VEGETATION ANALYSIS AND CARBON STOCK ESTIMATION IN KUNINGAN BOTANICAL GARDEN WEST JAVA

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Abstract. Research on plant biodiversity and carbon stock estimation are highlighted due to global issue on climate change. Therefore, this study was conducted to record plant diversity and estimate carbon stock in Kuningan Botanical Garden (KBG). Nested plots 20m × 20m were placed systematically with random start sampling to record tree species and to estimate carbon stock. Poles were recorded in subplots 10m × 10m; shrubs and sapling in subplots 5m × 5m; while seedling and herbaceous plants in subplots 2m × 2m. Data were analyzed to calculate Shannon Wiener diversity index and important value index (IVI). Destructive method was used to estimate soil carbon content, meanwhile tree carbon content was estimated by using allometric method. Biodiversity index in KBG is 2.8 with dominant trees were S. wallichii (IVI: 46.22%) and Gmelina arborea (IVI: 30.24%); S. wallichii (IVI: 65.87%) and Gnetum gnemon (IVI: 39.11%) in pole stage; Adenanthera Pavonina (IV: 41.56%) and G. gnemon (IV: 41.56%) in seedling stage. Dominant shrubs were Mimosa invisa (IV: 59.42%) and Mimosa pudica (IV: 42.90%); Centrocema pubescens (IVI: 26.52%) and Paspalum cartilagineum (IVI: 25.91%) as dominant herb in KGB. Plant composition in this area depicted human activity (plantation) changed natural forest composition. Carbon stock in tree stands is 25.45 tonC/ha (11.06%); understory is 11.29 tonC/ha (4.9%); litter is 6.32 tonC/ha (2.75%); necromass is 0.17 tonC/ha (0.07%); and soil organic carbon is 186.85 tonC/ha (81.21%). Therefore, we can estimate that total carbon stock in Kuningan Botanical Garden (156.4 ha) is 35985 tons.

1. Introduction

Forest is an ecosystem that has a certain composition and structure and has benefits both directly and indirectly. One of indirect benefit of forests is a carbon sink, with a different structure and composition, each forest or vegetation area have different potential of carbon stock. Carbon stock can be one indicator that forests or vegetated areas that have fulfilled their environmental service functions. Botanical Gardens including forest areas that are arranged in such a way both in composition and engineering that aims to get a beautiful area [1].

Kuningan Botanical Gardens which was inaugurated in 2015 has an area of approximately 156.4 ha and has a destination for research, ecotourism, education, conservation and environmental service providers. Until now, Kuningan Botanical Garden is still under development stage where there are still a lot of facilities and infrastructure that have not yet been built, vegetated land in the form of shrubs that have not been cultivated and land that has not been planted by planned plants. Based on the results of land cover analysis, Kuningan Botanical Garden is still dominated by shrub ecosystem around 71%. In addition, research for the development of the Kuningan Botanical Gardens is still not much done, such as...
information on plant species diversity and carbon stock. This research aims to determine the type of vegetation community based on the Importance Value Index (IVI) and estimation of carbon stock in Kuningan Botanical Garden.

2. Methodology
2.1 Study Area
The research was conducted in March to April 2019. Data was collected at the Kuningan Botanical Garden, Kuningan District, West Java. Geographically the Kuningan Botanical Garden is located at coordinates 6°49'1.9" latitude and 108°24'10.37" east longitude.

2.2 Data Collecting
2.2.1 Vegetation Analysis
Vegetation analysis was conducted to obtain an Important Value Index (IVI %). IVI was calculated based on plant habitus (i.e. seedlings, trees, poles, shrubs and herbs) measurement using 20 m × 20 m (0.04 ha) quadrant plot of 20 plots. The sample plots were established using systematic with random start sampling with a distance between plots was 250 meters.

![Figure 1. Design of observation plot and plot arrangement](image)

The measurements were conducted in the following sub-plots:
A: 20 mx 20 m : Trees, dead trees and soil
B: 10 mx 10 m : Pole
C: 5 mx 5 m : Stakes and shrubs
D: 2 mx 2 m : Seedlings and herbs
E: 1 mx 1 m : Roots and litter

The parameters taken to obtain data on trees, dead trees, poles and saplings are DBH (Diameter at Breast Height), height, number of individuals, basal area, density and frequency. As for the seedlings, shrubs and herb parameters that are calculated are the number of individuals, frequency, and shade.

2.2.2 Sampling of Undergrowth and Litter
The undergrowth and litter above the soil surface in the 1 m x 1 m subplot were taken destructively and weighed to determine the wet weight (WW). After that, the undergrowth and litter were put into a sample plastic bag and roasted to determine the dry weight (DW).

2.2.3 Soil Sampling
Soil samples were collected using a core sampler and putting the sample into a plastic bag, then put into microwave to determine the dry weight (DW) at furnace to determine the ash weight (AW)

2.2.4 Drying
Drying the sample undergrowth and litter made to obtain dry weight (DW) using an oven with a temperature of 70 °C for 4 days, while soil samples dried using an oven in the temperature of 105 °C for 24 hours and the ash weight obtained by drying the soil dry using a furnace in the temperature of 450 °C for 4 hours.

2.3 Data analysis
2.3.1 Type Composition
To get the value of density, stand, frequency, dominance and IVI calculated using the formula:
Frequency = \[
\frac{\text{total of similar species}}{\text{total plot or point}}
\]  
(1)

Density = \[
\frac{\text{individual in each plot}}{\text{total plot width}}
\]  
(2)

Lush = \[
\frac{\text{LAB total species}}{\text{total plot width}}
\]  
(3)

To get shrubs and herbs habitus use the middle class of Daubenmire values [15] in Table 1.

| Cover Class | Coverage Range | Middle Class Value |
|-------------|----------------|--------------------|
| 6 | >95-100 | 97.5 |
| 5 | >75-95 | 85 |
| 4 | >50-75 | 62.5 |
| 3 | >25-50 | 37.5 |
| 2 | >5-25 | 15 |
| 1 | 0-5 | 2.5 |

X. Relative = \[
\frac{X}{X_{total}} \times 100\%
\]  
(4)

IVP (%) = Kr. Relative + Kb. Relative + Fr. Relative  
(5)

Shannon-Wiener Diversity Index [16]

\[H' = -\sum_{k=0}^{n} P_{i} \ln p_{i}\]  
(6)

2.3.2 Stand Biomass

Calculation of dead tree biomass uses the following equation [16], where D is the diameter of the dead tree

\[B = 0.118 \times D^2 \times \% \text{ Wholeness}\]  
(7)

Data in the form of tree diameters and heights are entered into the allometric equation according to the type or character of the tree. The allometric equation used refers to Krisnawati et al. [14].

| Type of Tree | Volume Allometric Equation | Biomass Allometric Equation | Source |
|--------------|----------------------------|-----------------------------|--------|
| Scima wallichii | VT=0.000093D^{2.585} | B=Vtree × WD × BEF | Disastra (1982) |
| Swietenia macrophylla | logBBA=1.32+2.65logD | | Adinugroho and Sidiyasa (2006) |
| Vatica rassak | VT=0.0002953D^{2.57} | B=Vtree × WD × BEF | Directorate of Forest Inventory (1991) |
| Pinus merkusii | BBA=0.0936D^{2.4124} | | Sinegar (2007) |
| Dalbergia latifolia | BBA=0.7458(D^2H)^{0.3704} | | BPKH Wil. XI and MFP II (2009) |
| Gmelina arborea | BBA=0.06(D^2H)^{0.083} | | Agus (2002) |
| Hopea odorata | VT=0.00014454D^{2.52} | B=Vtree × WD × BEF | Soemarna (1971) |
| Toona sureni | VT=0.00013D^{2.5017} | B=Vtree × WD × BEF | Directorate of Forest Inventory (1990) |
| Durio zibethinus | VT=0.000295D^{2.5} | B=Vtree × WD × BEF | Haruni dkk. (2012) |
| Jenis Lain | V=1/4\pi D^2HxF | B=Vtree × WD × BEF | Haruni dkk. (2012) |
2.3.3 Understory Vegetation Biomass and Litter

\[
\frac{W_{tb}}{W_{ts}} = \frac{W_t}{A} \times \frac{W_{sk}}{W_{sb}}
\]  

(8)

\( W_{tb} \): Bottom Plant Biomass and Litter
\( W_t \): Fresh Sample Total Weight
\( W_{sk} \): Sub Sample Dry Weight
\( W_{sb} \): Sub Sample Fresh Weight
\( A \): Size of Area Sampled

2.3.4 Soil Organic Carbon

\[
SOC = BD \times d \times %C
\]  

(9)

\( BD \): Soil bulk density
\( D \): Depth of Sampling
\( %C \): Carbon concentration = 58% SOM

2.3.5 Total Carbon

According to Brown (1997) carbon is 47% of biomass, so that to convert biomass into carbon used the equation

\[
C = \text{Biomass} \times 0.47
\]  

(10)

So that, equation of total carbon resulted from accumulation of each carbon storage is

\[
CT = C_p + C_{pm} + C_{tb} + C_s + SOC
\]  

(11)

\( CT \): Total carbon
\( C_p \): Carbon on tree
\( C_{pm} \): Dead tree carbon
\( C_{tb} \): Bottom plant carbon
\( C_s \): Litter carbon
\( SOC \): Soil Organic Carbon

3. Result and Discussion

3.1. Land Cover Analysis

Land cover analysis was conducted to find out the percentage of land cover in di Kuningan Botanical Garden. The result of land cover analysis can be seen in Figure 2.

![Figure 2. Map of Kuningan Botanical Garden Land Cover](image)

According to land cover analysis conducted, most of the Kuningan Botanical Garden area is dominated by shrubs/meadow with percentage of 71%, while for forest area in low land has percentage of 24%, built-up area has percentage of 2.6% and water bodies has percentage of 2.1%. This is because Kuningan Botanical Garden is still in development stage and not yet cultivate land also plant collection plants optimally.

3.2 Vegetation Characteristic

According to result of vegetation analysis conducted in Kuningan Botanical Garden there were 27
types of tree from 18 families, 11 types of plants in the form of living poles from 11 families, 7 types of seedling from 7 families, 7 types of shrubs from 5 families and 25 types of herbs from 9 families.

3.2.1 Tree Important Value Index
Based on the result of IVI calculation from 27 types of tree in Kuningan Botanical Garden there were 5 trees with highest domination that are *Schima wallichii*, *Gmelina arborea*, *Swietenia macrophylla*, *Enterolobium cyclocarpum* and *Gnetum gnemon*

![Figure 3. Percentage of tree important value index](image)

*Schima wallichii* and *Gmelina arborea* are trees that dominate in Kuningan Botanical Garden. So that community name from Kuningan Botanical Garden is *Schima-Gmelina*. *Schima wallichii* is planted in 2008 for the greening program before the Kuningan Botanical Garden was inaugurated and in 2013. *Schima wallichii* was planted with donations from the Pasuruan Horticultural Seed Center. Thus, *Schima wallichii* is found in Kuningan Botanical Gardens and grows well because it is basically a highland plant that can grow well at an altitude of 700 to 3000 mdpl [2]. *Gmelina arborea* or Jati Putih grew in the Kuningan Botanical Garden because in 2013 the Kuningan Botanical Garden received donations from Pikiran Rakyat and Kuningan High School. In 2016 the Kuningan Botanical Garden suffered by fire from Gunung Ciremai National Park, former fire land planted by *Gmelina Arborea* which *Gmelina arborea* was fast growing and fire tolerant species [3].

3.2.2 Pole Important Value Index
IVI of pole from 11 types obtained 5 types with highest percentage of IVI that can be seen in Figure 4.

![Figure 4. Percentage of pole important value index](image)

*Schima wallichii* and *Gnetum gnemon* have highest IVI, because *Schima wallichii* is dominant tree that in KBG and in 2013 was newly planted on donations from the Pasuruan Holitikulutra Seed Center with an average diameter of *Schima wallichii* in the 5th year is 16 cm. *Schima wallichii* at the age of 5 year has height around 2 m until 8 m and diameter around 13 cm until 19 cm [4]. *Gnetum gnemon* or melinjo is
planted in 2010 by surrounding society, the average diameter of melinjo in Kuningan Botanical Garden is around 17 cm, melinjo at the age of 10 years have diameter around 16-25 cm without intensive treatment [5] so that most of melinjo plant is still in the form of pole.

3.2.3 Seedling Important Value Index
Important value index from 7 types of seedling can be seen in Figure 5.

![Figure 5. Percentage of seedling important value index](image)

It can be seen that Adenanthera pavonina, Gnetum gnemon and Swietenia macrophylla has IVI with equal percentage. This is because each seedling type was only found one plot with the same mid class value. To determine the seedling type that has the largest IVI can be seen from the number of individuals, Adenanthera pavonina or Saga has a greater number of individuals than Gnetum gnemon and Swietenia macrophylla. Saga seeds are seeds that are lightweight, easily fall by the wind and are favored by squirrels as well as several species of birds [6] Saga seeds are easy to grow quickly while melinjo seeds when they are ripe will fall to the ground and their skin rot, so that it becomes a nutrient for the seeds to grow [5].

3.2.4 Shrubs Important Value Index
IVI from 7 types of shrubs can be seen in Figure 6.

![Figure 6. Percentage of shrubs important index value](image)

Mimosa invisa and Mimosa pudica are plants that dominate habitus of shrubs in Kuningan Botanical Garden, because ecosystem of Kuningan Botanical Garden is still in the form of shrub, as well as both types of these plants are invasive plants [7] that can suppress other plant types. Mimosa is a genus that is tolerant of sunlight and grows fast in open fields [8] growing creeping and sometimes bushy between 0.1 m and 1 m. Clidemia hirta and Cordyline fruticosa have low IVI because both plants are intolerant of sunlight [9].

3.2.5 Herbs Important Value Index
There are 27 types of herbs in Kuningan Botanical Garden and 5 types that have the largest I VI can be seen in Figure 7.

![Figure 7. Percentage of herbs important value index](image)

*Centrosema pubescens* and *Paspalum cartilaginieum* are herbs that have highest I VI, because both species are cover plants that are tolerant of high porosity and can suppress the growth of weeds around [10]. Basically, the two plants are good plants to improve soil quality in terms of soil porosity. Besides, both types of these plants are rapidly grow in open place [11]. In addition, 5 plants with highest I VI are tolerants plants of the sun, so they can be found and grown in open fields.

### 3.2.6 Diversity Index

Based on the result of calculation to important value index with equation of Shannon Wiener (1988), Kuningan Botanical Garden has a Diversity Index of 2.8. Basically, the diversity index does not have a specific range classification to show the high or low diversity of a region. However, if it is compared to Gunung Ciremai National Park, where Kuningan Botanical Garden has purpose as site window from Gunung Ciremai National Park, that has diversity index of 4.9 [5], the diversity index of Kuningan Botanical Garden is still low. This is because Kuningan Botanical Garden has only 27 types of plants compared to Gunung Ciremai National Park that have 113 types of plants.

### 3.2.7 Carbon Stock Estimation

Estimation of carbon stock in Kuningan Botanical Garden is based on the stock of standing carbon, understory vegetation, litter, dead trees and soil organic carbon. Based on land cover analysis, Kuningan Botanical Garden is divided into two land cover types, i.e shrubs and lowland forests, with average of carbon stocs was 167.13 ton/ha and 62.95 ton/ha, respectively (Figure 8).

![Figure 8. Comparison of carbonstock in two land cover types](image)
density. For the shrub ecosystem, the average vegetation density is high and is supported by the number of undergrowth and at some point there is still vegetation in the form of trees and poles and dead trees. Thus, the amount of carbon per hectare can be higher than the lowland forest land cover. A more complete comparison of carbon storage in 2 types of land cover or ecosystem can be seen in Table 3.

Table 3. Comparison of Carbon in 2 Types of Land Cover

| Pole (ton/ha) | Understory (ton/ha) | Litter (ton/ha) | Dead Tree (ton/ha) | Soil (ton/ha) |
|--------------|---------------------|----------------|-------------------|--------------|
| Lowland Forest | 22.69               | 0.55           | 2.09              | 37.6         |
| Shrubs       | 2.77                | 10.73          | 4.23              | 149.25       |

Based on the result above it can be estimated the total of carbon storage in Kuningan Botanical Garden. Total carbon in ton/ha in Kuningan Botanical Garden can be seen in Table 4.

Table 4. Carbon Storage in each carbon storage place

| Pole | Understory | Litter | Dead Tree | Soil | Total |
|------|------------|--------|-----------|------|-------|
| 25.46| 11.28      | 6.32   | 0.17      | 186.85| 230.08|

Based on result in Table 4. the total carbon storage in the Kuningan Botanical Garden with an area of 156.4 ha is 35,985 tonC with the percentage of each carbon storage can be seen in Figure 9.

Figure 9. Percentage of carbon storage in each carbon storage place

Based on Figure 9, the biggest carbon store is land, this is because there are still few stands in the Kuningan Botanical Gardens. In addition, soil is the largest carbon pole that can store 4.2 to 6 times compared to biotic carbon storage [12]. In 2016 and 2018 the Kuningan Botanical Garden suffered fires because the Gunung Ciremai National Park that caught fire so that carbon on the soil increased, soil carbon would increase if carbonization or fire occurred. [13].

4. Conclusion

*Schima wallichii* (IVI: 46.22%) and *Gmelina arborea* (IVI: 30.24%) are dominant trees in KBG. Plants with the form of pole is dominated by *Schima wallichii* (IVI: 65.87%) and *Gnetum gnemon* (IVI: 39.11%). *Adenanthera pavonina* and *Gnetum gnemon* with IVI 41.56% is dominant seedling. Plant with form of shrubs are dominated by *Mimosa invisa* (IVI: 59.42%) and *Mimosa pudica* (IVI: 42.90%); and herbs are dominated by *Centrocema pubescens* (IVI: 26.52%) and *Paspalum cartilagineum* (IVI: 25.91%). Total carbon stock in Kuningan Botanical Garden West Java with area 156.4 ha was estimated 35.985 tonC that is dominated 81.21% in the ground.

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