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Submission date: 15-Jul-2025 04:45PM (UTC+0700)
Submission ID: 2715275871
File name: Coffee_Plantations_Inside_and_Outside_Protected_Forest_Areas.pdf (350.95K)
Word count: 4782
Character count: 25552

Sriwijaya Journal of Environment
Article
ojs.pps.unsri.ac.id

A Comparative Assessment of Vegetation Diversity Under Coffee Plantations Inside and Outside Protected Forest Areas

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Article history

Received	Received in revised for	Accepted	Available online
26 November 2021	01 February 2022	23 August 2022	05 November 2022

Abstract: The existence of tree vegetation planted in coffee plantations as shade trees is believed to have a positive influence on the growth and production of coffee plants. This study aims to analyze the diversity of coffee plant vegetation in three age classes planted inside and outside protected forest areas included in the administrative area of North Dempo and Central Dempo Districts, Pagar Alam City, South Sumatra Province. The results of observations and calculations of Value IVI found that *Albizia sumatrana* was the dominant species in all coffee plantations at various age levels. The IVI values of *Albazia Sumatrana* in coffee plants aged < 5 years were 157.32 (inside PF) and 720.92 (outside PF), in coffee plants aged < 10 years, were 84.30 (inside PF) and 155.51 (outside PF), while in coffee aged > 10 years is 75.46 (inside PF) and 95.92 (outside PF). Assessment using the Shanon Index and Simpon Index showed the same results; coffee plantations at all age levels had a moderate diversity index, except for vegetation in coffee plantations aged < 5 years which were outside protected forest areas and had low diversity index values. Through the availability of this information, it is hoped that it will be used as initial information for selecting vegetation types that will be used to support restoration activities in areas around protected forests.

Keywords: Vegetation diversity, protection forest, coffee plantation, shannon and simpson index, Pagar Alam

1. Introduction

Forests are of great importance to humankind because they can strongly affect the environment, economy, and socio-culture. Unfortunately, forest degradation continues to occur due to population growth and exploitative economic activities in forest areas. It is generally believed, that protected forests can promote biodiversity that hosts more species when compared to forests that are managed based on a specific designation, for example, forest for industrial plantations or other designated areas [1-6].

It has also been well known that forest management and biodiversity have a very complex relationship [5, 7-11]. Therefore, any intervention, such as the management pattern of a forest area, can affect the ecosystem changes and change the structure of forest stands [2, 12, 13]. The existence function as of protected forests often experiences pressures and threats [14-16]. The pressure, such as conversion into human-made ecosystems associated with population [17, 18].

In general, the existence of protected forest areas is always followed by the presence of the surrounding villages. The villagers usually have limited employment opportunities outside the agricultural sector, limited land ownership, and low per capita income [9, 19, 20]. Such conditions are sometimes the factors that encourage people to take advantage of the exploit existing forest resources [6, 11, 21].

Vegetation structure is a spatial arrangement described by diameter, height, distribution, and species diversity. In contrast, the vegetation composition is a floristic list of the types of vegetation that exist in a community [22]. The information on the structure and composition of vegetation can be used as study material to conserve its diversity from threats of decline to threats of extinction, both naturally and caused by illegal human activities [23, 24]. Therefore, knowing the structure, composition, and diversity of vegetation inside and outside the protected forest area will be valuable information to formulate a collaborative protected forest management model [25-27]. The current study investigated vegetation diversity under coffee plantations inside and outside the protected forest.

2. Material and Methods

2.1. Study Area

The study area is located in the North Dempo and South Dempo sub-districts of Pagar Alam City, South Sumatra Province, from 04 '00' - 04 '15 South Latitude, and 103 '00 - 103' 15 East Longitude. The sub-districts of North Dempo and South Dempo are included in the medium type zone A, with the ratio of dry months to wet months being 60-100 percent. Despite the shift in seasons, the rain season usually starts in October and ends in May, with an average annual rainfall of 2,325 mm per year. The air temperature is relatively the same throughout the year, with an average yearly temperature of 22ºC. The study area is located at an altitude of approximately 694 m above sea level, with slopes ranging from 8% to 45%. The soil is Latosol to Andosol.

2.2. Methods

The study area was located both in inside protected forests and outside protected forests. A sample plot of 20m x 20m was set up in each location where the number, species, diameter (DBH), and height of tree were measured. In each sample plot, a sub-plot of 10m x 10m to observe the pole level, a sub-sub plot of 5m x 5m to observe the saplings, and a 2m x 2m to observe the regeneration were also set up consecutively.

The location of the sample plots was determined randomly based on the age of the coffee plants, namely five years old, 6 to 10 years old, and > 10 years old. Each age class consisted of 4 sample plots. Therefore, there are 24 sample plots composed of 12 sample plots within the protected forest area and 12 sample plots outside the protected forest area.

2.3. Data Analysis

Data collected from each plot included:

- Tree species.
- Number of individual trees.
- The diameter of trees at breast height.
- Number of vegetation types at the seedling level.

The data is then used to calculate the Important Value Index (IVI), species density (D), frequency (F), dominance index (D), and species diversity index (H), using the following formula (Odum, 1993):

$$IVI = RD + RF + RO$$

Whereas:

RD = Relative Density
RF = Relative Frequency
RO = Relative Dominance

The diversity of a plant community determined using the Shannon-Wienner (H) and Simpson Index theory which is calculated using the formula:

$$H = \sum_{i=1}^{s} (pi)(\ln pi)$$

Whereas:

H = Species diversity index
Ni = Important Value of Species
N = Total important value of species
Ln = Logarithm Natural

The results obtained can then be categorized into 3 categories, namely:

- If $\hat{H} < 1$ then the diversity index is categorized as Low
- If $\hat{H}$ $1 < \hat{H} < 3$ then the diversity index is categorized as Medium.
- If $1 \hat{H} > 3$ then the diversity index is categorized as High

$$D = 1 - \left(\frac{\sum n\,(n-1)}{N\,(N-1)}\right)$$

Whereas:

n = Total number of particular species
N = Total number of all species
D = Simpson Index

The results obtained can then be categorized into 2 categories, namely:

- If D close to value1 then the diversity index is categorized as Low.
- If D close to value 0 then the diversity index is categorized as High.

3. Results and Discussion

Coffee farmers make the spacing of coffee plants inside and outside protected forest areas the same, namely 2m x 2m. it can be seen from the average number of coffee plants less than five years old in the sample plot areas inside and outside the protected forest area, which is 140 trees. The number of coffee plants under five years old in the sample plots is 113 trees (inside the protected forest area) and 136 (outside the protected forest area). Meanwhile, the average number of coffee plants aged over ten years is 103 trees (inside protected forest areas) and 108 (outside protected forest areas).

The results of observations of the diversity of vegetation identified 13 tree species belonging to 8 families in a coffee plantation located inside the protected forest area and 14 tree species belonging to 9 families in a coffee plantation located outside the protected forest area. The results also revealed that the ages of the coffee plantation seemed to exert a substantial effect on vegetation diversity. See the results of a study on the variety of vegetation in coffee plantations inside and outside the protected forest area, and it is as shown in Table 1.

Table 1. Comparison of vegetation diversity inside and outside protected forest areas.

Attribute	Inside Protected Forest			Inside Protected Forest		
	< 5	< 10	> 10	< 5	< 10	> 10
Vegetation Diversity	13	13	10	6	14	6
Family Diversity	6	8	6	6	9	4
Shannon Index	1.52	1.84	1.93	0.27	1.44	1.60
Simpson Index	0.40	0.26	0.15	0.90	0.45	0.20

Table 1 shows the results of a study of the diversity of vegetation in coffee plantations inside and outside the protected forest area, which generally indicates a difference in the variety of vegetation, the diversity of the vegetation family, and the values of the Shannon index and Simpson index. The diversity of vegetation in coffee plantations in protected forests tends to have a fixed amount, and this can be seen from the variety of vegetation in coffee plantations aged under 5 and 10 years. In comparison, the diversity of vegetation tends to decrease in coffee plants that are more than ten years old. Meanwhile, the variety of vegetation in coffee plantations outside the protected forest area shows an increase in vegetation diversity, especially in coffee plantations under five years old and less than ten years old. However, vegetation diversity decreases again when the coffee plantation is over ten years old.

Observations and measurements on sample plots can identify the relative density, relative frequency, and relative dominance of each species found. Family Leguminosae was found in almost all age classes of coffee plantations observed. The family Leguminosae dominates the diversity of vegetation in coffee plantations less than five years old in protected forest areas such as (*Albizia chinensis, Albizia sumatrana, Erythrina subumbrans, Gliricidia sepium, Indigofera tinctoria, Leucaena leucocephalla, Parkia speciosa hassk*). A similar situation also found that vegetation diversity in coffee plantations less than five years old outside protected forest areas is also dominated by the Leguminosae family (*Albizia sumatrana*).

The diversity of vegetation in coffee plantations less than ten years old in protected forest areas is dominated by the Leguminosae family (*Albizia chinensis, Albizia sumatrana, Parkia speciosa hassk*) and the diversity of vegetation outside the forest area is also dominated by the Leguminosae family (*Albizia sumatrana, Archidendron pauciflorum, Indigofera tinctoria, Leucaena leucocephalla*). Meanwhile, the diversity of vegetation in coffee plantations that are more than ten years old in protected forest areas is dominated by the Leguminosae family (*Albizia sumatrana, Archidendron pauciflorum, Erythrina subumbrans*) and the diversity of vegetation outside the forest area is also dominated by the Leguminosae family (*Albizia sumatrana, Leucaena leucocephalla*).

The illustration of the amount of diversity, frequency and dominance of vegetation represented by each family is shown in Figure 1.

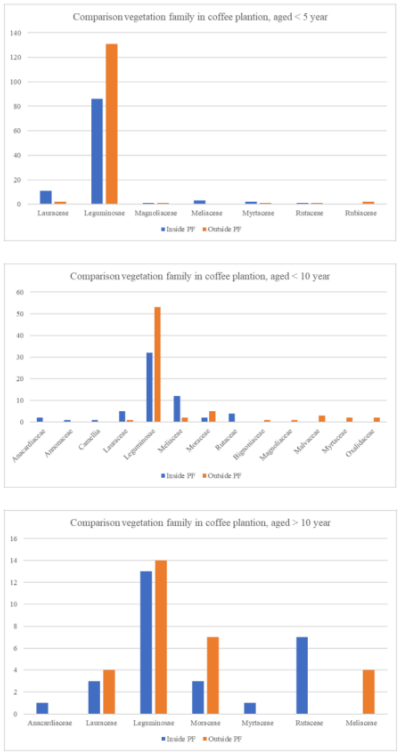

Figure 1. Comparison of diversity of vegetation family Inside and outside protected forest

Important value index (IVI) for *Albizia sumatrana* gives the highest value in coffee plantations at all age levels. IVI *Albazia sumatrana* in

coffee plants aged < 5 years was 157.32 (inside PF) and 720.92 (outside PF), in coffee plants aged < 10 years was 84.30 (inside PF) and 155.51 (outside PF), while in coffee plants aged > 10 years is 75.46 (inside PF) and 95.92 (outside PF).

Calculating the value of vegetation diversity based on the age class of coffee plantations using the Shannon-Wienner (H) and the Simpson Index (D) theory. Vegetation diversity in coffee plants under five years in protected forest areas (PF) has a diversity value above one, which is included in the 'medium diversity' category, while vegetation diversity in plants outside protected forest areas has a value below one or is included in ' low diversity. Meanwhile, the diversity of vegetation types in coffee plantations with an age class of fewer than ten years and above ten years, both inside and outside protected forest areas, has a diversity value in the 'medium diversity' category. The value of vegetation diversity using the Simpson Index (D) is to be identified based on the values 0 and 1; if the D value is close to 1, it is declared low diversity, and if the D value is close to 0, it is stated high diversity.

The value of vegetation diversity using the Shanon Index on coffee plants aged less than five years gave a value of 1.52 (inside PF) and 0.27 (outside PF). Species diversity in coffee plants with an age class of fewer than ten years gave a vegetation diversity value of 1.84 (inside PF) and 1.44 (outside PF). In contrast, the diversity of vegetation types in coffee plants over ten years old is 1.93 (inside PF) and 1.60 (outside PF).

The value of vegetation diversity using the Simpson Index on coffee plants aged less than five years gave a value of 0.40 (inside PF) and 0.90 (outside PF). Species diversity in coffee plants with an age class of fewer than ten years gave a vegetation diversity value of 0.26 (inside PF) and 0.45 (outside PF). In comparison, the diversity of vegetation types in coffee plants over ten years old is 0.15 (inside PF) and 0.20 (outside PF).

Initially, the number of tree vegetation planted on young coffee plantations (under five years) was quite large compared to the other two age classes. The existence of tree vegetation is expected to function as a shade tree for newly planted coffee seedlings. Over time, it is also seen that the number and diversity of tree vegetation types found in coffee plantations outside and inside protected areas are decreasing. The amount of tree vegetation tends to be more found in coffee plantations outside protected areas. Still, the variety and diversity of tree vegetation types tend to be more commonly found in coffee plantations located inside protected areas.

The study results showed that *Albazia Sumatrana* was a plant with a high IVI value in all sample plot locations. The Important Value Index (IVI) is one of the parameters to see the role of a plant species in its community as a form of the ability and adaptability of vegetation to environmental conditions. The greater the IVI value of a species, the greater the level of control over its community. Conversely, the smaller the IVI value, the smaller the level of community control.

Farmers around the observation site choose *Albazia Sumatrana* as shade tree vegetation for their coffee plants. Coffee farmers put several reasons during field interviews for the selection of this type, among others, because of the abundant availability of seeds. This vegetation has been proven to adapt to the surrounding environment. In addition, there are other benefits of *Albazia sumatrana*, which is a fast-growing trees pecies so that farmers can use the wood from this tree to be used as raw material for making house building materials or for carpentry, besides that, the leaves of the *Albazia sumatrana* species can also be used as feed cattle.

According to [28] stated that the consideration of choosing this type of vegetation to serve as a shade tree is usually influenced by the habits and interests of the community, the availability of shade tree seeds and growing locations that match the criteria for shade trees. This can be seen in the research report conducted by which states that the shade trees of coffee plants are commonly found in South Sulawesi Province is of *Leucaena leucocephala*, in Lampung Province is *Erythrina subumbrans* dan *Gliricidia sepium* [29], in West Java Province is *Parkia speciosa, Durio zibenthinus, Artocarpus integra, dan Persea americana* [30] and in East Java Province is *Leucaena leucephala, Falcataria mollucana, Gliricidia sepium, Cedrella toona*, dan *Erythrina lithosperma* [31].

Shade tree vegetation that can survive from the beginning of planting until the plant reaches a specific age class indicates that the plant is a type of plant that can adapt to environmental conditions. It is proven that the kind of Albazia sumatrana is the dominant shade tree in all coffee plantations at various age levels. It is generally believed that the plants of the family Leguminosae are fast-growing species, possessing strong roots, large diameters, and dense crowns.

Shade trees play an essential role in providing environmental services in the form of filtering and reducing sunlight because most coffee plant varieties are naturally not resistant to direct sunlight [32], in addition, according to [29] and the role of shade trees can produce litter to maintain soil moisture, reduce coffee leaf loss in the dry season [25], inhibit weed growth [33], increase coffee production [29, 31, 32, 34]. In addition, shade trees will be able to play a role in providing living habitats that can accommodate wildlife and various types of birds [35] which will help facilitate pollination and function as biological

insect control [36].

The value of vegetation diversity shows a fluctuating value. The occurrence of an increase or decrease in the amount of vegetation in coffee plantations is usually related to efforts to reduce the density of the canopy of shade trees to obtain better coffee production [35]. However, the increase in coffee production is not only determined by the presence of shade trees. Still, it is also influenced by the presence or absence of garden maintenance and the suitability of the growing location for coffee plants [27, 37].

In addition, the occurrence of increased and decreased vegetation diversity is also determined by the natural cycle, namely by looking at the peak of vegetation growth. Dominant species at the tree level that have reached the pinnacle of evolution will be replaced with pole-level species; this dominant shift will cause changes and differences in vegetation composition. Another explanation by [38] is that the natural growth process of a species is thought to be the cause of a shift in the design of the dominant tree that affects the level of vegetation diversity in a location.

The amount and diversity of vegetation in coffee plantations aged over ten years in protected forest areas tend to change slightly compared to the amount of vegetation diversity in gardens outside protected areas. It can be influenced by a natural regeneration process, as is suspected of having occurred in coffee plantations in protected forest areas. In contrast, changes in the composition and structure of vegetation in coffee plantations outside protected forest areas are influenced by garden maintenance activities, namely by reducing tree canopy density.

The form of garden maintenance activities carried out by farmers are generally carried out by pruning branches and using fertilizers and chemicals for pest control. However, the intervention of farmers in carrying out garden maintenance is influenced by the location of the altitude (landform). Coffee plantations outside protected forest areas tend to be at a lower or gentler elevation than coffee plantations inside protected forest areas, which have a steeper topography. This also causes the diversity of vegetation in coffee plantations within protected areas to have little change compared to the variety of greenery in coffee plantations outside protected forest areas.

The value of vegetation diversity from the calculation of the Shannon Index and Simpson Index gives the same value. Coffee plantations at all age levels have a moderate diversity index, except for vegetation in coffee plantations aged < 5 years which are outside protected forest areas and have a low diversity index value. Through the availability of information generated from this research, it is hoped that it can provide initial data to be used as a reference for selecting initial vegetation types to support restoration activities in areas around protected forests.

The types of vegetation that can grow and develop in various age classes of coffee plantations indicate that these species can become pioneer vegetation types to be cultivated in the area to be restored. Then, after the initial vegetation types grow, other vegetation types can be added to support efforts to restore the protected forest area so that it can return to a natural forest vegetation ecosystem.

4. Conclusion

The diversity of vegetation in coffee plantations outside and inside the forest area is dominated by the Leguminosae family vegetation with the type Albazia sumatrana. The IVI values for Albazia sumatrana on coffee plants aged < 5 years were 157.32 (inside PF) and 720.92 (outside PF), in coffee plants aged < 10 years, were 84.30 (inside PF) and 155.51 (outside PF), while in coffee aged > 10 years is 75.46 (inside PF) and 95.92 (outside PF). The Shannon Index and the Simpson Index show similar results: coffee plantations at all age levels have a moderate diversity index, except for vegetation in coffee plantations aged < 5 years outside protected forest areas with low diversity index values. Selecting vegetation types that will be used to support various activities is needed to consider the community's needs and proven its suitability to adapt to the surrounding environment.

Acknowledgment

The authors would like to thank all parties from Sriwijaya University and all parties in Pagar Alam City. The latter have provided assistance and support in the data collection and implementation of this research.

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