry beyond the CU campus and across Southeast Asia.

Keywords: tree failure, tree risk assessment, urban tropical forestry, tree risk management, Chulalongkorn University

INTRODUCTION

An urban tropical forest (i.e., green spaces embedded within tropical urban environments and covered with mature trees) in the heart of Bangkok contributes to a healthier microclimate, mitigates heat, and reduces energy consumption for buildings on the campus, benefiting the surrounding urban community. Chulalongkorn University (CU), Bangkok, Thailand, represents a significant example of an urban tropical forest situated in the metropolitan core area, where trees are an important part of the environment, living in harmony with people. The selection of tree species for campus green-space development requires different considerations compared to the traditional approach of planting trees primarily for direct utilitarian purposes (Chatakul & Janpathompong, 2022). However, the failure of these trees may cause public damage.

Tree risk assessment is especially important in urban environments, as large trees provide shading for people in high-frequency pedestrian areas. Unexpected tree failure can cause severe consequences, such as risks arising from tree age, structural weakness caused by defects[1], pests, or diseases, as well as physiological stress from environmental imbalances. Tree failure occurs when mechanical stresses exceed the capacity of roots, trunks, or branches, often exacerbated by hidden defects such as decay or cracks associated with trunk wounds in trees are compartmentalized (Shigo, 1977; Dunster et al., 2017; Lilly et al., 2022;).

Awareness of tree risk assessment and management is largely the work of Emeritus Professor Decha Boonkham, the founder of the Department of Landscape Architecture, CU, who has introduced arboriculture to Thailand over the last three decades. According to *Trees in Construction and Urban Development* (Boonkham, 2000), healthy urban trees provide essential cultural, social, and ecological services for the city. Healthy trees also serve as green infrastructure, an integrated network of green spaces that increases Bangkok's sustainability (Vanno, 2019). The Campus Green project has great potential in connecting to Bangkok's public spaces, such as Lumpini Park and Benchakitti Park, shown in Figure 1, where green infrastructure, nature-based solutions, and biophilic design can improve climate resilience, stormwater management, reinforce soil, protect soil erosion, and create a continuous ecological corridor integrating nature, wildlife and people (Vanno, 2011; Ristianti et al., 2024). Trees on campus serve as landmarks, cultural memory sites, and aesthetically crucial elements; many trees are part of the history and represent a strong emotional connection and relationship between nature and the campus (Chitrabongs, 2022). Yet, they are also subject to structural failure that has caused severe consequences for property, public safety, and city infrastructure due to extreme weather and climate change.

Branch failures are major causes of damage to property and power lines, as well as injury to people (Shigo, 1989; 1990). With this in mind, urban tree risk assessment and management have gained greater attention among urban tree caretakers and those in charge of management in Thailand. Tree risk assessment systematically evaluates trees to identify defects and other conditions that lead to tree failure within the framework, analyzes their potential (likelihood of failure) to impact the target (likelihood to impact), and considers the possible consequences (Dunster et al., 2017; Ellison, 2005; Smiley et al., 2025; van Haaften, 2021). Assessments employing International Society of Arboriculture (ISA) forms are suitable for trees in an urban tropical climate and were utilized in the establishment of the Database on Tree Health at CU, the first initiative for the systematic survey and analysis of the campus tree population.

The study aims to create a systematic tree health database, evaluate trees' physical conditions, identify their species, and analyze their overall health and structural stability. This study will evaluate the structural integrity of trees on the university grounds and potential hazards. The resulting data will support sustainable management, maintenance, and risk mitigation on campus. (Bakken, 1995)

Tree failure occurs when mechanical stresses exceed the capacity of roots, trunks, or branches, often exacerbated by hidden defects such as decay or cracks (Dunster, 1996; Smiley et al.,

[1] A defect refers to an identifiable structural fault within a tree.

Figure 1

Study Area: *Chulalongkorn University, Bangkok, Thailand*.

Note. Adapted from *Map of Chulalongkorn University, Bangkok, Thailand*, by Google Map, 2025 (https://shorturl.at/1VaYU). Copyright 2025 by Google LLC.

2006). Tree Species Failure Profiles (TSFP) in arboriculture describe known failure issues, patterns, or defects characteristic of specific species (Clark et al., 1993; Costello & Berry, 1991; Dunster et al., 2017; Fountain et al., 2019). As such, the study seeks to develop systematic TSFP data for tropical and subtropical regions on evidence-based insights to anticipate failures and prioritize maintenance (Costello & Smiley, 2013).

METHODOLOGY

Assessment Form Framework

Surveys of Chulalongkorn University's trees were conducted and compiled on available public tree health assessment forms in a comparative study as a reference framework. Most methods used by professional arborists have three main inputs: likelihood of impact, likelihood of failure, and consequences of failure. Tree risk assessment forms are available online and can be developed to meet the needs of different professions and use contexts. To ensure credible and high-quality outcomes, qualified arborists should conduct risk assessments. For this study, the following assessment forms were compiled as reference tools:

- International Society of Arboriculture (ISA) Basic Risk Assessment Form, 2017
- City of Seattle, Department of Planning and Development, Tree Hazard Evaluation Form
- USDA Forest Service, Hazard Tree Evaluation, 2012
- City of Lake Oswego, Oregon. Tree Hazard Evaluation Form, 2016
- Department of Rural Roads (Thailand), Large Tree Risk Assessment Form, 2018
- Kasetsart University Arborist Club (Kasetsart University), Preliminary Tree Risk Assessment Form, 2017

Table 1

Comparative Table of Tree Health and Risk Assessment Forms

Tree Assessment	ID	Target	Site Factors			Tree Health			Defects			Risk Assessment	Mitigations	Number of pages
			Soil Condition	Stie Change	Prevailing	Foliage	Pest/Biotic	Crown Density	Crown/branch	Trunk	Root/buttress			
ISA Basic Tree Risk	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	2
City of Seattle	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	2
USDA Forest Service (Southwestern Region)	✓	✓					✓		✓	✓	✓	✓		1
City of Lake Oswego, Oregon	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	2
Department of Rural Roads	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	3
KU Arborist Club	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	2

The six different forms for tree risk assessment, the aspects of which are shown in Table 1, are meant for use by professional arborists, though, in the course of this research, they were also developed into a new form appropriate for non-professional assessors. The above forms were, furthermore, applied to trees in temperate and continental zones, wherein the characteristics of the trees are different from those in the tropical zone**.** An additional two forms were also found in Thailand and were simply translated versions of the ISA forms**.** Comparing these forms, it was determined that an approach in which data assessors conduct their own assessments is more suitable for trees in large areas where assessors cannot analyze or evaluate trees by themselves, as the tree data collection process should be simple enough for anyone to collect information without difficulty. In the future, students or anyone interested in public participation may use this to help assess and update the physical data of the trees on campus, as CU does not have a certified arborist on staff and these are very rare in Thailand. Rather, tree workers are the experts within the CU tree care unit and can review and evaluate the collected information to form maintenance plans. There is no tree risk assessment and mitigation section on the tree assessment data collection form. This framework could encourage broader participation by the public in collecting data through accessible platforms.

The review of tree health assessment forms carried out in this study provided a better idea of their applicability to the context of CU and allowed for development of a more suitable form. Data assessors were central to analysis as they directly evaluated and recorded information, a method that has both advantages and disadvantages as follows:

- Individually performed data assessment:

  Individual judgments may vary or lack standardization. Additionally, aborists may be required to ensure accuracy by judging variables based on personal experience (Norris, 2007)

- Post-assessment based on data collected by others:

  Expert analysis and evaluation are required in this assessment. Incomplete and unclear data may be misleading and hinder evaluation.

Tree Assessment Form Design

An essential consideration in surveying and assessing trees is their influence on surrounding structures and site conditions. Trees in the urban environment are surrounded by infrastructure such as roads, buildings, and public utilities that may affect their root systems and branches, and cause stress. External factors influence tree life forms, problems encountered, and future adaptation of trees will affect their potential hazard. The locations of defects, visible signs that a tree has the potential to fail, signal where failure is most likely to occur, allowing for some predictability (Dunster et al., 2017; Pokorny et al., 2003).

The initial tree survey data collection incorporated quantitative and qualitative information to support expert analysis and health assessment of individual trees. Quantitative data, aligned with the assessment framework, were subjected to statistical analysis. Qualitative data were documented through photographs attached to each tree record. As such, evaluators can, in turn, observe the defects presented these images on-site and further evaluate a specific tree for potential failure (Pokorny et al., 2003).

Trees on the CU campus are relatively new plantings; there are few naturally leaning specimens. The campus is on flat terrain, and the natural environmental conditions across the sites vary only slightly. Consequently, it was unnecessary to collect detailed site-specific environment variables during this survey. Broader analyses of campus macro- and microclimate conditions are required to inform longer-term tree management and maintenance strategies.

As the city has expanded, denser campuses nestled among surrounding buildings and high-rise structures have substantially reduced the risk of lightning strikes and storms. Although occasional lightning damage to trees has been recorded, the frequency remains low. Broken branches are primarily associated with seasonal winds and storms, which may be intensified by wind tunnels formed between buildings. However, these windy storms are not considered as hazardous as storm events, but rather part of the regular monsoon season, and thus fall within the scope of risks that an in-house arborist can reasonably manage.

The tree assessment form designed for the CU tree survey (Table 2) was specifically designed for tropical tree species and incorporates additional data relevant to tropical tree environments. Mistletoe parasite infestations are frequently observed on trees in such climates, where they can significantly compromise host vitality. By absorbing water and nutrients from the host tree, these mistletoe parasites weaken physiological functions, impede wound recovery, and in severe cases, cause tree mortality. Excessive mistletoe parasitic growth may obstruct flow to distal branches, leading to dry branches and structural failure due to excessive load.

Data Collection

The data collection processes required qualified surveyors, clear agreements, and training to minimize errors. Surveyors possessed fundamental knowledge of tree species identification and how to use the form, and were given an area within which to work. For the survey and selection of trees, individuals with a trunk circumference greater than 60 cm were included in the dataset, as these are considered mature with higher structural characteristics, which are physiologically at greater risk. Measurements were taken at Diameter at Breast Height (DBH), 1.30 meters above ground level (Smilley et al., 2025). Trees with a trunk circumference less than 60 cm were ID’d with a name and Area Code (Figure 2); tree assessment was unnecessary. Specifications and criteria details were established to guide the data collectors in processing, ensuring accuracy, consistency, and standardization across all datasets.

Example area codes:

CUC Chulalongkorn University Common

ARC Faculty of Architecture

EDC Faculty of Education, Faculty of Communication Arts, and Faculty of Law

PLT Faculty of Political Science

Tree ID template: Area Code (XXX)_ID number (000) CUC_001

Table 2

Tree Assessment Form for Chulalongkorn University

Assessor Data	
Date:	Email:
Name:	Tel:

Tree Information	
Tree ID:	
Tree Name:	
Scientific Name:	
Circumference at DBH (1.3 m)	
Historic tree (0/1)	
Canopy area (m^2)	
Tree height (m)	
Density (1 Low / 2 Normal / 3 High)	

Leaves	
No leaves, leaf-shedding (0/1)	
No leaves, dead (0/1)	
Dry leaves (0/1)	
Yellow leaves (0/1)	
Spotted leaves (0/1)	
Torn leaves, insect marks (0/1)	

Branches	
Dead/dying branch (0/1)	
Conflict w/ building or structure (0/1)	
Power lines (0/1)	
Broken/Hangers (0/1)	
Epicormic shoots (0/1)	
Narrow crotches **/** Crossing branches **(**0/1**)**	
Mistletoe parasite (0/1)	

Trunk	
Posture (1 straight/ 2 lean/ 3 Codominant)	
Taper trunk (0/1)	
Cavity (0/1)	
Cavity size (W x H x D) (m)	
Peeled bark (0/1)	
Scraped bark (0/1)	
Canker (0/1)	
Insect damage / holes (0/1)	
Sap or resin bleeding (0/1)	

Roots	
Girdling roots (0/1)	
Pavement damage (0/1)	

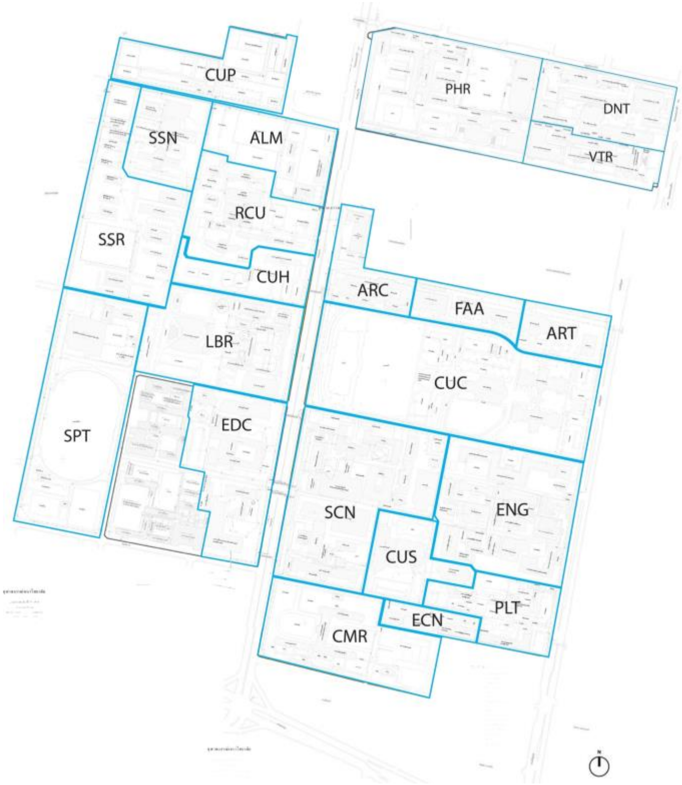
Other	
Conks / Mushrooms (0/1)	
Disease / Pests / Ficus stangler (0/1)	

Additional notes:

Note. All sections presenting numeric data must be accompanied by clear, appropriate illustrative images to ensure analysis without deviation.

Figure 2

Study Area Divisions and Codes



Tree condition data were recorded using an online data logging system on Google Forms. Assessors underwent an orientation wherein they were instructed on data collection practices in the field. Tree height was measured by using a laser rangefinder for accuracy. Photographic data collection was taken, and the renamed files were systematically labeled using a tree identification code with species' common names, e.g., PLT_0078_Raintree. For images of defects, a descriptive tag follows the identification code to indicate specific defects, e.g., PLT_078_dead branch and PLT_078_root injury. For trees exhibiting multiple defects, each defect was assigned a sequential number for clear documentation. Graphic illustrations were additionally employed to record canopy morphology, including a plan-view for the outline and a dimensions diagram. Each graphic sheet must be labeled in accordance with the tree identification code and a measurement scale to ensure accuracy and consistency.

The tree health assessment required qualitative data analysis on an individual tree basis to evaluate for specific factors affecting each case. This involved multiple interrelated variables and relied on quantitative scoring systems that were, in and of themselves, limited in their applicability. The overall health conditions of trees on campus were categorized according to criticality and urgency for management, providing a basis for future tree management strategies and tree care management planning.

Data Mapping

All tree locations were applied to a campus map, including the associated tree identification code and name. As an example, part of the CU Common (CUC) area mapping is shown in Figure 3. The survey found a total of 4,255 trees representing 256 species.

Figure 3

Tree Mapping Example within the Chulalongkorn University Common (CUC)

The tree surveys were conducted by more than 80 second- and third-year Landscape Architecture students at Chulalongkorn University. The total number of trees identified was approximately double the initial assumption prior to the commencement of the survey projects, which took two years to complete. The overwhelming number of trees and, subsequently, data posed unforeseen challenges in dataset management and storage for the research team.

RESULTS

Data Analysis and Risk Classification

The tree survey conducted within CU covered a total area of 0.875 km^2. This did not represent the entire campus, and was, therefore, less than the total area shown on Figure 1, as certain areas were inaccessible due to ongoing construction or renovation, while some were not under CU management and, as such, restricted. Qualified trees, i.e., those with a trunk circumference greater than 60 cm at DBH, totaled 2,883 individuals belonging to 165 species. A total of 2,883 trees across 165 species were surveyed over a period of 2 years. Assessors were briefed on how to use the assessment form before surveying. Examples of field survey data are shown below (Figure 4 and Table 3).

PLT_076 was in a very high-traffic zone, and the branch was touching the roof of the main campus bus station. The asphalt pavement of the parking lot was completed a few years before the survey at the same time as renovations to the bus station. A year later, with not much root remaining following re-pavement of the parking lot, this tree collapsed one weekend (with, fortunately, no cars in the parking lot). The event took place in the rainy season when there were high winds and the soil was saturated.

Figure 4

Example from the Survey including Tree Data and Photo

Tree ID: PLT 078 *Albizia saman* Tree Profile

Common name: Rain Tree

Scientific name: *Albizia saman*

Circumference at DBH: 167 centimeters

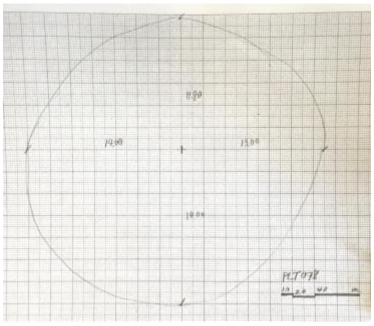
Canopy area: 547.4 square meters

Tree height: 21.3 meters

Canopy density: regular in the dry season

Table 3

Images of Defects to One Albizia Saman From the Data

Canopy shape and area 	Dead/dying branch 	Narrow crotches and crossing branches 
Conflict with building 	Buttress root injury 	Pavement and root conflict 

There are fifteen historic trees on CU, most of which are located within the CUC area, which is designated as a conservation zone by the university. Examples of listed historic trees are as follows:

CUC_061 *Albizia saman* planted by H.M.K. Bhumibol Adulyadej in 1962 (total of 5 trees)

CUC_327 *Schoutenia glomerata* planted by H.R.H. Princess Maha Chakri Sirindhorn in 1975

CUC_040 *Albizia saman* planted by Jimmy Carter (39th U.S. President) and Prof. Dr. Kasem Suwannakul, former President of Chulalongkorn University, in 1985

LBR_179 *Ficus religiosa* shoots from Bodh Gaya, India, planted on the 80th Anniversary of Chulalongkorn University on March 21, 1997, in front of the Maha Thirarajanusorn Building (CU Main Library)

Care and maintenance of the university's historic trees require special attention. As such, a yearly monitoring, maintenance, and health inspection schedule should be established. This will allow early detection of changes, abnormalities, pest infestations, or diseases, and facilitate timely treatment before the problems escalate beyond recovery. A dedicated maintenance team should be appointed to oversee and supervise all management aspects. Routine operations need to be reviewed and approved by the committee or relevant experts before implementation. General maintenance staff should not be authorized to make independent decisions, and any intervention involving a historic tree should first receive approval from the committee.

The 20 most common species, listed in Table 4, comprised 2,232 out of the 2,883 total trees, or 77.42%. Of the total number, 1,514 had defects (52.51%). The most common defects were found on:

- Bark and trunks (1,749 trees)
- Branches (1,346 trees)
- Roots (401 trees)

Figure 5 shows the defect categories (Wound on Trunk, Canker, Bulge, and Abnormal/Loose Bark; Narrow Crotch and Crossing Branches; Epicormic Shoots; Dead or Dying Branches; Decay and Open Cavity) and the rates of affected individuals among the three most-affected species for that category.

The defects contributing to branch and trunk failure were categorized into five types: decay and open cavities; dead or dying branches; epicormic shoots; narrow crotches and crossing branches; and wounds, cankers, bulges, and abnormal or loose bark. The number and percentage of trees with these defects for each species are shown in Figure 5 and Table 5. As delineated in the table key, pink highlighting indicates the top 10 species found on campus, which represent 1,737 trees, or 60.25% of the trees with significant numbers in the dataset. The highest rates of defect for each category, and in total, are highlighted in shades of orange–brown, while the lowest are highlighted in shades of green. Among the surveyed tree species, 11 were classified as introduced species, and 9 were species native to Thailand.

In this initial survey, all identified defects were preliminarily categorized as urgent to ensure further qualitative assessment of defects (e.g., branch size and wound severity) toward more accurate categorization, with the goal of differentiation of urgency levels over time. In this scheme, categorization would begin with "minor" defects to acknowledge that certain issues, such as epicormic shoots and water sprouts, may develop into urgent hazards if left unmanaged.

Table 4

The 20 Most Common Tree Species at Chulalongkorn University

Quantity	Scientific Name	Common Name	Percentage
416	*Albizia saman*	Rain Tree, Monkey-pod	14.43 %
413	*Pterocarpus indicus*	Angsana, Andaman redwood	14.33 %
197	*Tabebuia rosea*	Pink Poui, Rosy Trumpet Tree	6.83 %
183	*Peltophorum pterocarpum*	Golden Flamboyant	6.35 %
105	*Casuarina equisetifolia*	Coastal She-oak, Australian Pine	3.64 %
103	*Terminalia catappa*	Tropical Almond, Indian Almond	3.57 %
85	*Mimusops elengi*	Spanish Cherry, Bulletwood	2.95 %
85	*Millingtonia hortensis*	Indian Cork Tree, Tree Jasmine	2.95%
75	*Terminalia ivorensis*	Black Afara, Ivory Coast Almond	2.60 %
75	*Lagerstroemia speciosa*	Queen Crape Myrtle, Pride of India	2.60 %
71	*Plumeria rubra*	Frangipani, Temple Tree	2.46 %
66	*Ficus benjamina*	Weeping Fig, Benjamin Fig	2.29 %
65	*Bauhinia purpurea*	Purple Orchid Tree, Orchid Tree	2.25 %
58	*Lagerstroemia loudonii*	Thai Crape Myrtle, Salao	2.01 %
57	*Alstonia scholaris*	Blackboard Tree, Scholar Tree, Devil's Tree	1.98 %
55	*Mangifera indica*	Mango	1.90 %
52	*Monoon longifolium*	False Ashoka, Mast Tree	1.80 %
45	*Tamarindus indica*	Tamarind	1.56 %
35	*Delonix regia*	Flame Tree, Royal Poinciana	1.21 %
28	*Streblus asper*	Siamese Rough Bush, Sandpaper Tree	0.97 %
2,232			**77.42%**

Figure 5

Rates of Defects Among the Most-Affected Species, by Defect Category

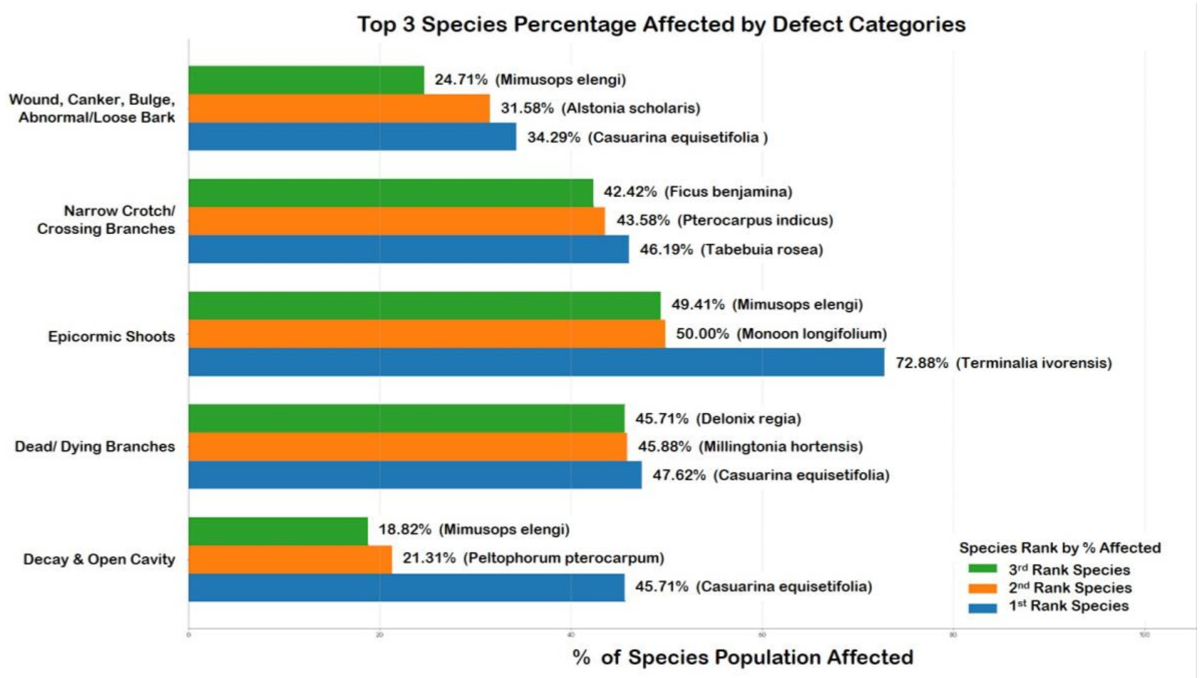


Table 5

The 20 Most Common Tree Species on the CU Campus and Their Defect Rates

#	Native/ introduced	Family	Scientific Name	Trees on CU Campus			Catagories of Defects: Decay/ Open Cavity		Dead/ Dying Branch		Epicormic Shoots		Narrow Crotch btw Branches/ Crossing Branch		Wounds/ Canker/ Bulges/ Abnormal and Loose Bark		Total Defects	Defects per Defected Tree
				# Total	Defected	%	#	%	#	%	#	%	#	%	#	%	#	
1	introduced	FABACEAE	*Pterocarpus indicus*	413	299	72.40	51	12.35	149	36.08	138	33.41	180	43.58	62	15.01	580	1.94
2	introduced	FABACEAE	*Albizia saman*	416	232	55.77	50	12.02	122	29.33	87	20.91	95	22.84	84	20.19	438	1.89
3	introduced	BIGNONIACEAE	*Tabebuia rosea*	197	135	68.53	10	5.08	64	32.49	96	48.73	91	46.19	16	8.12	277	2.05
4	Native	FABACEAE	*Peltophorum pterocarpum*	183	132	72.13	39	21.31	53	28.96	65	35.52	43	23.50	18	9.84	218	1.65
5	introduced	CASUARINACEAE	*Casuarina equisetifolia*	105	82	78.10	48	45.71	50	47.62	14	13.33	1	0.95	36	34.29	149	1.82
6	introduced	COMBRETACEAE	*Terminalia catappa*	103	76	73.79	3	2.91	17	16.50	43	41.75	10	9.71	24	23.30	97	1.28
7	Native	SAPOTACEAE	*Mimusops elengi*	85	63	74.12	16	18.82	20	23.53	42	49.41	19	22.35	21	24.71	118	1.87
8	Native	BIGNONIACEAE	*Millingtonia hortensis*	85	62	72.94	4	4.71	39	45.88	35	41.18	28	32.94	8	9.41	114	1.84
9	introduced	COMBRETACEAE	*Terminalia ivorensis*	75	59	78.67	0	0.00	26	34.67	43	57.33	23	30.67	5	6.67	97	1.64
10	Native	MORACEAE	*Ficus benjamina*	66	50	75.76	4	6.06	9	13.64	12	18.18	28	42.42	1	1.52	54	1.08
11	Native	LYTHRACEAE	*Lagerstroemia speciosa*	75	45	60.00	12	16.00	29	38.67	29	38.67	24	32.00	17	22.67	111	2.47
12	Native	LYTHRACEAE	*Lagerstroemia loudonii*	58	43	74.14	1	1.72	13	22.41	19	32.76	12	20.69	9	15.52	54	1.26
13	Native	APOCYNACEAE	*Alstonia scholaris*	57	41	71.93	7	12.28	6	10.53	10	17.54	7	12.28	18	31.58	48	1.17
14	introduced	FABACEAE	*Tamarindus indica*	45	39	86.67	2	4.44	18	40.00	15	33.33	7	15.56	3	6.67	45	1.15
15	introduced	ANNONACEAE	*Monoon longifolium*	52	35	67.31	2	3.85	11	21.15	26	50.00	7	13.46	5	9.62	51	1.46
16	introduced	APOCYNACEAE	*Plumeria rubra*	71	34	47.89	2	2.82	1	1.41	18	25.35	14	19.72	17	23.94	52	1.53
17	Native	ANACARDIACEAE	*Mangifera indica*	55	33	60.00	1	1.82	6	10.91	15	27.27	8	14.55	8	14.55	38	1.15
18	introduced	FABACEAE	*Delonix regia*	35	21	60.00	5	14.29	16	45.71	5	14.29	10	28.57	3	8.57	39	1.86
19	Native	MORACEAE	*Streblus asper*	28	21	75.00	3	10.71	7	25.00	8	28.57	8	28.57	2	7.14	28	1.33
20	introduced	FABACEAE	*Bauhinia purpurea*	28	12	42.86	2	7.14	5	17.86	7	25.00	2	7.14	4	14.29	20	1.67
				2,232	**1,514**													

Native species
introduced species

Ten most common trees found on the CU Campus
1,737

Species with highest rates of defect
The highest
The second highest
The third highest

Species with lowest rates of defect
The lowest
The second lowest
The third lowest

Tree Data Summary

From the 148 species and 86 genera reported in the global literature on tree species failure profiles (TSFP), 10 species and one genus overlapped with the 20 most common species recorded at CU. These *were Pterocarpus indicus, Albizia saman, Tabebuia rosea, Peltophorum pterocarpum, Casuarina equisetifolia, Terminalia cattappa, Mimusops elengi, Millingtonia hortensis, Terminalia ivorensis, Ficus benjamina, Lagerstroemia speciosa, Mangifera indica, and Delonix regia.*

Pterocarpus indicus, an introduced species, ranked second highest in occurrences of narrow and crossing crotches. When considering the total number of defects across all categories, furthermore*, P. indicus* recorded the highest overall, with 580 defects observed in 299 out of 413 trees—an average of 1.94 defects per defected tree, the third highest rate in that category. This indicates that individual trees commonly present multiple structural weaknesses, which, when combined with the species' reported association with SBD, may substantially elevate its likelihood of failure.

Albizia saman, an introduced species, ranked second in the number of defective trees, with 438 defects identified on 232 trees, across 416 individuals, averaging 1.89 defects per defected tree. The number of defective trees ranked second-highest. *A. saman* at CU did not exhibit one predominant failure mode. In fact, many such trees displayed multiple co-occurring defects, which may potentially compound overall structural risk. However, a large number of defects may not point to the defect related to the greatest risk. For example, small deadwood is generally more likely to fail than large codominant stems; however, depending on the consequence and failure likelihood, the codominant stem may be a far higher risk. Multiple defects are generally not considered or poorly considered by the risk methods (Norris, 2007).

Tabebuia rosea, an introduced species, showed the most defects on narrow and crossing branch crotches, at 46.19%, or 91 out of 197 trees. Trees of this species also had the third highest number of defects, 277, with 135 of its 197 trees affected. This resulted in the species having the second-highest average defects per defected tree, 2.05, ranking higher than *P. indicus.* In sum, *Tabebuia rosea* is arguably the highest-risk tree on campus.

Of the 183 specimens of ***Peltophorum pterocarpum*****,** a native species, on campus, 39 (21.35%) exhibited signs of decay and cavities, the second-highest such rate in the data set. *P. pterocarpum*'s life form is characterized by a narrow, cylindrical form that generally requires minimal pruning. However, due to its fast growth rate, periodic pruning for height control and canopy thinning is necessary. The observed decay and cavity formation could have been caused by improper pruning practices in the past.

Casuarina equisetifolia, an introduced species, exhibited the highest numbers of decay and cavities, 45.71%; dead or dying branches, 47.62%; and wounds, cankers, bulges, and loose bark, 34.29%. A total of 149 defects were recorded across 82 defected trees, out of the species' 105 total, for an average of 1.82 defects per defected tree. The species also exhibited the lowest rates of epicormic shoots, 13.33%, and narrow crotches between branches and crossing crotches, 0.95%, the latter of which was found on just a single tree. For this species, past maintenance practices appear to have exacerbated structural problems, particularly through topping, while planting in proximity to power lines has necessitated frequent pruning, further contributing to defect development.

Terminalia cattappa ranked second lowest in occurrences of narrow crotches between branches and crossing crotches at 9.71%. A total of 97 defects were recorded on 76 defected trees, out of 103 individuals, averaging 1.28 defects per defected tree. No other notable defect types were observed for *T. cattappa*.

Mimusops elengi exhibited the third highest rate of decay and cavities, 18.82%, the third highest rate of epicormic shoots, 49.41%, and, once again, the third highest rate of wounds, cankers, bulges, and loose bark, 24.71%.

Millingtonia hortensis showed a high proportion of dead or dying branches, 45.88%, among 39 defected trees out of its 85 trees on campus.

Terminalia ivorensis exhibited the highest rate of epicormic shoots, 57.33%. Notably, the species was the only in the data to exhibit no cases of decay or open cavities. *T. ivorensis* also showed the second lowest rate of wounds, cankers, bulges, and loose bark, 6.67%. However, it ranked second highest in its percentage of defected trees, with 59 defected trees out of 75 trees, or 78.67%. This species's distinctive life form, compared to other urban trees, suggests that improper pruning practices may have contributed to the development of epicormic shoots, thereby increasing structural vulnerability.

Ficus benjamina ranked third in its rate of narrow and crossing crotches, 42.42%, but lowest in wounds, cankers, bulges, and loose bark, 1.52%, with the latter found on only one tree. The species furthermore had the lowest average defects per defected tree, at 1.08. Owing to its natural growth habit as a fast-growing tree with relatively soft wood, it is able to rapidly close wound under normal conditions. However, following heavy pruning, recovery may be delayed, and the resulting structural defects could increase susceptibility to fungal colonization.

Lagerstroemia speciosa did not exhibit dominance in any specific defect category; however, it recorded the highest overall number of defects per tree, averaging 2.47 defects, with 111 defects observed among 45 defected trees, out of 75 individual trees on campus.

Lagerstroemia loudonii, a native species, showed the second-lowest rate of decay and open cavities, 1.72%, representing a single tree out of the 58 surveyed trees at CU.

Alstonia scholaris, a native species, exhibited the second-lowest proportion of dead and dying branches, 10.53%, and the third-lowest rate of epicormic shoots, 17.54%. Conversely, it ranked second-highest in its rate of wounds, cankers, bulges, and loose bark, at 31.58%. Trees of this species had a total of 48 defects recorded among 41 defected trees, out of 57 trees, or 1.17 defects per defected tree, the third-lowest such figure among the surveyed species.

Tamarindus indica, an introduced species, had the highest proportion of defected trees, with 39 out of 45 trees being defected, or 86.67%. Despite this, it ranked in the second lowest in its rate of wounds, cankers, bulges, and loose bark, at 6.67%. A total of 45 defects were recorded among 39 defected trees, out of 45 individuals, averaging 1.15 defects per defected tree.

Monoon longifolium, an introduced species, saw the second-highest rate of epicormic shoots, 50.00%, recorded among 35 defected trees out of a total of 52 individuals.

Plumeria rubra, also an introduced species, exhibited the second-lowest rate of defected trees, 47.89%, with 34 defected individuals out of 71 trees. The species also ranked lowest for dead and dying branches, at 1.41%, observed on only one individual. This low rate aligns well with this specific species and its thick, succulent trunk and branches that make dead and dying branches uncommon.

Mangifera indica, a native species, ranked among the lowest third in both decay and cavities, 1.82%, and dead or dying branches, 10.91%. Interestingly, it also had the second-lowest average number of defects per defected tree, 1.15, with 38 defects recorded among 33 defected trees, out of 55 individual surveyed trees observed at CU.

Delonix regia, an introduced species, demonstrated the third-highest rate of dead or dying branches, 45.71%, and the second-lowest rate of epicormic shoots, 14.29%. This species is characterized by its umbrella-shaped life form, making the occurrence of epicormic shoots relatively unusual.

Streblus asper, a native species, showed the second-lowest rate of wounds, cankers, bulges, and loose bark, 7.14%, as well as the second-lowest number of defects, with 28 defects among 21 trees, out of 28 trees, resulting in 1.33 defects per defected tree, which is not the lowest number surveyed. Overall, this species exhibited a comparatively low level of structural defects.

Bauhinia purpurea, an introduced species, recorded the lowest percentage of defected trees, 42.86%. It also ranked second-lowest for narrow crotches between branches and crossing crotches, 9.71%. In addition, it had the lowest number of defects, 20, among 12 defected trees out of 28 individuals.

These findings underscore the importance of conducting contextualized TSFP assessments. A single tree may exhibit multiple defects; however, existing tree risk assessment forms typically employ only the most likely defect to fail as the measurable input for determining the probability of failure. Furthermore, native species on campus exhibited significantly better health and had much fewer structural defects compared with the introduced species. Localized surveys are essential for identifying region-specific defect patterns influenced by climate, soil conditions, and maintenance practices. For tropical urban campuses such as CU, integrating international best practices with site-specific observations enables the development of adaptive tropical urban forestry strategies, more targeted maintenance interventions, and robust long-term tree risk management frameworks.

DISCUSSION

Based on assessments, the 2,883 trees surveyed on campus can be classified into three levels of tree management as follows:

1. Trees requiring immediate and critical attention

This category includes trees with major structural defects such as large dead or decayed branches, broken branches lodged in the canopy*, leaning or fallen stems, a hollow trunk**, and fungal fruiting, which increase hazard or the possibility of tree failure. Within the campus, 1,346 trees (46.69% of the dataset) were identified as requiring immediate and critical intervention.

* The risk associated with dead, decayed, or broken branches depends not only on branch size but also on the traffic intensity of site use beneath the tree, such as with pedestrian walkways or building entrances, which increases the potential consequences of failure. In some cases, dead branches may remain attached for years without immediate failure; however, precautionary issues were categorized as highly urgent and warrant immediate inspection. This aligns with the international tree risk assessment frameworks and the Tree Risk Assessment Manual (Dunster et al., 2017), which emphasized that the likelihood of failure and the occupancy rate of the target area must be considered when determining urgency management.

** The severity of trunk cavities cannot be evaluated solely by quantitative wound size; the significance depends on trunk size in relation to the wound. In many cases, cavity depth or extent could not be measured due to inaccessibility, height, or equipment limitations.

2. Tree requiring urgent attention

This category includes trees with defects such as branches overhanging or touching the building or utility lines, leaf symptoms, tree topping, abnormal wounds, borer damage, disease or pest symptoms, or girdling roots. A total of 1,024 trees (35.52%) fell into this category.

3. Trees requiring non-urgent attention

This category includes healthy trees or those with minor issues, such as small defected branches, slow-developing issues, or parasites. A total of 513 trees (17.80%) were classified in this group.

The findings indicate that tree care management within CU should be regarded as a high priority, as a substantial proportion of trees present immediate risks of failure or collapse. To mitigate potential risks to life and property, a systematic monitoring framework should be implemented, incorporating regular inspections focusing on areas of high pedestrian and building traffic. Figure 6 demonstrates where all the trees on campus are, and which approach would facilitate the development of an effective annual maintenance plan, prioritizing critical trees and essential management tasks. In less frequented areas, such as peripheral gardens and green spaces, inspection frequency may be reduced accordingly. Management of risk to and from trees constitutes the most cost-effective approach. It protects the trees and the benefits they provide to the campus, which in themselves provide further motive for continuing management integrating natural elements into built environment to enhance human well-being and biophilic design (Kaewmoracharoen et al., 2025) Furthermore, there is both a moral and legal obligation to assess and protect the safety of those who may be at risk from structural tree failure (van Haaften, 2024).

Figure 6

Completed Map of 4,255 Trees, Representing 256 Species on Campus

CONCLUSION AND SUGGESTIONS

This study highlights distinct structural and physiological patterns among tropical urban trees on the CU campus. The distribution of defected trees across 165 species revealed that species characteristics and past maintenance practices significantly influence tree structural integrity. The native and introduced tree species on campus raise questions about long-term ecological services and green infrastructure. Exotic species have been favored for aesthetic value and experiences, but often require higher maintenance while offering fewer ecological benefits. For Bangkok and other tropical cities, integrating native species into planning concept design would enhance ecosystem diversity and reduce maintenance costs over time.

From a management perspective, these results reinforce the necessity of developing detailed survey protocols tailored to regional contexts but aligned with international standards. Expanding defect recording to systematically capture failures and their associated response growth (e.g., bulging, epicormic shoots, and compensatory growth) will allow more accurate classification of TSFPs in Thailand. Standardized approaches will also facilitate future comparisons with global datasets, enabling Thai urban forestry practitioners to contribute to and benefit from the broader body of international research.

Even though the survey was conducted within a single campus, the findings reflect common structural risks found in Bangkok's urban tropical trees, particularly in areas with high pedestrian density. The frequency of tropical storms increases the likelihood of branch and stem failure, emphasizing the need for species-specific management to enhance urban resilience. This dataset provides a systematic model that can be adapted for other tropical cities in Southeast Asia, where tree failure profiles remain limited. The results highlight broader implications for Bangkok and other tropical cities, where urban adaptive green spaces exist alongside intensifying climate change.

Furthermore, the CU survey exemplifies the role of institutional landscapes as testbeds for a sustainable tropical urban forest. This example practice should apply to other institutional campuses and government properties for the maintenance and assessment of trees on their properties.

Beyond the scope of this survey, the maintenance of tree root systems is of great importance but has not yet been addressed. Future research should address this area of concern to inform long-term maintenance strategies. Such strategies should be incorporated into construction agreements to mitigate potential damage to trees, including construction activities, such soil compaction, changes in grade, and backfilling, which can directly harm the root system, or anything that can affect the trunk, roots, and surrounding soil. Construction-phase agreements are essential for ensuring healthy trees on the campus. *Albizia saman* (Figure 7) has several injuries on the trunk bark and buttress root from the landscape renovation construction site near the Faculty of Arts, CU.

Figure 7

Albizia saman Injuries From Landscape Renovation Construction Near the Faculty of Arts, 2020

Ultimately, strengthening local TSFP databases is essential for more effective and proactive urban tree risk management. By identifying high-risk species and linking observed defects with underlying biological or environmental causes, urban forestry professionals can design site-specific interventions, such as preventive pruning, soil enhancement, or targeted pathogen monitoring. Such measures not only improve public safety but also align with the broader vision of transforming Bangkok's green areas into multifunctional green infrastructure that supports both human well-being and ecological functions.

This study also offers practical insights for arborists, landscape architects, urban planners, and policymakers through the application based on Tree Species Failure Profiles (TSFP). As mentioned, the Western Tree Failure Database (WTFD), which compiles data from tree-care professionals, strengthening cross-departmental collaboration between the Thai Arboriculture Association, could enable the systematic collection and reporting of tree failure data in Thailand. This kind of initiative would provide the foundation for developing Thailand's specific TSFPs, which would integrate into broader urban tropical forest management strategies. By advancing localized knowledge in parallel with international practices, urban tree populations are better positioned to sustain long-term health and resilience. Advancing campus sustainability requires such evidence; carbon sequestration or the UI Green metric serves as a critical basis for effective solutions and guiding campus development strategies that can broaden sustainability goals (Anantsuksomsri et. al., 2024; Warianturi et.al., 2022). These critical efforts ensure that city canopies continue to deliver essential ecosystem services—including shade provision, urban cooling, biodiversity conservation, and cultural value—within rapidly urbanizing tropical environments. Nonetheless, integrating nature-based solutions into urban forestry positions trees as a cornerstone for their role in the city landscape with global sustainability agendas.

DISCLOSURES AND ACKNOWLEDGEMENTS

Surveying, Assessing, and Establishing a Database on the Tree Health in Chulalongkorn University (2019), led by Sirintra Vanno and Paron Chatakul. Grant by the Office of Physical Resources Management, Chulalongkorn University.

REFERENCES

Anantsuksomsri, S., Positlimpakul, K., Chatakul, P., Janpathompong, D., Chen, G., & Tontisirin, N. (2024). Carbon sequestration analysis of the university campuses in the Bangkok Metropolitan Region. *Journal of Infrastructure, Policy and Development, 8*(6), Article 3385. https://doi.org/10.24294/jipd.v8i6.3385

Bakken, S. R. (1995). Group-tree hazard analysis. *Arboriculture Urban Forestry (AUF), 21*(3), 150–155. https://doi.org/10.48044/jauf.1995.025

Boonkham, D. (2000). *Tonmai yai nai ngaan korsaang lae pattana muang* [Trees in construction and urban management]. Chulalongkorn University Press, Bangkok.

Chatakul, P., & Janpathompong, S. (2022). Identifying plant species and their usage for landscape on the historical mural paintings of Nan, Thailand. *Nakhara: Journal of Environmental Design and Planning*, *21*(3), Article 219. https://doi.org/10.54028/NJ202221219

Chitrabongs, C. (2022). Curartistry: Curating Everyday Artistry in Bangkok. *Nakhara: Journal of Environmental Design and Planning*, 21(1), Article 208. https://doi.org/10.54028/NJ202221208

Clark, J. R., Matheny, N. P., & Crews, V. (1993). *A handbook of hazard tree evaluation for utility arborists*. International Society of Arboriculture.

Costello, L. R. & Berry, A. M. (1991). The California tree failure report program: An overview. *Journal of Arboriculture, 17*(9), 250–256. https://doi.org/10.48044/jauf.1991.058

Costello, L. R. & Smiley, E. T. (2013). *International tree failure database - Report form* [Paper presentation]. The International Society of Arboriculture Annual International Conference.

Dunster, J. A. (1996). Hazard tree assessments: Developing a species profile for western hemlock. *Journal of Arboriculture*, *22*(1), 51–57. https://doi.org/10.48044/jauf.1996.007

Dunster, J. A., Smiley, E. T., Matheny, N.P., & Lilly, S.J. (2017). *Tree risk assessment manual* (2nd Ed.). International Society of Arboriculture.

Ellison, M.J. (2005). Quantified tree risk assessment used in the management of amenity trees. *Journal of Arboriculture, 31*(2), 57–65. https://doi.org/10.48044/jauf.2005.007

Fountain, W. M., Borden, S., & Purcell, L. (2019). *Species failure profile for trees common to the ohio river valley*. University of Kentucky, College of Agriculture, Food and Environment. https://publications.mgcafe.uky.edu/files/ID253.pdf

Kaewmoracharoen M, Aruninta A, Jongvivatsakul P, Parinyarux P (2025;), "Bridging policy and practice: understanding civil engineers' adoption of biophilic development in Thailand using the Theory of Planned Behavior and explainable AI". *Smart and Sustainable Built Environment*, Vol. 14. https://doi.org/10.1108/SASBE-03-2025-0135

Lilly, S. J., Bassett, C. G., Bassett, C., Komen, J., & Purcell, L. (2022). *Arborists' certification study guide, (4th ed.).* International Society of Arboriculture.

National Tree Safety Group. (2004). *Common sense risk management of trees: Guidance on trees and public safety in the UK for owners, managers and advisers* (2nd ed.). National Tree Safety Group.

Norris, M. (2007, May 1). Tree risk assessments - What works - What does not - Can we tell? A review of a range of existing tree risk assessment methods. *Proceedings of the ISAAC Conference Perth 2007, Perth, Australia* (pp. 1-31). Urban Natural Resources Institute. https://unri.org/ECO%20697U%20S14/norris-_tree_risk_assessments.pdf

Pokorny, J. D., O' Brien, J., Hauer, R., Johnson, G., Albers, J., Bedker, P., & Mielke, M. (2003). *Urban tree risk management - A community guide to program design and implementation*. U.S. Department of Agriculture, Forest Service. https://research.fs.usda.gov/treesearch/11070

Ristianti, N. S., Paulla Dewi, S., Susanti, R., Kurniati, R., & Syafira Zain, N. (2024). Using Biophilic Design to Enhance Resilience of Urban Parks in Semarang City, Indonesia. *Nakhara: Journal of Environmental Design and Planning*, *23*(1), Article 402. https://doi.org/10.54028/NJ202423402

Shigo, A. L. (1990). *A new tree biology: Facts, photos, and philosophies on trees and their problems and proper Care*. (2nd ed.). Shigo and Trees, Associations.

Shigo, A. L. (1989). *Branch failures: A closer look at crack drying*. Arboriculture & Urban Forestry (AUF*)*, *15*(1), 11–12. https://doi.org/10.48044/jauf.1989.003

Shigo, A. L. & Marx, H. G. (1977). *Compartmentalization of decay in trees*. Department of Agriculture, Forest Service.

Smilley, E. T., Matheny, N., & Clark, J. (2006). *International tree failure database: User manual.* International Tree Failure Database. USDA Forest Service. https://wwv.isa-arbor.com/events/conference/proceedings/2013/COSTELLO_SMILEY_ITFD_User_Manual_2006.pdf

Smilley, E. T., Matheny, N., Lily, S., Kane, B., Klein, R., & Brantley, B. (2025). *Best management practices: Tree risk assessment.* (3rd ed.). International Society of Arboriculture.

van Haaften, M., Liu, Y., Wang, Y., Zhang, Y., Gardebroek, C., Heijman, W., & Meuwissen, M. (2021) Understanding tree failure—A systematic review and meta-analysis. *PLoS ONE, 16*(2), Article e0246805. https://doi.org/10.1371/journal.pone.0246805

Vanno, S. (2011). Soil bioengineering for soil erosion protection. *Academic Journal of Architecture, Chulalongkorn University, 60*, 99–108.

Vanno, S. (2019). Bangkok's green infrastructure. *Journal of Architectural/Planning Research and Studies (JARS), 9*(2), 1–14. https://doi.org/10.56261/jars.v9i2.168541

Wurianturi, I., Sari Hasibuan, H., & Suganda, E. (2022). Optimizing open green space on urban campuses through the case of UI Salemba campus: A step towards improved green metric ranking. *Nakhara: Journal of Environmental Design and Planning, 21*(3), Article 224. https://doi.org/10.54028/NJ202221224