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Comparing Reliability of FHM and ISA Methods in Assessing Old and Large Dipterocarp Trees Health

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Abstract

Forest Health Monitoring (FHM) and International Society of Arboriculture (ISA) methods are used for individual tree health assessment. However, comparing the reliability of both methods in assessing large and old tree health has yet to be evaluated. This study aims to determine reliability of two methods in evaluating the health condition of old (>100 years old) and large Dipterocarp trees in Bogor Botanic Garden (BBG), Indonesia. The parameters observed were growth, morphometry, and tree health of 44 trees. The results showed that, overall, the two methods demonstrated quite similar in assessing the health condition of targeted trees. Visual tree damage domination by conks, fruiting bodies, and other indicators of advanced decay, open wounds, and termite gallery. The average risk rating of three parts of the tree (branches/crown, trunk, roots) is low to moderate. The two approaches could be used simultaneously or separately according to the purpose of the assessment.

Keywords: Tree health assessment, dipterocarp, heritage trees, Bogor Botanic Garden.

1. INTRODUCTION

Bogor Botanic Garden is the oldest and the largest botanic garden in Southeast Asia (Ariati & Widyatmoko, 2019), located in Bogor city, West Java, Indonesia. This ex-situ plant conservation area was established over two centuries ago, in 1817, covering an area of almost eighty hectares. In 2022, the number of living plant collections in the botanic garden will reach 11,656, with more than 66% endemic species. Among the living plant collection, there are 5,084 trees, of which 895 are categorized as old and large trees more than 100 years old and more than 100 cm in diameter (Rachmadiyanto et al., 2021; Registration of Bogor Botanic Gardens, 2022). Old and large trees in the landscape of the Bogor Botanical Gardens have played essential ecosystem functions. They are the key to recognizing the actual structure of a forest (Scipioni et al., 2019).

Old trees can store up to 415 Mg C ha^{-1} of carbon (Natalia et al., 2017) and absorb more carbon dioxide than young trees from the atmosphere (Gilhen-Baker et al., 2022; Luyssaert et al., 2008). Maybe carbon dioxide is stored in the trunks, branches, and leaves, which could help mitigate climate change's effects (Gilhen-Baker et al., 2022; Stecker, 2014). Another ecosystem function of old trees is to control the surrounding microclimate (Cell Press, 2022; J. Chen et al., 1999; Gilhen-Baker et al., 2022). Old and large trees also often have unique genetic variations, allowing them to survive in competition with other species and extreme climatic conditions (Frelich & Reich, 2003). Thus, it becomes crucial to maintain and preserve the existence and sustainability of old trees for the future (Gilhen-Baker et al., 2022).

One tree family that is predominantly old and large trees in Bogor Botanic Garden is Dipterocarpaceae. There are 67 Dipterocarp trees, consisting of 37 species. The main habitus is always standing upright compared to the surrounding plants. Seeds generally have wings and rotate like a helicopter when they fall from the tree (Fajri, 2008) and have inflorescences with

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a sweet fragrance (Smits, 1986). The tree trunk is cylindrical and mainly buttressed (Maria et al., 2016). The Dipterocarp trees can live up to ± 250 years, even 1000 years (Ashton, 1982). In addition, the Dipterocarp trees in Bogor Botanic Garden could be classified as heritage trees (HT) that have a significant ecological role in supporting nutrient cycling, carbon (H. Y. H. Chen & Luo, 2015; Slik et al., 2013), microfauna, and epiphytic (Lindenmayer, 2017; van der Hoek et al., 2017). Given their phenotype and ecological roles, it is understandable that Dipterocarp trees have become the attraction and icon of Bogor Botanic Garden. Therefore, their existence should be preserved. Moreover, the existence and the health condition of HT in many countries, such as China (Huang, Jin, et al., 2020; Huang, Tian, et al., 2020; Jin et al., 2020; H. W. Lin et al., 2020), Malaysia (Noor Anira et al., 2016), Australia (The National Trusts of Australia, 2021), the United Kingdom (Heritage Trees UK, 2018), Singapore (Singapore Botanic Gardens, 2001), Indonesia (Rachmadiyanto et al., 2022) and several states of the United States are increasingly getting much attention (American Heritage Trees, 2021). Recently, China has published scientific articles related to economic value (H. W. Lin et al., 2020), biogeography, distribution (Huang, Jin, et al., 2020), and the local culture of HT (Huang, Tian, et al., 2020).

Tree health is a scientific discipline that studies all the factors (biotic and abiotic) that affect the vitality of trees (strength and productivity). These factors are indicated as symptoms and signs of damage to a tree (Boa, 2003). Tree health is likely to be the most crucial issue when trees are near human activities, such as in yards (Zobrist, 2011), urban forests (Wolf et al., 2020), and tourist sites (Helmanto et al., 2019). Among the various methods for assessing tree health is that of the International Society of Arboriculture (ISA). A non-profit organization developed the ISA method in the State of Illinois, USA, providing a guide/framework on tree health (International Society of Arboriculture, 2022). The ISA method focuses on assessment targets, tree health, species profile, site factors, and tree defects and conditions affecting the likelihood of failure. A target is a person, property, or activity likely to be injured, damaged, or disturbed by a tree failure within striking distance (target zone) of the part of the tree in question. Tree parts of the assessment objects in the ISA method, namely (a) crown and branches, (b) trunk, and (c) roots and root collar, were observed in determining the likelihood of failure (International Society of Arboriculture, 2013). Furthermore, it will be entered into the risk categorization matrix to determine the risk rating of these parts and the whole tree (Rachmadiyanto et al., 2022). Meanwhile, the forest health monitoring (FHM) method assesses the health of trees in forest ecosystems. However, it can be focused on the individual tree level by assessing damage indicators (Stuckle et al., 2001).

Only now, many studies have been on the equality of each tree health assessment based on the ISA or FHM methods. This creates confusion for botanical garden employees to choose between the two methods based on their reliability. Various recent research results are based only on one of these methods, such as the use of the FHM method to determine tree health in green open spaces/urban forests (Abimanyu et al., 2019; Cumming et al., 2008; Waruwu et al., 2021) and botanic gardens (Rachmadiyanto et al., 2021; Rachmadiyanto & Rinandio, 2019; Zulkarnaen et al., 2021). The ISA method has been widely used to detect tree risk (Klein et al., 2021; O'Herrin et al., 2020). This study aims to determine the reliability of the two methods in evaluating the health condition of old and large Dipterocarp trees grown in Bogor Botanic Garden, Indonesia, and evaluate the simultaneous use of these methods. The results are expected to contribute to the HT dipterocarp's preservation and maintenance strategy in BBG for future benefits.

2. MATERIALS AND METHODS

2.1. Research location and targeted trees

The research was conducted in the Bogor Botanic Gardens, with an area of 78.6 ha. It is located around latitude 6º 35' 32.7" - 6º 36' 14.4" and longitude 106º 47' 39.9" - 106º 48' 17.4". The soil texture is dominated by clay, with soil fertility tending to be low to moderate (Rachmadiyanto et al., 2020). Sixteen species (44 individual trees) from the dipterocarps family were selected as targeted trees based on the heritage tree (HT) criteria: old age (>100 years) (Huang, Jin, et al., 2020; Huang, Tian, et al., 2020; Jin et al., 2020; H. W. Lin et al., 2020), historical, rare, or unique form (Coates, 2006; Lai et al., 2019; Yaacob et al., 2016). The criteria included live trees, multiple trees as replicates, and the selected tree species.

2.2. Parameter's measurement

2.2.1. Tree growth and morphometry

Tree morphometry measured included diameter at breast height (*dbh*), height, live crown ratio (*LCR*), mean crown diameter (*DCR*) (Coombes et al., 2019; Pretzsch et al., 2015; Velkovski et al., 2017), crown projection area (*PCR*) (Ritter & Nothdurft, 2018), and slenderness (Wang et al., 2011). Trunk *dbh* (1.3 m) was measured using girth tape. Tree height and *LCR* were measured using a Nikon Forestry Pro tool. Crown length (*HCR*) was measured by tree height (*h*) minus the height of the first live branch. *LCR* was calculated by dividing the crown's length by the tree's height ($LCR = HCR/h$). Parameter *DCR* was measured using SNDWAY laser digital distance and calculated as the average diameter of the longest (*cl*) and shortest (*cs*) crown with the formula ($DCR = (cl + cs)/2$). Moreover, *PCR* was calculated by the formula $PCR = (DCR^2 x /4$. The formula $S = h/dbh$ calculated Slenderness (S).

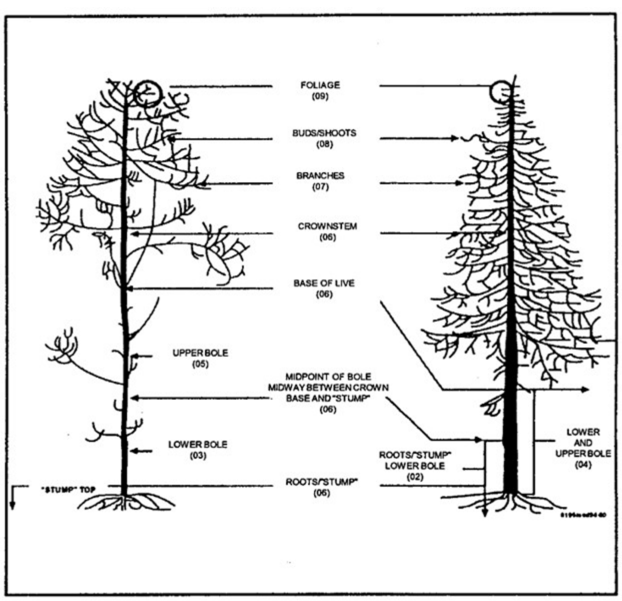
2.2.2. Tree health

The measurement of tree health is based on forest health monitoring derived from individual trees. The parameters measured were the location of the damage (Figure 1), the damage type, and the damage severity presented in Table 1. Location of damage is where signs and symptoms of damage to the tree are found, with priority from the bottom (roots) to the top (bud). Damage type is the signs and symptoms of damage that can be seen visually at each location. At the same time, the severity of the damage is the percentage of signs and symptoms of damage to one type and location of the damage.

The measured data (location, type, and severity) are transformed into values and weights (Table 2), then calculated to determine the value of the damage index (*DI*) (Nuhamura & Kasno, 2001; Tallent-Halsell, 1994) using the formula:

Information:
x = value of damage location
y = value of damage type
z = value of damage severity
1,2,3 = damage to i

Figure 1. Damage location classification (Nuhamura & Kasno, 2001; Stuckle et al., 2001)



Note: The number in brackets is the damage location classification code

Table 1. Damage types, descriptions, and thresholds in the order from highest to lowest significance to the tree's health (Nuhamura & Kasno, 2001; E. I. Putra, 2021).

Code	Description	Severity Threshold
01	Cancer	≥ 20% of the circumference at the point of occurrence
02	Conks, fruiting bodies, and other indicators of advanced decay	none, except for ≥ 20% of roots > 3 feet (0.91 m) from the bole
03	Open wounds	≥ 20% of the circumference at the point of occurrence
04	Resinosis/gummosis	≥ 20% of the circumference at the point of occurrence
05	Cracks and seams	1.52 m in length and on at least 20% of branches
06	Termite gallery	≥ 20% of the circumference at the point of occurrence
07	Woody liana	≥ 20% of the circumference at the point of occurrence
11	Broken bole or roots < 3 feet (0.91 m) from bole	none
12	Brooms on roots or bole	≥ 20% of roots
13	Broken or dead roots < 3 feet (0.91 m) from the bole	≥ 20% of roots
20	Vines in the crown	≥ 20% of live crowns affected
21	Loss of apical dominance, dead terminal	≥ 1% of crown stem
22	Broken or dead	≥ 20% of branches or shoots
23	Excessive branching or brooms	≥ 20% of branches or brooms
24	Damage foliage or shoots	≥ 30% of the foliage
25	Discoloration of foliage	≥ 30% of the foliage
31	Etc. (other descriptions that have not been mentioned in the coding)	

Indicators of tree health based on ISA methods include tree defects and conditions affecting the likelihood of failure, written in the ISA basic tree risk assessment form. The tree risk in each measurement section has two components: (1) the likelihood of the tree failing to reach the target, divided into the failure and then associated with the impact (Table 3), and (2) the results of the likelihood matrix are then linked with the consequences of failure to determine the risk rating matrix (Table 4). The result is a risk rating (*RR*), which relates to Table 4 and is converted into weighting.

Table 2. The weighting of tree damage values (Herliyana et al., 2022; Nuhamura & Kasno, 2001; E. I. Putra, 2021).

Damage code	values	Location code	values	Severity code	values
1	1.9	0	0.0	0-9%	1.5
2	1.7	1	2.0	10-19%	1.1
3	1.5	2	2.0	20-29%	1.2
4	1.5	3	1.8	30-39%	1.3
5	1.5	4	1.8	40-49%	1.4
6	2.0	5	1.6	50-59%	1.5
7	1.5	6	1.2	60-69%	1.6
11	2.0	7	1.0	70-79%	1.7
12	1.6	8	1.0	80-89%	1.8
13	1.5	9	1.0	90-99%	1.9
20	1.8				
21	1.3				
22	1.0				
23	1.0				
24	1.0				
25	1.0				

Table 3. Likelihood matrix (Coelho-Duarte et al., 2021; International Society of Arboriculture, 2013).

Likelihood of failure	Likelihood of Impacting Target			
	Very low	Low	Medium	High
Imminent	Unlikely	Somewhat likely	Likely	Very likely
Probable	Unlikely	Unlikely	Somewhat likely	Likely
Possible	Unlikely	Unlikely	Unlikely	Somewhat likely
Improbable	Unlikely	Unlikely	Unlikely	Unlikely

Table 4. Risk rating (*RR*) matrix (Coelho-Duarte et al., 2021; International Society of Arboriculture, 2013).

Likelihood of Failure & Impact	Consequences of Failure (*weighting*)			
	Negligible	Minor	Significant	Severe
Very likely	Low	Moderate	High	Extreme
Likely	Low	Moderate	High	High
Somewhat likely	Low	Low	Moderate	Moderate
Unlikely	Low	Low	Low	Low

Note: Weighting scale of low = 1, moderate = 2, high = 3, extreme = 4

2.2.3. Comparison of forest health monitoring and international society of arboriculture method

The similarity in the assessment between the forest health monitoring method and the International Society of Arboriculture lies in the object of observation in the form of signs of damage observed in the roots, trunk, and crown. The result of FHM in botanic gardens is the tree level index, which states whether the tree is healthy (Abimanyu et al., 2019; Helmanto et al., 2019). The ISA is a risk rating that calculates the risk to its target and tree part (International Society of Arboriculture, 2022; Rachmadiyanto et al., 2022). The final recommendation will be the same: our strategy in mitigating tree risks so trees remain sustainable and safe for humans. The risk rating is converted to value to compare the results of the two methods.

2.3. Data analysis

Data were analyzed using basic statistics such as average and standard deviation, which were processed with Microsoft Office Excel for Microsoft. Pearson correlation analysis determines the relationship between the damage index and the number of risk ratings. Categorize correlation values into five levels, namely negligible (0.00–0.10), weak (0.10–0.39), moderate (0.40–0.69), strong (0.70–0.89), and very strong (0.90–1.00) (Schober et al., 2018). Statistical analyses were done using R 3.4 for Windows.

3. RESULT AND DISCUSSIONS

3.1. Tree growth and morphometry

The average growth and morphometric characteristics of the Dipterocarp Heritage trees (*DHT*) are presented in Table 5. The average tree age was 109 years, with *Shorea leprosula* Miq. being the oldest tree (156 years), the youngest is *Hopea sangal* Korth. (101 years). Diameter at breast height (*dbh*) ranged from 57.0-194.7 cm with an average of 99.2 ± 22.1 cm, and height ranged from 22.4-44.5 m with an average of 34.4 ± 6,1 m. *Dbh* and tree height indicate that each *DHT* species has relatively uniform height characteristics but varied *dbh*. The dipterocarp family in East Kalimantan, Indonesia's forests, can grow to 76 m and *dbh* up to 222.8 cm (Yamakura et al., 1986).

Furthermore, the average live crown ratio (*LCR*) is 57.6% (± 13.3), so it is included in the category of high tree vigor (>50%) (Nandika et al., 2020). *LCR* indicates that *DHT* has high strength in fair competition with surrounding trees (Karlinasari et al., 2021). The high *LCR* also shows a higher photosynthetic capacity so trees can grow better, which is essential for their defense strategies (Zhao et al., 2012). Thus, *LCR* can be one of the essential variables in tree health assessment (Karlinasari et al., 2021). The mean crown diameter (*DCR*) was 16.7 ± 3.8 m with a crown projection area (*PCR*) of 260.1 ± 109.3 m^2. The *PCR* of each tree can exceed hundreds of square meters and indicates a tree's coverage in its growing area. The *PCR* values for *DHT* varied from 61.7 to 672.5 m^2, even at relatively uniform tree age (101-123 years). The *PCR* value is not directly proportional to the tree's age. *PCR* values are thought to be determined not only by age but also by the size of the aperture, which affects light distribution received by a tree (Karlinasari et al., 2021). Furthermore, the slenderness of the *DHT* ranged from 21.7 to 76.0, with an average of 41.0 ± 10.9. This slenderness value can be categorized as low (Ige, 2017), meaning slender trees have a higher failure rate (Kontogianni et al., 2011). In addition, the greater the DHT, the greater the impact on the target (Horacek, 2003; Popa, 2000).

Table 5. Morphometry characteristic.

Species	n	Age	dbh (cm)	Tree height (m)	LCR (%)	*DCR* (m)	PCR (m^2)	Slenderness (%)
Anisoptera marginata Korth.	2	112 ± 8,0	173,5 ± 20,5	38,1 ± 12,0	45,2 ± 27,7	20,9 ± 2,4	345,5 ± 79,0	21,7 ± 4,4
Dipterocarpus alatus Roxb. ex G.Don	2	106 ± 0,0	125,5 ± 24,7	43,9 ± 8,3	48,2 ± 21,1	15,9 ± 5,9	213,0 ± 147,8	35,0 ± 0,3
Dipterocarpus gracilis Blume	4	106 ± 0,0	83,4 ± 33,4	39,5 ± 9,8	49,6 ± 22,2	11,3 ± 4,9	114,3 ± 92,8	53,3 ± 23,3
Dipterocarpus retusus Blume	6	114 ± 21,0	74,7 ± 32,0	34,2 ± 8,3	50,8 ± 21,9	10,5 ± 4,5	99,2 ± 82,5	54,2 ± 24,6
Dipterocarpus turbinatus C.F.Gaertn.	2	106 ± 0,0	72,5 ± 12,0	26,1 ± 9,8	33,2 ± 8,7	17,4 ± 4,7	246,7 ± 129,5	37,6 ± 19,7
Hopea mengarawan Miq.	2	108 ± 0,0	83,5 ± 26,2	39,2 ± 0,8	44,2 ± 9,3	19,4 ± 5,8	308,9 ± 176,8	49,5 ± 16,5
Hopea pierrei Hance	2	106 ± 0,0	76,5 ± 9,2	24,9 ± 4,9	94,1 ± 1,7	13,3 ± 1,8	140,2 ± 36,9	32,4 ± 2,6
Hopea sangal Korth.	2	101 ± 0,0	144,0 ± 2,8	36,9 ± 1,0	36,8 ± 2,3	24,7 ± 1,5	479,3 ± 58,9	25,6 ± 1,2
Shorea balangeran (Korth.) Burck	3	120 ± 24,0	72,2 ± 25,9	26,7 ± 11,6	54,1 ± 33,7	19,8 ± 3,9	316,6 ± 125,1	36,3 ± 5,8
Shorea guiso (Blanco) Blume	3	105 ± 2,0	194,7 ± 58,6	44,5 ± 4,2	48,6 ± 4,5	28,8 ± 6,2	672,5 ± 287,9	24,0 ± 5,6
Shorea leprosula Miq.	3	123 ± 28,0	168,0 ± 8,2	41,7 ± 9,7	45,0 ± 9,5	28,0 ± 7,8	646,3 ± 356,4	24,7 ± 4,7
Shorea multiflora (Burck) Symington	2	115 ± 13,0	76,0 ± 41,0	28,2 ± 5,1	92,8 ± 1,3	12,9 ± 0,1	129,7 ± 2,9	45,5 ± 31,3
Shorea seminis (de Vriese) Slooten	2	106 ± 0,0	57,0 ± 15,6	22,4 ± 5,9	90,7 ± 2,5	16,9 ± 1,3	223,7 ± 33,7	39,3 ± 0,3
Vatica bantamensis (Hassk.) Benth. & Hook.f. ex Miq.	2	106 ± 0,0	63,0 ± 1,4	39,2 ± 0,3	80,6 ± 22,0	9,6 ± 2,1	73,3 ± 30,8	62,2 ± 0,9
Vatica pauciflora (Korth.) Blume	5	106 ± 0,0	64,0 ± 21,2	22,9 ± 3,4	81,3 ± 16,4	10,1 ± 4,1	90,1 ± 65,8	38,2 ± 10,3
Vatica teysmanniana Burck	2	106 ± 0,0	59,0 ± 21,2	42,3 ± 2,1	26,0 ± 8,4	8,6 ± 3,1	61,7 ± 42,4	76,0 ± 23,7

Notes: more or less (±) points out the standard deviation

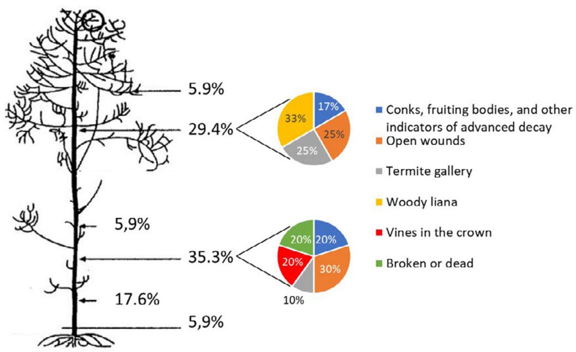
3.2. Tree Health

Locations of damage in Dipterocarp heritage trees (DHT) were found from roots to branches. The lower and upper boles dominated the location of damage (35.3%) and were followed by the crown stem (29.4%) (Figure 2). No damage was found to the location of the DTH tree's leaves and buds/shoots, so it has high vigor. As with urban trees, healthy leaves indicate a healthy tree condition (Petrova et al., 2014). The state of tree vigor and health can also be characterized by changes in morphological characteristics, especially in urban forests (Cisneros et al., 2019; Musio et al., 2007; Núñez-Florez et al., 2019).

Three types of damage dominate the DHT: a) conks, fruiting bodies, and other indicators of advanced decay; b) open wounds; c) termite gallery. All of this damage is found chiefly on the main trunk. A similar study by Rachmadiyanto & Rinandio (2019) at the Bogor Botanic Gardens (BBG) revealed that damages in *Intsia bijuga* were dominated by open wounds and the presence of termites. Open wounds caused by lawnmowers and vandalism make it easier for wood rot fungi to infect the tree (Núñez-Florez et al., 2019). Open wounds can also make it easier for organisms to move more quickly into the plant-carrying pathogen spores, ultimately causing wood rot (Fernández-Fernández et al., 2019; Hickman et al., 2011). Ultimately, the decay fungus destroys cell wall components, including cellulose, hemicellulose, and lignin, that make up the woody portion of a tree (Hickman et al., 2011). Decaying can lead to decreased absorption of plant water and nutrients (Sumardi & Widyastuti, 2007), internal damage, and increased risk of hazards (Hanum et al., 2020). The conks and fruiting bodies suggest that the main stem has been damaged. The second damage is the discovery of a termite gallery, which reaches 25%. The termites indicate that the wood has experienced decay (Zanne et al., 2022). Wood decay harms trees because the trunk can no longer support itself. It increases the risk of falling if stressed by wind, heavy rain, or other conditions (Hickman et al., 2011). Falling trees can cause economic losses in urban forest landscapes (Bari et al., 2021;

Kalleshwaraswamy et al., 2022). From the indicators, there is no doubt that there is decay so that tomography could estimate its extent (Durlak et al., 2017; Hanum et al., 2020; C. J. Lin et al., 2008; Rachmadiyanto et al., 2022).

Figure 2. Damage location and damage descriptions.



Regarding the description of the target, it was identified BBG employees, visitors, plant collection, and infrastructure (roads, sanitation channels). Damage to branches and crowns was found in only two trees, *Shorea multiflora* and *Vatica teysmanniana*. The average likelihood of failure on a DHT crown is possible, the impact is low, the possibility is unlikely, the consequences are negligible, and the risk rating is low. The average likelihood of failure in DHT trunks is improbable to probable, the impact is low to medium, the possibility is unlikely to somewhat likely, the consequences vary from negligible to significant, and the risk rating is low to moderate. No (or in a few trees) damage to tree roots was found, so the risk rating was low.

The average of the three parts of the tree (branches/crown, trunk, roots) has a low to moderate risk rating, meaning that mitigation measures do not need to be taken immediately and can be recommended to maintain and monitor progress (Smiley et al., 2012). Mitigation measures for cutting down trees are also not recommended in the risk category like this because the potential damage from the impact of falling trees is relatively low (Klein et al., 2019). However, one *Shorea multiflora* tree has a high-risk rating due to the root collar's termite nests and open wounds.

3.3. Comparison tree level index and risk rating

The tree-level index and risk rating value are presented in Table 6.

The results of calculating the health index value (HIV) and risk rating value (RRV) show that three tree species need to be watched compared to others, namely *Shorea balangeran*, *S. guiso*, and *S. multiflora*. All three have HIV values categorized as having mild damage (Rachmadiyanto & Rinandio, 2019). However, if not treated further, it is feared that this will increase to moderate damage. The same thing was also produced in measurements using the ISA method, which showed that *S. guiso* and *S. multiflora* had the highest risk rating. The risk rating value indicates that the tree poses a danger to surrounding targets, such as humans, trees, roads, and buildings.

Table 6. Comparison of tree level index and risk rating.

Species	Health index value (FHM)	Risk rating value (ISA)	Pearson correlation
Anisoptera marginata Korth.	3.6 ± 1.1	1.2 ± 0.0	0.93
Dipterocarpus alatus Roxb. ex G.Don	1.8 ± 2.5	1.0 ± 0.0	
Dipterocarpus gracilis Blume	0.8 ± 1.6	1.0 ± 0.0	
Dipterocarpus retusus Blume	0.6 ± 1.4	1.0 ± 0.0	
Dipterocarpus turbinatus C.F.Gaertn.	1.8 ± 2.6	1.2 ± 0.2	
Hopea mengarawan Miq.	2.0 ± 2.8	1.2 ± 0.2	
Hopea pierrei Hance	2.6 ± 1.7	1.0 ± 0.0	
Hopea sangal Korth.	0.0 ± 0.0	1.0 ± 0.0	
Shorea balangeran (Korth.) Burck	6.0 ± 5.2	1.2 ± 0.2	
Shorea guiso (Blanco) Blume	8.6 ± 2.5	1.4 ± 0.2	
Shorea leprosula Miq.	1.1 ± 1.9	1.0 ± 0.0	
Shorea multiflora (Burck) Symington	8.3 ± 4.6	1.5 ± 0.7	
Shorea seminis (de Vriese) Slooten	0.0 ± 0.0	1.0 ± 0.0	
Vatica bantamensis (Hassk.) Benth. & Hook.f. ex Miq.	3.4 ± 0.8	1.2 ± 0.2	
Vatica pauciflora (Korth.) Blume	2.7 ± 3.1	1.1 ± 0.1	
Vatica teysmanniana Burck	0.7 ± 0.9	1.0 ± 0.0	

The index correlation between the tree level index (FHM) and risk rating (ISA) resulted in a positive and very strong (0.93). So, the recommendation is that both methods are reliable for use simultaneously or separately. Only if we want to assess tree health in detail can we use the FHM method. Although FHM is used to determine forest ecosystem health, such as site quality, tree vitality, productivity, and biodiversity (E. I. Putra et al., 2010; I. E. Putra, 2004; Putri et al., 2016), we can use it at the scale of individual trees (Herliyana et al., 2022; Rachmadiyanto et al., 2021; Rachmadiyanto & Rinandio, 2019). We can see the health of individual trees from the location of the roots to the tips of the leaves and see the type of damage and severity. The results of the health measurements will be calculated and produce a tree health classification, namely healthy, experiencing light, moderate, or even severe damage (E. I. Putra, 2021; E. I. Putra et al., 2010). His method is easy to do, but we need to pay attention to the characteristics of the damage types so that they can easily differentiate one from another.

However, if we want to know the level of danger of a tree to the target (humans, buildings, surrounding trees), we can use the ISA method. This method is based on the results of our visual observations based on a reference form (International Society of Arboriculture, 2013). Generally, this method is used by city managers for assessment of the risk condition of the urban tree, which is relevant for society, aiming to determine risks and their management impacts (Calaza & Iglesias-Díaz, 2016). We must remember that no tree is risk-free because all trees carry risk (Coder, 2013; Pokorny, 1992). Some situations allow the risk of a tree to be accepted and managed. In contrast, others require treatment to reduce risks, such as pruning or felling (Coder, 2013). The final recommendations can serve as a basis for evaluating tree structure based on management practices, particularly pruning (Coelho-Duarte et al., 2021).

4. CONCLUSION

Dipterocarp heritage trees (DHT) growing in Bogor Botanic Gardens have high vigor but low slenderness, so the trees have a lower failure rate. The lower the slenderness, the lower the probability of failure if this variable alone is considered without the combined influence of other defects. The damage detected was predominantly in the trunk to the crown stem. The most frequent types of DHT damage were indicators of advanced decay, open wounds, and termite galleries. From the indicators, there is no doubt that there is wood decay so tomography could estimate its extent. The results of the correlation analysis show that the assessment of tree health using the forest health monitoring method with the International Society of Arboriculture has a very strong relationship. The two methods can be used together or separately according to the purpose of the assessment (tree level index or risk rating) in Botanic gardens.

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