The diversity of tree species at the buffer zone of Karst Citatah, West Java, Indonesia

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Abstract. Karst area is an ecosystem type that has an important function as water conservation. It is essential to know the composition and structure of the trees species of the karst area. This current study aims to determine the diversity of species and their potential in the buffer zone of Karst Citatah, West Java, Indonesia. The data on tree species composition were collected by using a plot employed on a community forest land, which was spread in three villages. Vegetation analysis was conducted by a census (100%) in all selected sampling areas. The importance value index (IVI) showed that sengon species (Paraserianthes falcataria) were dominant, both rejuvenation level (79.23) and tree-level (165.71). The diversity index of rejuvenation level was very stable as it had a range of $H' > 2$ compared to the tree level that had a range of $H'$ value 1-2. The dominance index was only seen at the tree level, i.e., sengon (Paraserianthes falcataria) species, where the $C$ value was one. At the level of rejuvenation, there was no visibility of the domination of one species to other species. The similarity index at rejuvenation level and tree-level were quite high (> 55%). The regeneration at the rejuvenation level grows well until it reached the tree level. The suggested pattern of management that is suitable according to the vegetation structure in the research area is a public forest with a mixed garden system.

1. Introduction

In the world, karst areas occupy 22% of the proportion of land mass [1]. One of the largest karst area distribution is in Indonesia. In Indonesia, karst areas occupy 20% of the total land area [2]. In Java Island, karst areas occupy 4% of the mainland area [3]. One of the karst regions in Java Island is the karst Citatah.

The Karst Citatah area is located in the Cipatat subdistrict, with an area of 10.230 Ha [4]. However, three sub-villages, which are part of the Gunung Masigit village area, remains covered with community forest (1.065 Ha), viz Cibukur, Rancamoyan, and Liunggunung. Average rainfall from 2004 to 2013 reached 2.272 mm per year. The highest rainfall reached 965 mm (December 2005), while the lowest rainfall was 0 mm (July to September). The average daily temperature at the study site reached 31°C. According to the Oldeman classification, the study site is classified as C2 climate type with six consecutive wet months and three consecutive dry months. Broadly, land ordo in this area is grouped into alfisols and ultisols.

Karst area is one type of unique ecosystem because it functions as a giant underground water storage tank, namely the epicarstic layer. According to [2], the epicarstic layer is the water concentration obtained from rainwater infiltration into the lower layer. This zone contributes as a...
reliable stream provider, especially in long periods of drought [5]. In areas directly adjacent to the sea, the karst function serves as a deterrent to seawater intrusion that enters the terrestrial ecosystem [6].

Along with the rapid development and economic growth, the Karst Citatah area has experienced a high decrease in environmental quality, due to a large number of land uses converted to rock group mining areas (limestone, marble). This condition will gradually reduce the quality and capability of the carrying capacity of the environment so that the role of the buffer zone as a protective area for karst areas is important to know the carrying capacity. Optimal buffer zone conditions will provide good protection for karst areas.

Several studies related to the Karst Citatah area have been carried out by [4, 7-9]. Research related to the utilization of the biological resources of the Karst Citatah ecosystem has also been carried out by [10-11]. However, the previous studies have not yet examined the Karst Citatah area in terms of trees species structure and composition. By understand the condition of the trees species, we will find out the carrying capacity in preserving the Karst Citatah area as well as the most appropriate management pattern to improve the quality of the site.

This research aims to determine the diversity of trees species and their potential to develop the buffer zone of the Karst Citatah.

2. Method

2.1. Location

This study was conducted in sub-village Cibukur, Rancamoyan and Liunggunung, Gunung Masigit Village, Sub District of Cipatat, West Bandung Regency (figure 1). Geographically, the location of the study is at 107º 26' 07,08'' BT– 107º 26' 01,08 '' and 06º 48' 26.4'' LS - 06º 38' 34.5'' LS.

2.2. Research methods

Data were collected using purposive plots samples on community forest land, owned by communities with an area ± 77.94 Ha. To determine the level of diversity of species at the study site, we carried out vegetation analysis. For the tree level, the observation plot was made with 20 m x 20 m; the sampling plot was made with 10 m x 10 m, while for the seedling level, the observation plot was made with the 2 m x 2 m. The plots were made as a sub-system (nested sampling) [12].

Figure 1. Map of research location at Gunung Masigit Village.
Observation and measurement of vegetation were carried out by census (100%) in all selected plots sampling. The location of the observation plot was determined purposively as many as 94 plots. The distance between one plot to another plot was different. The classification of trees level used in this study refers to [12]:

- Trees are plants that have a circumference of stems > 31.4 cm or diameter ≥ 10 cm.
- Saplings are plants that have a circumference of 6.3 -31.4 cm or diameter between 2-10 cm.
- Seedlings are plants that have a circumference of the stem < 6.3 cm.

2.3. Data analysis
Observations data of trees species in community forests area were analyzed to find out the importance value index (IVI), species diversity index, dominance index, and similarity index.

2.3.1. Importance value index (IVI). The IVI value was used to determine the tree species that dominate the standing community. IVI values were calculated using the formula [13]:

\[ IVI = FR + KR + DR \]  

Where:
- IVI: Importance Value Index
- FR: Relative frequency (number of types / area of study plot),
- KR: Relative density (total number of plots found / total number of plots)
- DR: Relative dominance (Area of Standing Base/area of research plot)

The higher the IVI value, the higher the level of dominancy species in the community.

2.3.2. Diversity index. Species diversity was determined and calculated using the Shannor-Wiener formula [14], as follows:

\[ H' = -\sum [pi \ln pi] \]  

Where:
- \( H' \): Species diversity index
- \( Ni \): Number of individuals of one type
- \( N \): Number of individuals of all types
- \( Pi \): Proportion of the number of individuals of type i with the number of individuals of all types

- If the value of \( H' < 1 \), means the vegetation community with environmental conditions is less stable;
- If the value of \( H' \) between 1-2, means the vegetation community with stable environmental conditions;
- If the value of \( H' > 2 \), means the vegetation community with environmental conditions is very stable.

2.3.3. Dominance index. To determine the index of dominance, we used The Misra [15], as follows:

\[ C = \Sigma \left( \frac{ni}{N} \right)^2 \]  

Where:
- \( C \) = Dominance index
- \( ni \) = Important value type-i
- \( N \) = Total importance

2.3.4. Similarity index. The index of species equality between two different sample communities was calculated using the formula of 'Jaccard' Mueller-Dombois and Ellenberg [16]:

\[ S = \frac{2C}{(A+B+C)} \]
Where:
S = Community similarity index
A = Number of species at the tree level
B = Number of types at level rejuvenation
C = Number of the same type in tree and rejuvenation levels (seedlings and saplings)

The higher value of the community similarity index (S), the more similar and uniform the compositions of two communities. The community are significantly different when the similarity index value is <50%.

3. Results and discussion
3.1. Importance value index (IVI)

According to the data processing conducted on 94 plot samples in the fieldwork area of 77.94 Ha at the tree level, 21 species were identified. The most dominant species is Sengon (*Paraserianthes falcataria*) with an Importance Value Index (IVI) of 165.71. Nine other species, such as Coconut (*Cocos nucifera*), Jackfruit (*Artocarpus heterophyllus*), Tisuk (*Hibiscus macrophyllus*), Kihaji (*Dysoxylum alliaceum*), Mahoni (*Swietenia macrophylla*), Durian (*Durio zibethinus*), Teak (*Tectona grandis*), Bamboo (*Bambusa bambos*) and Rambutan (*Nephelium lappaceum*), have the highest IVI values ranging from 8.31 to 18.60 as presented in table 1.

| No | Type                          | Family            | IVI   |
|----|-------------------------------|-------------------|-------|
| 1  | Sengon (*Paraserianthes falcataria*) | Leguminosae      | 165.71|
| 2  | Kelapa (*Cocos nucifera*)      | Arecaceae         | 18.60 |
| 3  | Jackfruit (*Artocarpus heterophyllus*) | Podocarpaceae    | 15.80 |
| 4  | Tisuk (*Hibiscus macrophyllus*) | Malvaceae         | 14.02 |
| 5  | Kihaji (*Dysoxylum macrocarpum*) | Meliaceae         | 11.55 |
| 6  | Mahoni (*Swietenia macrophylla*) | Meliaceae         | 10.03 |
| 7  | Durian (*Durio zibethinus*)    | Malvaceae         | 9.55  |
| 8  | Teak (*Tectona grandis*)       | Lamiaceae         | 8.93  |
| 9  | Bamboo (*Bambusa bambos*)      | Poaceae           | 8.74  |
| 10 | Rambutan (*Nephelium lappaceum*) | Sapindaceae      | 8.31  |

At the rejuvenation level, 26 species were identified at the study site. The most dominant species at this level is Sengon, with an IVI value of 79.23. Nine other species, such as Kihaji (*Dysoxylum alliaceum*), Tisuk (*Hibiscus macrophyllus*), Mahagony (*Swietenia macrophylla*), Rambutan (*Nephelium lappaceum*), Acacia (*Acacia mangium*), Jackfruit (*Artocarpus heterophyllus*), Teak (*Tectona grandis*), Jabon (*Anthocephalus chinensis*) and Cloves (*Syzygium aromaticum*), have the highest IVI values ranging from 4.31 to 21.56 as presented in table 2.

A high IVI value indicates that this species dominates the ecosystem where it grows (figure 2) [17]. A high IVI value also indicates that this species matches the location. At the research location, Sengon grows well compared to other species, because Sengon does not require fertile land conditions to grow well. Sengon is generally easy to cultivate and able to grow at low nutrient lands [18].

The existence of dominant species compared to other species will also create the canopy stratification. It is in line with [19], who stated that the existence of varying IVI values will create the canopy stratification. Sengon trees in the study area generally occupy the top of canopy stratification and have the highest IVI value. In contrast, the other species will occupy the lower canopy strata.
Table 2. Importance Value Index (IVI) of several species at the rejuvenation level (seedlings and saplings) in the buffer zone of Karst Citatah.

| No | Type (Family) | Family | IVI  |
|----|---------------|--------|------|
| 1  | Sengon (Paraserianthes falcataria) | Mimosaceae | 79.23 |
| 2  | Kihaji (Dysoxylum alliaceum) | Meliaceae | 21.56 |
| 3  | Tisuk (Hibiscus macrophyllus) | Malvaceae | 20.12 |
| 4  | Mahoni (Swietenia macrophylla) | Meliaceae | 19.10 |
| 5  | Rambutan (Nephelium lappaceum) | Sapindaceae | 7.03 |
| 6  | Akasia (Acacia mangium) | Leguminosae | 5.70 |
| 7  | Nangka (Artocarpus heterophyllus) | Podocarpaceae | 5.18 |
| 8  | Jati (Tectona grandis) | Lamiaceae | 5.07 |
| 9  | Cengkeh (Syzygium aromaticum) | Myrtaceae | 4.44 |
| 10 | Jabon (Anthocephalus chinensis) | Malvaceae | 4.31 |

The existence of diversity canopy stratification will also provide good carrying capacity for the habitats of various existing fauna. At the research location, several species of birds identified live in that habitat, including species of Church birds (Passer montanus), Bondol Java (Lonchura leucogatroides), and Bondol Peking (Lonchura punctulata). Stratified vegetation will provide suitable habitat for various species of birds [20], [21] revealed that variations of trees create a suitable habitat for Black Hawk species (Ictinaetus malayensis), Ivory Hornbill (Buceros vigil), Srigunting (Dicrurus remifer), and Forest Sepah (Pericrocotus flammeus) in Batang Gading National Park.

Species with a low IVI value, such as Ganitri (Elaeocarpus serratus), generally have growth requirements that are less suitable for growing well at the study site. The site conditions at the study site were dominated by folded hills of marine rocks [4], causing the soil solu to be generally thin (the effective depth of roots becomes shallow). This condition often becomes an obstacle factor for the plant to grow.

Figure 2. Trees condition at the study site.

3.2. Diversity index
The diversity index value for the tree level was 1.64 (table 3). It shows that the species community in the buffer zone of Karst Citatah is still stable with its environmental conditions. At the tree level, high species diversity will tend to be more stable because individuals have reached a more stable stage. Individuals have experienced selection between different populations.
Table 3. Value of diversity index in the buffer zone of Karst Citatah.

| No | Level | \( (H')^a \) | Criteria     |
|----|-------|-------------|--------------|
| 1  | Trees | 1.64        | Stable       |
| 2  | Rejuvenation (seedlings dan saplings) | 2.04 | very stable |

\(^aH':\) Species diversity index.

For the rejuvenation level, the value of the diversity index in the study location was 2.04 (table 3). It shows that the species community in the buffer zone of Karst Citatah is very stable with its environmental conditions. More environmentally stable conditions will make the ecosystem for the rejuvenation level more resistant to plant pests. The environment can create ideal habitats for natural enemies to grow because diverse trees species will be able to provide suitable food for the natural enemy. It is in line with [22], who stated that mixed trees (heterogeneous) consisting of diverse plant species can reduce pest attacks due to the abundant number and diversity of natural enemies of insect pests.

Ecosystems with high species diversity tend to be more robust against the presence of interference from outside, especially against pests and diseases. The risk of insect pests attacking mixed trees can be reduced through an associative resistance mechanism between biotic and abiotic elements in their ecosystem [22]. The high value of diversity indicates the stability of a growth environment, and high interaction causes the environmental community to have a higher ability to deal with the interference of other components from outside [23].

3.3. Dominance index

For tree level, Sengon (Paraseriathes falcataria) had very dominant control to other species. It can be seen from the C value, which is 1 (table 4). The community is dominated by Sengon. In terms of site quality, this condition presents that the level of land suitability for Sengon growth is classified as Very Suitable (S1). The growth rate of Sengon is very fast and able to adapt to various types of soil [24].

The value of the dominance index at the rejuvenation level is moderate at 0.67 (table 4). It shows that there are several types of tree species that control the community. At the rejuvenation level, interactions between species in the population are positive (0.67). Each species supports each other to grow in the same habitat. [25] stated that the medium value of the dominance index show that there is no dominance of a species in a particular habitat. [17] also reported that this condition showed a positive association because plant species were present simultaneously with other plant species.

Table 4. Value of domination index in the buffer zone of Karst Citatah.

| No  | Level                      | \( (C)^a \) | Criteria |
|-----|----------------------------|-------------|----------|
| 1   | Trees                      | 1           | High     |
| 2   | Rejuvenation (seedling dan saplings) | 0.67 | Medium   |

\(^aC:\) Domination Index.

Several factors influence the level of species dominancy, including the level of competition for nutrition and ease of growth, the ability to remove allelopathy, and the level of pest vulnerability and diseases. It is similar to [26-27] who stated that species having a high dominance index value tends to more easily adjust to the quality of the existing site so that it dominates the other species. The fact that they can adjust to the existing site was in line with [28]. Some trees species, such as bamboo species that own allelopathy substances, can dominate the control of their community by spreading poison, as stated by [29]. Species that are vulnerable to pests and diseases will tend to have a low dominance index value. Trees species that are difficult to adjust to site conditions will also tend to have a low level of dominancy over other species.

3.4. Similarity index

According to the results carried out on the composition and structure of trees species in the buffer zone of Karst Citatah, the similarity index value was 55% (table 5). It shows that the species growing at the
rejuvenation community are not too different from the species at the tree community. Species that grow at the rejuvenation level will grow well until reaching the tree level.

Table 5. Value of similarity index in the buffer zone of Karst Citatah.

|       | A^b (Type) | B^c (Type) | C^d (Type) | S^e (%) |
|-------|------------|------------|------------|--------|
| Value | 21         | 26         | 18         | 55     |

^aS = Community similarity index.
^bA = Number of species at the tree level.
^cB = Number of species at the level of rejuvenation.
^dC = The same number of species at the level of seedlings and trees.

[19] reported that high species similarity values show good regeneration from the seedling to the tree level; only a few species at the rejuvenation level do not grow to the tree level. The rejuvenation level that is well-regenerated to the tree level is tolerant species and gets good lighting [14]. The similarity index value of this species also shows that there is not a large enough selection among the species that grow in the same habitat. Besides, the condition of the habitat where it grows is still relatively suitable for the existing species to grow side by side.

3.5. Management implications

Based on observations in the study area, the buffer zone of the Karst Citatah has good potential to be developed as a community forest with a mixed garden cultivation system and Sengon species as the main tree. This condition is supported by land suitability, which is suitable for Sengon [30]. Existing structure and composition that are already planted by the farmer in the community forests have shown high stability of vegetation with the environment. It can be seen from the good canopy stratification, in which it has a good regeneration level from the rejuvenation level to the tree level. In Java Island, several types of seasonal crops were suitable for development in mixed forests with Sengon plants, such as Cardamom or Coffee [24]. [31] reported that some commodities can be paired with Sengon as the main plants, such as coconut, banana, and cassava.

By employing mixed cropping management patterns, ecosystems can still create a balance that supports the carrying capacity of the environment. Mixed gardens provide many benefits, namely 1) economic aspects: creating income periodically and continuously, 2) ecological aspects: improving soil structure, improving unstable and unproductive land, and improving water management, 3) psychological aspects: providing output choices and ways for more flexible management [31].

In terms of the results obtained, the mixed farming system will get a different combination of income. Also, to obtain continuous timber production from various types of trees species, the community also receives by-products in the form of annual crops that can meet the community's economy until the main trees are ready to be harvested. From the ecological point of view, harvesting trees in mixed plantations does not have a negative impact on ecosystem balance, because species diversity can still be maintained. Heterogeneous trees and stratified structures create ideal habitats conditions for natural enemies of invading pests.

4. Conclusion

Sengon (Paraserianthes falcataria) is very dominant in the buffer zone of Karst Citatah. It is indicated by the highest IVI value at the tree level of 165.71 and the rejuvenation level of 79.23. The conditions with the environment are more stable at the rejuvenation level (2.04) than at the tree level (1.64). The level of species dominancy only occurs at the tree level, namely Sengon. At the level of rejuvenation, there is no dominancy of one type over another. The value of similarity at the plant level of rejuvenation and tree level is ≥ 55%, which indicates the rejuvenation grows well until it reaches the tree level. Land management patterns that are suitable in the study area are the pattern of community forests with mixed garden cultivation systems. This aims to keep the creation of canopy stratification to maintain the balance of the ecosystem well maintained.
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