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Decay Tree Detection in Bogor Botanic Gardens Collection Using Sonic Tomograph Technology

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Abstract

Bogor Botanic Gardens is an ex-situ plant conservation area in Indonesia. Since BBG is 103 years old, many *collections are 100 years old or older. These antique collections may sustain damage, such as broken or collapsing, endangering visitors and employees. As a result, monitoring tree health at BBG is a critical task. According to the tree health monitoring data, 73 of 244 trees were further checked using the PiCUS Sonic Tomograph. Trees from the Fabaceae (31%) and Myrtaceae (10%) families were the most frequently checked. Walnut trees from the Burseraceae family had the most specimens (47,94%). The PST effectively provides an immediate picture of the stem condition by calculating solid and decaying wood percentage values*.

Keywords: Tree Health Monitoring; Plant Collection; Old Trees; PiCUS Sonic Tomograph

Introduction

The Botanic Gardens are an ex-situ conservation area that preserves biological wealth away from its natural habitat. Based on its geographical location, the botanic garden is located in a strategic area in urban areas (urban spaces). These advantages can directly connect nature and humans and are not limited to ecological, social, economic, or cultural values (Forbes, 2008). According to Forbes (2008), botanical gardens can also change the world through medicine, plant naming, economic botany, and modification.

According to Presidential Decree No. 93 of 2011, Botanic Gardens are ex-situ plant conservation areas with documented plant collections that are organized based on taxonomic, bioregional, thematic classification patterns or a combination of these patterns for conservation, research, education, tourism, and environmental service activities. Bogor Botanic Gardens is Indonesia's oldest botanic garden (BBG). Furthermore, BBG serves as a mentor and catalyst for developing Regional Botanic Gardens (KRD) throughout Indonesia (Purnomo et al., 2020).

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The Bogor Botanic Gardens, strategically located in the heart of Bogor City, have emerged as the undisputed queen of eco-friendly tourism for Bogor residents and visitors alike (Affandi et al., 2020). The beautiful natural charm and trees are the main draws for visitors to the BBG, which spans an area of 87 hectares. However, the presence of old trees prone to falling and breaking endangers visitors and even employees working within the BBG itself. Damage caused by biotic and abiotic factors can result in falling or broken trees (Safe'i and Machya, 2017). Weathering of the stem can result from this damage.

One effort that can be made to reduce the risk of these old trees is to detect their health. This tree health detection system aims to predict the occurrence of damage so that employees working in the BBG and visitors traveling in the BBG are safer. The same was done at the urban forest located in the Metro City Forest, which aims to ensure the safety of visitors (Abimanyu et al., 2019).

According to Zulkarnaen et al. (2020), there were 22 fallen trees in the BBG (Zulkarnaen et al., 2020). Furthermore, according to the BBG tree health analyst team's observations, four trees fell between January and February 2021. As a result, to mitigate and minimize the impact of damage caused by fallen trees, it is necessary to check the health of trees regularly. This paper will explain how the checks were conducted between 2017 and 2020.

Research Methods

From 2017 to 2020, the research was carried out at the Bogor Botanic Gardens (Figure 1). All collection and non-collection plants in the Bogor Botanical Gardens that are at risk are being monitored for their health. Monitoring is carried out using a combination of FHM (forest health monitoring) (Mangold, 1997) and ISA (forest impact assessment) (International Society of Arboriculture).

The FHM and ISA results that showed the occurrence of stem weathering were checked further using the PiCUS Sonic Tomograph (PST). On the main stem, PST detects weathering (damaged wood) and density (solid wood). The tool operates on the speed of vibration propagation at each sensor point to generate an illustration that describes the condition of the rod based on color degradation (Figure 2).

Research Results and Discussion

Risk Tree Observation Results

The summary of BBG tree health monitoring checks from 2017 to 2020, BBG conducted 244 tree health checks, with 73 trees recommended for further observation using the PiCUS Sonic Tomograph (Figure 3). (Helmanto et al., 2017; Mujahidin et al., 2018; Suhatman et al., 2019; Zulkarnaen et al., 2020). The distribution of these trees in the BBG was random, but most were in strategic locations along the main road and visitor gathering areas. When trees fall in these areas, they could cause significant damage. The Fabaceae and Myrtaceae families dominated the tree composition, accounting for 31% and 10% of the total (Figure 4). This confirmed that the potential for stem damage in Fabaceae and Myrtaceae species was relatively high. Based on visual inspection, these trees appeared in good condition with normal growth vigour. However, additional PST tool observations were required for a more accurate justification.

Figure 1
Map of Bogor Botanic Gardens

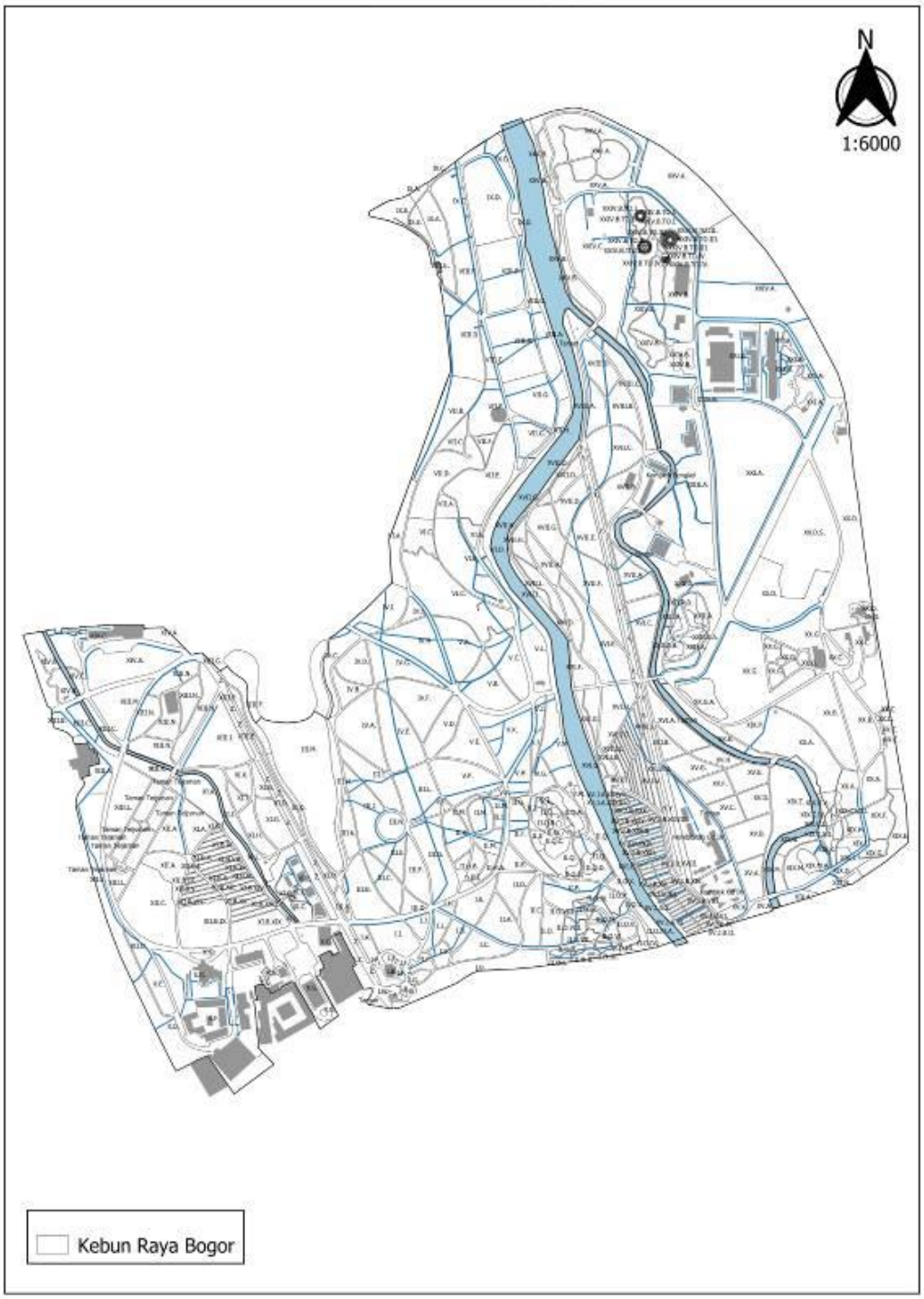
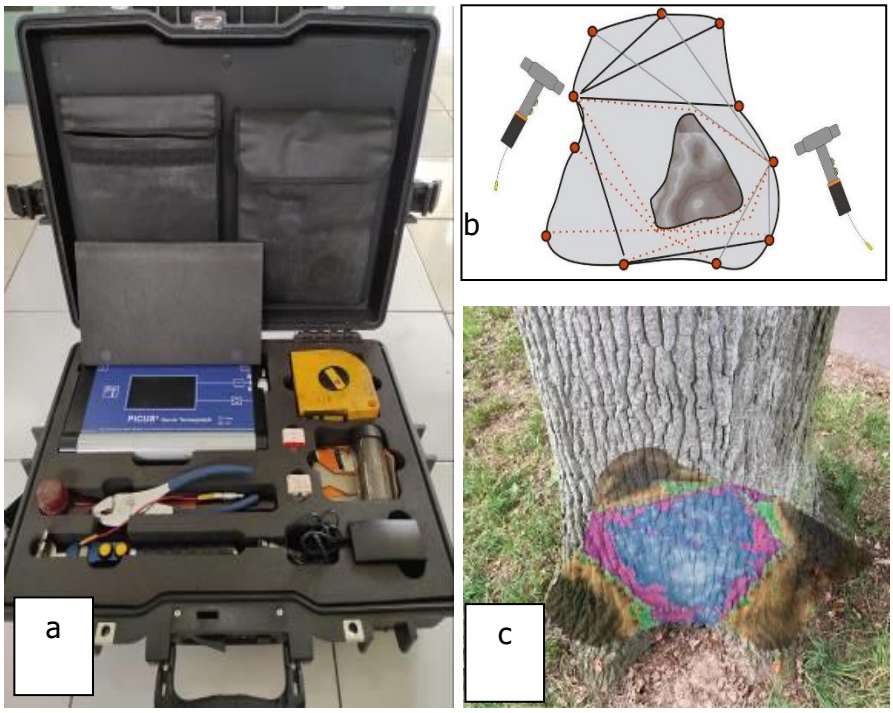


Figure *2*
A=PiCUS Sonic Tomograph Tool, b=schematic procedure for using the tool with a sensor hammer, c=schematic tomogram image after checking. Color Description: black (100% solid), brown (solid), green (no indication of weathering initiation), purple (weathered process), light blue-blue (weathered-already hollow)



The PST tool made walnuts (Canarium spp.) the most frequently checked tree species (Table 1). Most of the walnut trees in BBG were planted on the main roads, also known as Jalan Kenari I and Jalan Kenari II. In addition to the location factor, the age of planting the walnut trees was generally more than 100 years (old trees), requiring regular and periodic monitoring and checking. According to Mujahidin et al. (2018), at least three walnuts had a high percentage of rotting stems, ranging from 76.1% to 74.5% to 66.8%.

Trees Check Results Using PiCUS Sonic Tomograph

A. Walnut (*Canarium* spp.) PST had been used to inspect 35 walnut trees. Visual observations of walnut tree trunks revealed they were in good condition, with normal trunk vigor, but some trees had advanced weathering. The results of checking the walnut trunks at various height levels revealed that weathering had occurred inside the walnut trunks, as evidenced by the dominance of the bright blue color (Figure 5a-c).

Mujahidin et al. (2018) discovered that using the PST tool in conjunction with the FHM method strongly correlated with the category of rootstock damage in walnuts. The fruiting body of the Ganoderma mushroom was the main feature that usually appears and could be seen directly on weathered walnut trees

Figure 3
Application of using PST tool on Michelia alba collection number I.B.15

Figure 4
Percentage of families checked using PST

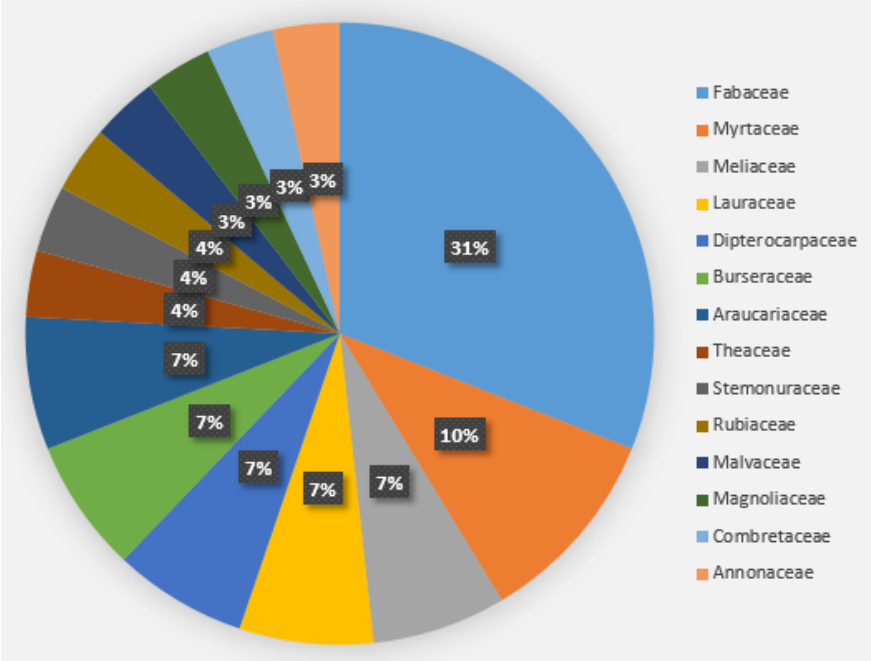
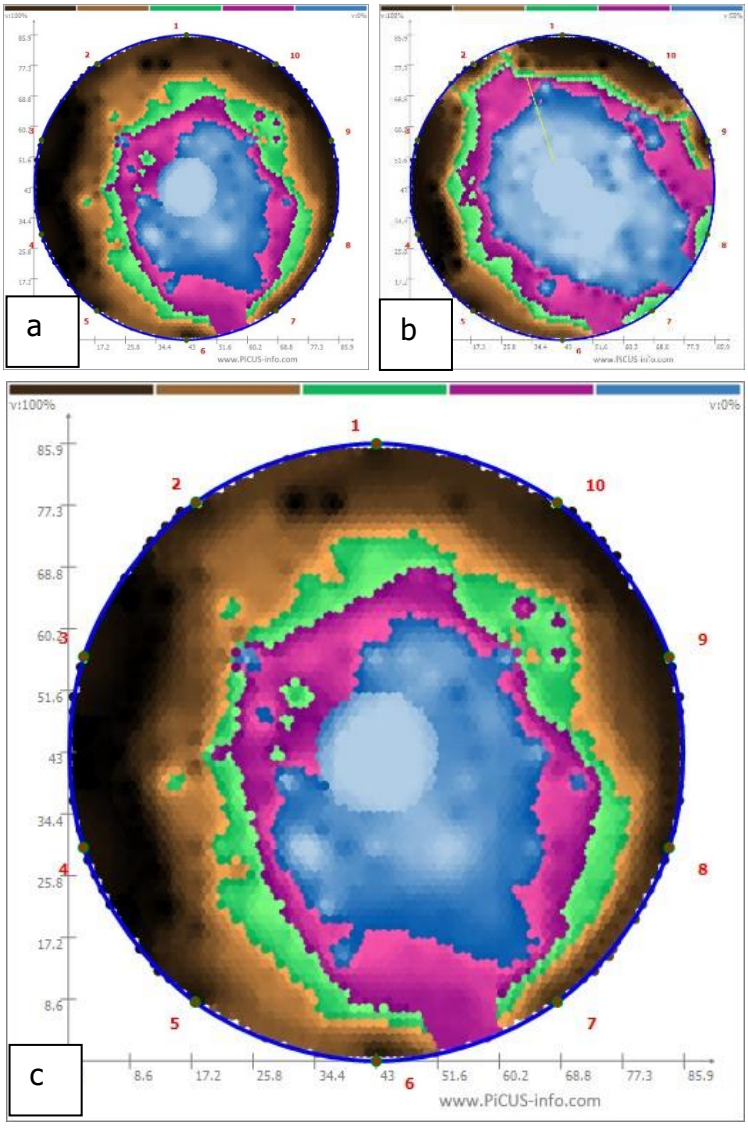


Figure 5

The tomogram of Walnut's stem using PST. a=height 50 cm, b=height 100 cm, and c=height 150 cm



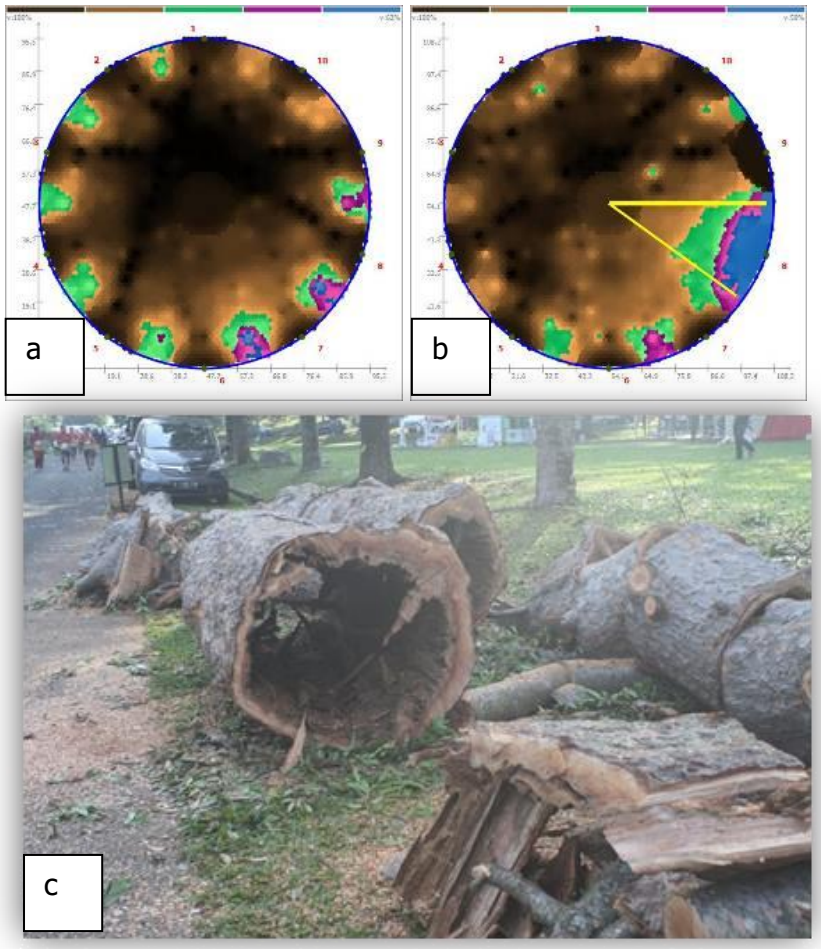
Damar (Agathis dammara)

The damar (*A. dammara*) tree was the second largest tree checked with PST. On January 11, 2015, a fallen tree caused four deaths, and three other fatalities were treated in a hospital on Jalan Astrid (personal communication with Sumarno). The percentage of trunk density of the Damar tree trunk is shown as dominant in black-brown colour (Figure 6) in the tomogram. This means the Damar stem is still solid. However, periodic inspections are still required for signs of weathering, which are indicated by a bright blue colour (Figure 6b). Periodic inspections are expected to provide information on the weathering development of stems in the resin.

Table 1
List of trees checked using PiCUS Sonic Tomograph

No	Species	Family	Total
1	*Canarium* spp.	Burseraceae	35
2	*Agathis dammara*	Araucariaceae	3
3	*Pterocarpus indicus*	Fabaceae	3
4	*Albizia falcaltaria*	Fabaceae	2
5	*Araucaria columnaris*	Araucariaceae	2
6	*Delonix regia*	Fabaceae	2
7	*Intsia bijuga*	Fabaceae	2
8	*Ceiba pentandra*	Malvaceae	2
9	*Swietenia mahagoni*	Meliaceae	2
10	*Canarium decumanum*	Burseraceae	1
11	*Cyathocalyx cf martabanicus*	Annonaceae	1
12	*Dipterocarpus intricatus*	Dipterocarpaceae	1
13	*Eucalyptus alba*	Myrtaceae	1
14	*Hymenaea stilbocarpa*	Fabaceae	1
15	*Koompassia excelsa*	Fabaceae	1
16	*Litsea umbellate*	Lauraceae	1
17	*Metrosideros petiolata*	Myrtaceae	1
18	*Michelia alba*	Magnoliaceae	1
19	*Myristica sp.*	Myrtaceae	1
20	*Neolitsea sp*	Lauraceae	1
21	*Neonsuclea calycina*	Rubiaceae	1
22	*Parkia timoriana*	Fabaceae	1
23	*Pterocarpus echinatus*	Fabaceae	1
24	*Sandoricum koetjape*	Meliaceae	1
25	*Schima wallichii*	Theaceae	1
26	*Shorea multiflora*	Dipterocarpaceae	1
27	*Sindora bruggemanii*	Fabaceae	1
28	*Stemonurus celebicus*	Stemonuraceae	1
29	*Terminallia bellirica*	Combretaceae	1

Figure 6
a-b=tomogram of Damar tree trunks using PST, c=the hole caused by the Coptotermes curvignatus attack



Helmanto et al. (2018) discovered that the termite *Coptotermes curvignatus* attack was the leading cause of severe weathering of the Damar tree core wood based on previous checks on Damar trees (Figure 6c). In four trees, the weathering of the damar trunk reached 60%.

C. Fabaceae

Many Fabaceae tree species were suspected of being damaged, so additional checks were performed using the PST tool (Helmanto., 2018). Falcataria falcata, Intsia bijuga, Pterocarpus indicus, Delonix regia, and Koompassia excelsa were among the species seen (Figure 7).

The Fabaceae family generally has a relatively dense percentage of stem density. However, in K. excelsa, the collection number I.I.58A shows a high percentage of weathering, reaching >70%. This species has a planting age of 107 years and is one of the BBG icon trees (Figure 8). This iconic type is a collection of plants grown from seeds that E.F. de Vogel collected from Kalimantan (Latifah et al., 2020).

Figure 7
Tomogram results checking on several species of the Fabaceae family. a=Falcataria falcata, b=Intsia bijuga, c=Pterocarpus indicus, d=Delonix regia, and e=Koompassia excelsa

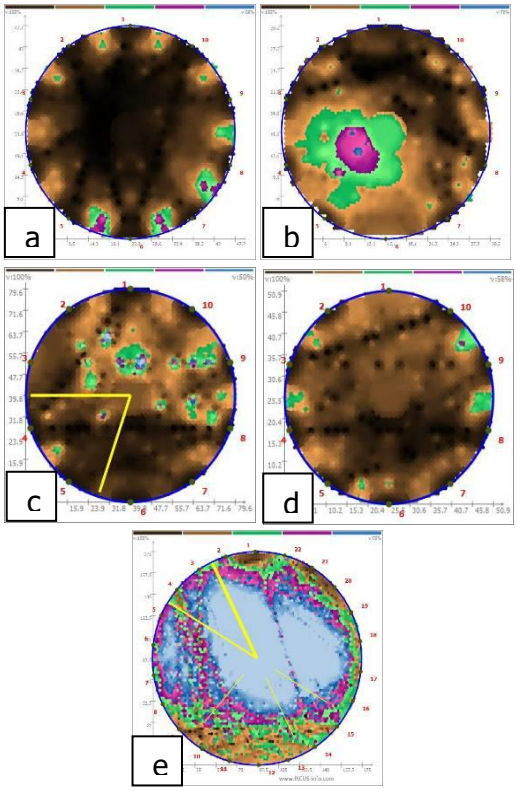


Figure 8
Koompassia excelsa tree in BBG, a 107 years old collection

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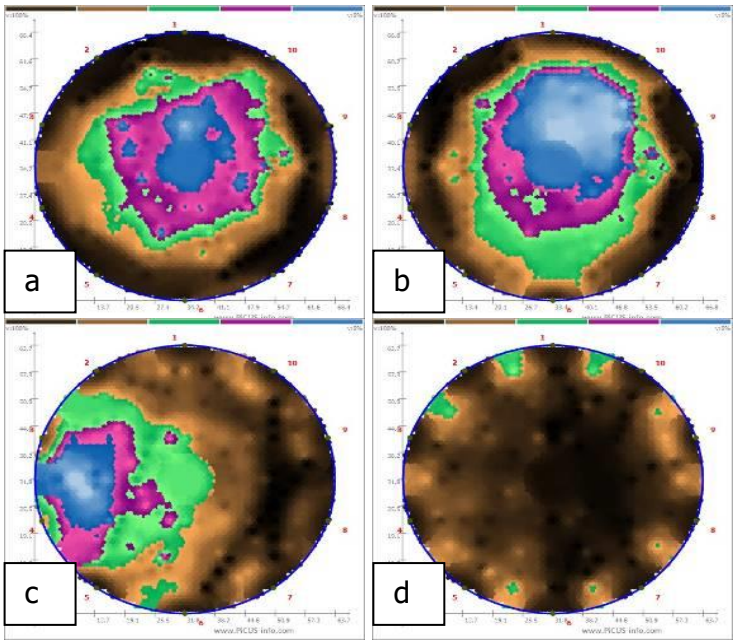
The appearance of *K. excelsa* is intriguing, with excellent vigour, normal growth, and a shady canopy. However, the main stem condition has a high percentage of weathering behind the visual conditions. As a result, the preventive measure is to reduce the crown load through pruning.

Araucaria (Araucaria columnaris)

The condition of *Araucaria columnaris* trees was examined on two specimens collections of V.F.40 and V.F.40a. The weathering percentage was 51% when the collection number V.F.40 was checked in layer one at the height of 50 cm from the ground (Figure 9 a-b). These findings indicate that the weathering process occurred at two different height levels, and it is suspected that weathering occurred at 1 m and above the stem.

Figure 9

Measurements in the Araucariaceae family. a-b=collection A. columnaris V.F.40 layer one and layer 2; c-d=collection A. columnaris V.F.40A layer one and layer 2



The checking for collection number V.F.40A reveals various results. The appearance of the tomogram in layer 1 (50 cm) shows a 37% treatment percentage, whereas layer 2 tends to be dense (Figure 9c-d). Both specimens are in the exact location and have been there for more than 100 years. After feeding termites with termite bait containing the ingredient hexaflumuron, it was discovered that the termites Coptotermes sp. cause tree weathering. This termite is thought to frequently attack the Araucariaceae family species (Helmanto et al., 2018).

Challenges of Monitoring Tree Health in BBG

The difficulty in checking tree health monitoring in BBG stems from the fact that BBG is an ex-situ conservation area with the primary goal of saving plant species throughout Indonesia and replanting them as a collection. However, in terms of visitor, employee, and other plant collection safety, monitoring trees' health is critical to minimize the impact of risks so that conservation and safety can coexist.

Bogor Botanic Gardens has plant collections of old trees ranging from 99 to 198 years old, totalling 2238 trees (Suhatman, 2020). Many

collection plants make mapping the health class of the collection plants difficult. As a result, regular and periodic checks are an efficient method of classifying three Health classes. PST testing is a more practical approach to assessing tree trunk health because it can identify the percentage of stem density and decay, allowing preventive measures to be considered and implemented.

The location of tree damage is divided into three sections: the main trunk, the branching-top area, and the root neck. According to Helmanto et al. (2018), tree damage is commonly found in BBG at the crown and branches, with visible symptoms such as dryness, rot, and rot. This is related to environmental factors such as tree competition, stand density, and humidity, which cause tree branches to die/damage (Kint et al., 2010). Furthermore, the location of the canopy and branching is usually vulnerable to parasitic attacks, which can harm the aesthetics and even result in the death of the host plant (Hutabarat et al., 2020).

Conclusion

In 2017-2020, 244 trees were checked for health, with 73 further examined. The families checked with PST were Fabaceae and Myrtaceae, with walnut having the most specimens. Termites and *Ganoderma* sp. are the most common causes of stem weathering. Furthermore, checking tree health monitoring in the Bogor Botanical Gardens is important because it is not only for safety but also has a high conservation value. Because the BBG collection plants will age and be subject to weathering, both naturally and through termite attacks, the use of PST is a necessary and highly effective step in determining tree health.

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Author Contribution Statement

We declare Rizmoon N. Zulkarnaen to be the Main Contributor in the preparation of this paper, with other authors serving as Supporting Contributors.

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