Soil fertility status at Kuningan Botanical Garden, Kuningan Regency, West Java, Indonesia

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Abstract. Kuningan Botanical Garden (KBG) is an ex-situ conservation area adjacent to the Mount Ciremai National Park. Soil characteristics are an essential information, especially to determine zonation at KBG. This research was conducted to describe soil fertility status at KBG through physical and chemical properties of soil (Cation Exchange Capacity/CEC, Base Saturation/BS, Soil Organic Carbon/C-Organic, Total Soil Phosphorus (total-P), and Total Soil Potassium (total-K)). Soil from eight locations were sampled by using a diagonal systematic and a purposive sampling method. Soil samples (9 sub sample points at each location) were mixed, then analyzed at Integrated Testing Laboratory in Vegetable Research Center (BALITSA) Lembang, Indonesia. Land in this research area is dominated by volcanic rocks with various levels of slope and soil fertility. Soil type divided into Andosol and Podzolic soils with soil textures dominated by clay and clay loam. CEC value at KBG is categorized as low to moderate (10.83 – 19.21 cmol/kg); BS value is categorized as low to very high (21 – 81 %); C-Organic is categorized as low to very high (1.33 – 7.05 %); total-P is categorized as low to very high (46.54 – 73.6 mg/100g); and total-K is categorized as low to high (7.25 – 44.67 mg/100g). The result also showed that Total Soil Nitrogen (total-N) at KBG is categorized as low to very high (0.15 – 0.78 %) and soil pH levels around 5.2 to 6.3. Therefore, the soil fertility status at the Kuningan Botanical Garden can be categorized into low and medium soil fertility.

1. Introduction
Kuningan Botanical Garden (KBG) is an ex-situ conservation area located in Kuningan Regency, West Java, Indonesia. This botanical garden is adjacent to the Mount Ciremai National Park with an area approximately 156.4 hectares. KBG is directly managed by the Kuningan Regency Government through the Technical Implementation Unit of the Kuningan Botanical Garden. Based on the Kuningan Regency Regent Regulation No. 83 of 2017, it is stated that the use of KBG is carried out through conservation, research, educational, and tourism activities also environmental services utilization.

KBG’s plan to improve their collection plants needs to be supported by the information about the condition of the soil, especially to find out the condition of the soil fertility. The soil plays an important role in sustaining plant growth because the soil contains many nutrients that can be used by plants. Therefore, the availability of the soil nutrients can be said to be the soil fertility.

Land characteristics of KBG’s are dominated by rocks with a high level of slope. This causes the soil in KBG has the various fertility condition. Moreover, at the beginning of the KBG development
plan, the area allocated to become a botanical garden were banana plantations area, rice fields, and shrubs. The nutrients contained in the soil are always changing depending on the season, soil management techniques and plant species that grow on it [1]. An effort that can be made to determine the soil fertility status in KBG is by evaluating the soil fertility. One method that can be used to assess the soil fertility status is by soil analysis or soil chemical testing [2].

Therefore, this research was conducted to determine the soil fertility status in the KBG as a basis for optimizing the growth of the collection plants. Information about the status of the soil fertility is also important as a reference in determining an area’s management plan.

2. Research Methodology

2.1. Time and Location

The study was conducted in March to May 2019 in the Kuningan Botanical Garden, Pasawahan District, Kuningan Regency, West Java Province. KBG is located at coordinates 6°49'1.9" South Latitude and 108°24'10.37" East Longitude and located at an altitude of 500 to approximately 900 meters above sea level.

2.2. Data Collecting Methods

Soil sampling is done by diagonal sampling and purposive sampling methods. There are eight soil sampling locations representing nine areas in the KBG and at each location, there are nine sub-sample points for obtaining composite soils. The location of sampling points is presented in Figure 1.

![Figure 1. Map of Soil Sampling Points at KBG.](image)

2.3. Analysis of Soil Chemical Properties

Composite soil samples taken in the field, then analyzed for their chemical properties in the Integrated Testing Laboratory at the Vegetable Research Center (BALITSA), Lembang, West Java. Five parameters of soil chemical properties like Cation Exchange Capacity (CEC), Base Saturation, Soil Organic Carbon, and the total of Phosphorus and Potassium of the soil were analyzed to determine the soil fertility status.

| No. | Tested Parameter | Testing Method (Unit Results) |
|-----|------------------|-------------------------------|
| 1   | Soil pH          | Peach in Black                |
| 2   | Organic Carbon   | Kumies (%)                    |
| 3   | N – Kjeldahl     | Kjeldahl (%)                  |
2.3.1. Soil Chemical Properties Evaluation Criteria
Predetermined criteria by the Soil Research Center is used to determine the soil chemical property values category. Presented in Table 2.

| No. | Soil Chemical Properties Parameters | Unit | Values |
|-----|-------------------------------------|------|--------|
| 1   | Soil Organic Carbon                | %    | Very Low | Low | Medium | High | Very High |
| 2   | P₂O₅ HCl 25%                       | mg/100g | <15 | 15 – 20 | 21 – 40 | 41 – 60 | >60 |
| 3   | K₂O HCl 25%                        | mg/100g | <10 | 10 – 20 | 21 – 40 | 41 – 60 | >60 |
| 4   | CEC                                | cmol(+) /kg | <5 | 5 – 16 | 17 – 24 | 25 – 40 | >40 |
| 5   | Base Saturation                    | %    | <20 | 20 – 40 | 41 – 60 | 61 – 80 | >80 |

2.3.2. Soil Fertility Status Determination
Primary data obtained from the soil testing, then being matched according to the soil fertility level assessment criteria presented in Table 3.

| No. | CEC | Base Saturation | P₂O₅, K₂O, Soil Organic Carbon | Fertility Level |
|-----|-----|-----------------|--------------------------------|----------------|
| 1   | H   | H               | ≥ 2 H without L | High |
| 2   | H   | H               | ≥ 2 H with L | Medium |
| 3   | H   | H               | ≥ 2 M without L | High |
| 4   | H   | H               | ≥ 2 M with L | Medium |
| 5   | H   | H               | H M L | Medium |
| 6   | H   | H               | ≥ 2 L with H | Medium |
| 7   | H   | H               | ≥ 2 L with M | Low |
| 8   | H   | M               | ≥ 2 H without L | High |
| 9   | H   | M               | ≥ 2 H with L | Medium |
| 10  | H   | M               | ≥ 2 M | Medium |
| 11  | H   | M               | Other Combinations | Low |
| 12  | H   | L               | ≥ 2 H without L | Medium |
| 13  | H   | L               | ≥ 2 H with L | Low |
| 14  | H   | L               | Other Combinations | Low |
| 15  | M   | H               | ≥ 2 H without L | Medium |
| 16  | M   | H               | ≥ 2 M without L | Medium |
| 17  | M   | H               | Other Combinations | Low |
| 18  | M   | M               | ≥ 2 H without L | Medium |
3. Result and Discussion

3.1. Physical Condition Overview of Kuningan Botanical Garden

3.1.1. Topography

KBG has a diverse topography and it is dominated by steep to very steep slope. Slopes have an important role in the formation and development of the soils through three processes, namely erosion, transportation and sedimentation [3].

**Table 4.** Slope Class at KBG.

| No. | Slope     | Area (ha) | Percentage |
|-----|-----------|-----------|------------|
| 1   | Flat      | 5.937     | 4%         |
| 2   | Slight    | 16.638    | 10%        |
| 3   | Moderate  | 38.833    | 25%        |
| 4   | Steep     | 45.241    | 29%        |
| 5   | Very Steep| 49.791    | 32%        |

Figure 2. Slope Map of KBG.
3.1.2. Soil Types
There are two types of soil found in the KBG, namely Andosol Soils (covering area 75.426 ha) and Podzolic Soils (covering area 81.059 ha) (Figure 3). Andosol soil characteristics are gray or black in color and have the accumulation of organic matter on the soil surface. Podzolic soils have brown to yellow color, have strong soil consistency, low permeability and dominated by clay fractions. In dry conditions, Podzolic soils tend to be very hard and very sensitive to erosion.

Figure 3. Soil Types Map of KBG.

3.1.3. Bulk Density
The highest soil bulk density value is found at Point 4 which is 0.97 grams/cm$^3$, while the lowest soil bulk density is at Point 3 which is 0.50 grams/cm$^3$. The low value of bulk density at Point 3 allegedly because the type of soil at that location is Andosol soils [4]. The value of soil bulk density can be affected by many factors, including soil processing, organic matter content, human activity, soil texture, soil structure, soil water content, and others.

| Field Code | Bulk Density (grams/cm$^3$) |
|------------|-----------------------------|
| Point-1    | 0.96                        |
| Point-2    | 0.67                        |
| Point-3    | 0.50                        |
| Point-4    | 0.97                        |
| Point-5    | 0.92                        |
| Point-6    | 0.90                        |
| Point-7    | 0.51                        |
| Point-8    | 0.80                        |

3.2. Result of Soil Chemical Properties Analysis

3.2.1. Cation Exchange Capacity (CEC)
Soil CEC is the ability of colloidal soil to absorb and exchange cations. Cations that have been absorbed by the colloidal soils are generally difficult to wash off with water, but their existence can be replaced by other cations in the soil [5]. CEC values in Kuningan Botanical Gardens mostly belong to the low CEC class and only Point 7 has a medium CEC value.
Table 6. Soil CEC Value of KBG.

| Field Code | CEC cmol(+)/kg | Criteria |
|------------|----------------|----------|
| Point-1    | 13.33          | Low      |
| Point-2    | 12.30          | Low      |
| Point-3    | 14.53          | Low      |
| Point-4    | 15.07          | Low      |
| Point-5    | 10.83          | Low      |
| Point-6    | 12.57          | Low      |
| Point-7    | 19.21          | Medium   |
| Point-8    | 13.23          | Low      |

Several factors that affect the value of the CEC in the KBG are the availability of organic matter and soil texture (Table 7). Soils with high organic matter and clay tend to have a higher CEC value compared to soils with low organic matter or sandy soil. Organic matter in the soil can also function as a natural fertilizer.

| Field Code | Fraction (%) | Texture Class |
|------------|--------------|---------------|
| Point-1    | 17 29 55     | Clay          |
| Point-2    | 38 27 35     | Clay Loam     |
| Point-3    | 37 26 37     | Clay Loam     |
| Point-4    | 33 34 33     | Clay Loam     |
| Point-5    | 19 35 46     | Clay          |
| Point-6    | 12 26 62     | Clay          |
| Point-7    | 29 24 47     | Clay          |
| Point-8    | 18 35 47     | Clay          |

The low value of CEC in KBG can be caused by other factors like soil mineral types. Andosol and Podzolic soils are two types of soil found in the KBG. Both types of soil are generally classified as acidic soils which are contained aluminum (Al), iron (Fe) and active silica (Si). Al and Fe minerals decrease the CEC value of the soil because they reduce the negative charge of the soil [6].

3.2.2. Base Saturation
Base saturation (BS) is a comparison of all the cations contained in the soil sorption complex. BS represent the percentage of the CEC occupied by bases (Ca\(^{2+}\), Mg\(^{2+}\), K\(^{+}\), and Na\(^{+}\)). BS value in KBG varies from low to very high (Table 8).

| Field Code | Base Saturation (%) | Criteria |
|------------|---------------------|----------|
| Point-1    | 81                  | Very High|
| Point-2    | 37                  | Low      |
| Point-3    | 21                  | Low      |
| Point-4    | 78                  | High     |
| Point-5    | 49                  | Medium   |
| Point-6    | 57                  | Medium   |
| Point-7    | 33                  | Low      |
| Point-8    | 48                  | Medium   |

BS usually has a positive correlation with CEC values [7]. However, in the case of the soils in the KBG, the high value of the CEC is not always followed by an increase of the BS value. High or low
BS value at the research location reflects the presence of base cations in the soil [2]. The higher BS value indicates that the cation sorption complex in the soil is dominated by base cations [8]. Base cations are generally dissolving easily in the nutrients leaching process, so if a soil has a high BS value it shows that the soil has not been washed intensively and can be categorized as a fertile soil [8].

3.2.3. Soil Organic Carbon and C/N Ratio
Soil organic carbon is an essential macro nutrient needed by plants. The soil organic carbon in the KBG is classified as low to very high (Table 9). The value of soil organic carbon in an area can be affected by many factors like the type of soil, the presence of vegetation, and soil or land management [9].

| Field Code | Organic Carbon | Organik Matter | Nitrogen | C / N Ratio |
|------------|----------------|----------------|----------|-------------|
|            | %              | 1,74 x C-org (%) | %        | Status      |
| Point-1    | 2.10           | Medium         | 3.65     | 0.21        | Medium 10 |
| Point-2    | 6.12           | Very High      | 10.65    | 0.56        | High 11  |
| Point-3    | 6.22           | Very High      | 10.79    | 0.60        | High 10  |
| Point-4    | 2.12           | Medium         | 3.69     | 0.21        | Medium 10|
| Point-5    | 1.33           | Low            | 2.31     | 0.15        | Low 9    |
| Point-6    | 2.26           | Medium         | 3.93     | 0.21        | Medium 11|
| Point-7    | 7.05           | Very High      | 12.27    | 0.78        | Very High 9 |
| Point-8    | 2.57           | Low            | 4.47     | 0.21        | Medium 12|

Point 2, Point 3, and Point 7 are the locations with the highest organic carbon. This can occur because the location has Andosol soil types. Andosol soil is a type of soil that contains a lot of organic matter. The existence of soil organic carbon cannot be separated from the decomposition process that occurs in the soil. Microorganisms play an important role in this decomposition process [10].

To find out the decomposition process, the microbial activity can be discovered from the quality of organic matter and the C/N ratio. The C/N ratio of soil in KBG is relatively good. This is reflected by the value of the C/N ratio at each point is less than 25 which is ideal for plants [1]. If the organic material has a C/N ratio more than 30 then N will be immobilized and cannot be used by plants [11].

3.2.4. Total Phosphorus (Total-P)
The results of the soil Total-P in KBG (Table 10) show that the soil Total-P values are classified as high to very high.

| Field Code | Total P (mg/100g) | Criteria |
|------------|-------------------|----------|
| Point-1    | 69.19             | Very High|
| Point-2    | 52.82             | High     |
| Point-3    | 49.76             | High     |
| Point-4    | 73.67             | Very High|
| Point-5    | 61.66             | Very High|
| Point-6    | 46.54             | High     |
| Point-7    | 67.12             | Very High|
| Point-8    | 49.97             | High     |

The main source of phosphorus in the soil comes from organic matter (manure and crop residues), artificial fertilizers, and minerals in the soil, especially apatite minerals [8]. Apatite mineral is a mineral derived from igneous, sedimentary, and metamorphic rocks. Moreover, KBG is located at the
foot of Mount Ciremai making it rich in igneous rocks from the eruption of the volcano. Phosphorus is one of the essential nutrients for plant growth. However, a high value of phosphorus does not necessarily indicate good soil fertility. Phosphorus in the soil tends to bind to other elements to form compounds that are relatively stable and settle so that cannot be absorbed by plants [12]. Plants can only absorb phosphorus in the form of phosphate ions such as $\text{H}_3\text{PO}_4^-$ and $\text{HPO}_4^{2-}$, so that only a few elements of phosphorus are available for plants.

3.2.5. Total Potassium (Total-K)
The results of the soil Total-K in KBG (Table 11) show that the Total-K values are classified as high to very high.

| Field Code | Total K (mg/100g) | Criteria |
|------------|-------------------|----------|
| Point-1    | 24.71             | Medium   |
| Point-2    | 8.48              | Low      |
| Point-3    | 7.52              | Low      |
| Point-4    | 44.67             | High     |
| Point-5    | 25.18             | Medium   |
| Point-6    | 35.90             | Medium   |
| Point-7    | 9.42              | Low      |
| Point-8    | 29.59             | Medium   |

Potassium mostly sourced from the weathering of soil-forming parent rock. The low potassium value can occur due to several factors, including potassium absorption by plants, nutrient leaching, and erosion [13]. The availability of potassium in the soil needs to be very well calculated. Potassium is one of the essential nutrients for plants whose existence cannot be replaced by other elements. Plants that lack of potassium will show symptoms like weak plant stems, so plants can easily collapse.

3.3. Evaluation of Kuningan Botanical Garden Soil Fertility Status
Soil fertility status at KBG can be categorized as low and medium. The result is, 124.438 ha area of KBG has a low soil fertility while the 32.057 ha area has a medium soil fertility (Figure 4).

The low value of the CEC provides a major impact in reducing soil fertility at KBG (Table 12). Thus, one of the important steps that can be done at KBG is by adding some organic material to the soil (can be by fertilization or by planting trees to increase litter production). Furthermore, to increase
the soil pH value can be done by liming. Soil fertility is very important to know because it shows the ability of the soil to provide nutrients for plant growth. Evaluation of soil fertility as soil monitoring effort is also useful for managing area, especially to save production costs such as fertilizing, and providing seeds.

| Field Code | CEC (me/100g) | Base Saturation (%) | Soil Organic Carbon (%) | Total P (P2O5) (mg/100g) | Total K (K2O) (mg/100g) | Fertility Status |
|------------|---------------|---------------------|------------------------|--------------------------|-------------------------|------------------|
| Point-1    | 13.33 (L)     | 81 (VH)             | 2.10 (M)               | 69.19 (VH)               | 24.71 (M)               | Medium           |
| Point-2    | 12.30 (L)     | 37 (L)              | 6.12 (VH)             | 52.82 (H)               | 8.48 (L)              | Low              |
| Point-3    | 14.53 (L)     | 21 (L)              | 6.22 (VH)             | 49.76 (H)               | 7.52 (L)              | Low              |
| Point-4    | 15.07 (L)     | 78 (H)              | 2.12 (M)              | 73.67 (VH)             | 44.67 (H)              | Medium           |
| Point-5    | 10.83 (L)     | 49 (M)              | 1.33 (L)              | 61.66 (VH)             | 25.18 (M)              | Low              |
| Point-6    | 12.57 (L)     | 57 (M)              | 2.26 (M)              | 46.54 (H)              | 35.90 (M)              | Low              |
| Point-7    | 19.21 (M)     | 33 (L)              | 7.05 (VH)             | 67.12 (VH)             | 9.42 (L)              | Low              |
| Point-8    | 13.23 (L)     | 48 (M)              | 2.57 (M)              | 49.97 (H)              | 29.59 (M)              | Low              |

Note: L = Low, M = Medium, H = High, VH = Very High

4. Conclusion
Generally, the soil fertility status of the Kuningan Botanical Garden is classified as low. Area with medium soil fertility status allegedly due to intensive land and soil processing by the management of KBG and/or by the farmer in several locations.

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