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Analysis of Tree Fall Hazard Risk: A Case Study at the University of Mataram Campus

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Abstract: The Mataram University campus has shade trees in almost all area units, some of which are still quite ideal and some of which show problems with tree architecture deviations, such as trunk declivity and canopy inclination, which can cause the risk of tree fall. This study was conducted to analyze the distribution of tree fall risk based on tall, trunk declivity and canopy inclination on the Mataram University campus. The sample area was taken using the purposive sampling method and then sampling trees in each sample area unit using the quarter method. Tree variables observed were tall, trunk declivity and canopy inclination. The data were processed respectively to produce tree tall, trunk declivity, and canopy inclination classes. These data were then further analysed in an integrated manner to produce a value of tree-fall hazard risk. These tree-fall hazard values were interpreted into 5 categories, namely not hazardous, somewhat hazardous, quite hazardus, hazardous, and very hazardous. The results show that of the 108 shade trees on the Mataram University campus, 38.01% of the trees were in categories requiring immediate attention or action (moderately hazardous to very hazardous). Zone 1 was the only zone with the highest risk (0.93% very hazardous).

Keywords: Declivity; Hazard; Inclination; Treefall

Introduction

The presence of trees in a public area can not only increase the aesthetic and property value, but can also increase the ecological value of the environment. However, if the structure and distribution of the trees are not ideal, then the presence of the trees can cause the risk of the trees-fall hazard and reduce the level of comfort (Hadinoto & Suhesti, 2018; Mashar, 2021; Hendarso et al., 2022; Tochaiwata et al., 2023; Mulyana, 2025). The Mataram University campus has shade trees in almost all area units. Some trees are in a fairly ideal condition, but others show problems with their architectural deviations, such as sharp trunk declivity and unbalanced canopy tilt (Suripto et al., 2019; Suripto & Aksari, 2020; Suripto et al., 2024).

Tree architectural deviation variables, such as trunk tilt and canopy inclination, can each be used to determine the risk of tree fall hazard (Sulistyantara, 2014; Rejoni, 2017; Hidayat et al., 2018; Kurniawan et al., 2020). Tree fall risk assessments will be more reliable if processed using data from both factors in an integrated manner (Saroh & Krisdianto, 2020; Simanjuntak et al., 2022; Monalisa et al., 2022; Li et al., 2022; Rahmawati et al., 2022). There are even other variables such as tree tall that must be taken into account to make the assessment results more valid (Susanti et al., 2025; Ningrum, 2020; Nurchayati & Ardiyansyah, 2021).

Evidence of less reliable hazard risk assessment results can be shown by the treefall incident, even though the tree had previously been assessed based on trunk declivity and canopy inclination, as having a very

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low risk. The tree in this case has also been assessed for health and is known to be at no risk of falling based on the level of tree wound closure (no rot or decay on the roots, trunk and main branches) (Shiels et al., 2015; Suripto et al., 2019; Suripto et al., 2024). Thus, tree hazard risk assessment needs to be carried out by observing the tree architecture deviation variables, in this case the height, trunk declivity and canopy inclination of the tree which synergistically cause the risk of falling hazard, and the data needs to be analyzed in an integrated manner. The interaction of the influence of internal factors of tree architecture on the risk of falling needs to be understood first before studying the interaction of influence with other internal factors, such as the tree health factors mentioned above, and even more comprehensive interactions with external factors such as wind speed and direction, and land factors.

Based on the background of the problem above, this research was conducted with the aim of determining the distribution of treefall risk based on their architectural deviation variable on the Mataram University campus.

Method

In general, the work flow chart for the research on the distribution of tree fall hazard risks on the Mataram University Campus can be seen in Figure 1.

Determining the sample area using purposive sampling

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Tree sampling in each sample area unit using the quarter method

↓

Measurements of tall, trunk declivity and canopy inclination variables of trees

↓

Data analysis

Figure 1. Work flow chart of tree fall hazard risk study on the Mataram University Campus

Determination of Area and Tree Samples

The sample area was determined using a purposive sampling method modified from Widodo & Widayanti (2022), Suripto et al. (2024), and Widyanti et al. (2025), namely selecting area units based on the similarity in the size of the public population and the type of activity as well as the presence of tree vegetation. In this case, 9 sample area units or zones were determined within the Mataram University Campus. The nine observation zones were 1. Faculty of Teacher Training and Education, 2. Faculty of Animal Husbandry, 3. Faculty of Agriculture, 4. Faculty of Mathematics and Natural Sciences, 5. Faculty of Engineering, 6. Faculty of Law, 7. Faculty of Economics and Business, 8. Faculty of Food Technology, 9. Faculty of Medicine (Figure 2).

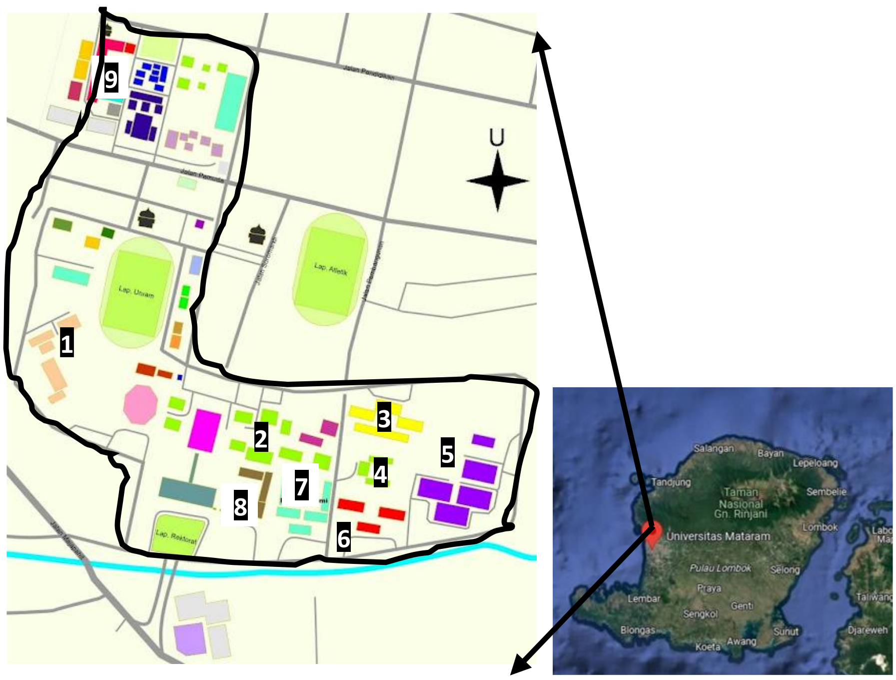


Figure 2. Distribution of sample area units for tree observations on the Mataram University Campus

Sample trees in each zone were selected using the quarter method modified from Putri et al. (2021) and Karyaningsih et al. (2024). In each zone, three quarter points were randomly selected to select one individual tree in each quadrant of each quarter, namely the tree closest to the quarter point (Figure 3).

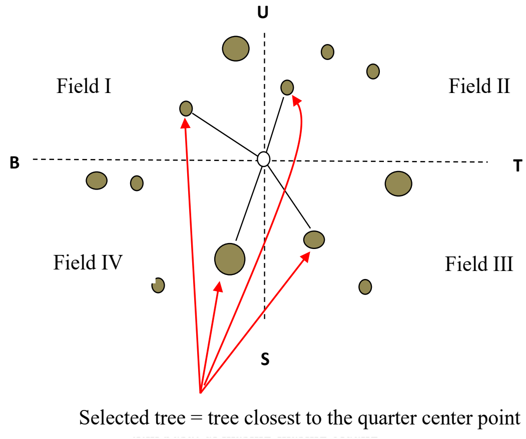
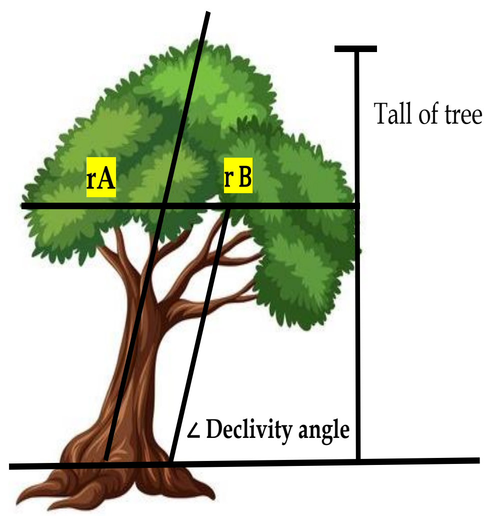


Figure 3. Scheme for determining tree samples using the quarter method

Procedure for Measuring Tree Architecture Variables

The tree architecture variables observed were tree tall, tree trunk declivity, and tree canopy inclination. Tree tall was measured in meters using a meter stick. The slope of the tree trunk (declivity) was measured in angular degrees (°) using an arc ruler, with techniques adapted from Muşat (2015), Pakaya et al. (2024), Suripto et al. (2024), and Peterson (2025) (Figure 4).



rA = shorter radius; rB = longer radius

Figure 4. Scheme for measuring tall, stem declivity angle, and canopy inclination of tree

Data Analysis

Tree tall (T) data from all zones were classified quarterly into 5 classes with criteria adjusted from Suripto et al. (2024) (Table 1).

Table 1. Classification of tree tall values (T)

Tree tall range	Tree tall value
T = Minimum data	0
T = Data range in Q1	1
T = Data range in Q2	2
T = Data range in Q3	3
T = Maximum data	4

Tree tilt angle data in degrees angle (o) is converted into 5 value classes with criteria adjusted from Canonne et al. (2025) (Table 2).

Table 2. Classification of tree declivity values

Declivity angle	Declivity value
$x < 6^{O}$	0
$6^{O} \leq x < 12^{O}$	1
$12^{O} \leq x < 24^{O}$	2
$24^{O} \leq x < 30^{O}$	3
$x \geq 30^{O}$	4

Tree canopy inclination is determined by calculating the ratio (%) of the length of the two opposing spokes at the thickest diameter position of the tree canopy (%) by using a formula adapted from Huang (2025) as follows (Equation 1):

$$IR = \left(1 - \frac{rA}{rB}\right) \times 100 \quad (1)$$

Description:
RI = Inclination ratio
rA = length of the shorter radius (cm)
rB = length of the longer radius (cm)

The tree canopy inclination ratio (IR) was converted into 5 classes of crown slope (I) with criteria adjusted from Huang (2025) (Table 3).

Table 3. Classification of tree canopy inclination levels

Inclination ratio	Inclination value (I)
IR < 10	0
10 ≤ IR < 20	1
20 ≤ IR < 30	2
30 ≤ IR < 40	3
40 ≤ IR	4

Data on trunk declivity (D), canopy inclination (I), and tree tall (T) for each tree sample were analyzed in an integrated manner to determine the hazard risk of tree fall (H) using the formula adapted from Ningrum (2020), Hendarso et al. (2022), Rahmawati et al. (2022), and Suripto et al. (2024) as follows (Equation 2):

$$H = \frac{3}{8}\left[(D + 1) + \sqrt{(D - !)^2}\right] + \frac{1}{4}T \quad (2)$$

Description:
H = Tree fall hazard risk value

D = Declivity of tree trunk value
I = Inclination of tree canopy value
T = Tree tall value

The tree fall hazard risk value can be classified into 5 hazard categories (Customized from Suripto et al. (2024); with criteria adjusted from Suripto et al. (2024), Canonne et al. (2025), and Huang (2025) (Table 4).

Table 4. Risk categories of tree fall hazard (H)

Tree fall hazard risk value (H)	Hazard category
$H < 1$	Not hazardous
$1 \leq H < 2$	It's a bit hazardous
$2 \leq H < 3$	It's quite hazardous
$3 \leq H < 4$	Hazardous
$H \geq 4$	Very hazardous

Result and Discussion

A total of 108 sample trees spread across 9 (nine) observation zones on the University of Mataram campus were observed and identified into 33 tree species. Of all the trees observed, the majority (51.85%) had a fall risk score of 1, or slightly hazardous category. Then followed by a smaller number of trees in succession by 32.41% of the quite hazardous, 10,19% non-hazardous, 4.63% hazardous, and 0.93% very hazardous (Table 5).

The results above show that 38.01% (32.41% + 4.63% + 0.93%) of trees were in the category that requires attention or immediate action (quite to very hazardous). Zone 1, which was the only zone that had trees (0.93%) with the highest risk of falling (very hazardous) really needs special attention or immediate action. Immediate action is needed especially to address canopy imbalance, as most trees are at risk of moderate to very dangerous falls due to canopy imbalance.

However, the distribution of treefall risk varies in different zones. The distribution of trees with treefall risk from non-hazardous to very hazardous in each zone on the Mataram University campus can be seen in Figure 5. The results above show that trees with quite hazard risk can be found in all zones in varying numbers and trees with hazardous risk were in several zones (2, 4, 8 and 9), and there was 1 tree with very hazardous risk in Zone 1.

Table 5. Distribution of tree fall hazard values of 108 trees (33 species) observed in 9 zones on the Mataram University campus

Local name and species of tree	Zones								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Akasia (*Acacia auriculiformis*)			0		1				
Angsana (*Pterocarpus indicus*)	4			3	2				
Asam (*Tamarindus indica*)		0			1		1		
Baujan (*Albizia saman*)	2; 2	1	1	2	1	2	2	2	1; 2; 3
Beringin (*Ficus benyamina*)							0	1	
Bohinia (*Bauhinia purpurea*)						1			2
Bungur (*Lagerstroemia speciosa*)		3							2
Cemara (*Araucaria heteropylla*)		2	1						
Dadap merah (*Erythrina variegata*)								2	2
Flamboyan (*Delonix regia*)							1	1; 1	
Glodogan (*Polyalthia longifolia*)		2							
Jati (*Tectona grandis*)	1	1		1; 2	1	2	1		
Johar (*Cassia siamea*)*			1						
Johar Pink (*Cassia grandis*)			1						
Kenari (*Canarium commune*)		1	1						
Ketapang (*Terminalia catappa*)	2		2		1				1;2
Ketapang Kencana (*T. mantaly*)	1	2							
Kikencrut (*Spathodea campanulata*)	2			1	0				
Mahoni (*Swietenia mahogani*)	1			1	1	2	1	1; 2	1
Mangga (*Mangifera indica*)					2		2		
Mengkudu (*Morinda citrifolia*)								2; 2	
Nyamplung (*Calophyllum inophyllum*)	2	0	0						
Pohon ara (*Ficus carica* L.)			0						
Pohon eboni (*Diospyros* sp.)		1							
Salam (*Syzygium polyanthum*)			1						
Pulai (*Alstonia scholaris*)				3					2
Saga (*Adenanthera pavonina*)	1	0		0	1	1; 1			
Sawo kecik (*Manilkara kauki*)	2		1			1			
Sengon (*Albizzia chinensis*)				1		1	1	1	
Tanjung (*Mimusops elengi*)	2		1	2	1	2	1	3	1; 1

Local name and species of tree	Zones (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Trengguli (*Cassia fistula*)		1		1		1	1		
Waringin (*Ficus rumphii*)					1	1	0		
Waru (*Hibiscus tiliaceus*)				0		2	1	1	
Number of trees observed: 108	12	12	12	12	12	12	12	12	12

Information: Values and categories of tree fall hazard risk: 0 = not hazardous; 1 = a bit hazardous; 2 = quite hazardous; 3 = hazardous; 4 = very hazardous

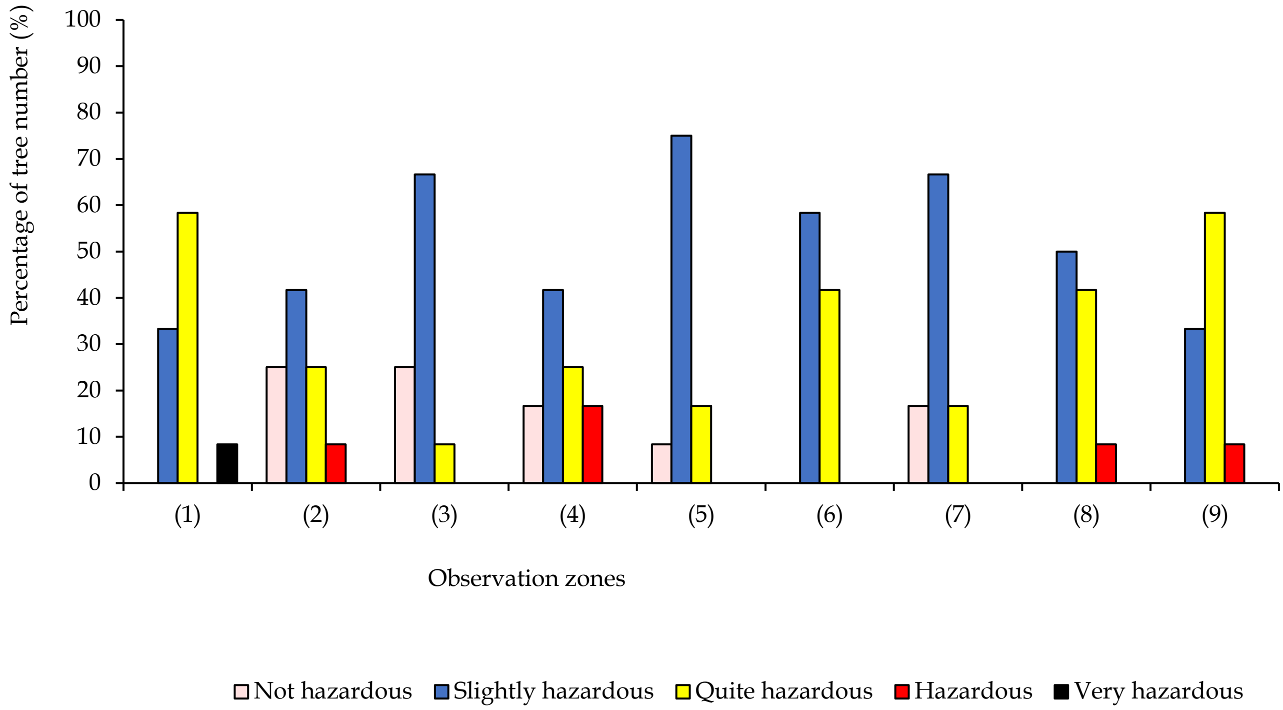


Figure 5. Distribution of trees with treefall risk hazard in each zone on the Mataram University campus (Description of zone numbers can be seen in Figure 2)

Partially, taller trees are at greater risk of falling due to greater wind-induced torque. Trees with leaning trunks are at greater risk of falling due to unstable balance. Trees with unbalanced crowns are also at greater risk of falling due to uneven load distribution. The above-mentioned fall risk values will be even greater if these three variables interact (Joye, 2019; Ningrum, 2020; Nurchayati & Ardiyansyah, 2021).

Integrated analysis of tree architecture deviation data can facilitate management in taking anticipatory action. For trees with a quite or greater risk of treefall, with a canopy imbalance value higher than its declivity hazard value, treatment is prioritized to restore canopy balance with professional pruning, and this is monitored semiannually. However, if the risk value of the trunk's decitivity is greater, then stabilizing the canopy is not enough, even for old trees that have a hazardous to very hazardous treefall risk, it is better to cut them down (Hanum et al., 2023; Kogut et al., 2024; (Weissenborn & Tomesh, 2025).

Visualization of the contribution of the influence of trunk declivity alone or canopy inclination alone or the influence of both in an integrated manner in producing the risk value of tree fall hazard, can be seen in Figure 6.

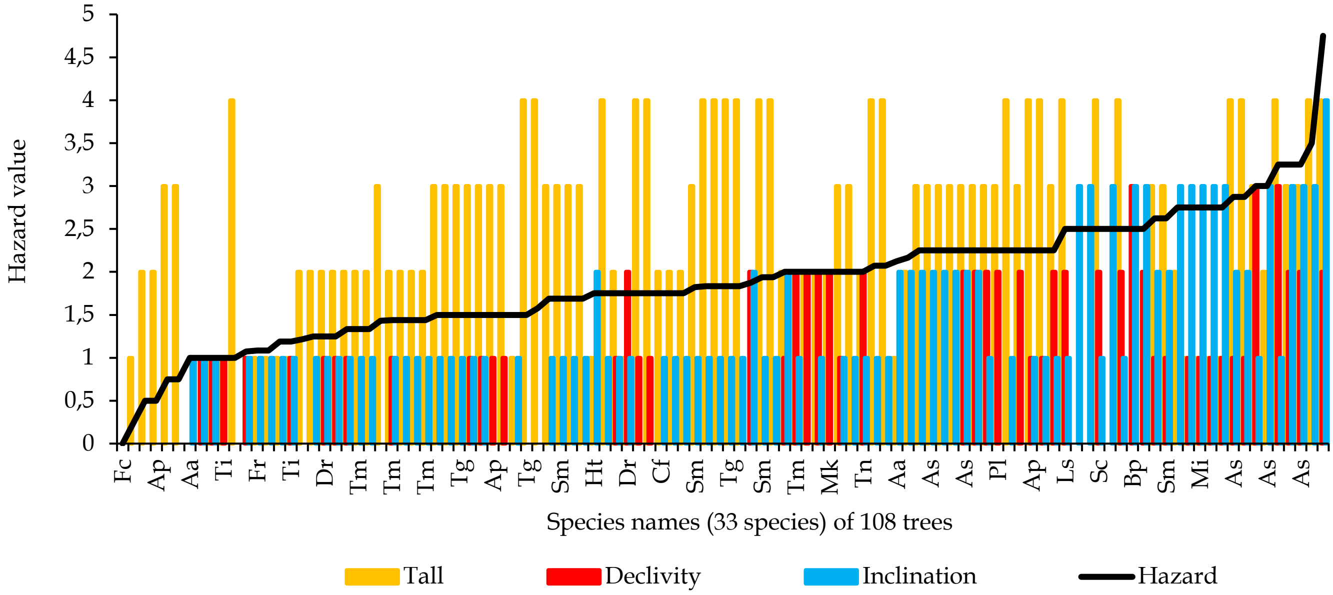


Figure 6. Visualization of the comparison of the values of tree tall, trunk declivity, canopy inclination and risk of tree fall hazard (108 trees) on the Mataram University campus

The causes of tree crowns growing unbalanced can be caused by several factors, including uneven light, strong winds, damage to branches or twigs, unbalanced roots, environmental influences, improper pruning and genetic factors. Trees can grow more towards the light source, causing the tree canopy to become unbalanced. Strong winds can cause tree branches to grow more in the opposite direction to the wind. Damage to the branches or trunk of a tree can cause the tree crown to grow unbalanced. Unbalanced tree roots can cause the tree to grow unbalanced. The influence of the surrounding environment, such as buildings or other trees, can cause the tree canopy to grow unbalanced. Improper pruning can cause the tree canopy to grow unbalanced. Some tree species have a natural tendency to grow with uneven crowns. These factors can interact with each other and with the surrounding environment to cause tree canopies to grow unbalanced (Seidel et al., 2019a, 2019b; Rosalina, 2019; Reich et al., 2021; Nurchayati & Ardiyansyah, 2021; Drénou, 2025; Morrison, 2025).

Several trees have very low to low treefall risk values (1 to 2), even though they have quite risk values (3) based on trunk declivity and canopy inclination, partially. This is because these trees have heights that fall into the very low to low category (0 to 1). Trees in this condition, especially young ones, require attention, as their height growth will ultimately increase their treefall risk. The use of tree architecture deviation variables in an integrated manner is more valid and reliable than using them partially to produce tree fall risk values, although it must be acknowledged that in fact the deviation in tree architecture is not the only factor that determines the risk of a tree falling. The habitus of several sample trees with a risk of falling category can be seen in Figure 7.

The figure showed a tree with a non-hazardous trunk declivity and a fairly hazardous canopy inclination resulting in a quite hazardous risk of falling (A), while trees with somewhat hazardous trunk declivity and canopy inclination are both somewhat hazardous, resulting in a quite hazardous risk (B).

There are other factors that are also very significant in determining the risk, such as wind, gravity, light, unbalanced roots, unstable soil, damage from pests or disease and genetic factors. Strong winds can cause a tree to lean in one direction, especially if the tree has shallow roots or a weak trunk structure. Trees growing on slopes or sloping ground can lean downwards due to the force of gravity. Trees can lean towards a light source, such as the sun, to get more light for photosynthesis. Unbalanced or damaged tree roots can cause the tree to lean in one direction. Unstable ground or landslides can cause trees to lean or even fall. Damage to the tree trunk or roots due to pests or disease can cause the tree to lean. Some tree species have a natural tendency to grow with a slanted or leaning trunk. These factors can interact with each other and with the surrounding environment to cause or produce a degree of tree trunk tilt (Pretzscha et al., 2015; Dorji, 2020; Suripto & Ahyadi, 2022; Putra et al., 2023; Qin et al., 2023; Hera, 2025; Williams, 2025).

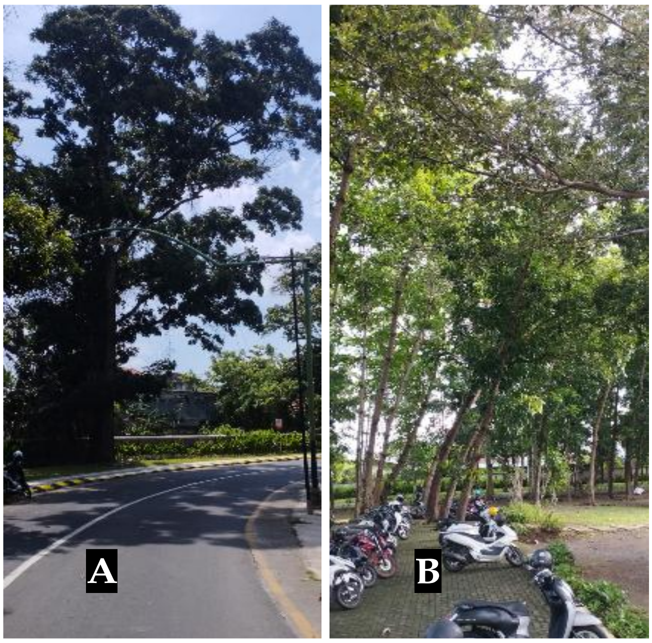


Figure 7. Sample trees with a quite hazardous risk

The problem of architectural deviations in trees in public areas that are at risk of falling can actually be prevented early on through good green open space planning and its proper implementation. If the public area is a campus, then it requires appropriate policies from the leaders of the relevant agencies, in addition to that, it requires expert implementing personnel and awareness from all parties such as students, lecturers, and employees in the campus environment to play an active role in maintaining the health of trees in particular and maintaining the health of the environment in general (Fetiana et al., 2022; Febria et al., 2023; Putri et al., 2025).

To increase the awareness and participation of the community, especially students, in maintaining the beauty of the environment due to the presence of shade trees, this can be done by holding regular seminars or training with adapted methods. Efforts to include material about an issue, for example environmental issues, in the curriculum have often been proven to increase public awareness and role in preserving the environment (Eliyawati et al., 2023; Islami et al., 2023; Ratnasari et al., 2024). In this case, including material about the dangers of tree architectural deviations and other factors into the teaching materials of certain courses, for example Ecology, will increase students' awareness and participation, in maintaining the natural beauty of the trees on the campus.

Conclusion

Of the 108 shade trees on the Mataram University campus, 38.01% of trees were in categories requiring immediate attention or action (moderately hazardous to very hazardous). Zone 1 was the only zone with the highest risk (0.93% very hazardous).

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Author Contributions

Conceptualization, writing—original draft preparation, S.; methodology, S. and S.S.; software, data curation, S. and F.A.G.; formal analysis, S., R.N.R. and L.M.A.D.; investigation, S., S.S., R.N.R., L.M.A.D., and F.A.G.; writing—review and editing, F.A.G.; visualization, L.M.A.D.; supervision, S.S.; project administration, funding acquisition, R.N.R. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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