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Assessing the conservation value of medicinal plant collections in Bogor Botanic Gardens, Indonesia

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Abstract. *Hidayat S, Zuhud EAM, Widyatmoko D, Bahruni. 2021. Assessing the conservation value of medicinal plant collections in Bogor Botanic Gardens, Indonesia. Biodiversitas 22: 691-701.* Botanic gardens contain plant collections for the purpose primarily for ex-situ conservation, yet the public rarely appreciates these collections. As such, assessing the conservation value of botanic gardens collections is very important as an effort to increase public awareness of the importance of botanic gardens and their plant collections. This research aimed to assess the conservation value of plant collection in Bogor Botanic Gardens (BBG), Indonesia using quantitative and qualitative methods. We focused our assessment on medicinal plant collections with the habitus of tree. Conservation value of a plant collection was approached by preservation value and utilization value both quantitatively using monetary units and qualitatively using non-monetary index. Based on these two approaches, quantitatively most (91%) of the medicinal plant collections in BBG assessed in this study have a value of more than one million rupiahs, even 21% have a value of more than 100 million rupiahs, implying the high monetary value of medicinal plant collection in Bogor Botanic Gardens. Meanwhile, qualitatively, the conservation value score of a species will be strongly influenced by the existence of protection laws issued by the government and the cultural level of plants' use by the community. Our framework of assessing the conservation value of plant collections, especially those with medicinal purposes, can be replicated in other botanic gardens.

Keywords: Conservation value, quantitative, qualitative

INTRODUCTION

Botanic gardens is a garden for *ex-situ* plant conservation that is usually located in urban areas. According to Demir (2013), it has current and future values. Current value is a value or benefit of the botanic gardens and their collections that can be felt at this time, while future value is a value or benefits of botanic gardens and their collections that are not felt today but will be felt in the future in line with advances in the level of knowledge and technology achieved by humans at the time. Most major botanic gardens stated species conservation as one of their missions, yet it is often not clear how such mission in conservation would be achieved (Cavender et al. 2015; Cannon and Kua 2017). One of the causes is the lack of critical biological and ecological information at the species level for the majority of plant collection (Cavender et al. 2015).

The survival of plant collections in a botanic gardens does not only depend on the maintenance carried out by the management of the garden, but can also be influenced by the attitudes and behavior of the communities, including the visitors and the governments. The importance of plants' existence in botanic gardens is perceived by the community based on its benefits in terms of monetary and non-monetary value. A clear understanding of the value of a plant collection will positively affect people's perceptions and appreciations on the plant collection. Nonetheless, such benefits and perceptions can only be accrued for the state and society if the plant collections are maintained and developed properly (Muhaimin and Efendi 2018).

According to Cibrian-Jaramillo et al. (2013), the first step to make better use of plant collections in botanic gardens is by determining their conservation value. Conservation value is the values contained in an area or an object where these values are calculated as very significant or very important values locally, regionally, or globally. Information on the conservation value of a plant species can provide insights and motivations for the community to appreciate the existence of a plant species. This is because natural resources, such as plants, are often considered as common property resources, so that these resources are valued too low compared to their supposed value. Undervaluation, or giving a low value of a plant species, has resulted in a lack of motivation by the community to maintain and care for the existence of these plants even though the plants are in conservation areas such as botanic gardens.

Efforts to determine the conservation value of plant collection in botanic gardens are often difficult to perform since there is no clear framework on how to do that. To date, there have been limited studies defining the term

conservation value of plant collection in botanic gardens. Although Capmourteres and Anand (2016) and Ziliang et al. (2017) stated that in general, conservation value (CV) refers to the more general idea and goal of prioritizing conservation efforts, yet this definition is generally applied to a forest area with various criteria, one of which is based on species diversity.

Study on the conservation value of plant collection in botanic gardens is very important to increase public awareness of the importance of botanic gardens and their plant collections. Therefore, this research aimed to assess the conservation value of plant collection in Bogor Botanic Gardens (BBG), Indonesia using quantitative and qualitative methods. We focused our assessment on medicinal plant collections with the habitus of tree. Preliminary studies about medicinal plants of Bogor Botanic Gardens have been conducted (e.g., Astuti et al. 2018; Siswadi et al. 2016), however these studies focused on ethnobotany, ecology, exploration and studies related to bioactive compounds with medicinal properties. We expected this study to provide a generalizable framework for assessing conservation value of plant collection in a botanic gardens, especially for medicinal plant collections.

MATERIALS AND METHODS

Study area and period

The main research activity was carried out at the Bogor Botanic Gardens (BBG), Bogor, West Java, Indonesia. Supporting activities were carried out in some drug and herbal stores in Bogor. The research was conducted from February to July 2020.

Research materials and tools

The main research materials were medicinal tree species of plant collection of BBG. The supporting information and tools used were catalog books, annual budget of BBG, etc.

Data collection

Data collection was conducted in three stages of activity. First, desk studies were carried out to collect data on the budgets related to plant collection activities, such as exploration, maintenance and preservation costs, as well as other data, such as the origin and the year of the collection. Second, inventory was conducted to measure stem diameter and height of each medicinal tree species in BBG using diameter tape and range finder. Third, a survey was conducted randomly to some drugs or traditional medicine retailers in Bogor City to collect data on the price, ingredient, and composition of the drugs or medicinal herbs. The survey was also conducted digitally on online shops selling herbs and medicinal plants.

Data analysis

Conservation value of a species was approached by preservation value and utilization value both quantitatively (monetary) and qualitatively (non-monetary).

Preservation value

Quantitative/monetary: Procurement value. The procurement value is defined as the cost incurred to carry out all activities related to the conservation of medicinal plant species which is still alive in the collection to date. This value is based on the cost of exploration, maintenance costs, and cost of making herbarium specimens.

Species procurement value (N) = E + P + A

Where:
E = cost of collection = cost of exploration
P = maintenance costs = fertilizer + water + wages + signboard
A = herbarium specimen cost

Qualitative/non-monetary: Species importance value. The species important value is the value indicating the level of importance of a species for conservation action. This value was obtained by summing conservation status based on four variables: (i) The level of endangerment based on the IUCN Red List category; (ii) Species protection level based on PP.No. 7/1990, Permen LHK No.20/2018 and Permen LHK No.106/2018; (iii) Endemicity status based on relevant literature (Keßler et al. 2002; Sidiyasa 2015; IUCN 2020); and (iv) Protection in trade based on the CITES criteria and other relevant agencies such as the ITTO, WHO and BGCI (Mark et al. 2014). Based on these four variables, the species important value was classified into: high (score 41-80), moderate (score 21-40), and low (score 1-20).

Utilization value

Quantitative/monetary: Substitution value. Substitution value is the value of a plant species if the plant is used commercially in traditional medicines or drugs.

NS = HO x PO

Where:
NS = substitution value for a particular traditional medicine
HO = the price of a package of medicine
PO = number of medicine packages produced by an individual plant from a particular part

PO = Bb / Bs

Where:
Bb = weight of plant parts
Bs = weight of simplicia

To get the weight of the plant part, first the stem weight was calculated using the following formula

$Bb = \pi D^2 h \rho / 40$

Where:
D = stem diameter
h = tree height
ρ = wood density

If several types of medicines were produced from different plant parts from one species, the value was the sum of the substitutions identified.

NS tot = Ns1 + Ns 2 + ... etc.

Qualitative/non-monetary: Index of Cultural Significance. The cultural significance of medicinal use is a value that shows the level of cultural closeness of community to the use of a plant species. This value is calculated using the ICS (Turner 1988) with modification on the use of plants as medicine.

ICS: Index of Cultural Significance = Σ (q x i x e)

Where:

q: The quality of use-value. Quality score (q): score 5 is very important, score 4 is important, score 3 is normal, score 2 is less important, and score 1 is not important.

i: The intensity of use-value. Intensity score (i): score 5 when used by 23-28 ethnicities, score 4 when used by 17-22 ethnicities, score 3 when used by 11-16 ethnicities, score 2 when used by 5-10 ethnic ethnicities, and score 1 when used by 1 - 4 ethnicities.

e: The exclusivity of use-value. Exclusivity score (e): Score of 2 when used singly, score of 1.5 if it can be used singly or as a mixture, and score of 1 if only used as a mixture.

Furthermore, the ICS values were categorized as follows: Very high if ICS ≥ 100; High if ICS 50-99; Medium if ICS 20-49; Low if ICS 5-19; Very low if ICS 1-4.

RESULTS AND DISCUSSION

In summary, the results of the assessment of conservation value of medicinal plant collections in Bogor Botanic Gardens can be seen in the Appendix.

Preservation value

Conservation value from the perspective of preservation value was approached by calculating the procurement value and species important value. In terms of procurement value, 83 species have a value of more than one billion rupiahs (7 species are worth more than 5 billion rupiahs and 76 species have a value between 1-5 billion rupiahs), and only one species is worth less than 500 million. The seven species with a value of more than 5 billion are those with average age of over 150 years, namely *Kleinhovia hospita, Pterocarpus indicus, Dimocarpus longan, Averrhoa bilimbi, Altingia excelsa, Parkia timoriana,* and *Pterospermum javanicum*. Such tree collections with long ages have incurred much longer maintenance, resulting in very high conservation cost accumulation. In this study, 62% of the plant's age was over 50 years.

As much as 75% of the sixteen species with the highest procurement value (Table 1) with an average age of over 100 years were originated outside of Java. Efforts to collect species from their habitats, especially from outside of Java, required high costs, especially in terms of transportation costs and operational costs for the exploration team. Thus, the aspects of tree age and tree origin when collected are the main factors determining the procurement value. For example, *Kleinhovia hospita* is not at the top sixteen of importance value but in total procurement, value occupies the top position. This is because *K. hospita*, which was collected from Papua in 1823, is still growing well in the BBG today. This means that during 197 years this tree has taken a lot of maintenance costs. Likewise, *Pterocarpus indicus* which ranks second in the procurement values was collected from Maluku in 1844, still looks well preserved at BBG.

From the perspective of the species important value, 16% of the listed species in Table S1 have high important value (score 41-80), 61% have moderate important value (score of 21-40), and 23% have low important value (scores 1-20) (Table 1). In general, species that have high important value are more influenced by aspects of protection score than other aspects. All species of high important value have a score of 20 in terms of protection, meaning that these species are very important to the Indonesian people since the Indonesian people have long used these and their presence in nature is decreasing.

Horsfieldia iryaghedhi and *Santalum album* are at the top position in terms of species important value (Table 1). *H. iryaghedhi* is included in the commercial timber group. According to the IUCN Red list, it is already in the Critically Endangered category (CR). As a commercial timber, this species has a strong legal aspect of protection. *S. album* or sandalwood has natural distribution in the East Nusa Tenggara area, but the level of use is very wide and even traded internationally. Indonesia has a long history of sandalwood utilization, particularly in East Nusa Tenggara (Nurochman et al. 2019). *S. album* is one of the oldest and precious sources of natural fragrance with immense medicinal and commercial significance (Kumar et al. 2015). This species is increasingly rare in nature so that the aspect of protection is considered very important. The main reason for the rarity and low regeneration of sandalwood was exploitation activities that exceeded the tree reproduction capacity, the high annual logging rate of the tree, forest degradation, conversion of sandalwood forests into agricultural and residential areas forest fires (Seran et al. 2018).

The next most important species is *Pometia pinnata* or matoa. This species is the flora of identity for West Papua Province. Apart from being an ingredient for diarrhea treatment, this species is also a first-class commercial timber and includes the major timber species (ITTO 2020), so it has a high protection aspect. Matoa stem bark extract has been shown to have antidiabetic effects that affect blood sugar levels (Prihanti et al. 2020).

Pterocarpus indicus and *Pterospermum javanicum*, which population distribution is limited in certain areas, have been known and used by the public widely (nationally and internationally). *P. indicus* is one of the most important multipurpose trees for timber and medicine. It has many medicinal properties especially for fever, diarrhea, dysentery and heavy menstruation (Senthilkumar et al.

2020). Meanwhile, *P. javanicum* also has various medicinal benefits in Indonesia while its population is decreasing in nature. In Lombok, the root of this species is used as a mixture of tuak and is believed to be a diabetes medicine (Hidayat. 2017), while the bark is used for treating dysentery, toothache, boils, and sprains (Salempa et al. 2014). The use of roots and bark threatens the survival of a plant species. Apart from medicinal ingredients, *P. javanicum* is also a commercial timber group according to ITTO and BGCI. So that the two species mentioned above deserve a high score in the aspect of protection.

The aspect of endemicity also plays an important role in determining conservation value, followed by aspects of trade status and level of threat. Of the 16 species that are categorized as having high important value, most of them are plants from tropical Southeast Asia, some of which are native to Indonesian, such as *Myristica fragrans, Santalum album, Pometia pinnata, Protium javanicum* and *Pterospermum javanicum.*

Based on Table 1, there are only three species with the highest value both in terms of procurement value and species important value, namely *S. album*, *P. javanicum*, and *P. indicus*. These three species have high protection and endemicity values even though they are not yet included in the CR category based on the IUCN Red List. These species are commercial plants that are protected by the state. Efforts to procure these species were quite challenging because these species were originated from the Lesser Sunda and Maluku regions (Eastern Indonesia) which were quite far from the BBG. Also, these three species have age of more than 100 years old, so that cumulatively they have accumulated quite a lot of costs in terms of maintenance. Based on these results, it can be said that active conservation efforts such as protection (variable for species important value) and maintenance (variable for procurement value) affect the magnitude of the conservation value of these species.

However, suppose the score of the important value of species is used as the multiplier for the procurement value. In that case, the ranking of the 16 species with the highest conservation (preservation) value is presented as in Table 2.

From Table 2, there is *Michelia champaca*, which previously did not appear in the group of 16 species with the highest value both in terms of procurement value and species importance value. In the procurement value, *M. champaca* was in 37th position while in species important value it was in 29th position, with a score of 38, which was influenced by protection score. Even though it is in the 37th position in procurement value, *M. champaca* has a value of over 3 billion. This value is relatively high and only differs from 0.35 billion with *the Santalum album* in the 15th position in the procurement value. *M. champaca* is more than 100 years old, which means that it has incurred significant maintenance costs during that period of its life.

Table 2. Sixteen species with the highest preservation value obtained by multiplying the procurement value and species important value

Species name	Value (Rp.)
Pterospermum javanicum Jungh.	292,972,219,796.00
Pterocarpus indicus Willd.	265,850,960,130.00
Dimocarpus longan Lour.	230,192,629,446.00
Altingia excelsa Noronha.	222,617,190,332.00
Parkia timoriana (DC) Merr.	221,910,981,942.00
Santalum album L.	211,431,290,895.00
Averrhoa bilimbi L.	210,986,896,104.00
Horsfieldia iryaghedhi (Gaertn.) Warb.	194,059,023,730.00
Pometia pinnata J.R.Forst. & G.Forst.	189,280,801,958.00
Alstonia scholaris (L.) R. Br.	155,578,274,984.00
Swietenia mahagoni (L.) Jacq.	151,908,815,880.00
Hibiscus tiliaceus L.	144,574,805,474.00
Calophyllum inophyllum L.	138,513,971,196.00
Gnetum gnemon L.	135,092,170,115.00
Magnolia champaca (L.) Baill. ex Pierre	132,689,707,048.00
Guazuma ulmifolia Lam.	132,431,814,556.00

Table 1. Top sixteen species with the highest procurement value and species important value

Species name	Procurement value (Rp.)	Species name	Species important value
Kleinhovia hospita L.	6,581,865,389.00	*Horsfieldia iryaghedhi* (Gaertn.)	55
Pterocarpus indicus Willd.	5,907,799,114.00	*Santalum album* L.	55
Dimocarpus longan Lour.	5,902,375,114.00	*Pometia pinnata* J.R.Forst. & G.Forst.	53
Averrhoa bilimbi L.	5,860,747,114.00	*Pterospermum javanicum* Jungh.	53
Altingia excelsa Noronha.	5,858,347,114.00	*Protium javanicum* Burm.f.	51
Parkia timoriana (DC) Merr.	5,690,025,178.00	*Myristica fragrans* Houtt.	47
Pterospermum javanicum Jungh.	5,527,777,732.00	*Swietenia macrophylla* King	46
Vitex pinnata L.	4,410,081,096.00	*Cinnamomum sintoc* Blume	45
Hibiscus tiliaceus L.	4,252,200,161.00	*Cryptocarya massoy* (Oken) Kosterm.	45
Morinda citrifolia L.	4,155,451,693.00	*Eusideroxylon zwageri* Teijsm. & Binn.	45
Phaleria macrocarpa Scheff. Boer	3,912,534,289.00	*Pterocarpus indicus* Willd	45
Guazuma ulmifolia Lam.	3,895,053,369.00	*Swietenia mahagoni* (L.) Jacq	45
Gnetum gnemon L.	3,859,776,289.00	*Alstonia scholaris* (L.) R. Br.	44
Calophyllum inophyllum L.	3,847,610,311.00	*Tamarindus indica* L.	43
Santalum album L.	3,844,205,289.00	*Anacardium occidentale* L.	41
Sterculia foetida L.	3,663,494,353.00	*Melaleuca leucadendra* (L.) L.	41

In contrast to *K. hospita* which in terms of procurement value occupies the highest position, its position bounces off from 16 plants with the highest preservation value. This is because the aspect of protection is minimal for *K. hospita*. The lack of protection effort from the state, makes this species out of the group of 16 plants with the highest preservation value, as was *V. pinnata* and *P. macrocarpa*. Meanwhile, there has been no statement of threat either nationally or internationally, *Sterculia foetida* and *Morinda citrifolia* also left the group of 16 plants with the highest preservation value.

Species with high score of species important value such as *Myristica fragrans*, *Swietenia macrophylla*, *Cinnamomum sintoc*, *Cryptocarya massoy*, *Eusideroxylon zwageri*, *Tamarindus indica*, *Anacardium occidentale*, and *Melaleuca leucadendra* are not included in the group of 16 plants with the highest preservation value. Although these species are already popular in the community and generally have a high protection score and level of threat, in the BBG these collections are on average less than 50 years old. Some of them are between 50-80 years old but they come from areas not far from the BBG, so that the collection costs of these species are not too high.

Our findings indicate that the age of the plant collection and the legal aspects of protection really determine the preservation value. As such, the conservation value of a species can be illustrated as follows: the older the collection, and the more legal protection, the higher the conservation value tends to be (Figure 1.).

Utilization value

Conservation value in terms of utilization is approached by calculating substitution value for medicinal uses and index of cultural significance. In detail, the results of the calculation of utilization value are shown in the Appendix. In summary, the results of the calculation of the substitution value (Ns) for medicinal plant collection species in BBG can be grouped as follows: 9 species are worth <1 million, 32 species are worth 1 ≤ Ns <10 million, 38 species are worth 10 ≤ Ns <100 million, 13 species are worth 100 million ≤ Ns <1 billion, and 8 species are worth Ns ≥ 1 billion.

Based on the substitution value, there are 8 species that have value above one billion, namely *Punica granatum* (Rp. 9,647,190,171.00), *Alstonia scholaris* (Rp. 7,029,541,774.00), *Melaleuca leucadendra* (Rp. 5,900,400,000.00), *Dimocarpus longan* (Rp. 3,334,090,909.00), *Syzygium polyanthum* (Rp. 1,784,800,000.00), *Cinnamomum burmanni* (Rp. 1,214,082,000.00), *Plumeria rubra* (Rp. 1,149,600,000.00), and *Myristica fragrans* (Rp. 1,027,549,028.00).

Punica granatum or pomegranate has the highest substitution value since in the last decade, pomegranate has fairly high popularity as an ingredient in health drinks and medicines. Pomegranate has prominent medical history, and possesses remarkable medicinal properties (Bassiri-Jahromi 2018), fruit or fruit juice has for the past decade been advocated as an interesting functional food that can confer health benefits beyond basic nutrition (Rummun et al. 2013). Pomegranate, ethnically in Madura and Sulawesi, is used as a medicinal ingredient and aphrodisiac for women. Commercially, this fruit is sold fresh or in processed form as a health drink, especially for women, while the skin of the fruit is used as an ingredient in diarrhea medicine.

Alstonia scholaris and *M. leucadendra* are two collections of BBG with a stem diameter of more than one meter. Apart from being an ingredient in malaria medicine, they are also commercially known in various medicinal products such as itching drugs and stamina enhancers. *A. scholaris* has been used in traditional systems of medicine for treating various ailments. The bark is the most intensively used part of the plant and is used in many compound herbal formulas (Kaushik et al. 2011). *Melaleuca leucadendra* oil is a commercial non-timber forest product (NTFP) in Indonesia. This oil is used in herbal remedies, including antiseptics, antispasmodics, antineuralgics, antirheumatics, and cosmetics manufacture. Several studies have also demonstrated Melaleuca species' efficiency as antibacterial, antiviral, anti-termite, and antifungal (Pujiarti et al. 2011).

Apart from having a high substitution value, *A. scholaris* also ranks first in terms of index cultural significance (ICS). Furthermore, the second and third positions are occupied by *Moringa oleifera* and *Morinda citrifolia*. These two plants are popular in various regions of Indonesia, apart from being medicinal ingredients, these species are also known as vegetable food ingredients. Several ethnic groups use both *M. citrifolia* and *M. oleifera* to treat various kinds of diseases, so that these two species have a strong relationship in the culture of Indonesian society. *M.oleifera* can be one of the national foods because it is considered as a local plant in Indonesia (Riastiwi et al. 2018). Meanwhile, *Morinda citrifolia* or noni plant, has been established by the National Agency for Drug and Food Control of Republic of Indonesia (NADFC) as one of the main medicinal herbs, The efficacy of the noni plant also has been proved hereditary by the community to cure various diseases (Wahyuningsih et al. 2020).

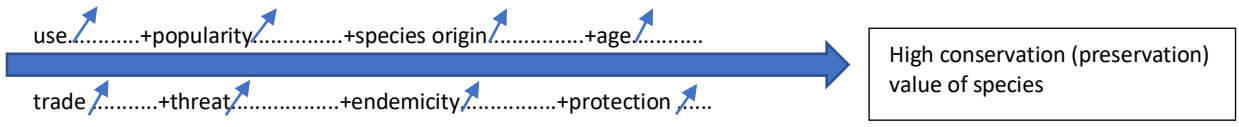

Figure 1. Important variables that support the value of conservation (preservation)

There are four plant species at the top 16 positions both in the substitution value and in the ICS value, namely *A. scholaris, M. leucadendra, Areca catechu,* and *Terminalia catappa* (Table 3). *A. scholaris, A. catechu,* and *T. catappa* are plants that are spread almost all over Indonesia and have been used by all ethnic groups in Indonesian. The popularity of *A. scholaris* as a medicinal substance with sufficient knowledge in various regions has attracted the attention of drug manufacturers to produce medicine in various forms and is increasingly competitive. *Terminalia catappa* or ketapang is used primarily as an ornamental tree, a shade tree, and a meal and medicinal herb for its fruits and seeds (Marjenah dan Putri 2017). Commercially, ketapang is known as an ingredient for diarrhea medicine. Apart from fruit, the leaves can also be used as raw materials for medicine. There are some natural ingredients in ketapang leaves and fruit: flavonoids or known as vitamin P or citrin, tannins (punicalin, punicalagin or terpatin), saponins, and phytosterol (Santi et al. 2020). *Areca catechu,* locally known as pinang or betel nuts, has long been used by various ethnic groups in Indonesia as part of the 'sirih pinang' culture and is believed to strengthen teeth. It has been used for a long time as a source of herbal medicine to treat dysentery or dysuria in Indonesia (Lee et al. 2014). Commercially, pinang is also packaged as a medicine to increase sexual arousal, either in the form of real fruit or in the form of a drink or juice. Meanwhile, *M. leucadendra,* although the distribution of this plant population is more limited than the previous three species, its popularity has long been widely recognized by the Indonesian people. *M. leucadendra* or kayu putih is known as a medicinal ingredient for various diseases, especially in the form of 'kayu putih' oil. The four species of medicinal plants in BBG have fairly large trees trunks, thus contributing to the high value of medicine substitution. On the other hand, *M. oleifera* and *M. citrifolia* do not have a high substitution value because these two collections of BBG are not as large as other trees. Besides that, the raw material prices for these medicinal plants on the market are still relatively cheap compared to others.

However, if the score of ICS is used as the multiplier for the substitution value, then the ranking of the 16 species with the highest conservation (utilization) value is as follows (Table 4).

Of the 16 species listed in Table 4, almost all species belong to the highest substitution value group with only two species are not included, namely *Barringtonia asiatica* and *Lagerstroemia speciosa*. However, these two species actually have high substitution values, respectively ranked 17th and 19th, only slightly different in value with *Lannea coromandelica,* which ranks 16th. So it is very reasonable to include the top 16 in the total utilization value.

Table 4. Sixteen species with the highest conservation (utilization) value obtained by multiplying the substitution value and cultural value.

Species name	Utilization value (Rp.)
Alstonia scholaris (L.) R. Br.	667,806,468,530.00
Melaleuca leucadendra (L.) L.	200,613,600,000.00
Punica granatum L.	130,237,067,309.00
Areca catechu L.	33,480,000,000.00
Cinnamomum burmanni (Nees & T.Nees) Bl.	24,281,640,000.00
Plumeria rubra L	18,393,600,000.00
Syzygium polyanthum (Wight) Walp.	17,848,000,000.00
Dimocarpus longan Lour.	16,670,454,545.00
Myristica fragrans Houtt.	15,413,235,420.00
Gnetum gnemon L.	14,400,000,000.00
Terminalia catappa L.	8,587,500,012.00
Magnolia champaca (L.) Baill. ex Pierre	6,974,921,740.00
Cananga odorata (Lam.) Hook.f. & Thomson	6,428,571,426.00
Lannea coromandelica (Houtt.) Merr.	4,056,556,260.00
Barringtonia asiatica (L.) Kurz	3,850,000,000.00
Lagerstroemia speciosa (L.) Pers.	3,443,948,266.00

Table 3. Sixteen species with the highest substitution value (NS) and cultural significance (ICS)

Species name	NS (Rp.)	Species name	ICS
Punica granatum L.	9,647,190,171.00	*Alstonia scholaris* (L.) R. Br.	95
Alstonia scholaris (L.) R. Br.	7,029,541,774.00	*Moringa oleifera* Lam.	83
Melaleuca leucadendra (L.) L.	5,900,400,000.00	*Morinda citrifolia* L.	70
Dimocarpus longan Lour.	3,334,090,909.00	*Averrhoa bilimbi* L.	62
Syzygium polyanthum (Wight) Walp.	1,784,800,000.00	*Cocos nucifera* L.	55.5
Cinnamomum burmanni (Nees & T.Nees) Blume	1,214,082,000.00	*Areca catechu* L.	54
Plumeria rubra L	1,149,600,000.00	*Calophyllum inophyllum* L.	45
Myristica fragrans Houtt.	1,027,549,028.00	*Phyllanthus acidus* (L.) Skeels	43
Gnetum gnemon L.	800,000,000.00	*Terminalia catappa* L.	42
Magnolia champaca (L.) Baill. ex Pierre	697,492,174.00	*Cratoxylum sumatranum* (Jack) Blume	38
Areca catechu L.	620,000,000.00	*Oroxylum indicum* (L.) Kurz	36
Cananga odorata (Lam.) Hook.f. & Thomson	357,142,857.00	*Tamarindus indica* L.	36
Cinnamomum sintoc Blume	285,178,095.00	*Melaleuca leucadendra* (L.) L.	34
Peltophorum pterocarpum (DC.) K.Heyn	229,903,200.00	*Hibiscus elatus* Sw.	33
Terminalia catappa L.	204,464,286.00	*Sterculia foetida* L.	33
Lannea coromandelica (Houtt.) Merr.	202,827,813.00	*Pterocarpus indicus* Willd	32

On the other hand, two species that were initially included in the 16 highest substitution values, after being multiplied by the ICS score, were not included in the 16 highest utilization values, namely *Peltophorum pterocarpum* and *Cinnamomum sintoc*. In the ranking of substitution values, these two species respectively occupy the 13th and 14th positions with values above 200 million. This value is quite reasonable because the price of medicinal products from these species is quite high. The parts used from these two plants are wood and bark. Medicines made from wood are usually more expensive than medicines made from other parts, this is due to the limited availability of raw materials, especially for *P. pterocarpum* which is actually better known as natural coloring agents (Sutara 2016; Kaswinarni et al. 2019). Meanwhile, *C. sintoc* is known as one of the essential oil-producing plants and has even been used as a building material in some areas. Both of these species are included in the protected NTFP group. In addition, these two species in the BBG collections have a fairly large stem diameter, for example, the diameter of *P. pterocarpum* stems reaches 1 meter. However, these two species have a low ICS value, because as a medicinal ingredient, *P. pterocarpum* is only used by one ethnic group in Merauke, while *C. sintoc* is used by Sundanese and Javanese ethnicities for lumbago medication.

There are only three species with the highest ICS included in the 16 species with the highest utilization value (Table 4), namely *A. scholaris, M. leucadendra* and *A. catechu.* The three species actually have their own peculiarities in their use, so that the tendency to be produced as medicine is quite high in value compared to other species. *A. scholaris* as an ingredient in malaria medicine is more popular than other species, as well as *M. leucadendra* as cajuput oil for various purposes, especially for those with colds. Cajuput oil, extracted from the kayu putih tree *Melaleuca leucadendron*, is an important non-timber forest product in Indonesia (Pujiarti et al. 2011). Cajuput oil is a complete all-purpose home medicine, is widely used in Indonesia as an expectorant, for throat preparations such as gargles, as medication for stomach upsets, and as insecticide (Budiadi et al. 2005). Meanwhile, there is a lot of information regarding *A. catechu* as a medicinal ingredient in some regions (ethnics). *A. catechu* is also known as an aphrodisiac ingredient for women. *A. catechu* is very popular in Indonesia as a medicinal ingredient for various purposes.

Based on this research's findings, the conservation value in terms of utilization value can be illustrated that the wider the culture of species use and the more specific its use, the more likely it is to have high conservation value (Figure 2.).

The highest conservation value

Four plant species have the highest conservation value, both in terms of preservation and utilization, namely *Alstonia scholaris, Gnetum gnemon, Dimocarpus longan,* and *Magnolia champaca.* None of the four species is threatened under the IUCN Red List, but these species have a very strong legal aspect of protection at national level, especially as NTFPs and their use as the flora identity of a city or district. The cultural use of medicinal plants in society, especially related to the treatment for major diseases in the community such as malaria and diarrhea, has influenced four species' position. The WHO estimated that there were 2.5 million cases of malaria in Indonesia in 2006 (Iqbal et al. 2011). Malaria has almost certainly been presented throughout the Indonesian archipelago for as long as humans have inhabited it.

Alstonia scholaris has become an ingredient in malaria medicine in various regions of Indonesia, in this study at least 12 ethnic groups reported its use as a malaria medicine. Although internationally it is not yet categorized as a threatened species, IBSAP (2003) has included it as a rare medicinal plant. Nationally, *A. scholaris* includes NTFPs that need to be protected while nationally (Minister of Forestry Decree No.163 /kpts-ii /2003) and internationally (BGCI; ITTO) *A. scholaris* are included as commercial timber. BBG has this collection since 1916 and currently has a stem diameter of 1.1 m, so it deserves to have high conservation value both in preservation and utilization.

Gnetum gnemon known as melinjo tree is a very popular vegetable ingredient and can be found in various regions in Indonesia. The indigenous people of Indonesia use melinjo as vegetables or processed delicacies (Supriyadi et al. 2019). Beside its seed can be processed as chip, almost all parts can be consumed. Apart from being a vegetable, both the fruit and the leaves are produced in various medicinal packages such as melinjo fruit skin capsules, melinjo seed extract, and melinjo leaf powder. According to BPS or Indonesian Central Bureau of Statistics (2016), melinjo production increased from 213,025 tons in 2015 to 238, 419 tons in 2019. The species, which are included in the NTFP group, have been collected by BBG since 1907. This plant originates from Tidore and grows well in BBG, currently reaching a more than 50 cm stem diameter.

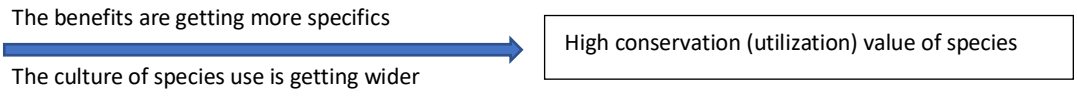

Figure 2. Important variables that support the value of conservation (utilization)

Although *Dimocarpus longan* is not very popular as a medicinal plant, this species can be used to cure diarrhea, which is a common disease in Indonesia. Diarrhea is included in Indonesia's 10 most common diseases (Purnamasari 2018). Most of the species mentioned in Tables 2 and 4 are raw materials for diarrhea medicine. *D. longan* has quite strong legal protection as NTFPs. It is even used as a flora identity for Semarang, while internationally this species is one of the commercial timber (BGCI). BBG has collected this species since 1844, so it has a high conservation value.

Magnolia champaca also has a strong legal aspect of protection. This species, which has been in the BBG's collection since 1917, is used as the flora identity of Nanggroe Aceh Darussalam province. Apart from being NTFPs, internationally this species is also one of the commercial timber (ITTO). As a medicinal plant, this species is used by the community as a back pain medication, a health problem that is quite common for Indonesians the age of 30 years and over. This health problem ranks second most frequently mentioned after headache. Low back pain is the most common skeletal muscle disorder among other skeletal muscle disorders. Nine out of 10 adults have experienced back pain throughout their life (Tana and Delima 2013). Four of the 16 species with the highest utilization value are back pain medication. Besides that *M. champaca* is also an aphrodisiac for women, so it has a unique use. All this makes *M. champaca* has high conservation value in preservation and utilization.

In conclusion conservation value of medicinal plant species in Bogor Botanic Gardens can be calculated in various methods, including through preservation and utilization approaches as demonstrated in this study. In terms of preservation value, a national protection law is an important aspect in assessing species conservation value, followed by endemicity and international threat status. In addition, the older the collection in the Bogor Botanic Gardens and the more legal aspect of protection of the species, the higher the conservation value tends to be. In terms of utilization value, the popularity of plants as medicinal ingredients for major diseases in the community, and the closeness of their use culture by ethnic groups in Indonesia is important aspects. By summing the value of preservation and utilization quantitatively, the value of species conservation is mostly above 1 million rupiahs (91%), even 21% is above 100 million rupiahs, implying the high value of medicinal plant collection in Bogor Botanic Gardens. Meanwhile, qualitatively, the conservation value score of a species will be strongly influenced by the existence of protection laws issued by the government and the cultural level of plants' use by the community. Our framework for assessing the conservation value of plant collection can be replicated in other botanic gardens.

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Table S1. Conservation value of medicinal plants species in Bogor Botanic Gardens

Species name	Preservation value		Utilization value	
	Procurement value (Rp.)	Species important value	Substitution value (Rp.)	Cultural significance value
Adenanthera pavonina L.	1,350,093,104.00	37	75,419,080.00	16
Aleurites moluccanus (L.) Willd.	3,292,563,971.00	36	5,753,600.00	19
Allophylus cobbe (L.) Raeusch	2,030,388,911.00	13	8,555,000.00	10
Alstonia angustifolia Wall. ex A.DC.	3,535,869,886.00	38	8,548,640.00	10
Alstonia scholaris (L.) R. Br.	2,207,807,336.00	44	7,029,541,774.00	95
Altingia excelsa Noronha	5,858,347,114.00	38	2,294,475.00	20
Anacardium occidentale L.	765,947,296.00	41	1,013,100.00	18
Areca catechu L.	1,543,621,571.00	38	620,000,000.00	54
Arenga pinnata (Wurmb) Merr.	926,103,764.00	29	4,955,383.00	16.5
Artocarpus altilis (Parkinson ex F.A.Zorn) Fosberg	1,397,145,104.00	35	17,035,467.00	14
Artocarpus elasticus Reinw. ex Blume	1,039,575,721.00	38	17,400,000.00	17
Artocarpus heterophylla Lam.	838,104,785.00	35	1,580,860.00	10.5
Averrhoa bilimbi L.	5,860,747,114.00	36	1,125,000.00	62
Averrhoa carambola L	1,520,146,550.00	26	9,734,627.00	8
Azadirachta indica A.Juss.	3,375,367,198.00	39	102,604,987.00	22
Baccaurea racemosa (Reinw. ex Blume) Müll.Arg.	3,543,741,886.00	30	12,000,000.00	21
Barringtonia acutangula (L.) Gaertn.	3,661,340,353.00	35	18,000,000.00	10
Barringtonia asiatica (L.) Kurz	1,818,988,464.00	20	175,000,000.00	22
Bischofia javanica Blume	3,524,283,886.00	34	87,000,000.00	23
Bixa orellana L.	3,264,687,971.00	34	653,250.00	10
Brucea javanica (L.) Merr	1,025,573,210.00	16	57,640,000.00	10
Buchanania arborescens (Blume) Blume	2,170,767,846.00	34	73,794,500.00	10
Caesalpinia sappan L.	928,224,742.00	38	99,935.00	13.5
Calophyllum inophyllum L.	3,847,610,311.00	36	5,000,000.00	45
Cananga odorata (Lam.) Hook.f. & Thomson	3,337,458,950.00	36	357,142,857.00	18
Cassia fistula L.	1,317,643,614.00	16	7,643,385.00	30
Ceiba pentandra (L.) Gaertn	3,375,751,464.00	24	2,535,920.00	18
Cinnamomum burmanni (Nees & T.Nees) Blume	2,176,631,336.00	40	1,214,082,000.00	20
Cinnamomum sintoc Blume	580,886,361.00	45	285,178,095.00	8
Citrus hystrix DC.	1,619,325,018.00	11	1,729,400.00.	24
Clausena excavata Burm.f.	2,048,585,379.00	10	14,964,613.00	20
Clausena indica (Dalzell) Oliv.	3,524,283,886.00	10	22,860,000.00	10
Cocos nucifera L.	2,323,602,782.00	23	7,524,721.00	55.5
Corypha utan Lam.	1,350,093,104.00	30	33,720,000.00	14
Cratoxylum formosum (Jacq.) Benth & Hook.f. ex Dyer	3,037,516,546.00	37	2,726,000.00	8
Cratoxylum sumatranum (Jack) Blume	579,122,361. 00	38	172,890.00	38
Crescentia cujete L.	1,748,983,486.00	8	4,800,000.00	20
Cryptocarya massoy (Oken) Kosterm.	909,912,829.00	45	12,988,477.00	10
Dimocarpus longan Lour.	5,902,375,114.00	39	3,334,090,909.00	5
Elaeocarpus grandiflorus Sm.	2,161,355,336.00	36	3,819,957.00	12
Elaeocarpus serratus L.	584,574,252.00	35	152,250,000.00	20
Eusideroxylon zwageri Teijsm. & Binn.	1,811,231,954.00	45	56,142,857.00	18
Fagraea racemosa Jack	3,620,463,886.00	34	1,636,364.00	10
Garcinia celebica L	3,531,129,886.00	16	33,797,888.00	20
Garcinia mangostana L.	807,803,296.00	32	11,256,796.00	19
Garcinia dulcis (Roxb.) Kurz	3,548,283,886.00	11	49,500,000.00	10
Garcinia parvifolia (Miq.) Miq	773,819,296.00	17	16,000,000.00	8
Gardenia augusta (L.) Merr.	3,524,283,886.00	19	3,424,513.00	14
Gnetum gnemon L.	3,859,776,289.00	35	800,000,000.00	18
Guazuma ulmifolia Lamk.	3,895,053,369.00	34	13,014,450.00	10
Hibiscus elatus Sw.	4,252,200,161.00	34	13,274,667.00	33
Horsfieldia iryaghedhi (Gaertn.)	3,528,345,886.00	55	740,000.00	20
Inocarpus fagifer (Parkinson) Fosberg	3,191,314,504.00	20	1,512,000.00	8
Kleinhovia hospita L.	6,581,865,389.00	12	32,327,260.00	30
Knema tomentella Warb.	610,904,361.00	34	6,000,000.00	8
Lagerstroemia speciosa (L.) Pers.	1,646,200,507.00	35	156,543,103.00	22
Lannea coromandelica (Houtt.) Merr.	1,447,441,571.00	17	202,827,813.00	20
Lansium parasiticum (Osbeck) K.C.Sahni & Bennet	3,548,283,886.00	31	20,625,000.00	25
Lunasia amara Blanco	1,558,792,550.00	19	12,388,800.00	18
Magnolia champaca (L.) Baill. ex Pierre	3,491,834,396.00	38	697,492,174.00	10
Mangifera indica L.	3,548,283,886.00	36	160,000,000.00	10

Manilkara zapota (L.) P.Royen	1,785,224,161.00	32	1,350,000.00	18
Melaleuca leucadendra (L.) L.	910,377,764.00	41	5,900,400,000.00	34
Microcos ceramensis Burret.	3,571,335,886.00	25	15,015,929.00	16
Morinda citrifolia L.	4,155,451,693.00	27	7,857,143.00	70
Moringa oleifera Lam.	1,479,891,061.00	35	3,409,290.00	83
Myristica fragrans Houtt.	909,249,764.00	47	1,027,549,028.00	15
Oroxylum indicum (L.) Kurz	3,524,283,886.00	18	979,620.00	36
Pangium edule Reinw.	1,299,771,636.00	39	89,600,000.00	16
Parkia timoriana (DC) Merr.	5,690,025,178.00	39	45,000,000.00	22
Peltophorum pterocarpum (DC.) K.Heyn	3,545,643,886.00	29	229,903,200.00	10
Peronema canescens Jack	3,377,312,439.00	38	11,232,000.00	10
Phaleria macrocarpa Scheff. Boerl.	3,912,534,289.00	12	31,350,000.00	10
Phyllanthus acidus (L.) Skeels	571,250,361.00	28	6,070,250.00	43
Pittosporum moluccanum Miq.	988,550,232.00	15	69,300,000.00	10
Planchonia valida (Blume) Blume	1,274,079,636.00	22	406,920.00	24
Plumeria rubra L	455,167,428.00	11	1,149,600,000.00	16
Pometia pinnata J.R.Forst. & G.Forst.	3,571,335,886.00	53	6,840,000.00	10
Protium javanicum Burm.f.	1,568,790,039.00	51	15,400,000.00	10
Psidium guajava L.	3,533,919,886.00	15	1,229,050.00	27
Pterocarpus indicus Willd	5,907,799,114.00	45	1,791,666.00	32
Pterospermum javanicum Jungh.	5,527,777,732.00	53	10,398,987.00	16
Punica granatum L.	571,250,361.00	22	9,647,190,171.00	13.5
Santalum album L.	3,844,205,289.00	55	12,279,167.00	5
Schleichera oleosa (Lour.) Merr.	1,280,595,636.00	38	19,600,000.00	16
Stelechocarpus burahol (Blume) Hook.f. Thomson	2,834,370,121.00	40	44,175,479.00	18
Sterculia coccinea Roxb.	3,552,159,886.00	29	179,091.00	20
Sterculia foetida L.	3,663,494,353.00	27	3,600,000.00	33
Swietenia macrophylla King	2,258,703,804.00	46	40,181,818.00	10
Swietenia mahagoni (L.) Jacq	3,375,751,464.00	45	3,913,000.00	10
Syzygium cumini (L.) Skeels	3,353,586,950.00	36	19,857,143.00	20
Syzygium polyanthum (Wight) Walp.	1,688,590,507.00	36	1,784,800,000.00	10
Syzygium samarangense (Blume) Merr & L.M.Perry	1,682,441,996.00	11	1,103,436.00	10
Tamarindus indica L.	2,713,021,654.00	43	39,510,000.00	36
Terminalia catappa L.	2,239,728,825.00	34	204,464,286.00	42
Tristaniopsis whiteana (Griff.) Peter G.Wilson & J.T.Waterh.	3,542,289,886.00	32	590,660.00	12
Vitex cofassus Reinw. ex Blume	3,628,836,864.00	33	8,693,658.00	10
Vitex pinnata L	4,410,081,096.00	22	92,339,350.00	8
Voacanga grandifolia (Miq.)	1,958,283,911.00	17	51,620.00	10
Zanthoxylum rhetsa DC.	1,025,573,211.00	26	10,407,158.00	14