Vegetation structure, composition and diversity in agroforestry system in Andongrejo Village, Jember Regency, East Java

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Abstract. Andongrejo Village is one of the buffer villages of Meru Betiri National Park (TNMB). The lack of baseline data related to the diversity of vegetation in agroforestry system surrounding TNMB requires further research as a conservation effort and sustainable ecosystem management purpose. The objectives of this research were to: (a) analyze the structure and composition of vegetation in agroforestry system, (b) analyze the diversity of vegetation in agroforestry system, as well as (c) analyze correlation of canopy density with the diversity of seedlings and understorey in agroforestry system in Andongrejo village, Jember Regency, East Java. The method used was purposive vegetation sampling and vegetation analysis. The number of individual (ind/ha) in all three canopy density classes did not show reverse J-curve. The dominant species found were Banana (Musa sp.), Teak (Tectona grandis), and Sengon (Paraserianthes falcataria). The species richness and diversity index at all tree level growth were classified into low diversity and low species richness. The higher percentage of canopy density results in the higher individuals per ha and the number of species per ha (r = 0.500 and r = 0.696). The implementation of enrichment planting with species that has high economic value at all tree level growth are necessary. Introducing fruit species is one of alternative ways to increase the local community’s income and conserve the diversity in agroforestry system. Silviculture technique (eg pruning) is necessary to maintain the diversity and tree level growth in this location.

1. Introduction

Forest has the important role in social, economy, and ecological aspects [1]. Forests provide variety of products, such as timber and non-timber such as hydrology function, tourism, and genetic pool. Therefore, forest management should be conducted through proper forest utilization in considering the sustainable yield, as well as biodiversity conservation. The efforts of forest management which can ensure the sustainability of forest are very necessary. One of that efforts is through the implementation of agroforestry system.
Agroforestry is a system and optimalization of land use technology which combined both timber and crops and/or livestocks with a proper planning, in the same land unit area and time or in a rotation, which will result in interaction of each ecological and economic components [2]. The implementation of agroforestry system considers a complex aspects, such as ecological, social, and economy. According to Lahjie et al. [3] social aspect is related to the forest management that increasing the employment and at the same time decreasing the conflict between the land manager, such as the manager of company and the local communities surrounding of forest. Economic aspect related to costs and benefits for the land manager and the local communities surrounding the forest. While ecological aspects related to the impact of forest on hydrology cycle, soil fertility, sources of water and so on. A well-balanced ecological, social, and economic aspects of forest could decrease the forest degradation and increase the well-being and prosperity of the local communities surrounding the forest. Land optimalization could improve the productivity of crop yield in sustainable way as well as increasing the profits. Indonesia has several agroforestry systems that proven to be effective in economic and ecological aspect [4]. Recently the existing management of agroforestry systems show that the local communities are capable in managing the beneficial resources.

Generally, commodities that often found on agroforestry system is forestry commodity and crops, livestock feed, and firewood [5]. The diversity of these commodities formed a complex canopy levels and root system, thus agroforestry could take a part in soil and water conservation such as reducing soil erosion rates, surface run-off and sedimentation of the soil, maintaining soil fertility, improve the physical properties of the soil, chemical and biological element of soil, consequently, the improvement of these characteristics could support the cultivation of plants on top of it for the welfare of human-beings. Agroforestry is one of form of land management which is effective in maintaining and increasing the variation of biodiversity, as well as maintaining carbon stocks [6 - 8]. Agroforestry also has an important role in conservation of biodiversity where many species are found locally or introduced is semi-natural [9, 10]. Jose [11] explains that agroforestry has four ecological benefits namely carbon sequestration, preserving and improving soil fertility, biodiversity conservation, as well as maintaining and improving air and water quality.

Agroforestry system has been known and applied by the local communities around Meru Betiri National Park (TNMB), Andongrejo Village, Jember Regency, East Java. This agroforestry system is implemented in the rehabilitation zone in TNMB and the communities’ land as an effort to rehabilitate the ecosystem which had been damaged. Local community participation in this system has the key role in biodiversity conservation efforts along with the balance between socio-economic aspects. The lack of baseline data related to the diversity of vegetation in agroforestry system surrounding TNMB requires further and in-depth research as a conservation effort and sustainable ecosystem management purpose. The objectives of this research were to: (a) analyze the structure and composition of vegetation in agroforestry system, (b) analyze the diversity of vegetation in agroforestry system, as well as (c) analyze correlation of canopy density with the diversity of seedlings and understorey in agroforestry system in Andongrejo village, Jember Regency, East Java.

2. Methods

2.1 Location and Time Research
This research was conducted in the local communities land surrounding Meru Betiri National Park (TNMB), Andongrejo Village, Jember Regency, East Java on June 2018. The location of this reasearch is shown in Figure 1.
2.2. Tools and Research Objects
The tools used in this research were meter ribbon, tape measure, hagameter, compass, GPS (global positioning system), Minitab software, Sexi-FS software, densiometer and camera. The object of this research was the vegetation on the local community land around TNMB Andongrejo Village.

2.3. Procedures of Research
The types of data used in this research are primary and secondary data. Primary data is collected from the field made up of plant species, tree height and diameter, and interviews with local communities. Secondary data is collected composed of general conditions of the region, such as geographical aspect.

2.3.1 Plot Establishment. The sample of the plot in the local community lands around TNMB by using a purposive sampling method. The criteria for selecting research sites was applying agroforestry system, accessible, and supported by the local community. The characteristics of selected agroforestry practices consist of two or more species combinations and at least one woody plant species [2]. Data collection in the field was conducted using vegetation analysis techniques 20 x 20 m in size was used to record trees and poles. A sub plot of 2 x 2 m in size was used to record seedlings and understorey, while 5 x 5 m was used to record saplings. Trees are considered as vegetation with greater than or equal to 20 cm in diameter. The pole is considered as tree with greater than 10 cm below 20 cm in diameter. The sapling is a young tree with a height of ≥1.5 m and a diameter of <10 cm, while the seedling is a young tree with a height of <1.5 cm. The plot design uses a combination of the path method and the plot line method (Figure 2).
2.3.2. The Structure Composition of Vegetation on Agroforestry System. The calculation of important value index (IVI) aims to observe the dominance of plant species in the groups in each site. IVI is obtained from the sum of relative density, relative dominance, and relative frequency in each species [12]. The formula used to calculate IVI according to Cox [13], as follows:

\[
\text{Density (D)} = \frac{\text{Total number of individuals}}{\text{Size of plot}}
\]

\[
\text{Relative Density (RD)} = \frac{\text{Number of individuals of the species}}{\text{Number of individuals of all species}} \times 100
\]

\[
\text{Frequency (F)} = \frac{\text{Number of quadrats in which species occurred}}{\text{Total size of plots}}
\]

\[
\text{Relative frequency (RF)} = \frac{\text{Number of occurrence of the species}}{\text{Number of occurrence of all species}} \times 100
\]

\[
\text{Dominance (Dm)} = \frac{\text{Total basal area of the species}}{\text{Total size of plots}}
\]

\[
\text{Relative dominance (RDm)} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all species}} \times 100
\]

\[
\text{IVI of tree and pole} = \text{RD} + \text{RF} + \text{RDm}
\]

\[
\text{IVI of sapling and seedling} = \text{RD} + \text{RF}
\]

\[H' = -\sum Pi \ln(Pi)\]

Where:

- \(H'\) = Diversity index Shannon
- \(Pi = ni/N\)
- \(ni = \) Density of each species
- \(N = \) Total of density
According to Michell [15], the value of diversity index lower than 1.50 (<1.50) means the diversity is low, while the value range from 1.50 – 3.5 in diversity index is moderate, higher than 3.5 (>3.5) means the diversity index is high.

2. **Margalef’s Index (Dmg)**
The species richness index is calculated using the Margalef index formula [16], as follow:

\[
D_{mg} = \frac{(S - 1)}{\ln (N)}
\]

where:
- \(D_{mg}\) = Index of richness
- \(S\) = Total of species that be founded
- \(N\) = Total of individual

Margalef [16] explained there are 3 categories of species richness index, namely low (\(D_{mg}\) <2.5), moderate 2.5 <\(D_{mg}\) <4.0), and high (\(D_{mg}\) > 4.0).

3. **Evenness Index (E)**
The evenness index (E) shows the level of evenness of individuals per species. E values are calculated using the formula [17]:

\[
E = \frac{H'}{\ln S}
\]

where:
- \(E\) = Index of evenness
- \(H'\) = Index of diversity
- \(S\) = Total of species

According to Odum [18], species evenness index are classified in order, starts from evenly distributed, moderate, and uneven, based on the rating \(E \geq 0.75\), \(0.5 \leq E \leq 0.75\), and \(E < 0.5\).

4. **Dominance Index (C)**
The species dominance index is used to determine the dominance of a species in a community. This index is calculated using the formula [19], namely:

\[
C = \sum_{i=1}^{n} \left( \frac{n_i}{N} \right)^2
\]

where:
- \(C\) = Index of dominance
- \(n_i\) = Density to-i
- \(N\) = Total of density

Dominance index (C) has a value ranging from \(0 \leq C \leq 1\), the dominance is high as the value Dominance Index close to 1. The opposite, if the \(C\) value close to 0, by that means there’s no species dominates the ecosystem.
3. Result and discussion

3.1. The Implementation of Agroforestry System in Andongrejo Village

The majority of local community in Andongrejo Village is doing agricultural practices on their owned land (in the house area or farming land) and/or on the land which they occupied in Rehabilitation Zone in TNMB. In rainy season, the planting model and the variety of plant they focused on is rice, whilst in summer, they tend to focus on commodities like corn, soy bean, and mung bean. The plantation of agricultural commodities is alternately conditioning to the season, by the time of harvest one commodity, they plant another commodity right after the harvesting time, so that in one year the farmer plants several commodity alternately [20] with a combination of still timber plantation such as multi purpose tree species for later they take the fruit, timber, and leaves.

3.2. Canopy Density in the Agroforestry System in Andongrejo Village

Local community in Andongrejo Village plants crops combined with woody species (Figure 3). The selection of woody species and agroforestry patterns which planted by the local community is might be different depends on the output they’re aiming. The difference in planting caused each cultivated land to have a different canopy density. Table 1 shows that the density of tree canopies in each agroforestry system varies. The local community in Andongrejo Village planted crops in the yard of a house or land owned by a community close to a settlement. The area of land occupied and cultivated by local community varies, depending on the size of the land. According to Subaktini [21] the total yard area in Andongrejo Village is 53.03 ha. The data collected from local community in Andongrejo Village has an area ranging from 225 m$^2$ to 1,600 m$^2$.

According to Mahendra [22] canopy closure consist of high dense, moderate dense, and low dense. High dense canopy is a condition where less than 25% of sun light can reach the ground. Moderate dense is a condition where the sunlight can reach the ground in 25%-27% range. While low dense is a condition where the sunlight could reach the ground for over than 75%. The range of sunlight reaching the ground may varies they’re effected by the density of the crown. The denser canopy affects the less on the sunlight. This location classified into low dense. We made class interval of statistical method. These land cultivated and owned by the local community showed the percentage of canopy density ranging from 8% to 17.12%. Class 1 ranging from 14-17.12%, class 2 ranging from 11-14%, and class 3 ranging from 8-11%.

| Table 1. Canopy density in agroforestry system in Andongrejo Village |
|-----------------------------|-------------------|-----------------|
| Canopy density               | Plot              | Percentage of canopy density (%) |
|-------------------------------|-------------------|-----------------------------|
| Class 1                       | 1                 | 17.12                      |
|                               | 2                 | 17                         |
| Class 2                       | 1                 | 13.86                      |
|                               | 2                 | 11.72                      |
| Class 3                       | 1                 | 8.93                       |
|                               | 2                 | 8                          |
Figure 3. Agroforestry systems in Andongrejo Village

Sengon is popular species among local community in Andongrejo village. Sengon is considered as long-term investment, beside it they also grow fruit-producing plants for personal consumption. More people plant sengon with high density on their land as a long-term investment and grow fruit-producing plants for personal consumption. The community land is often neglected without proper maintenance, for the tree branches are not pruned and left to make a dense crown.

3.3. Structure and Composition of Vegetation in Agroforestry System in Andongrejo Village

The composition of vegetation in a community is a list of existing vegetation types and vegetation structures as a consequence of layout of stand components and life forms, stratification, and vegetation cover which described through diameter, height, distribution in the area, canopy diversity, and sustainability. The number of individuals at each growth level in a stand or ecosystem shows regeneration aspect of the stand or ecosystem. In this study, species structure and composition were analyzed by counting the number of individuals and species per hectare and the importance value index (IVI) at each growth level.

Figure 4. The number of individual (ind/ha) by growth level of plants on local community land in Andongrejo Village

Figure 4 shows the number of individuals per hectare in the three class of canopy density in agroforestry system in Andongrejo Village. The highest of total individual (ind/ha) of seedling and understorey was found in the agroforestry system in class 1 approximately 2 419 (ind / ha), while the highest of total
individual (ind/ha) of sapling level was 3131 (ind/ha). This indicated that total saplings was higher than seedlings and understorey. However the plots with high dense (class 1) had fewer poles and trees than found in class 2 and 3.

All three canopy density classes did not show reverse J-curve (Figure 4). Reverse J-curve shows a normal regeneration process in natural forest due to the availability of adequate number of seedling and juvenility [10]. The distribution curve of the number of trees forming an reverse J usually occurs in tropical forests which describe one dynamic forest [23, 24].

![Figure 5](image)

**Figure 5.** Visualization of stand structure in the local community land in Andongrejo Village a) vertical view and b) horizontal view

Identification of important values index on tree growth level in agroforestry shows the type of species in high canopy dense has more variety of plants that play significant role in the community compared to low and moderate canopy dense. Density classes showed the dominant species, in class 1 was Teak (*Tectona grandis*), while the dominant species in class 2 & 3 were Banana (*Musa* sp.). Banana (*Musa* sp.) and Coconut (*Cocos nucifera*) were found in all classes (Table 2). The dominant species in a community has an important role so that it can be an indicator of habitat suitability with the type of vegetation in it so it is necessary to know the importance value index of banana plants [25].

| No | Species                | IVI (%) in class- |
|----|------------------------|------------------|
| 1  | Coconut (*Cocos nucifera*) | 94.91 100.99 93.83 |
| 2  | Banana (*Musa* sp.)     | 45.07 148.31 107.68 |
| 3  | Mango (*Mangifera indica*) | -      -      42.17 |
| 4  | Teak (*Tectona grandis*) | 104.09 -     -      |
| 5  | Sengon (*Paraserianthes falcataria*) | -      50.70 -      |
### Table 3. Three highest IVI on pole growth level in agroforestry system in Andongrejo Village

| No. | Species                      | IVI (%) in class- |
|-----|------------------------------|-------------------|
|     |                              | 1    | 2    | 3   |
| 1   | Banana (*Musa* sp.)          |      | 172.27 | 174.09 |
| 2   | Jack fruit (*Artocarpus heterophyllus*) |      | -    | 32.65 |
| 3   | Sengon (*Paraserianthes falcata*) | 62.60 | 78.03 | -   |
| 4   | Rambutan (*Nephelium* sp.)    | 80.41 | -    | -   |
| 5   | Teak (*Tectona grandis*)      | 81.95 | -    | -   |
| 6   | Kapuk (*Ceiba pentandra*)     |      | -    | 47.95 |

The dominant species at the pole level in class 1 was Teak (*Tectona grandis*), and Banana (*Musa* sp.) in class 2 and 3. The dominant species at the sapling level in class 1 and 2 was Sengon (*Falcatarinia moluccana*), while Banana (*Musa* sp.) was dominant species in class 3 (Table 3 & 4). The selection of species are affected by economic factors of community. The community planted this species for later use it as commercial timber and fruit products. On local community land, Sengon has the highest IVI with low and moderate canopy dense. The local community planted medicinal herbs such as curcuma, fingerroot, and so on. At low dense canopy, species with higher IVI are typically fruit tree species (Figure 5). Based on Table 5, the dominant species at seedlings and understorey in class 1, 2 and 3 in order were Kanyere badak (*Bridelia glauca*), Kangean (*Panicum repens*), and Guava (*Syzygium* sp.).

### Table 4. Three highest IVI on sapling growth level in agroforestry system in Andongrejo Village

| No. | Species                      | IVI (%) in class- |
|-----|------------------------------|-------------------|
|     |                              | 1    | 2    | 3   |
| 1   | Banana (*Musa* sp.)          |      | 59.34 | 75.94 |
| 2   | Sengon (*Falcatarinia moluccana*) | 115.67 | 87.80 | -   |
| 3   | Gamal (*Gliricidia sepium*)   |      | 15.05 | -   |
| 4   | Petai (*Parkia speciosa*)     |      | -    | 40.60 |
| 5   | Kelor (*Moringa oleifera*)    |      | -    | 24.81 |
| 6   | Rambutan (*Nephelium* sp.)    | 16.97 | -    | -   |
| 7   | Pulai (*Alstonia scholaris*)  | 16.97 | -    | -   |
Table 5. Three highest IVI on seedlings and understorey in agroforestry system in Andongrejo Village

| No. | Species                        | IVI (%) in class- |
|-----|--------------------------------|------------------|
| 1   | Sawi langit (*Cyanthilium cinereum*) | 24.36            |
| 2   | Jotang kuda (*Synedrella nodiflora*) | 10.40            |
| 3   | Kanyere badak (*Bridelia glauca*)   | 15.43            |
| 4   | Kangean (*Panicum repens*)         | -                |
| 5   | Guava (*Syzygium sp.*)             | -                |
| 6   | Kapuk (*Ceiba pentandra*)          | -                |
| 7   | Hawar-hawar (*Ficus septica*)      | -                |
| 8   | Kirinyu (*Chromolaena odorata*)    | -                |
| 9   | Rumput malela (*Pennisetum purpureum*) | 11.17            |

Sengon and teak are commercial timber that usually be planted by the local community. Bananas is distributed largely than the other species. This exist for the fact that many cultivators plant bananas as a plant combined with forestry plants and bananas have higher productivity compared to other fruit-producing plants. The high productivity of banana makes a major contribution on the economy of land owner. In line with what was stated by Swaminathan [26] that the selection of types of agroforestry components in tropical regions such as Indonesia and Sri Lanka is based on economic considerations. Additionally, according to Hartoyo et al. [10], the selection of species in agroforest practices depends on ecological site, socio-economic aspects, and market.

3.4. The Diversity of Vegetation in Agroforestry Systems in Andongrejo Village

The stability of species diversity of an area would determine the regeneration for the future. The level of community stability and dominant species is studied by calculating the importance value index, dominance index, species evenness index, and species richness index. According to Accordind to Michell [15], the value of diversity index lower than 1.50 (<1.50) means the diversity is low, while the value range from 1.50 – 3.5 in diversity index is moderate, higher than 3.5 ( >3.5) means the diversity index is high. Evenness Index (E) has a range of values, that is, the value of E <0.3 indicates that it has low evenness, E = 0.3-0.6 classified as moderate, and when all species are equally abundant, it shows E > 0.6 and classified as high evenness. As for the value of the dominance index (C), the value explained dominance in different growth rates. The value of 0 <C <0.3 indicates the dominance index is low, if it shows 0.3 <C <1 then the dominance index is said to be high. Margalef richness index (Dmg) has a range of values, namely R1> 3.5, which shows that species richness is low, R1 3.5-5.0 indicates species richness is moderate, and R1> 5.0 indicates high species richness.

Table 6. Tree and pole diversity index in agroforestry systems in Andongrejo Village

| Canopy density class | Tree | Pole |
|---------------------|------|------|
|                     | Dmg  | H'   | E    | C    | Dmg  | H'   | E    | C    |
| Class 1             | 1.34 | 1.32 | 0.82 | 0.31 | 1.34 | 1.44 | 0.90 | 0.26 |
| Class 2             | 0.80 | 0.96 | 0.87 | 0.43 | 0.49 | 0.90 | 0.82 | 0.48 |
| Class 3             | 1.56 | 1.41 | 0.88 | 0.28 | 1.02 | 0.94 | 0.68 | 0.51 |
Based on Table 6, the species richness and diversity index both at tree and pole level in all classes classified into low diversity and low richness. The species evenness index (E) at tree and pole level in all classes were relatively high and there was no dominance species at tree and pole level of agroforestry system in Andongrejo Village. The trees species planted on community land are generally timber commercial and MPTS (multi purpose tree species).

### Table 7. Sapling and seedling/understorey diversity index in agroforestry systems in Andongrejo Village

| Canopy density class | Sapling | Seedling and understorey |
|----------------------|---------|--------------------------|
|                      | Dmg     | H' | E | C | Dmg | H' | E | C |
| Class 1              | 0.72    | 0.07 | 0.04 | 0.98 | 0.72 | 0.98 | 0.40 | 0.61 |
| Class 2              | 0.62    | 0.93 | 0.67 | 0.45 | 1.08 | 1.34 | 0.54 | 0.43 |
| Class 3              | 1.70    | 1.41 | 0.79 | 0.31 | 2.65 | 1.80 | 0.82 | 0.21 |

Based on Table 7, the species richness and diversity of sapling and seedling/understorey were classified into low classification, except in class 3. Class 3 was classified into moderate species richness and diversity. The evenness index of sapling and seedling/understorey were higher in line with the higher of canopy openness. There was dominant species of sapling and seedling/understorey only in class 1.

Land management has been implemented on the lands occupied by local community, thus the species found on the lands are planted based on the needs of the community itself. Nahlunnisa et al. [27] stated that, because the value of diversity is affected by the value of richness and evenness of the species resulting in a diverse combinations, the value of diversity itself is very complex to interpret. Species richness value can be increased by selecting and applying a proper species planting management by considering shade and selecting the right type (semi-tolerant or intolerant) [10].
3.5. Correlation between Canopy Density with the Diversity of Seedlings and Understorey
Correlation between canopy density and diversity of seedlings and understorey was studied by using Pearson test to find the correlation value between two variables.

Figure 6. Correlation between canopy density with total individual (ind/ha), total species per ha (b), and diversity index

Correlation between canopy density with total individual (ind/ha), and total species per ha showed positive correlation ($r = 0.500$ and $r = 0.696$). It is showed in Figure 6. This implies that the higher percentage of canopy density results in the higher individuals per hectare and the number of species per hectare. Correlation between canopy density (%) and diversity index was negative correlation ($r = -0.262$). It means that the higher canopy density will result in a lower diversity index, where the temperature and humidity of the air had no significant effect on diversity while the openness of the canopy had a significant effect.

4. Conclusion
The number of individual (ind/ha) in all three canopy density classes did not show reverse J-curve. Sengon (Falcatarina moluccana) and Teak (Tectona grandis) are commercial timber that usually be planted by the local community. Banana (Musa sp.) is distributed largely than the other species.

The species richness and diversity index at all tree level growth were classified into low diversity and low species richness. There was no dominance species at tree and pole level, on the other hand there was a dominant species of sapling and seedling/understorey in agroforestry system in Andongrejo Village. The
higher percentage of canopy density results in the higher individuals per ha and the number of species per ha ($r = 0.500$ and $r = 0.696$).

The implementation of enrichment planting by increasing the number of individual and species that has high economic value at all tree level growth are necessary. Introducing fruit species is one of alternative ways to increase the local community’s income and conserve the diversity in agroforestry system. Additionally, silviculture technique (e.g. pruning) is important to maintain the diversity and tree level growth in this location.

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