Study of biophysical land characteristics to support the sustainability of Gunung Batu Arboretum as a miniature botanical garden in Bogor City, Indonesia

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Abstract. Gunung Batu Arboretum is part of the nature conservation area in Bogor City, West Java, Indonesia. It holds an essential role in supporting conservation effort activities through ex-situ of various trees species. Land biophysical research been carried out aimed at protecting the role of the Arboretum, which supports the growth of various plant collections of forest resources totaling 1,178 stems. The research was conducted in the field by making a soil profile and observing the characteristics of the environment and trees. The results showed that the location of the Arboretum was at the feet of stratovolcano, elongated ridges landform of Salak Mountain. The old volcanic rock covering this region form reddish-brown Latosol soil with deep solum, delicate texture, very friable and low aggregate stability, a very steep slope topography (slope >40%), supported by high rainfall, with an increased risk of erosion even it has landslide potential. The chemical character of the soil fertility is classified as acidic, low to moderate base saturation, low nutrient content, potentially the degradation of the soil fertility, especially the loss of topsoil, which is very supportive to the growth of the various types of trees collection in the Arboretum area.

1. Introduction
Based on the dictionary of forestry (1989) referred by Hastari [1], Arboretum is defined as tree plantations which are one of the conservation ways of artificial germ plasma. Arboretum was created by Joseph Struut and JC. London, which was inaugurated on 16 September 1840 in Derby, England, starting now referred to as Derby Arboretum [2]. Arboretum was originally created to accommodate outdoor recreational activities with trees, bushes, and wood vegetation (arbor) collection as the object which contains research and education purposes. Unlike the Botanical Garden, which is a place that has a collection of various types of plants that primary purpose for science research, conservation, and education also to protect the global environment that plays a role to preserve the natural wealth, mainly to save the world flora biodiversity [3].
Referred by the Center for Forest and Nature Conservation Research and Development [4], that the Gunung Batu Arboretum was founded in 1922 by Dutch Landlord. Arboretum area of approximately five ha divided into 27 blocks which each block is planted with tree species and limited by the road network. The Arboretum complex is bordered by steep cliff rivers that are susceptible to erosion. According to The Center for Forest and Nature Conservation Research and Development [4], the amount of Gunung Batu Arboretum are 234 species consisting of 136 genera and 50 families. Two hundred thirty-five of tree collections, 167 of them are Indonesian native trees. Meanwhile, 67 species are exotic imported trees. The total numbers of trees collection are 866 trees. Arboretum is very important as the effort to protect a natural genetic resource that changes a lot due to spatial changes. Many institutions are revising the spatial design into a new designation by ignoring the existing spatial design [5].

The development of Bogor City is uncontrolled nowadays, consequently reducing the Urban Open Space (UOS). The Arboretum’s existence and role should be integrated into unity with Bogor Urban Planning. According to Darmawati [6], the regulation related to Urban Planning law must be integrated into all fields, and institutes have a textual role in coordinating with all parties. Urban planning as the general plan to regulating the spatial planning serves as a guidance of development coordination between the sectors in order to realize the region development integration [7].

The Arboretum existence cannot be separated from the land conservation role. Moreover, Bogor is a rain city with >2.500 mm/year precipitation became the main factor causing erosion and nutrients washing in wet tropics areas [8]. To maintain the existence and continuity of the role of the Conservatory Arboretum must be maintained both from land degradation and the soil fertility role, so it is necessary to conduct land and soil assessment of physical, chemical, and morphological characteristics of the soil. Since not all plants follow the formal plan, there are times when the programs only for the temporal needs that the society wants are not institutional [9]. The case can happen because there was a formal planning failure and also the lack of proper planning legitimation [10].

This research aim is to obtain information about land and soil characteristics of Gunung Batu Arboretum to maintain the existing built ecosystem and make the model of urban forest for the urban environment in Bogor.

2. Methods

2.1. Location

The research activity was conducted at Gunung Batu Arboretum, located around the Forestry Research and Development Complex, Gunung Batu, Bogor, West Java. This land is located on the Cisadane River Bank, in the west region of Bogor City. The Arboretum area is 5 ha and located at 250m above sea level altitude, including climate type A with 4,962 mm precipitation average per year [11]; [12]. The soil and land/environment observation are conducted on different land facet and soil characteristics. The land facet is a further division of physiographic consisting of a single slope.

2.2. Method of the Study

The research was conducted in the field using soil survey tools consisting of: digital camera, Belgian soil auger, Munsell Soil Color Charts, Truog pH, Abney level, hoe/shovel, meter roll/ gauge length, ground knife, field, and manual data field filling, and soil sampling equipment [13].

Some of the supporting data used in this study are; Topographic map sheet of Bogor (1209) 1:250,000 scale [14]; Agro-Ecology Zone map of West Java Province of 1:250,000 scale [15]; Topography Dutch map scale of 1: 50,000 in 1912 of Batavia; Geology map sheet of Bogor (1209-1 or 9/XIII-D) scale 1:100,000 in 1998 Directorate of Geology, Bandung.

The field observation was conducted by determining some observation points as representative of soil conditions in the area. Determination of the observation is done by the lithotoposequence method, namely by considering the relationship between the soil, landscape, and the shape of area [16]; [17]. The classification of the landform follows the guidelines outlined in the Landform Classification Guidelines [18]. The field study of soil characteristics were the morphological properties of the soil and some physical and chemical soil characteristic. Morphological soil survey conducted on the field by making
soil profile by following Soil Survey Manual Guidance [19]. The soil profile is excavated holes that of rectangle form of length x width x height = 2 m x 1m x 1.5 m. one of these profile is used to identify the horizon and morphological characteristic. Soil characteristics were recorded in the Profile Soil classification is determined by the Subgroup category, according to Soil Taxonomy System [13] is synchronized with National Soil Classification System [20].

To Support the field data soil samples were taken from the representative profile to analyze the soil physical and chemical characteristics in the laboratory of the Centre for Soil Research, Bogor, following the methods contained in the Technical Guidelines for Soil, Water, Plant, and Fertilizer analysis [21]; [22]. An example is taken from each layer/horizon. The top layer, or so-called the topsoil is a rooting zone for shallow-rooted plants, while the lower layer is referred to as the sub-soil as the rooting zone of deep-rooted plants. Topsoil is usually determined based on the depth of 0-25 cm or 0-30 m or A Horizon (Epipedon) based on the needs of land use/plant species of the diagnostic horizon or development horizon.

The identification of tree collection is made by measuring all trees of ≥ 10 cm in diameter so that the scientific data of the tree collection can be accounted for its accuracy. The identification of herbarium samples conducted at the herbarium Center for Forest and Nature Conservation Research and Development and Herbarium Bogoriense LIPI.

3. Results and Discussion
3.1. Geology and Parent Material
Based on the Indonesia Geological Map of the scale of 1:100,000 pieces of Vogor (1209-1 or 9/ XIII-D) in 1998 [23], the study location is in a transitional position between two geological formations i.e., in the west-south east is Qvst formation which is volcanic rock from Mount Salak. While the East-Northeast has a similar boundary pattern with Cisadane River flow, it has similar characteristics to the area in the Bogor City until the Ciliwung River flow limit, which is Qypo formation, volcanic rock arranged from Mount Pangrango.

The Qvst formation is composed of the tufts of sandstone, while the Qypo Formation composed by the sediments of the older volcanoes compared to the other deposits, laced with basalt-andesine lava with oligoclase-andesine, labradorite, olivine, pyroxene, and hornblende.

3.2. Physiographic and Regional Form
The research area is the lower limit of the Mount Salak ridges, which is the Mount Salak Stratovolcano eruption tip. The characteristic of this stratovolcano is formed elongated ridges along with very sharp but spaced incisions. The ridge area includes a flat expanse to slightly sloping hill ridges (0-8%), at the desection slope forms very steep slopes up to (>40%). The desection part with a very steep slope has a high risk of erosion.

3.3. The Morphological Soil Characteristic
Based on the Soil Taxonomy Classification System at the Sub-Group level, the three soil characters observed in this region belong to the same soil classification that includes the Reddish Brown Latosol soil [24]; [20], equal to Typic Dystrudepts [13]. The characteristic of the soil: very deep solum (>150 cm), delicate texture, good development level, the color tends to brown – dark brown – yellowish brown to red. The soil’s physical character is good that is very friable to friable, and the level of structure development is medium to good/ strong structure.

Although they have the same classification level, there is the difference between those three samples based on several specifically characteristics. The soil profile of the location is referred in Figure 1. This profile represents the soil distribution on the slope or the dissection side of the field, a very steep slope (55%), it belongs to the Cisadane River cliff part. The soil is dominated by pumice tuff stone material, characterized by the top layer soil color is reddish dark brown-dark brown (5 YR-75 YR 3/2), the bottom layer soil color is brown-reddish brown to yellowish (5 YR-75 YR 4/4-5/6-5/8). The dark color is one of the characters indicating a high degree of fertility. The soil depth is a very deep solum (>150 cm), the
upper layer is granular, the bottom part is subangular blocky, fine to medium with sufficient
development, the soil consistency in humid conditions is a very friable to friable, in wet condition rather
sticky and plastic, soil pH of the upper layer of 5.0 bottom layer of 4.5.

In Figure 2, it represents the soil that spread over the flat to slope ridge area (slope <3%), which is
also widespread in the Bogor and surrounding area. The soil is dominated by pumice tuff with the
characteristic: the soil color on the top layer is reddish-dark brown (5 YR 3/3), the bottom layer of the
soil is yellowish red (5 YR 4/6), the color tends to dark is one of the characteristics that indicate the
fertility rate is likely high, the soil texture is clayey, particularly in layer IV on 78-103 cm depth found
saprolite are molded remnants of pumice tuff material, it is yellowish brown (10 YR 6/6), but it is not a
soil constrain; the soil solum is very deep (> 150 cm), the structure of the topsoil is granular, sub angular
blocky, the bottom of the sub angular blocky, smooth to medium smooth with enough development, the
consistency in the humid condition is very loose to loose, in wet conditions somewhat sticky, plastic,
with an inlet pH of upper layer field of 5.0 and bottom layer of 4.5.

![Figure 1](image1.png)

**Figure 1.** A. Soil profile position at the Hill, B. Soil profile.

![Figure 2](image2.png)

**Figure 2.** A. Soil profile position at the ridge, B. Soil profile.

The profile in Figure 3, represents the soil spread over the flat to slope ridge (slope <3%). The soil
characteristic based on their morphological character is dominated by basalt-andesine lava material. The
soil color is essentially redder, the upper layer is reddish dark brown (5 YR 4/4-4/6). The dark color
tends to be one characteristic that indicates a high fertility rate, even darker than the other soil color.
The soil texture is clayey; the soil solum is very deep (>150 cm).

The upper soil structure is friable, subangular blocky, the bottom soil is subangular blocky, fine to
medium smooth with enough development, the consistency in the humid condition is very friable to
friable, in a wet condition somewhat sticky to sticky, plastic, with an inlet pH of upper layer field of 5.0 and bottom layer of 4.5.

Figure 3. Soil profile at the plain.

### 3.3.1. Characteristics of Soil Fertility

The value of the soil fertility rate is determined from the laboratory analysis data whose sample is derived from 3 soil profiles made in this region. The laboratory analysis data include; pH (H$_2$O and KCl), C, N, and C/N, CEC, P$_2$O$_5$ (total and available), K$_2$O (total and available), exchangeable cation (Ca, Mg, K, and Na), free iron and saturated Aluminium. The laboratory analysis result is more fully presented in Table 1. The level of soil fertility in the study area is expressed by the qualitative value of each fertility factors, based on the guidelines for assessing soil fertility in Table 2 which are described below.

| Sample number | Horizon | Serial Number | Texture | HCl 25% | Organic matter | HCl 25% |
|---------------|---------|---------------|---------|---------|----------------|---------|
|               | Up-     | Down          | pH      | Walkley & Black | Kjeldahl | C/ N  | P$_2$O$_5$  | K$_2$O |
| cm            | %       | %             | %       | mg/100 g       | mg/100 g       | mg/100 g       | mg/100 g       | mg/100 g       |
| 1             | RM/GB - 01/1 | 0-28    | 19 | 5 | 19 | 76 | 4.7 | 3.8 | 2.25 | 0.29 | 8 | 79 | 32 |
| 2             | RM/GB - 01/II | 28-54  | 20 | 2 | 17 | 81 | 4.9 | 3.9 | 0.90 | 0.10 | 9 | 95 | 7 |
| 3             | RM/GB - 01/III | 54-82  | 21 | 2 | 16 | 82 | 5.0 | 3.9 | 0.84 | 0.08 | 11 | 89 | 7 |
| 4             | RM/GB - 01/IV | 82-116 | 22 | 2 | 15 | 83 | 5.0 | 4.0 | 0.65 | 0.06 | 11 | 102 | 7 |
| 5             | RM/GB - 01/V | 116-150 | 23 | 2 | 18 | 80 | 5.0 | 4.0 | 0.57 | 0.06 | 10 | 116 | 8 |
| 6             | RM/GB - 02/I | 0-22  | 24 | 13 | 26 | 61 | 5.6 | 4.6 | 1.82 | 0.20 | 9 | 67 | 14 |
| 7             | RM/GB - 02/II | 22-48  | 25 | 2 | 18 | 80 | 4.8 | 3.8 | 0.36 | 0.04 | 9 | 95 | 7 |
| 8             | RM/GB - 02/III | 48-78  | 26 | 9 | 15 | 76 | 4.8 | 3.7 | 0.23 | 0.03 | 8 | 99 | 5 |
| 9             | RM/GB - 02/IV | 78-103 | 27 | 4 | 18 | 78 | 4.7 | 3.8 | 0.18 | 0.02 | 9 | 87 | 5 |
| 10            | RM/GB - 02/V | 103-165 | 28 | 7 | 22 | 71 | 4.7 | 3.9 | 0.14 | 0.02 | 7 | 92 | 6 |
| 11            | RM/GB - 03/I | 0-28  | 29 | 11 | 38 | 51 | 5.5 | 4.5 | 1.27 | 0.12 | 11 | 108 | 22 |
| 12            | RM/GB - 03/II | 28-57  | 30 | 11 | 28 | 61 | 5.4 | 4.2 | 0.96 | 0.10 | 10 | 101 | 9 |
| 13            | RM/GB - 03/III | 57-88  | 31 | 8 | 22 | 70 | 5.3 | 4.3 | 0.61 | 0.07 | 9 | 122 | 10 |
| 14            | RM/GB - 03/IV | 88-118 | 32 | 7 | 20 | 73 | 5.3 | 4.3 | 0.53 | 0.06 | 9 | 137 | 10 |
Table 2. Soil chemical characteristic

| Soil Characteristics          | Very low | Low       | Medium    | High      | Very high |
|------------------------------|----------|-----------|-----------|-----------|-----------|
| C-organic (%)                | < 1,00   | 1,00 - 2,00 | 2,01 - 3,00 | 3,01 - 5,00  | > 5,00    |
| N (%)                        | < 0,10   | 0,10 - 0,20 | 0,21 - 0,50 | 0,51 - 0,75  | > 0,75    |
| Ratio C/N                    | < 5      | 5 - 10    | 11 - 15   | 16 - 25    | > 25      |
| P2O5 HCl 25 % (mg/100 gr)    | < 10     | 10 - 20   | 21 - 40   | 41 - 60    | > 60      |
| P2O5 Bray (ppm)              | < 10     | 10 - 15   | 16 - 25   | 26 - 35    | > 35      |
| P2O5 Olsen (ppm)             | < 10     | 10 - 25   | 26 - 45   | 46 - 60    | > 60      |
| K2O HCl 25 % (me/100 gr)     | < 10     | 10 - 20   | 21 - 40   | 41 - 60    | > 60      |
| KTK tanah (me/100 gr)        | < 5      | 5 - 16    | 17 - 24   | 25 - 40    | > 40      |
| Cation arrangement:          |          |           |           |           |           |
| K (me/100 gr)                | < 0,1    | 0,1 - 0,2 | 0,3 - 0,5 | 0,6 - 1,0  | > 1,0     |
| Na (me/100 gr)               | < 0,1    | 0,1 - 0,3 | 0,4 - 0,7 | 0,8 - 1,0  | > 1,0     |
| Mg (me/100 gr)               | < 0,4    | 0,4 - 1,0 | 1,1 - 2,0 | 2,1 - 8,0  | > 8,0     |
| Ca (me/100 gr)               | < 2      | 2 - 5     | 6 - 10    | 11 - 20    | > 20      |
| Base saturation (%)          | < 20     | 20 - 35   | 36 - 50   | 51 - 70    | > 70      |
| Aluminium saturation (%)     | < 10     | 10 - 20   | 21 - 30   | 31 - 60    | > 60      |
| Mineral reserve (%)          | < 5      | 5 - 10    | 11 - 20   | 21 - 40    | > 40      |
| Electric Conductivity        |          |           |           |           |           |
3.3.2. **Soil Reaction (pH)**

Based on laboratory analysis showed that the soil pH at the study site is acid (pH 4.7-5.5) except the upper layer, the result is higher that is slightly acid (pH 5.6). The soil on the lower location on the slopes has lower pH. This may be due to the presence of the higher amount of base saturation leaches in slope areas, as evidenced by the lower amount of base saturation on the slope areas. It has a possibility of soil fertility degradation in the steeper slopes.

3.3.3. **Organic Materials**

Organic material in the soil could be N source also could determine the amount of CEC, improve soil structure, and increase water holding capacity. Nitrogen is one of the macronutrients that are labile, easily lost due to the washing and denitrification process followed by evaporation due to chemical physics changes in the soil. The soils in the survey area contained a low amount of C-organic and N (in the bottom layer). Meanwhile, on the topsoil to the depth of 20 to 30 cm is low to medium.

3.3.4. **Base saturation (BS)**

Base saturation is the reflection value of the number of bases in the soil (Colloidal exchange complex) with CEC. The soil that has high alkaline content will provide a high base saturation value. The base saturation value is also defined as the number of cations that substitute H⁺ ions in the exchange complex bound by the colloidal complex. The soils in the research area had low to moderate base saturation from 25 to 60%, tend to be higher on the third location.

3.3.5. **The Cation Composition (Ca, Mg, K, and Na)**

The soil colloid-like clay and humus adsorb some of the amounts of the cations on the surface. The adsorbed cation can be traded to other cations. The higher the cation exchange of an element, the colloidal potential to supply the soil solution with the corresponding elements is greater. Ca, Mg, K and Na are the adsorbed cation on the surface of the soil adsorption complex. The analysis result showed that generally showed that the content of K and Na tends to be higher, i.e., between medium to high.

3.3.6. **Phosphate and Potassium.**

Phosphate is the second nutrient that many plants need after nitrogen. The source P in the soil is determined by primary and secondary minerals composition. At the sometime, its availability depends on the pH, the amount of ion and elements of Al, Fe, Mn, Ca, Cu, Zn, organic material content, soil temperature, and humidity, and micro-organ activity. The analysis result of P levels shows that the total P content is very high, more than 70 mg/100gr, but the availability is very low, only the top layer is rather high. This situation is prevalent in high AI soil made of the volcano. Potassium is the 3rd most needed nutrient most of the plants need after N and P. The potassium content of the soil is low to very low, about 5 to 10mg/100 g, and very low availability.

3.4. **The Physical Soil Properties**

Bulk density (BD) is fixed dry soil weight (105°C) of an entire soil volume, expressed in g/cc unit. The content weight is used to know how much the land can hold water as well as for calculating the total soil pore space. The total pore value of the soil depicts the porosity of the soil. Total pore chamber analysis results show that the soil on the slopes at Cisadane River has a higher porosity; the upper layer is higher than the bottom. If it happens in the rain, the soil is quickly saturated with water, and with Volkan soil characteristics that are easily shaken structured so that the soil usually landslide. Besides
erosion problem or landslides, the soil’s problem in the high rainfall area is clay leaching that causes the density of layers below the manner layer. To some extent, this condition could interfere with the growth of the crop if it is not treated by the soil management [25].

The aggregate stability index is an index used for the quantitative assessment of soil aggregate stability from external forces. Divide less stable soils when exposed to disturbance above. The aggregate is easily broken into clay grains that can clog macropores, resulting in more compact and dense, aerated pores and drainage is reduced and eventually created a hindrance to the permeability and hort development. In the research location with relatively high rainfall, the aggregate destruction process by rain is quite large, so it needs more concern. The soil on the slopes has a weaker structure, the texture missed with rocks or gravel due to avalanche material, it is shakier, and it has a higher risk of erosion. Meanwhile, the soil in the flat ridges is more stable, especially in the lower layer, which has higher aggregate stability. Based on the analysis of the soil aggregate stability index, the soil is also unstable to approximately stable either on the land above or on the slope.

The analysis showed that the land on the slope is high on the upper land/the ridge is medium. This illustrates that the porosity of the soil on the sloping area is more porous, and it has a higher risk of erosion. The increased amount of rainfall in the Bogor area, supporting the erosion and high weathering that characterizes the wet tropical regions. The result of leaching and bottom layer compaction causes lower permeability [26]. This condition is riskier on the ridge than the slopes area. Meanwhile, the slow drainage pore is related to the groundwater availability level to support the plant needs. The result of the analysis showed high to very high value. This condition also relates to soil permeability. Permeability is the speed of water in the soil mass medium. This characteristic is vital in the term of drainage and groundwater systems. The analysis result showed that the soil permeability in the slope area is faster than the land in the ridge. In the slope areas, the permeability ranges from fast (top layer) to rather fast (bottom layer) whereas in the ridges is medium (topsoil) so it rather fast (bottom layer), whereas in the ridges, including medium (top layer) to relatively slow (bottom layer).

3.5. The Types of Tree Collection
The type of tree of \( \geq 10 \) cm diameter, Gunung Batu Arboretum collection, Bogor presented in Table 3. The table describes 27 blocks (A to Z), each block is planted with trees and is limited by the road network. The most significantly of trees in block \( D_2 = 123 \) trees with 25 species, block \( A = 110 \) trees with 54 species, and block \( W = 104 \) trees with 30 types. Based on 2008 data, the number of trees in the Arboretum area is 1,178 trees with 246 species included in 55 families, the most common types in the field are *Shorea selanica* Blume, *Shorea stenoptera* Burck., *Shorea javanica* Koord. & Valet., *Hopea sangal* Korth., *Hopea odorata* Roxb., *Hopea bancana* (Boerl.) van Slooten (Dipterocarpaceae), *Castilloa elastic* Cerv. (Moraceae), and *Strombosia javanica* Blume (Olacaceae).

Based on the morphological nature, fertility, and physical condition of P;H&KA, the Arboretum area is divided into two zones: Cisadane Riverbank and Cisadane Office Complex. Those two zones are relatively different in characteristic, it is suspected that vegetation grows along the Cisadane River Bank is still complete start from the low plant, from seedlings to the level of trees. Thus the site is more fertile than the office zone. The two types intended are Cisadane River Bank Zone includes Block A, I, S, and Block Q; the rest belong to the office zone.

| Number | Location | Number of species | Number of trees | Dominant species |
|--------|----------|-------------------|-----------------|-----------------|
| 1.     | Block A  | 54                | 110             | *Khaya senegalensis* A. Juss., *Gyrinops versteeghii* (Gilg) Domke, dan *Duabanga moluccana* Blume |
| 2.     | Block B  | 26                | 40              | *Eucalyptus platypylla* F. Muell., *Dipterocarpus retusus* Blume, dan *Manilkara kauki* Dubard |
| 3.     | Block C  | 24                | 36              | *Pometia pinnata* Forst., *Spondias mombin* L., dan *Agathis dammara* (Lambert) Rich. |
4. Conclusion

Based on the study of biophysical land characteristics is very potential to support the growth of various crops collection of forest resource amount of 1,178 stems in this Arboretum Area, but also have the potential for degradation that needs to be protected. The old volcanic rock covering this region form Reddish Brown Latosol soil with solum, fine texture, very friable, and low aggregate stability, with a very steep slope topography, supported by high rainfall, with increased risk of erosion even it has landslide potential. The chemical character of the soil fertility is classified as acidic, the organic C content, nutrient capacity, and low to moderate base saturation, with some low nutrient content.
potentially the degradation of the soil fertility, especially the loss of topsoil, which is very supportive to the growth of the various types of trees collection in the Arboretum area.

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