The consequence of increasing tree diversity was reducing tree basal area at across different management of agroforestry system of Bangsri Watershed

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Abstract. The Planting more trees in terrestrial ecosystem had provided on the increasing on many ecosystem services including carbon storage, water supply and soil cover. The relationship between the impact on increasing tree density on tree diversity across various land use type are limited. Using a survey and collecting field measurement within the plot in the size of (100 m x 20 m), we investigated the effect of different type land use on tree diversity, basal area, and species composition at Bangsri Watershed-East Java, comparing different agroforestry system to various young to old production forest of Mahogany (Sweitenia mahogany), Pines (Pinus merkusii) and Rekisi (Magnolia × alba (D.C.). The result showed that seedling population under complex agroforestry system was almost twice (389 individuha-1) higher that those simple agroforestry system or production forest. Young Mahogany (4-5 years) provide the highest number of poles, whilst old Mahogany and Pines production forest (30-40 years) were contributed the greatest tree population at (500 – 600) individuha-1 providing the highest value of basal area since the average of those tree diameter within the size of (25-40 cm). Tree population of complex agroforestry system were lower 50% than production forest. However, diversity indices (H’) of sapling, pole and tree under complex agroforestry system were between 1 to 2.5, while the others plot were<1, except for seedling diversity. In particular the increasing of tree population impact of greater basal area but however it reduced the diversity of, seedling, sapling, pole and tree as the consequences of the implementation of different tree and land management.

Keywords: agroforestry system, land management, tree diversity indices.

1. Introduction

Agroforestry is expected to be able to improve the economy of rural community through diversification of planting food crops, trees and raising livestock while preserving the environment [1]. Biodiversity is all living things that exist on earth (plants, animals and microorganisms) including the genetic diversity they contain and the diversity of ecosystems they form [2]. Biodiversity provides enormous direct economic benefits, a series of services indirectly through natural ecosystems, has an important role in ecosystem function and stability [3]. It preserves farming systems and recycles nutrients, reduces insect problems, pests and diseases, controls weed, maintains good water and soil conditions, handles climate pressures while producing commodities needed for human survival [4]. In
the context of watershed management, agroforestry has an important role not only as a provider of water and carbon environmental services but also to protect the diversity of plants and animals. Agroforestry also has the potential to maintain a higher level of biodiversity compared to conventional agriculture [3,5,6].

Bangsri micro watershed (DAS) covering an area (2985 ha), Wajak District (Malang Regency) there are 4 land use systems (SPL), namely: (1) Bromo Tengger Semeru National Park (TNBTS), (2) Production Forest (managed by Perhutani), (3) Community Forests or intercropping systems or under agroforestry system, or (4) Annual crops which are vulnerable to land and environmental damage. The extent of forest land in the area was reported to have declined and was eventually feared to be lost, in 2016 forest land was recorded as 1,573 ha and in 2017 it was felled more than 50% to only around 900 ha [7]. The condition of production and protected forests on the upper slopes (upstream) is still managed by Perhutani. The Perhutani area is generally planted with pine (*Pinus mercusii*), Mahogany (*Swietenia mahogany*) while in the community-owned land the trees that are still found are Waru (*Hibiscus tiliaceus*), avocado (*Persea americana*), coffee (*Coffee sp*), Suren (*Toonasurenii*) and mindi(*Melia sp.*) and the recessed flower tree (*Canarium asperum Bentham*) or Rekisi (*Magnolia × alba* (*D.C.*)) and other trees species, planted under agroforestry system.

However, the current condition of the Bangsri watershed is very poor. The activity of illegal sand mining also contributes to the lowering condition of the land, causing erosion and sedimentation as well as the loss of some plants or wood from the ground [6]. Land use changes in this area are very fast changes in the last 10 years because of the demand for people who want to use forest land into agricultural land could not be avoided, although some people try to replant some of the area with various types of crops with agroforestry patterns. Agroforestry is an alternative system which accommodate planting crops along with tree species for maintaining water, biodiversity and conserving environment [1]. Community knowledge and perception about the advantages agroforestry is low and this system is not well adopted. This can be seen from the diversity of the agroforestry which is mostly only dominated with single tree species such as Sengon (*Paraserianthes falcata*) as one of promising Multi Purpose Tree Species (MPTS) under monoculture system, which could be harvested in the short period of cultivation (7-8 years) or under monoculture production forest system sort of Pines (*Pines merkussi*) or Mahogany (*Swietenia mahogany*). Each those above planting system will greatly affect plant diversity and their capacity for sequestering carbon from the atmosphere into plant biomass carbon storage or even further deposited as soil organic carbon stock [8-11]. Efforts to increase biodiversity in a landscape will cause the increasing of species richness as the had opportunity to grow at the same time, but the impact of this was that competition arises between plants in which it will causes reducing in tree growth and its performance.

Information on biodiversity in the use of private land or even in forest area of the Bangsri sub-watershed is very limited, therefore a comprehensive study of the aspect of plant biodiversity and those consequences on tree sustainability is needed under various cropping system including the existing agroforestry system. This research is intended to identify biodiversity, as well as assess the value of biodiversity in relation to its benefits for people in the Bangsri sub-watershed. The purpose of this study was to: (1) evaluate the relationship between the basal area and the diversity of plant species (trees) in various types of land management, and (2) assess the value of the vegetation diversity index at various stages of growth in various types of land management in the Bangsri watershed sub-watershed. The hypothesis of this study is the higher the diversity index (H′) value of a land use, the lower the basal value of the area of the tree that inhabits it.

2. **Methodology**

2.1. **Research location**

The research was carried out in Bambang Village, Wajak District, Malang Regency which was included in the Bangsri sub-watershed from April 2017 to May 2019. Bambang Village is a village in
Wajak District, Malang Regency which was located at coordinates of 8°07'59.7 S to 8°06'20.0S and 112°46'52.9 E to 112°51'09.7 E (Figure 1).

Figure 1. Location of study Bangsri-subwatershed (source: GIS laboratory Fac.of Agriculture University of Brawijaya)

2.2. Experimental design
This study was conducted using a Randomized Block Design (RBD), where the treatment was a land use system encountered in the Bangsri sub-watershed, then repeated plots 3 times. The details of the land use system were explained in Table 1.

Table 1. Selected land use system at Bangsri sub watershed for data collection and analysis

| No | Code | Land use system                                                                 |
|----|------|--------------------------------------------------------------------------------|
| 1  | AFS  | Simple agroforestry (1-2 species) : 5-10 year                                   |
| 2  | AFM  | Complex multi-strata agroforestry (4-5 tree species) : 10-20 year               |
| 3  | HP_MT| Production forest : Old mahogany 25-30 year                                     |
| 4  | HP_MM| Production forest : Young mahogany 4-5 year                                     |
| 5  | HP_PM| Production forest : Old monoculture Pines 30-40 year                            |
| 6  | HP_PS| Production forest : Old monoculture Pines 30-40 year + vegetables (perennial crop) |
| 7  | HP_Rekisi | Production forest :Old monoculture Rekisi 40 year                           |

The activity was included field surveying and plot selection. Furthermore, data collection from each plot was made for all stages of plant growth: seedlings, saplings, poles, and trees according to the
classification of [12]. The size of the plot for all vegetation is the area of 20 m x 100 m. Inside these, there was a plot with a size of 20x20 for observing tree stages (D>20cm), plot size of 10x10 m for observing poles (D = 1-10 cm), plot size of 5x5 m for observing saplings (D<5 cm, t > 2 m), while for 2x2 m size to observe seedlings (t<2 meters) (Figure 2).

![Figure 2. Design of observation plot for measuring vegetation diversity and their abundance](image)

ANOVA, regression and correlation analysis were performed using Genstat 18.00, while least significant differences were used to determine the effect of land use to diversity, population and composition in each tree stage of growth.

2.3. Vegetation Analysis

Every vegetation found in the observation plot was observed and photographed in the leaf blade and leaf bone. Leaf samples are taken and identified in the field by asking the local name of the plant to the surrounding community. If it has not been identified, a search for the related plant is carried out using a guide from the Herbarium Collection and the Asian Plant Collection and records of all species found [13].

All data obtained were analysed to determine the density, frequency, dominance and INP of each vegetation in each sample observation plot (PCP). Data collected from plot A (tree), plot B (poles) and plot C (sapling) were consisted of: diameter of trees (Dbh), type of plant, number of individuals. Whereas Plot D (seedling) collected data which were reported the number of individuals and types of plants. The data obtained were calculated using the formula, to determine values: Density (K), Relative Density (KR), Frequency, Relative Frequency, Dominated, Relative Domination, Area of Base Area [14]. Furthermore, the level of biodiversity is calculated by knowing the diversity index value, species richness index, species evenness index, and important value index of a type of plant [10].

3. Results and Discussion

3.1. Vegetation Composition and Structure of Bangsri Watershed

Based on the results of the analysis of variance, it was found that the level of density of tree populations in various land use systems in the Bangsri Watershed at each growth stage was
significantly different (p<0.05). Vegetation density classes in the Bangsri sub-watershed have varying degrees on each land use type. In term of seedling growth stage and sapling there are no significant differences amongst those land use system, means that the dominant species in those stages are similar. However, the highest number of individuals at multi-strata agroforestry system was to about 389,667 individuals ha-1 and the smallest number of individuals was detected at monoculture pine production forest land resulted in 159,833 individuals ha-1. In the sapling stage, the highest number of individuals was also found at multi-strata agroforestry system at about 1200 individuals ha-1 and the smallest number of individuals has been observed at monoculture pine production forest which reached 53 individuals ha-1. In addition to the tree density, poles stage at young mahogany production forest which has a tree density of 513 individuals ha-1 had a significantly different (p<0.05) to other land uses, which was the lowest density is found in monoculture pine production forests, pine production forests + annual crops and reclaimed production forests with each of 7 individuals ha-1, 7 individuals ha-1, and 13 individuals ha-1 which were nor significantly one to the others. It was clearly indicated that at young pines production forest is not reach optimum timber production and it will take several years to be mature and can be harvested. The highest tree density in the tree stage has been detected at the monoculture production forest and annual pine production forest with a value to about 567 individuals ha-1 and 533 individuals ha-1, respectively, while the lowest density was found at young mahogany with a value of density of 78 individuals ha-1 (Figure 3).

Figure 3. Vegetation density across different land use system
3.2. Tree dominancy base on tree basal area (BA)

Based on ANOVA results, the basal area (BA) value at various land use systems in the Bangsri watershed was significantly different (p<0.05). This can be seen at various land use system HP_PM, HP_PS, and SHP Rekisi showed the greater LBD values, each of which at about 129 m² ha⁻¹, 131 m² ha⁻¹, 128 m² ha⁻¹ respectively which is not significantly different one to another. However, those above basal area was significantly different to basal area value for HP_MM with a value of 6 m² ha⁻¹ or even basal area for AFS, AFM and HP-MT land use system. The lowest value at HP_MM land use system was due the young ages of this land use with an average diameter of tree at 10 cm (Figure 4).

![Figure 4. Basal area across different land use system](image)

3.3. Level of vegetation diversity

3.3.1. Diversity index

Based on ANOVA results, the level of diversity found in various land use systems in the Bangsri watershed showed a significant different (p<0.05) at each growth stage. In the seedling stage there was no significant difference in each land use (p>0.05), but for sapling, poles and tree stages there were significant differences in all land uses has been observed. It can be seen in the seedling stage that the level of diversity is classified as moderate (H = 1-3). Furthermore, diversity at stage of sapling, pole and tree were classified as low (H’ <1), except for AFM land uses system, which was classified to
moderate with an index value of $H' = 1.48$ and a tree stage with an index value of $H' = 2.01$ (Figure 5). This is because, AFM is mostly occupied by various types of plants.

![Figure 5. Diversity indeks at various stadia of tree growth across different land use](image)

Note: AFS=Simple Agroforestry, AFM=Complex Multistrata agroforestry, HP_MT= Production forests: Old Mahogany, HP-MM= Production forest: Young Mahogany, HP_PM= Production forest: Old monoculture of Pines, HP_PS= Production forest: Old monoculture Pines + vegetable (perennial crop), HP_Rekisi= Production forest: Old monoculture of Rekisi.

### 3.3.2. Evenness Index

Based on ANOVA results, it shows that the distribution of plant species in various land use systems varies at each growth stage. In the seedling stage and tree density value did not significantly affect the entire land use ($p > 0.05$). In the sapling and poles stages there is a significant effect of multi-strata agroforestry land use when compared to other land uses ($p < 0.05$). It can be seen that the seedling stage in each SPL has a fairly high evenness index value. In the sapling stage the highest level of plant species was found in AFM and HP_PM, while in other land uses the evenness was very low even the index value was 0. This is also because the AFM SPL is occupied by many types of plants whose growth is almost evenly found in each sub plot in a large plot of 2000 m².
This research showed that plant species in different land use systems are different. It can be seen that, the highest tree diversity and their distribution was found at complex agroforestry. This is because the complex agroforestry system is composed of many types of plants that live in it compared to other systems. Based on the results of Garrity’s (2006) that high diversity is found in the secondary forest system when compared to both complex and simple agroforestry systems [15]. Whereas the largest basal area is in production forests (old Mahogany, Pinus, and Rekisi) compared to agroforestry systems. This is because the agroforestry system is inhabited by many types of plants, so the diameter of the trees that inhabit the system is relatively smaller.

3.4 Relationship between tree diversity and basal area
Based on the results of correlation analysis and regression of the relationship between the basal area (BA) with biodiversity showed an inverse relationship. Where with increasing base area in an area will reduce the level of biodiversity of vegetation (Figure 7). According to Herianto (2017) explains where the higher the diameter of the tree, the less the number of trees [16]. Supported by the opinion of Saridan and Soegiharto (2011) that the amount of vegetation in natural forests is inversely proportional to the large diameter, the larger the diameter of the tree, the fewer the number [17]. With the reduced number of trees in an ecosystem, the level of diversity of plant species will be low [10].
4. Conclusion

The composition and structure of vegetation in the Bangsri watershed were consisted of 26 species at AFS (simple agroforestry), 35 species at AFM (complex multistrata agroforestry), 20 species at Production forest : Old Mahogany HP_MT, 24 species at Production forest: Young Mahoni HP_MM, 21 species at Production forest : Old monoculture Pine Forest HP_PM, 17 species at Production forest : Old monoculture Pinus + vegetable (perennial), and 22 species at Production forest of Rekisi. The level of biodiversity in the Bangsri watershed was low to moderate (1 < H < 3), and at complex agroforestry system the value of the diversity index was higher than the other land use. The greater the value of basal, the lower the level of vegetation diversity was found.

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