Mapping the Dynamics of Dead Trees Collection to Support Sustainable Landscape Management at Bogor Botanic Gardens

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Abstract. The main activity of botanic gardens is the recording of plants collection data in the accessible database form which also includes the dead record of trees collection. The dynamic data of dead tree collection not only important as a monitoring tool of the number of garden specimens, but also as a base of the decision-making process in entire botanic gardens’ landscape management especially in facing an increased worldwide threat to the plants’ diversity and its habitat. Bogor Botanic Gardens (BBG) has been developing over 202 years since the institution establishment in 1817. The research about dead trees collection at BBG was conducted using a quantitative descriptive method by identifying dead trees specimen’s data based on the number, family and location during the last 20 years. From the field of specimen’s location in the database, data was analyzed spatially to produce a map of dead trees distribution based on planting blocks (vak). A deeper interpretation of the distribution map might be a valuable source for the management recommendation for the collection’s maintenance practice of sustainable management’s support in the future.

Keywords: Bogor Botanic Gardens, dead trees, plants collection, sustainable landscape management

1. Introduction

Botanic Gardens Conservation International (BGCI) defined botanic gardens as institutions holding documented collections of living plants for of scientific research, conservation, display, and education¹. To provide an additional definition, Peraturan Presiden No. 93/2011 explained botanical gardens are ex-situ plant conservation areas that have a collection of documented plants arranged according to taxonomy, bioregion, thematic, or a combination of patterns suitable for conservation programs, research, education, tourism, and environmental services⁷. As a consequence of these definitions, botanic gardens have taken on significantly broader roles in many areas of scientific, horticultural and educational endeavor, including living collection management. The management’s priorities should have to enhance the practice of botanic gardens in conservation that focused and planned; however, a better approach in institutional ex-situ and in-situ conservation programs has to be developed and implemented³.

Over the last decade, there are up to 3,571 botanical institutions worldwide that concerned with conserving plant diversity². Bogor Botanic Gardens (BBG) is the oldest botanic garden in Southeast Asia that plays an important role in conserving tropical
biodiversity. As of December 2018, BBG has collected about 213 families, 1,202 genera, 3,156 species and 12,141 plant specimens for conservation. The diversity value of the collection is significant because it contains up to 38 vulnerable species, 19 endangered species and 22 critically endangered species in the approximately 87 hectares area. These collections data should be provided as an institutional base of ex-situ conservation strategy and guidelines for sustainable landscape management. Otherwise, various deaths cases decrease the collection count and this important issue has received less attention.

In this perspective, we investigate on living collection’s data focused on the dynamics of dead tree specimens considering trees were the landscape major elements. Our objectives were to (1) described dynamics of BBG’s dead trees collection number; (2) mapping the distribution of dead trees collection; (3) identify the general major cause of dead tree collection; and (4) suggest further action for sustainable trees collection management.

2. Methods
2.1. Study area
This research was located in Bogor Botanic Gardens, in the center of Bogor Municipality, West Java, Indonesia. The gardens have an area of nearly 87 ha and are located of 260 m above sea level.

2.2. Methods of the Study
This research was conducted using the last two decades of dead tree collection data from the year 1999 to 2018. The data consist of the scientific name of tree, family, location, year of the dead and supplementary notes. The number and year of the dead tree and scientific family data were analyzed by Microsoft Excel by getting regression equation to find the trend of general dynamics tree number. ArcGIS 10 software was used to map the distribution of dead trees based on location data. The field observation was also conducted to explore the existing conditions as data validation.

3. Result and discussion
3.1. The dynamics of BBG’s dead trees collection number
The database of dead trees collection in this research was supplied by the Collection Registration subdivision of BBG. From the initial sorting process, there are 3,197 tree specimens (21.15%) among entirely 15,115 dead specimens of 113 families ranged from the year 1931 until 2018. From the 87 years data range, we were focused only in the last 20 years.

The dynamics of BBG’s collection displayed in Figure 1 shows the positive trend line in the last two decades. This trend indicates that the number of dead tree collection increased year by year. A higher number was occurred in 2004 that reach 376 dead specimens and the lowest number 42 specimens occurs at 2011. The variation of number was also influenced by the change of management system including monitoring and evaluating, because of continuous improvement and technology.

By the equation of the trend line that shows \( y = 3.6767x - 7420.2 \) (Figure 1), we can predict the number of dead tree collection in the next years. For example, there would be 186,734 specimens die in the next 2020 and as much as 223,501 specimens would be lost in 2030. In other words, there will be an increased rate of the number of the death of trees collection every 10 years 36,767 specimens every 10 years.
3.2. The distribution map of BBG’s dead trees collection
Among the total of 3,197 dead tree specimens were consist of 113 families. The greatest 20 dead trees collection-number based on family shows in Figure 2. The largest number of dead trees, 410 specimens, was regarded for the Arecauceae (palm family) and the lowest number occured on Malvaceae (malus family).

Figure 1. The dynamics of BBG’s dead trees collection number at 1999-2018
(Source: Collection Registration subdivision of BBG)

Figure 2. Dead trees collection number of Bogor Botanic Garden based on family (1999-2018)
(Source: Collection Registration subdivision of BBG)
Figure 3 displayed the distribution map of BBG’s dead trees collection based on family blocks/vak (‘Vak’- Dutch derived term is still used until now). Teijssmann arranged the garden collection based on the phylogenic taxonomy system that brings consequences on placing the same family at the same block. The percentage number was divided based on a total population of dead trees, 3,197 specimens. The percentage hopefully can describe the distribution better. The value of percentage ranged from 0% (0 specimen) to 4.42% (131 specimens). The largest number was on vak VI.C. that consist of both Myrtaceae (myrtle family) and Clusiaceae (mangosteen family). The blocks were noted as the most severely affected by natural disaster in the form of stormwind in 2006. The record says over 200 specimens were damaged at once and caused the requirements of garden’s closing to make it accessible again for the visitors.

However, the distribution map fails to show the greatest number of dead trees from the Arecaceae family. The Arecaceae family in the garden was spread among several blocks, e.g. II.F, II.G, II.J, V.H, V.I, V.J, V.L, V.M, X.D, X.E, X.G, XI.B., XI.C, XII.A, XII.B, XII.C, XII.E, XIII.A, XIII.B, XIII.L, and XIV.A, so the percentage was variously divided into the blocks in the third color range of 1,0001 - 2,0000% (Figure 3).

The distribution map could indicate as a risk map that means the blocks should be receiving more attention in daily maintenance practices although the possible cause still needs further investigation. Either internal factors such as plant physiology, or external factors, such as mishandling in maintenance, misplaced, visitor activities impact or environment microclimate, can bring the death of them. Some research could be conducted, as well as thoroughly soil analysis until best practices in plant maintenance to support decision making in more sustainable landscape management.
3.3. Identify the general major cause of dead tree collection

The supplementary notes from Collection Registration subdivision of BBG provide preliminary data for the cause of the death of the tree collection. Some general detection about the words that describe the cause of death in trees collection listed in Table 1. However, the complete searching cannot be done due to lack of data, only 30.18% specimen data indicated the cause and need deeper investigation in the next research for the rest of the unknown death cause (68.82%).

| Words Indicated | Quantity (specimens) |
|-----------------|----------------------|
| **Internal factors** |                      |
| - old (tua)      | 20                   |
| - fallen (roboh/tumbang/cabut/tebang) *429 |
| - physical damage (patah/akar/batang) | 42 |
| **External factors** |                      |
| Pest             |                      |
| - pest (hama)    | 2                    |
| - deer (kijang/rusa) | 21               |
| - termite (rayap/keropos/bolong) | 32 |
| - borer (penggerek) | 5                  |
| - ant (semut)    | 1                    |
| Disease          | 27                   |
| - rotten (busuk) | 24                  |
| - fungus (jamur/cendawan) | 3     |
| Environment      | **386**              |
| - soil erosion (longsor) | 5       |
| - storm wind (bencana/anginputingbeliung) | 67 |
| - lightning (petir) | 20              |
| - fallen of other trees (tertimpapohon lain) | 7 |
| - drought (kekeringan) | 287         |
| **Total cause recorded** | 965                   |
| **Unknown**      | **2.232**            |
| **Total dead trees collection** | **3.197**          |

Source: Collection Registration subdivision of BBG

There are two general categorizations for the cause of death, internal and external factors. The words indicated the cause of the internal factors were included old (tua), fallen (roboh/tumbang/cabut/tebang), and physical damage (patah/akar/batang). The internal factors that reach a higher number due to fallen were happened in 429 specimens. Otherwise, the external factors cause detection were included pest (hama) type, such as: deer (kijang/rusa), termite (rayap/keropos/bolong), borer (penggerek), ant (semut); disease symptoms, such as: rotten (busuk), fungus (jamur/cendawan); environment impact, such as: soil erosion (longsor), stormwind (bencana/angin putting beliung), lightning (petir), fallen of other trees (tertimpapohon lain), dandrought (kekeringan). The external factors that cause the death were happened because of environment conditions in 386 specimens, especially for drought (287 specimens).

3.4. Suggestion for a further action for sustainable tree collection management

The findings on dynamic of dead trees collection to support sustainable landscape management needs the application of best practice guidelines for ex-situ living plant collections that may be incorporated into a comprehensive conservation strategy for botanic gardens and arboreta. The guidelines provided thorough steps about how to manage ex-situ living collections are provided although a revision of these important guidelines is still needed through further studies, preliminary experiments, and expert advice.
4. Conclusion
The dead tree collection tended to increase during 1999-2018 period. The most dense location needs further attention in daily maintenance practices. The threat to living collection was mainly caused by a natural disasters, such as: wind that brings fallen tree, drought, pest, and disease. These facts should bring the awareness of the institution to more sustainable landscape management so that BBG can preserve the significant number of valuable collections.

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