Tree health assessment of Agathis borneensis Warb. in Bogor Botanical Garden using arborsonic

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Abstract. Bogor Botanical Garden has ± 14,000 living plant collections including shrubs, herbs, climber and trees. Tree collections exhibit different characteristics, larger dimensional shapes and can reach old ages. However, trees collections possess some flaws that could result in materials harm and other losses. The aim of this research was to define health condition of Agathis borneensis trees, as a base of determining treatment in Bogor Botanical Gardens. The method used was a combination of visual and sound waves assessment using arborsonic. Targeted trees were selected based on accessibility, tree diameter and age, and pest attack. Each tree was assessed with high risk by visual assessment and assessed using arborsonic on main stem. The height level of measurement point was based on sound, which was produced by rubber hammer tapping. This study concluded that there were 32 Agathis borneensis trees observed, where 4 trees were chosen as first priorities due to their decay level of above 60%, whereas the other 11 trees turned as the second priorities (30-60% decay level) and the last 17 trees became the third priorities (<30% decay level).

1. Introduction
Bogor Botanical Gardens (BBG) has a primary function as an ex-situ plant conservation. Based on Presidential Decree No. 93 Year 2011, in addition to conservation, BBG also carries some functions as an environmental services provider, research, education and tourism [1]. As an excessive conservation organization, BBG owns many collections of living plants with a considerable number approximately fourteen thousand species of plants in form of shrubs, herbs, climber and trees.

Tree collections have different characteristics compared to the other collections. One of them, trees have larger dimensions than other collections and can reach old ages. However, tree collections undergo with some flaws that could result in some materials harm and other losses. Older trees have a greater potential to fall down. Based on such conditions, management of BBG shall take preventive actions to prevent the occurrence of fallen trees by assessment the health level of trees. This health assessment of trees was implemented to avoid the occurrence of tree fallings or other damage. In 2015, there were approximately 150 trees observed using arbosonics and more than 150 trees were visually checked. One species of plant which suffered with high risk of falling and required the tree health condition check is Agathis borneensis.

Agathis borneensis is a member of Araucariaceae family which is derived from the Borneo island. According to the IUCN red-list [2], A. borneensis currently is enlisted with Endangered A4cd status.
A. borneensis is an emergent tree with 55 metre in height and 100 cm in diameter in BBG. This species is beneficial as medicinal plant, where its powdered wood is used to treat headache and myalgia [3] and its leaves extract has antiplasmodial and cytotoxic activities [4]. A. borneensis trees are widely planted in BBG as a collection and non-collection trees for ornamental needs. Some trees were infested by suspected subterranean termites. Visually the disturbance is difficult to detect since it is not visible from outside and trees may appear normal. Therefore, we need technology that can be used to assess the damage more accurately.

Arborsonic is a tool which can choose and develop for helping in tree health assessment. Some products and techniques are now marketed for detecting and assessing decay in trees, reviews of which can be found in the literatures [5,6,7,8]. Equipments and techniques such as the resistograph, drilling, and the increment borer involve drilling through the bark into the xylem [9,10], though there may be some disadvantages associated with drilling [7]. Picus Sonic Tomograph [11] and Arborsonic were developed as non-invasive methods to quantify and locate wood decay. It can produce an image of the internal structure of a solid object by recording differences in the speed of sound wave transmission.

The purpose of this research was to determine the A. borneensis health condition using arborsonic as a basis for its maintenance treatment.

2. Methods
This research located in Bogor Botanical Gardens (S: 06° 036’155”, E: 106° 047’825”) with altitude f 291 metre above sea level A. borneensis tree health assessment was held during May - August 2015. There were 32 trees assessment undertaken using arborsonic located at several areas in BBG. The tools used were rubber hammer, arborsonic equipment set (sensors, hammer, and software from arborsonic) and diameter tape.

Assessment of damage using arborsonic was held at 0-200 cm high of main stem. Measuring point of damage should be decided before checked by arborsonic. Measuring point was chosen based on sound on the stem while beaten with a rubber hammer or through visual assessment. After measuring point of damage was decided, the circumstance of stem was measured next to decide amount of sensor. Arborsonic consisted of a set of sensors (typically 8 to 10) that were connected to the trunk. Sound waves were produced by tapping each sensor with a small hammer. The system measured the transmission time from each impact with the hammer to each sensor. By measuring the distances between sensors, apparent sound velocities were calculated by the system software, from which wood density was determined [11].

Area of decay was calculated as a percentage of squares identified as decayed divided by the total area of wood. For the tomograms, the area of decay was calculated by the arborsonic software. The tomograms consisted of some colours gradients, where green indicates good condition, yellow meant the on-going decay process, red meant higher decay level, blue meant hollow condition. Each measured tree portrayed different handling priority scale depending on several conditions thus treatment for every single tree could be different. Trees with higher priority would get faster and more attention-forward treatments than low prioritized ones. Trees with high priority are trees located at crowded area, with large diameter stem, older trees or disclosing visible attack of diseases and pests.

3. Result and discussion

3.1 Trees health condition
Results of this research are showed by 32 trees health assessment summary. Table 1 denoted that four trees of A. borneensis suffered with high risk damage with decay level higher than 60% and located in main road of Bogor Botanical Garden. In addition, there were 11 trees which have moderate risk damage, approximately were 30-60% decay. Then at last, there were 17 low risk trees indicated healthy enough with decay level under 30%.
Table 1. Tree health assessment result of *Agathis borneensis* using arborsonic at Bogor Botanical Gardens.

| No | Code          | Status       | Decay level High (cm) | Decay level (%) | Maximum decay (%) | Description                                  |
|----|---------------|--------------|-----------------------|-----------------|--------------------|----------------------------------------------|
| 1  | AB 8 4/6/2015 | Non collection | 120                   | 75              | -                  | 75 The first priority requires heavy pruning |
| 2  | AB 27 23/6/2015 | Non collection | 130                   | 68              | 200 69            | 69                                           |
| 3  | AB 33 25/6/2015 | Non collection | 100                   | 63              | 200 63            | 63                                           |
| 4  | AB 28 23/6/2015 | Non collection | 50                    | 60              | 150 61            | 61                                           |
| 5  | AB 3 3/6/2015  | collection    | 100                   | 37              | 200 57            | 57 The second priority needs light pruning and periodical checks |
| 6  | AB 16 10/6/2015 | Non collection | 100                   | 38              | 200 57            | 57                                           |
| 7  | AB 21 11/6/2015 | Non collection | 100                   | 56              | -                  | 56                                           |
| 8  | AB 26 23/6/2015 | Non collection | 110                   | 43              | 150 51            | 51                                           |
| 9  | AB 22 11/6/2015 | Non collection | 100                   | 43              | 150 50            | 50                                           |
| 10 | AB 24 10/6/2015 | Non collection | 100                   | 49              | 170 47            | 49                                           |
| 11 | AB 23 11/6/2015 | Non collection | 100                   | 45              | 200 49            | 49                                           |
| 12 | AB 24 23/6/2015 | Non collection | 100                   | 49              | 170 47            | 49                                           |
| 13 | AB 11 5/6/2015  | Non collection | 100                   | 46              | 170 40            | 46                                           |
| 14 | AB 25 23/6/2015 | Non collection | 100                   | 22              | 200 41            | 41                                           |
| 15 | AB 18 10/6/2015 | Non collection | 100                   | 34              | 200 21            | 34                                           |
| 16 | AB 2 13/8/2015  | Non collection | 110                   | 22              | 200 19            | 22 The third priority tree is stated in good, healthy condition and requires periodical pruning. |
| 17 | AB 17 10/6/2015 | Non collection | 100                   | 19              | 200 5             | 19                                           |
| 18 | AB 34 25/6/2015 | Non collection | 50                    | 16              | 100 0             | 16                                           |
| 19 | AB 2 15/8/2015  | Non collection | 120                   | 5               | 180 14            | 14                                           |
| 20 | AB 4 13/8/2015  | Non collection | 50                    | 11              | 180 0             | 11                                           |
| 21 | AB 1 13/8/2015  | Non collection | 60                    | 0               | 200 10            | 10                                           |
| 22 | AB 3 13/8/2015  | Non collection | 110                   | 1               | 160 9             | 9                                             |
| 23 | AB 1 3/6/2015   | Non collection | 178                   | 2               | 203 7             | 7                                             |
| 24 | AB 4 4/6/2015   | Non collection | 100                   | 4               | 200 7             | 7                                             |
| 25 | AB 32 24/6/2015 | Non collection | 120                   | 5               | 200 1             | 5                                             |
| 26 | AB 2 3/6/2015   | Non collection | 100                   | 2               | 170 3             | 3                                             |
| 27 | AB 31 24/6/2015 | Non collection | 100                   | 3               | 200 0             | 3                                             |
| 28 | AB 1 15/8/2015  | Non collection | 80                    | 1               | 180 3             | 3                                             |
| 29 | AB 5 4/6/2015   | Non collection | 120                   | 2               | 200 0             | 2                                             |
| 30 | AB 6 4/6/2015   | Non collection | 120                   | 0               | 200 1             | 1                                             |
| 31 | AB 7 4/6/2015   | Non collection | 120                   | 1               | -                 | -                                             |
| 32 | AB 3 3/6/2015   | Non collection | 100                   | 0               | 180 0             | 0                                             |

Figure 1 is an example of *A. borneensis* image results with code AB 8 4/6/2015 using arborsonic. The shape of imaging was not perfectly circular but had ten corners. This was because the influence of sensors numbers that were used in assessment method, where there were 10 sensor points. Images were dominated by blue colors that indicated hollow or heavy decay. Meanwhile red color had meaning of weathered/rotten, yellow had meaning as starting-point of decomposition process and green was a part of well-conditioned trees. In this figure, the percentage of decay level reached 75%. 

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IOP Publishing
DOI: 10.1088/1755-1315/203/1/012032

ISATrop2017

IOP Conf. Series: Earth and Environmental Science 203 (2018) 012032
Figure 1. Imagery of the stem of Agathis borneensis (AB 8 4/6/2015) seen with arborsonic compared with real conditions after logging.

Symptoms of porosity in the stem should be defined and treated as early as possible. According to Nuhamara et.al [12], even the slightest level of damage condition occurred in the trunk of tree may brings very large influence on the tree health itself compared to which occurred in the canopy. In the stem of tree, there are phloem system which serves to transfer food and water from roots to the leaves and buds. In addition, decay which occurs in the base of stem also is more dangerous because base of stem becomes the heavy point of stem and tree canopy. So, the trees which are damaged on main stem are more dangerous than ones in branches or twigs.

3.2 Cause of damage
After detailed damage observation of A. borneensis, a major damage of A. borneensis tree was found. Most dominant cause was subterranean termites’ attack. Termite attack on trees may impact directly physical damage and often affects to the root structure of plants. Other effects are disruption of nutrients and water supply process in plants, decreased plant resistance from other destructive attack factors such as diseases and other pests [13].

The results showed that there are four kinds of termites discovered in A. borneensis trees. The four kinds of termites were Microtermes, Macrotermes, Schedorhinotermes, and optotermes. From all termites’ attacks, optotermes is the most malignant termite. Based on identification, type of termite that attacked A. borneensis tree was Coptotermes curvignathus (figure 2). The main characteristic of soldier termite or C. curvignathus is a lean body with a white abdomen [13]. C. curvignathus nest is in the ground by depth approximately 1.5 meters. In certain circumstances, this termite will make secondary nest (subsidiary nest) on the object of attacks, both in soil and above soil surface. In lowlands forests or gardens of Java and Sumatra, main nest of this termite is often found undersides of rubber trees and pine trees. The initial attack is difficult to detect and will be known after tree has been several times damaged (decay and broken).
3.3 Tree health treatments

The trees with more than 60% decay level received pruning treatment with different intensities according to field conditions. The four trees with more than 60% decay level are given heavy pruning treatment to reduce the burden of tree so it would not easily fall. Heavy pruning is carried out by cutting branches of trees in large amount. In addition, besides trees with decay level above 60%, there are trees with decay level between 30%-60%. Those particular trees are recommended to get pruning with different intensity depending on location and circumstances. Trees with moderate damage can be pruned and get periodical condition assessment. Light pruning is undertaken by cutting the tree branches in small amounts. Whereas, the other seventeen healthy trees only need to be checked periodically.

Pruning is trees treatment by cutting branches or main stem. Pruning serves numerous benefits if done at the right time and condition. For example, pruning at cacao plants aims to achieve efficiency of sunlight utilization as much as possible, hence plant can achieve higher productivity [14]. Pruning would add more space for light to reach the ground, decrease moisture and reduce pests risk, diseases and fungi attack. [14] stated as well that less pruning (too mild) leads to unhealthy microclimate that can increase pest and disease attacks. In addition, pruning purpose is to provide sufficient space, form canopy that can increase flowering and seed production for higher propagation.

4. Conclusion

There were 32 A.borneensis assessed using arborsonic in BBG. Total 4 trees were classified to first priority treatment due to decay level percentage above 60%. Other 11 trees were in second priority treatment (damage of 30-60%), while the last 17 trees were grouped into the third priority. The major cause of A. borneensis damage was C. curvignathus termites’ attack.
Acknowledgments
The author would thank Dr. Didik Widyatmoko, M.Sc. and Dr. rer. hort. Reni Lestari who has provided cooperation opportunities between Center for Plants Conservation Botanic Garden – LIPI with Forest Products Research and Development Center. Also for all technicians who have given technical support at field during this research.

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