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Full Length Research Article

Tree Health Monitoring of Risky Trees in the Hotel Open Space: A Case Study in Rancamaya, Bogor

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ABSTRACT

Tree health monitoring of risky trees is necessary, especially in areas with a high level of accessibility, such as in hotels and tourist areas. The increased accessibility of hotel visitors and the green space require increased awareness of the risk of falling trees. This research aimed to estimate the amount of internal decay and damage of living trees, with special attention to the large tree in the open space of R Hotel Rancamaya. Tree health monitoring was carried out using two approaches, namely visual observation Sonic Tomography method. The visual parameters were observed following the standard method of the International Society of Arboriculture. A total of 8 trees consists of four types of plants such as *Melia azedarach*, *Durio zibethinus*, *Falcataria falcata*, and *Ficus subcordata* were evaluated. The eight trees visually showed no significant damage to their organs. The results of internal trunk inspection by PiCUS-3 Sonic Tomograph also showed a similar result with decay or weathering ranges ranging from 1-3% in healthy trees, except for the stem base of tree 7 (*M. azedarach*) with weathering of 18%. Handling that needs to be done on six trees at the green area hotel is through light pruning and installing warning signs so that visitors and staff are careful in the tree area. Substantial pruning is recommended specifically for tree 7 because there is significant weathering, and it could be dangerous if the tree is not appropriately handled. The assessment showed that mitigation, warning signs, and physical handling are essential to prevent any unpredicted fallen trees, especially for tree 3 (*D. zibethinus*) and tree 7 (*M. azedarach*).

1. Introduction

The risk of trees can vary from low to high damage effect. The definition of risk is the damage that will be occurred (Smiley et al. 2017). Trees that are damaged if they break or fall will be at risk of causing material and immaterial losses (Van Haaften et al. 2016). Tree health problems can be caused by disease, lightning strikes, pests, fungus attacks, and the wind blows (Fontes et al. 2018; Stone and Mohammed 2017). Generally, dangerous trees can be identified by defects or characteristic features of trees prone to fall. The tree can lose its branches where there is no physical damage, and human injury is called a low-risk tree (Hanum et al. 2020; Lazim and Misni

2016). In contrast, a high-risk tree is located in areas with rapid human activity and valuable assets (Smiley et al. 2017; Watson et al. 2018). A fallen or collapsed tree generally begins with the appearance of symptoms of health problems in the tree (Tattar 2012). A risky tree showed a damaged structure that can cause a tree to fall (Hanum et al. 2020). Several preventive activities are needed against such incidents. Inspection and monitoring of tree health are an approach that follows silvicultural principles to maintain tree health, particularly by carrying out the stages of controlling, facilitating, protecting, and saving (Nyland 2016; Puettmann et al. 2012).

Various tree health and risk assessment methods have been developed to guide professionals through the tree inspection process (Koeser et al. 2013). One commonly used standard method was International Society Arboriculture (ISA). Tree Risk Assessment Best Management Practice (BMP) Method (Dunster et al. 2013; Smiley et al. 2011). The BMP is a systematic tree risk assessment based on several decision matrices and described a notable variation from the approach (Koeser et al. 2016). Another method has been developed to detect infection and decay of the internal structure of tree trunk using sonic tomography (Durlak et al. 2017). They explained that it could analyze the result of the tree measurement by the picture's color from the resulting tomogram (map density of wood) that showed by the PiCUS-3 instrument. Furthermore, different colors represent the different speeds of sound inside the trunk, depending on the elasticity and density of the wood (Durlak et al. 2017; Feng et al. 2014).

Today, the potential of green space improving some environmental degradation directs the public attention, particularly in urban areas (Newman and Jennings 2008; Register 2006). Urban residents benefit from a range of environmental services of greenspace, including air quality improvement, storm-water flooding prevention, energy and wildlife conservation, and noise and carbon pollution mitigation (Burden 2006; Low et al. 2005; McPherson et al. 2011). The definition of green space in urban areas refers to various open spaces that urban residents can utilize for many activities, such as parks, sporting fields, plazas, community gardens, bikeways, bushland, any green area that links those areas or elements (Byrne et al. 2010). Green spaces also encompass communal space around the apartment building, street trees, cemeteries, street verges and medians, school grounds, parking lots, open areas in restaurants or shopping malls, botanic gardens, golf courses, and greenways (Byrne et al. 2010; Vesely 2007; Young 2010). Today, many hotels integrate various facilities to improve the hospitality services such as restaurants, sports and shopping areas, parks, gardens, utility easements, and any green open spaces.

Trees are essential elements within publicly accessible green spaces, including individual trees and those occurring in stands, patches, and groups (Roy et al. 2012). However, the presence of urban trees has ecosystem disservices when they cause problems for the environment, economy, health, and visualization or negatively affect human well-being. Like other publicly accessible green spaces, the hotel's green space is susceptible to a hazard tree that is likely to property damage and people injury. The tree risk in the green hotel spaces can be associated with storm damage, diseases, local climate, growth patterns, and damage by people. The trees planted in the green area of hotels are mostly urban trees uniform in shape and character, fast-growing, less maintaining, shading potential, and having aesthetic benefits. However, the risk of each tree can be different depending on the growing location. The open public area around the hotel building is the most susceptible to the hazard trees due to the intensity of guests, staff, and public activities. Therefore, reducing the risk of hazard trees in green areas requires a regular tree health and risk assessment (Coder 2013).

A reputable hotel in Rancamaya, South Bogor, has an integrated parking lot, restaurant, swimming pool, gardens, and educational area accessible for guests and visitors. The mature trees growing in the green space or near buildings are susceptible to decay, windthrow and breakage. The fact that a mindi tree (*Melia azedarach*) in the green spaces fell during heavy rains confirms the urgency. Former observations showed that the lower trunk of the fallen mindi tree had holes caused by fungal and termite activity. The high accessibility of hotel visitors to the area requires high vigilance against the risk of fallen branches or fallen trees. It is essential to be observed further since the hotel area is known to have high rainfall and is often passed by sudden strong winds. The hotel management had concerned about the existence of 8 trees that are thought to be prone to falling. Visitor and public safety are the priority and must be maintained, including in the hotel's green area. Therefore, it is necessary to check and monitor the health of trees around the hotel so that the risk factors of falling trees can be determined. This study aimed to assess the health condition of those eight trees through visual observations using visual observation by the International Society of Arboriculture (ISA) form (Dunster et al. 2013) and decay determination using the sonic tomography method. Those assessments and recommendations would be valuable for management to carry out the appropriate policy for the trees.

2. Materials and Methods

The tree risk assessment and health monitoring at R Hotel Rancamaya was conducted in September 2020. The assessment was performed by visual observation on eight locations (**Fig. 1**) and the sonic tomography method using PiCUS-3 Sonic Tomograph. The eight locations were chosen because they are located in the public area of R Hotel Rancamaya (**Fig. 1**). Tree 1 (*M. azedarach*) and tree 2 (*M. azedarach*) were located in the main entrance, and tree 3 (*Durio zibethinus*) was located near the parking lot. Tree 4 (*Falcataria falcata*) was located near the meeting room and restaurant. Tree 5 (*M. azedarach*), tree 6 (*M. azedarach*), tree 7 (*M. azedarach*), and tree 8 (*Ficus subcordata*) were located near the visitor room.

Fig. 1. Location of tree risk assessment in R Hotel Rancamaya, Bogor.

2.1. Visual Observation by the International Society of Arboriculture (ISA) Form

The visual observation follows the Tree Risk Assessment form based on the International Society of Arboriculture (ISA) (Dunster et al. 2013). The method principle assesses the possible consequences of each event to determine the risk level to be estimated or compared with the observed qualitative criteria. The forms have numerous purposes, i.e., pulling out and summarizing critical ideas within each assessment methodology and guiding the user through a systematic assessment of root, trunk, and crown conditions. Ensure the collection of standardized data, and provide a written record of the evaluation and any prescribed risk abatement measure (Koeser et al. 2016). The assessment is carried out in the following sections.

2.1.1. Tree determination

The determination was carried out in open areas that have potential risks of targets. Eight trees with high-risk potential were evaluated, consisting of *M. azedarach* (5 individual), *F. falcata* (1 individual), *D. zibethinus* (1 individual), and *F. subcordata* (1 individual) (**Table 1**).

Table 1. The information of eight observed risky trees

Tree No.	Species	Family	Local Name	Coordinate	DBH (m)	Tree height (m)	CD (m)
1	*Melia azedarach*	Meliaceae	Mindi	-6.659423, 106.823347	2.20	12	5
2	*Melia azedarach*	Meliaceae	Mindi	-6.659522, 106.823308	1.80	10	7
3	*Durio zibethinus*	Malvaceae	Durian	-6.658498, 106.824443	2.30	12	6
4	*Falcataria falcata*	Fabaceae	Sengon	-6.658561, 106.823677	2.88	11	9
5	*Melia azedarach*	Meliaceae	Mindi	-6.658285, 106.823268	2.05	12	5
6	*Melia azedarach*	Meliaceae	Mindi	-6.658258, 106.823194	1.74	12	5
7	*Melia azedarach*	Meliaceae	Mindi	-6.658237, 106.823139	2.00	11	6
8	*Ficus subcordata* Blume	Moraceae	Beringin	-6.658145, 106.822618	3.50	10	12

Notes: DBH = diameter at breast height, CD = crown diameter.

2.1.2. Data collection

Primary data collection includes target assessment, growing site factors, health conditions and tree species, tree load factors, defects, tree conditions that damage the crown location, the trunk and roots, risk categorization, and identification and assessment of targets. Targets can be people, property, or activities that can be damaged or disturbed due to tree failure. Targets were also categorized based on distance (target zone) from the tree section.

2.1.3. ISA data analysis

Data analysis was carried out by making a matrix of possible damage and impact on the target following the ISA (Dunster et al. 2013) (**Fig. 2**).

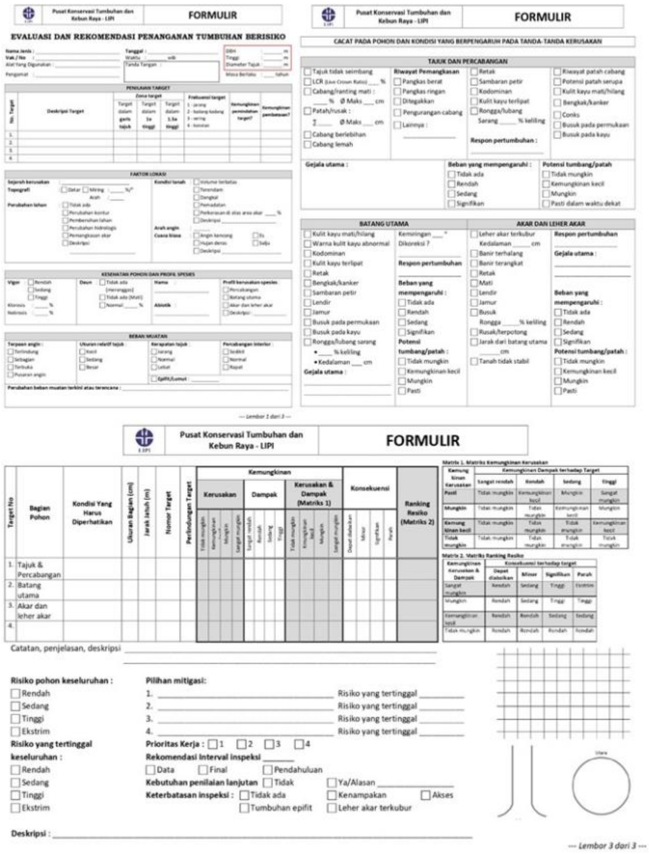


Fig. 2. The ISA basic tree assessment form and the possible damage and impact matrix on the target.

2.2. The Decay Quantification by PiCUS-3 *Sonic Tomograph*

A PiCUS-3 Sonic Tomograph was provided by Argus Electronics GmbH, Rostock, Germany. Tomograph measurements were taken on 3-4 cross-sections from 8 risky trees evaluated after the visual observation. 12-18 sensor pins were equally spaced around the trunk and driven into the sapwood on a horizontal level according to the manufacturer's instructions. A magnetically attached sensor to each nail and tapped three times with a steel hammer. A tomogram was created for each cross-section. A tomogram will show color degradation, indicating the trees' solidity and weathering (**Fig. 3**). Area of decay and wood solidity was calculated as a percentage of squares identified as decayed divided by the total area of wood. For the tomograms, the size of decay was calculated by the PiCUS-3 software (Gilbert et al. 2016).

3. Results and Discussion

3.1. Visual Observation

There are eight trees observed and checked in the garden of R Hotel Rancamaya consisting of 4 species, namely *M. azedarach*, *D. zibethinus*, *F. falcata*, and *F. subcordata*. The tree condition varies from the healthy, healthy with notes, and high-risk tree (**Table 2**).

Fig. 3. PiCUS-3 Sonic Tomograph setup showing sensors and modules, and a description of color degradation from tomogram.

Table 2. Visual condition of eight risky trees

Tree No.	Species	Tree Condition	Epiphyte	Status
1	*Melia azedarach* (Meliaceae)	Tilted 80°, scar on the root collar	*Asplenium* sp.	Healthy tree
2	*Melia azedarach* (Meliaceae)	Tilted 70-75°, unbalanced crown	*Ficus* sp., *Dendrobium crumenatum*, *Pyrrosia piloselloides*	Healthy tree
3	*Durio zibethinus* (Malvaceae)	dried/ died half of the crown, a lightning strike damage, traces of termite nests at the base of the trunk, peeling and cracking bark	*Ficus* sp., *D. crumenatum*, *P. piloselloides*	Healthy tree with notes
4	*Falcataria falcata* (Fabaceae)	dried branches and withered leaves. Damp and a fungal infection on root collar	*D. crumenatum*, *P. piloselloides*, lichens, bryophyte	Healthy tree
5	*Melia azedarach* (Meliaceae)	dead branches	-	Healthy tree
6	*Melia azedarach* (Meliaceae)	dead branches	*D. crumenatum*, *P. piloselloides*,	Healthy tree
7	*Melia azedarach* (Meliaceae)	cracking and peeling bark, *Macrotermes* termites, and fungi on root collar	lichens	High-risk tree
8	*Ficus subcordata* (Moraceae)	Former *Ganoderma* in the aerial root, ribs, or a natural indentation in the trunk	*Ficus* sp.	Healthy tree

3.1.1. Melia azedarach (tree 1)

The visual observation results show that the condition of the trunk is slightly tilted towards the parking area (around 80^o) but is still within reasonable limits. The tree crown and branching condition were still reasonably good, the crown density was average and balanced in all directions, and there was no damage to the tree crown (**Fig. 4a**; **4c**). At the base of the trunk, there is a scar/pruning process that is in the process of closing the wound, but there are no signs of further damage and rot in the scar (**Fig. 4b**). In the trunk, epiphytic plants from the ferns, *Asplenium* sp., which does not damage the host, but in the long term, can increase the moisture and substrate deposition around the roots can invite disease rot the bark (**Fig. 4c**).

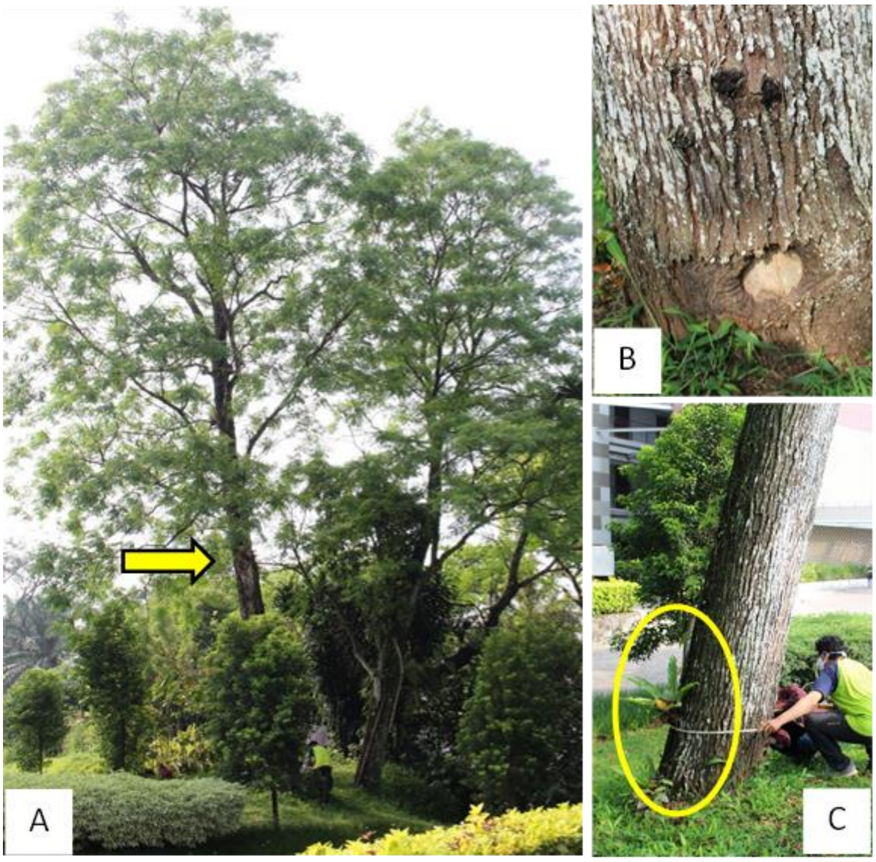


Fig. 4. Tree 1 (*M. azedarach*). A. In whole natural appearance; B. Damage to the lower trunk has scars that are in the process of closing; C. The condition of the trunk with a slope of 80° and the presence of epiphytes in the trunk.

3.1.2. Melia azedarach (tree 2)

The visual observation results show that the trunk is tilted (about 70-75°) towards the parking and lower pedestrian areas (**Fig. 5a**). The topography of the tree-growing site is also a cliff with a 45° slope. The condition of the tree crown and branching is still reasonably good. The crown density is average, and there is no damage to the tree crown, but branches or large tree branches point towards the slope (**Fig. 5a**; **5c**). This large branch is the main burden on the tree, which is thought to cause the tree's pitch. On the trunk and main branches, there are two strangler or strangler plants (*Ficus* sp.) (**Fig. 5b**) and several epiphytic plants of pigeon orchid (*Dendrobium crumenatum*), *Pyrrosia piloselloides*, and other types of ferns. Strangler plants that have stabilized and whose roots reach the ground will grow larger and choke the host plant to death slowly, and a strangler plant crown will replace the crown. Epiphytic plants, especially dragon scales ferns, accelerate weathering of the bark (**Fig. 5c**).

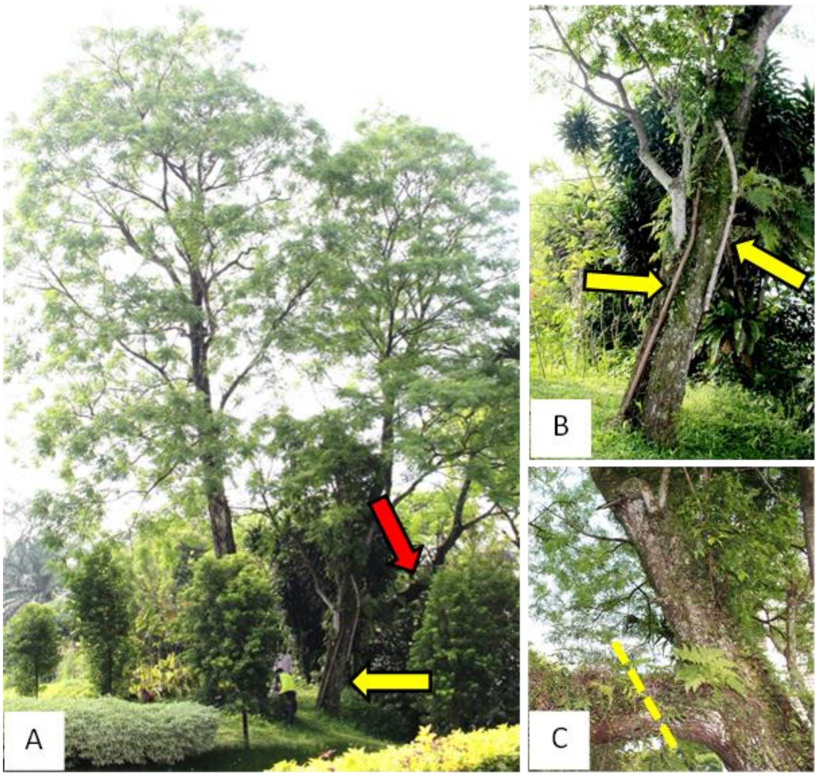


Fig. 5. Tree 2 (*M. azedarach*). A. In whole natural appearance, the trunk tilts to the south or cliff area (yellow arrow) with large branches towards the cliff (red arrow); B. Presence of two strangler plants C. Presence of epiphytic plants on the trunk and large branches, as well as the pruning area (yellow dashed line).

3.1.3. Durio zibethinus (tree 3)

The Durian tree, located in the center of the playground area of R Hotel Rancamaya, has a crown diameter of 6 m and height of up to 12 m. The leaves on the crown are 50% tone, with any visible damage in the broken branches. Epiphytes like *Ficus* sp., parasites, and *D. crumenatum* orchids in the crown. The visual inspection results show that the primary trunk condition is still quite good even though it has been struck by lightning. The crown shows the presence of some dry and dead branches. On the tree trunk, there are Ficus roots (**Fig. 6c**, yellow arrows), and there is damage peeling bark so that some of the trunks are torn and dry, concave indentations (**Fig. 6c**). On the other hand, parts of the bark are also cracked and loose to not stick to the inner wood (**Fig. 6d**). In addition, at the base of the trunk and root neck, a nested path for the termite *Macrotermes* sp. attacks dead tissue/bark.

3.1.4. Falcataria falcata (tree 4)

Sengon tree, which is located on the edge of the playground area of R Hotel Rancamaya, has a height of up to 11 m with a crown diameter of 9 m. The leaves on the crown look withered. On the main branch, there are epiphytic *P. piloselloides*, mosses, lichens, and *D. crumenatum*. The visual observation results showed that the condition of the trunk was quite strong, although the crown showed some dry branches and withered leaves. On the trunk of the main branching tree, there are many *P. piloselloides* spikes. On the side of the root neck, it was found that it was pretty damp and fungal infection started to appear caused by the covering of the root neck by the thick grass (**Fig. 7c**).

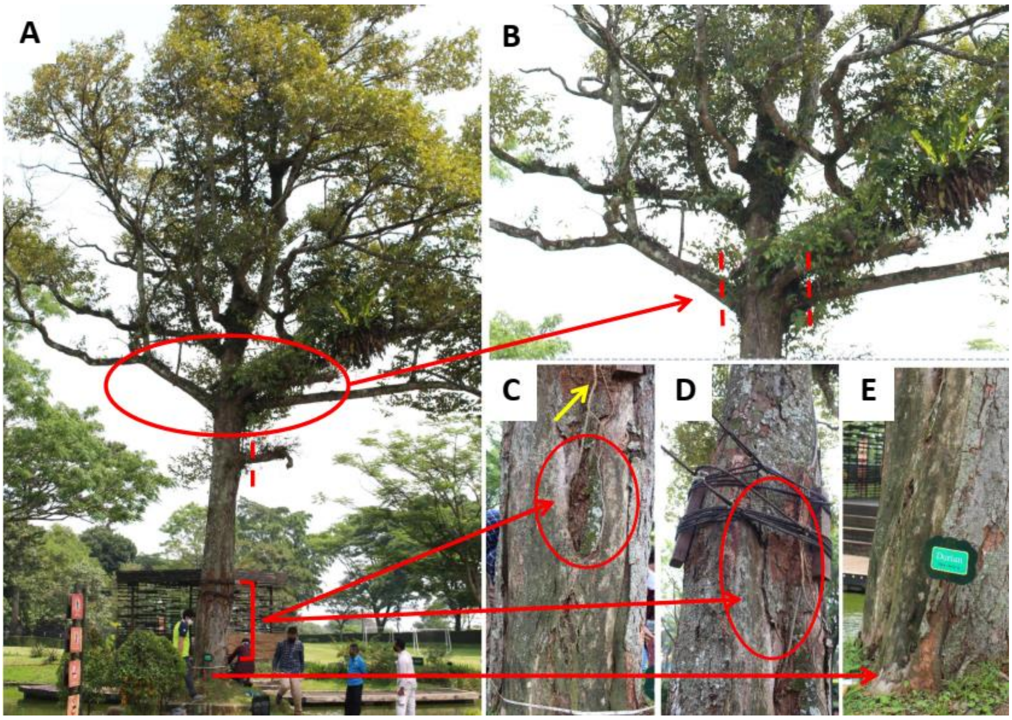


Fig. 6. Tree 3 (*D. zibethinus*). A. In whole natural appearance; B. Branches recommended for cutting (*dotted red line*); C. The damaged trunk with indentations are attached by *Ficus* roots (*yellow arrows*); D. The condition of the enduring trunk stretching of the bark; E. The root neck area shows the location of the termite trench.

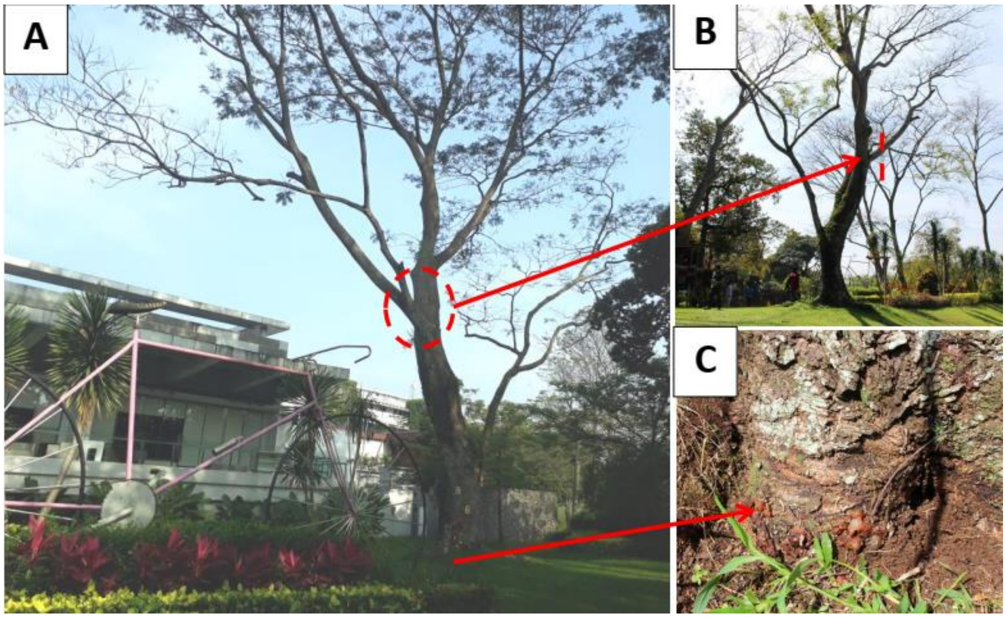


Fig. 7. Tree 4 (*F. falcata*). A. In whole natural appearance; B. Branches recommended for cutting (dotted red line); C. The base of the trunk/root neck was previously covered by lush grass and looks like there is a fungus.

3.1.5. Melia azedarach (tree 5)

The visual observation results showed that the crown shapes of tree 5 (*M. azedarach*) were growing well, and the canopies were balanced with an estimated 5 m of diameters. The crown density is relatively average even though there are branches/dead branches of about 5-10% (**Fig. 8ab**). The growth of the trunk was reasonably good, with a trunk diameter of 2.05 m in the first layer of observation. The character of the mindi bark is known to have cracked on the outside of the trunk. Ornamental plants mainly cover the base of the trunk, so it can become damp and be attacked by fungi or termites (**Fig. 8c**).

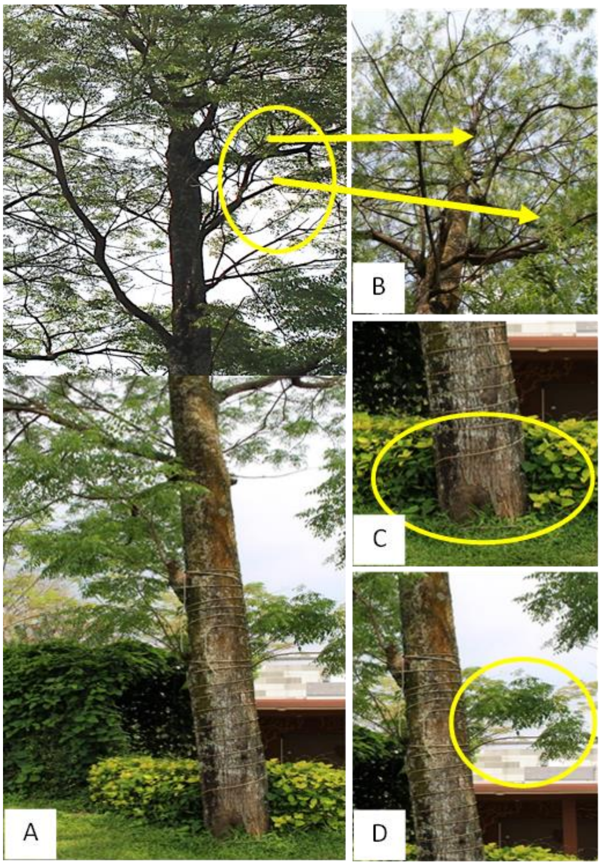


Fig. 8. Tree 5 (*M. azedarach*). A. In whole natural appearance; B. Dead branches; C. The base of the trunk is covered with bushes; D. Branches leading to buildings will be cut off.

3.1.6. Melia azedarach (tree 6)

The visual observation results showed that the crown condition of tree 6 (*M. azedarach*) tree was observed to grow relatively well. The crown was quite balanced, with an estimated crown diameter of 5 m. The crown density is relatively standard, although there are branches/dead branches of about <5%. The growth of trunks is rather good, with a trunk diameter of 1.74 m in the first layer of observation (**Fig. 9a; 9b**). On the trunk, it can be seen that it is overgrown with epiphytes such as nails and orchids. Similar to other mindi trees, the bark is known to have cracks on the outside of the trunk. The trunk base is mainly covered by grass, which can become damp and easily attacked by fungi or termites (**Fig. 9c**).

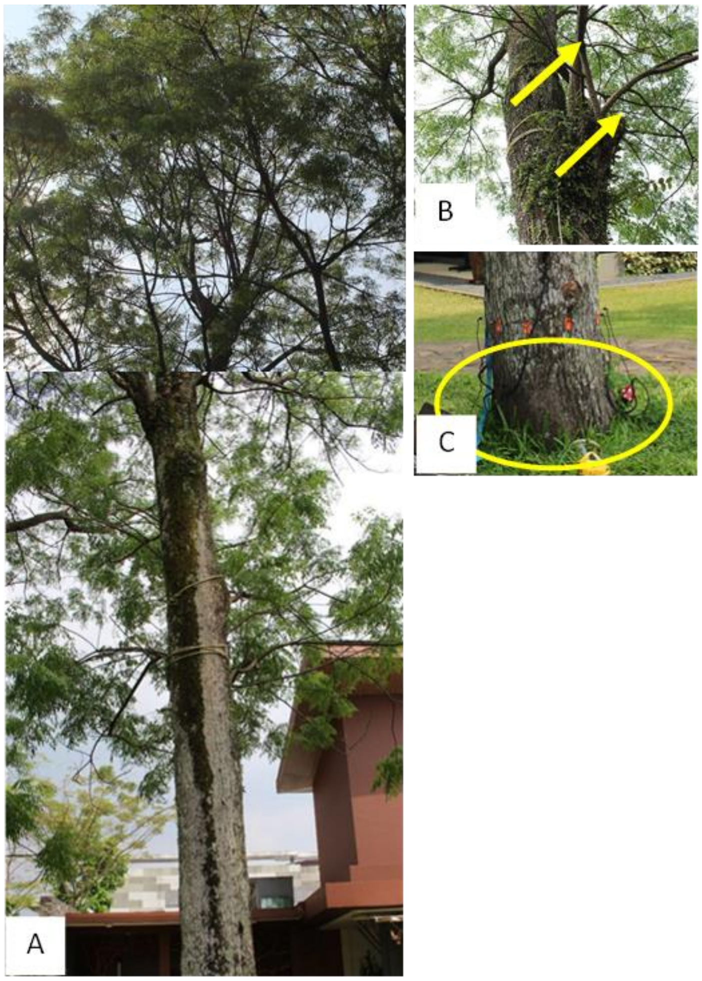


Fig. 9. Tree 6 (*M. azedarach*). A. In whole natural appearance; B. Dead branches and epiphytes plants; C. The base of the trunk is covered with grasses.

3.1.7. Melia azedarach (tree 7)

The visual observation results showed that the trunk was damaged at the tip of the trunk (**Fig. 10b**) and the trunk/root neck (**Fig. 10c**). Damage to the tip of the trunk is cracked the skin peels off. In addition, there are logging residues that have weathered due to an alleged error in felling techniques. The type of trunk wound on the tree is an advanced level of destruction caused by pests to form holes inside the tree, especially in woody trees (Costa et al. 2020). The base of the trunk/root neck termites *Macrotermes* sp., which attacks dead tissue/bark. In addition, fungi were also found in that section. It indicates that the weathering process has occurred.

3.1.8. Ficus subcordata (tree 8)

The visual observation showed that the trunk had no symptoms of damage. The cavities/indentations in the trunk are the natural shapes that are common in the development of *F. subcordata*. A hole at the trunk base happens due to a pile of soil that causes weathering. The former *Ganoderma* fungus was also found. However, the chance of falling is relatively low due to the adaptability of *Ficus* sp., which supplies growth to a form of self-defense by emerging new hanging roots (**Fig. 11**).

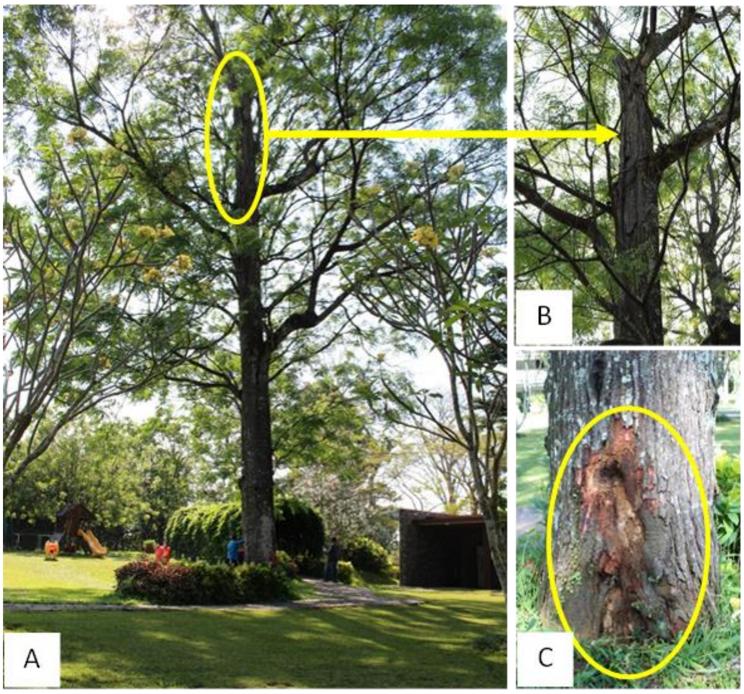


Fig. 10. Tree 7 (*M. azedarach*). A. In whole natural appearance; B. Damage to the upper trunk, there are cracks and weathering processes on the rest of the previous felling; C. The base of the trunk that attacked by termites.

Fig. 11. A. The whole appearance of *F. subcordata*; B. Cavities due to the natural curve of the tree growth.; C. Cavity condition with no symptoms of damage.

3.2. Decay Quantification

In general, the decay quantification of the trees at the Rancamaya hotel shows a high level of solidity (>80%) which indicates a healthy condition (**Table 3**). The percentage of solid wood was more than 80% (health), 50-80%(moderate), and lower than 50% (unhealthy) categories of the trunk (Karlinasari et al. 2018). Some trees with a higher percentage of damage than others are tree 7 and tree 8. However, the solid wood percentage is still above 80%, so the trees can be said to be in healthy condition. The application system using sound waves transversing through decay is more slowly than solid wood. The relative speed of the sound can be calculated by sending sound waves from several points around a tree trunk. A tomogram, a two-dimensional image of the cross-section of the tree, can be generated and preserved for publication (Gilbert et al. 2016).

Table 3. Decay/weathering and wood solidity percentage of the 8 risky trees on various layers by PiCUS-3 Sonic Tomograph

Tree No.	Species	Layer	Height measurement (cm)	Decay/ weathering (%)	Wood solidity (%)	Notes
1	*Melia azedarach*	Layer 1	30	1	95	
		Layer 2	80	1	95	
		Layer 3	180	1	95	
2	*Melia azedarach*	Layer 1	30	1	96	
		Layer 2	80	1	93	
		Layer 3	180	0	98	
3	*Durio zibethinus*	Layer 0	20	0	93	
		Layer 1	70	0	96	
		Layer 2	140	0	98	
		Layer 3	210	0	97	
4	*Falcataria falcata*	Layer 1	78	0	98	
		Layer 2	130	0	95	
		Layer 3	200	0	99	
5	*Melia azedarach*	Layer 1	50	1	96	
		Layer 2	120	2	93	
		Layer 3	200	0	98	
6	*Melia azedarach*	Layer 1	25	2	93	
		Layer 2	114	3	92	
		Layer 3	200	1	94	
7	*Melia azedarach*	Layer 0	5	18	68	
		Layer 1	48	1	98	
		Layer 2	118	0	91	
		Layer 3	200	3	92	
8	*Ficus subcordata*	Layer 1	200	2	81	A cavity occurred naturally, a common trait in a *Ficus* tree
		Layer 2	230	17	53	
		Layer 3	280	21	54	

Notes: The data source is processed from the results of the PiCUS-3 Sonic Tomograph.

The tomogram of eight risky trees is presented in **Fig. 12** and the detailed assessment results for each tree are described in the following sections. The PiCUS-3 Sonic Tomograph in tree 1 was carried out on three layers at the height of 30 cm (L1), 80 cm (L2), and 180 cm (L3). Good condition of the trunk at the height of 30 cm (L1), 80 cm (L2), 180 cm (L3) indicated that it had only experienced a 1% weathering process with 95% wood solidity. This condition is considered good and has a low risk of falling. Hence, the recommended mitigation efforts for tree 1 are as follows: (1) cleaning of epiphytic plants attached to the trunks, (2) installing warning signs such as “beware of broken branches” because the tree is close to the road and parking area, and (3) maintenance around the root neck, such as mulching treatment to ensure and prevent a dampened root neck.

The PiCUS-3 Sonic Tomograph in tree 2 was carried out on three layers at the height of 30 cm (L1), 80 cm (L2), and 180 cm (L3). Good condition of the trunk at the height of 30 cm (L1), 80 cm (L2), 180 cm (L3) showed that the weathering process of 1%, 1%, and 0% (respectively) with wood solidity 96%, 93%, and 98% (sequentially). This condition is considered good and has a low risk of falling. Heavy pruning of large branches that leads to the cliff is recommended because it becomes a burden on the tree and causes the slope of the trunk. Pruning can be adjusted to the recommendations, or the branch can be cut and left about 1 m in height from the base. Cleaning epiphytic plants attached to the trunks, especially *P. piloselloides* and other ferns, is also vital to be conducted. Two strangler plants are relatively established and challenging to destroy. We recommend leaving them alone, considering that the roots of the strangler plants will strengthen the stand of the host tree. In the long run, the host tree will be replaced by the whole strangler plant. Installing warning signs to warn about broken branches' potential hazards is strongly recommended because the tree location is close to vehicle roads, pedestrians, and parking areas. In addition, mulching around the root neck can be done to ensure the condition of the root neck is not damp.

The PiCUS-3 Sonic Tomograph in tree 3 was carried out on four layers at the height of 20 cm (L1), 70 cm (L2), 140 cm (L3), and 210 cm (L4). Conditions at the height of 20 cm (L1) indicate a wood solidity of 93%. Meanwhile, the subsequent layers are relatively not weathered with a very high resilience of wood, reaching >95%. Although the condition of the durian tree does not show any alarming characteristics, based on the previous history where the tree has been struck by lightning, it is necessary to do some handling to ensure that the durian trunk can support the crown’s load. Several handling advice can be done. Suppose the durian tree is preserved, the recommended mitigation efforts are as follows: (1) reduction of the lowest branch because it is feared to increase the load on the trunk because the trunk is also used as a flying fox terminal, (2) transferring the flying fox sling rope to another support panel, the burden of the sling rope is feared to aggravate the trunk load, (3) provision of termiticide so that the termite queen can be attacked directly and the termite colony can be wholly eradicated, (4) installing warning signs to warn about broken branches potential hazard. If the durian tree is cut down, cut off the trunk because it is worried that it will not support the load of the crown and sling ropes.

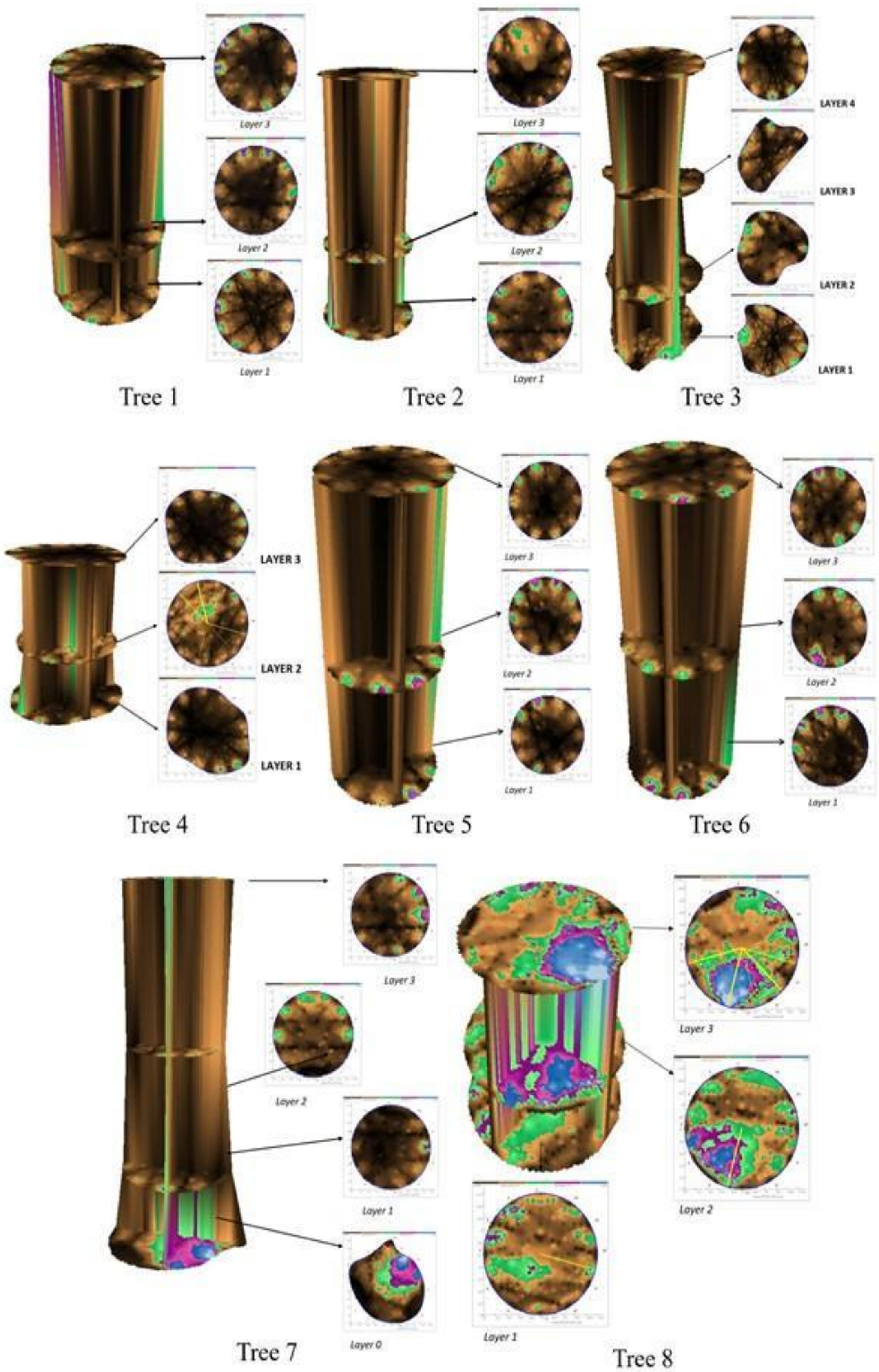
The PiCUS-3 Sonic Tomograph in tree 4 was carried out on three layers at the height of 78 cm (L1), 130 cm (L2), and 200 cm (L3). Conditions at the height of 20 cm (L1) indicated 98% wood solidity. Meanwhile, the subsequent layers are relatively not weathered with very high stability of wood, reaching 95%. Although the condition of the sengon tree does not show any worrying characteristics, some measures need to be taken to ensure that the sengon branches are not dangerous, considering that sengon wood is a wood with a low durable class in categories IV-V (Wardyani et al. 2017). The recommended mitigation efforts are as follows: (1) trimming branches that lead to the building are feared to break and endanger visitors or staff walking in the area, (2) removing the *P. piloselloides* because the epiphytes can weather the bark, (3) clean the root neck area regularly, particularly the root neck covered with lush grass that moistens and trigger fungal growth, and (4) installing warning signs.

The PiCUS-3 Sonic Tomograph in tree 5 was carried out on three layers at the height of 50 cm (L1), 120 cm (L2), and 200 cm (L3). The condition of the trunk in the three layers observed was known to be relatively good, with a solid wood density of 96%, 93%, and 98%, respectively. This mindi tree is located in the parking area and is often a place for children to play and is visited by families of visitors. Therefore, visual inspection of the base of the trunk and dead branches is expected to regularly be carried out by the relevant department at R hotel. The recommended mitigation efforts are as follows: (1) crown reduction should be conducted by reducing the components that lead to the building but by still paying attention to the balance of the tree crown, (2) cutting dead branches is done by cutting the base of the dead branch, (3) maintenance around the root neck to get direct sunlight to prevent damp, inviting fungus and termites, (4) checking the base of the trunk and dead branches is recommended to be carried out periodically by the relevant department at R Hotel Rancamaya, and (5) installing warning signs.

The PiCUS-3 Sonic Tomograph in tree 6 was carried out on three layers at the height of 25 cm (L1), 114 cm (L2), and 200 cm (L3). The condition of the trunk in the three layers observed was known to be relatively good, with a solid wood density of 93%, 92%, and 94%, respectively. This mindi tree is located in the parking area and is often a place for children to play and is visited by families of visitors. Therefore, visual inspection of the base of the trunk and dead branches is expected to regularly be carried out by the relevant department at R hotel. The recommended mitigation efforts are as follows: (1) crown reduction is made by reducing the components that lead to the building but by still paying attention to the balance of the tree crown, (2) cutting dead branches is done by cutting the base of the dead branch, (3) efficiency reduction, carried out by removing the efficiency plants periodically, (4) maintenance around the root neck to get direct sunlight, prevent dampness, fungus, and termites, (5) checking the base of the trunk and dead branches are recommended to be carried out periodically by the relevant department at R Hotel Rancamaya, and (6) installing warning signs around the tree.

The PiCUS-3 Sonic Tomograph in tree 7 was carried out on four layers at the height of 5 cm (L0), 48 cm (L1), 118 cm (L2), and 200 cm (L3). The condition at the height of 5 cm (L0) is indicated to have experienced a weathering process of 18% with a wood solidity of 68%. Meanwhile, the following layers are relatively not weathered, with wood solidity reaching >90%. However, in our opinion, this condition has a higher risk of falling because the root neck has been weathered while the layers above are still solid so that the top load is heavy. Therefore, the recommended mitigation efforts are as follows: (1) complete felling because the load on the crown and trunk is solemn while the trunk/root neck base has weathered, (2) heavy felling, not cut down, but the trunk is left 1-2 m for artistic optimization with attractive decorations for hotel visitors, (3) maintenance around the root neck ensures direct sunlight, not damp, inviting fungus and termites.

The PiCUS-3 Sonic Tomograph in tree 8 was carried out on three layers at the height of 200 cm (L1), 230 cm (L2), and 280 cm (L3). In general, the trunk of *F. subcordata* is still in a safe condition. As for the check results, the blue color results from natural cavities/indentations that do not indicate weathering/damage. In addition, the position of the crown is included in a balanced condition according to the contour and direction of the crown slope. Therefore, we assessed that the condition of *F. subcordata* is in a relatively safe situation. Therefore, the recommended mitigation efforts are as follows: (1) tree felling is not necessary, (2) pruning branches to the building can perform in a limited way by considering the balance of the tree's weight, and (3) placing signage for caution to visitors.



Notes: Tree 1, 2, 5,6,7 are *M. azedarach*; tree 3 is *D. zibethinus*; tree 4 is *F. falcata*; tree 8 is *F. subcordata*

Fig. 12. The tomogram of eight risky trees.

The tree's root neck should be maintained by cleaning the grass around the trees by mulching. The mulching should not be accumulating and cover the root collar to maintain good air circulation and avoid excess moisture. However, if it feels like it will erode the soil, it is better to do a routine check on the root collar by cleaning the grass around the trunk base. Heavy pruning of large branches or branches should be done slowly following several steps. Pruning the first stage is the diameter of the branch from the bottom. The second stage of pruning is pruning the branches from the top side of the branch. This second pruning aims to reduce the burden of the branch crown to be pruned. Finally, pruning the third stage is a clean pruning of the trunk. This pruning is easier and perfect to do because the burden of the branch has been lost. The thing to note is that pruning close to the trunk must leave a little branch collar so that the rest of the pruning is not susceptible to disease and can recover perfectly. Regular maintenance in light pruning is preferred to reduce more severe damage, which is influenced by the age and height of the trees (Zulkarnaen et al. 2021).

3.3. Discussion

R Hotel Rancamaya is a five-star hotel located at the foot of Mount Salak, about 460 masl in Bogor. This hotel is built on an area of 700 ha, so it has an extensive green area (park, outbound, and golf). The hotel, built-in 2015, implements a landscape and layout that upholds conservation values. It can be seen from many large trees around the hotel, older than the hotel itself. Healthy trees are essential in reducing the risk of accidents of the staff and visitors, so the hotel management decided to assess several risky trees in the hotel's green area. A healthy tree is the interaction effect between trees and environmental factors (Liang et al. 2021). Beneath specific conditions, the interaction can cause tree damage (Fuller et al. 2016; Winarni et al. 2012). The damage can appear in material and non-material losses (Van Haaften et al. 2016).

A visual assessment is carried out before a more profound examination to find external symptoms of internal defects in a reasonably short time. It also diagnoses external threats causing defects and increasing risk factors for fallen trees. Eight trees in the green area of the hotel show several symptoms ranging from mild to severe. Signs of defects that we found were generally found on the trunk and root collars, such as peeling or cracked bark, dents, dead branches, cracks, ribs, fungal infections, and termites attacks on the trunk or root neck (Luley 2012).

The six trees were in reasonably good condition with minor defects. The other two trees, *D. zibethinus* (tree 3) and *M. azedarach* (tree 7), needed further examination because the symptoms of external defects are usually indicators or caused internal damage. However, signs of external defects do not always confirm internal decay in the tree. Otherwise, a visually healthy tree may decay internally (Allikmäe et al. 2017). Therefore, further internal checks are required for all trees to avoid inaccurate justification.

Mindi trees (*M. azedarach*) were planted in the hotel's green area as a garden tree, likely due to their fast-growing and low maintenance habits (Palakit et al. 2018). Two Mindi trees (Tree 1 and 2) growing next to each other did not show significant defect symptoms. However, the slightly tilted trunk and unbalanced crown required some pruning and cleaning to maintain the tree's health. Tree 5 and 6 were similar in condition. The trunk did not show any defect, other than the small dead branches caused by inappropriate mechanical force in the past. The only threats found were the hemi-epiphytes *Ficus* or strangler *Ficus* growing on the trunk of Tree 2.

Mindi (tree 7) was the only one who experienced fungal and termites attacks on the trunk base and root collar. Fungal conks or mushrooms are positive decay indicators (Luley 2012). The invasion of termites was also the indicator of dead tissue occurring in the trunk or root collar. Since the positive indicators are present, further and more rigorous inspection may be required to ascertain the severity of the decay. Fungal attacks were identified at *M. azedarach* (tree 7) and *F. subcordata* (tree 8). Fungal attacks are predominantly wounds caused by animal chewing, branch breaking, pruning, and motor traffic. Effect of fungal attack was accumulation from several processes in many years, which frequently remain hidden for a long time, until the fruit bodies appear, or the tree is broken, thrown by the wind, or felled (Blanchette and Biggs 2013). Depending on the fungi and tree species, brown, white, or even soft-rot decay can develop in the tree. Sapwood or heartwood can be colonized. Fungi may be saprobionts of parasites. Development and spread of decay are influenced by the tree species, which can be susceptible, like birch or poplar, or exhibit natural durability in its heartwood due to inhibiting accessory compounds.

Termites attacks found at *D. zibethinus* (tree 3) and *M. azedarach* (tree 7). Nandika (2014) showed that various agents damage the wood of the trees, including termites and fungi. Termites identified in both trees are allegedly the *Macrotermes* genus. *Macrotermes* are commonly found in Southeast Asia and could be a trouble at the plantations (Nandika 2014). *Macrotermes* attacked fast and were detected by the nest presence at the surface ground. *Macrotermes* digest cellulose from the trunk then executes the wood decay (Nandika et al. 2015). Furthermore, the Macrotermes nest also supports fungi as food sources, so the Macrotermes attack was less dangerous than other termites such as *Coptotermes* (Nandika et al. 2015).

The epiphytes plant species recorded on tree trunks and branches are orchids, ferns, and strangler *Ficus*. The orchid is *D. crumenatum*, an epiphyte that does not disturb or harm the host tree. The orchid and the host tree undergo a commensalism symbiosis (Rasmussen and Rasmussen 2014; Sayago et al. 2013). The ferns were *Asplenium* sp. and *P. piloselloides*. *Asplenium* is a fern with a reasonably comprehensive cover and is non-invasive, while *Pyrrosia* has an invasive growth profile with an extra diminutive stature. The presence of ferns, particularly *P. piloselloides*, is thought to increase the exposure of trunks and branches to fungal because their roots may provide access (Rasmussen and Rasmussen 2014, 2018).

The strangler *Ficus* develops the primary and aerial roots with a complex structure and forms the pseudo-trunk. At that point, the strangler *Ficus* will damage the host tree and kill it by strangulation (Ebika et al. 2015). The strangulation of *Ficus* found in *M. azedarach* (tree 2) and *D. zibethinus* can cause death within the host tree due to competition between the two. However, the presence of *Ficus* on the tree can stabilize the slanted trunk to support the establishment of the tree while minimizing the potential for fallen trees (Cottee-Jones et al. 2016).

The decay quantification can be estimated by the Sonic Tomography method. The PiCUS-3 Sonic Tomograph is a non-destructive instrument for evaluating decay and weathering in risky trees (Gilbert et al. 2016). The decay part was arranged for each cross-section visual photographic. If the decay was not clearly defined, the actual trunk cross-section was visually examined to clarify whether decay was present. Decay was characterized as the softness of wood that deflected with finger pressure. The PiCUS-3 Sonic Tomograph did a great job identifying tree parts containing decay in this research. The instrument detected significant decay of the present in a section of the trunk. Visual assessment is not enough to detect a damaged tree. Hence, PiCUS-3 Sonic Tomography inspection will support visual evaluation. Tree risk assessment initiated with visual tree observed and advanced with PiCUS-3 Sonic Tomography measurement is suggested to be done regularly, especially in the public area. To reduce high-risk trees in public spaces, the recommended strategy is to install high-risk tree signs (Hanum et al. 2020).

4. Conclusions

Eight trees in the green area of the hotel show several symptoms ranging from mild to severe. The six trees were in reasonably good condition with minor defects. In comparison, *D. zibethinus* (tree 3) and *M. azedarach* (tree 7), a visually healthy tree, may decay internally. Further internal checks using PiCUS-3 Sonic Tomograph showed that the observed trees' solidity ranged from 53-99%, with the most decay, 18%, found in *M. azedarach* (tree 7). Visual assessment is not enough to detect a damaged tree. Tree risk assessment initiated with visual tree observed and advanced with PiCUS-3 Sonic Tomography measurement is suggested to be done regularly, especially in the public area. To reduce high-risk trees in public spaces, the recommended strategy is installing the high-risk tree signs, installing the pole-supporting wood, regular mulching, excess branch pruning, and removing the epiphytic *P. piloselloides* to prevent weathering of the trunk and suddenly fallen trees.

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