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Productivity of Arabica Coffee in Brawijaya University's Agroforestry

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Abstract— *Agroforestry is an agricultural system that combines annual crops with various woody or annual plants. The research carried out in arabica coffee agroforestry of Brawijaya University's forest with pines as shading plant. Differences in management mechanisms result in differences in arabica coffee production and environmental conditions in the four pine-arabica coffee agroforestry management models in UB forests. The research's purpose is to analyze production and biodiversity of arabica coffee in UB forests. Based on the results, it can be concluded that different levels of cultivation management have a significant influence on productive branches, number of unproductive branches, branch length, number of clusters each branch, and harvest yield. The average harvest yield BMP treatment was 3473.39 g each plant. The total diversity index value of understorey plants in UB Forest's coffee and pine agroforestry ranges from 1.4 – 2 (the diversity index values obtained for each plot from LC, MC, HC, and BMP management were (1.4), (1.52), (1.73), and (2.02)) with the value of H'= 1 – 3.322 (Shannon-Wiener diversity index). This result indicated that vegetation especially understorey diversity is classified as moderate.*

Keywords— ***coffee management, ecological services, understorey biodiversity***

I. INTRODUCTION

Indonesia's forests have abundant biodiversity. Apart from direct benefits of forest products (wood, rattan, etc.), other benefits that can be obtained are forests as ecosystem services. Ecosystem services are services received by humans from ecosystems (Agroforestri, 2013). Agroforestry is an agricultural farming system, which is a model that integrates annual crops with a variety of woody or annual plants.

Indonesia is the fourth largest coffee producing country in the world, after Brazil, Vietnam and Ethiopia (Dihni, 2020). Based on data from BPS (2021), coffee plant production in Indonesia in 2021 was 774.6 thousand tons. It is hoped that coffee cultivation using agroforestry can increased coffee production and better forest management. Forestry plants provide shelter and coffee plants become an additional source of income from non-timber plants that farmers can obtain. Coffee plants do not require direct light (100%), but the light intensity required is around 40 to 70% (Muschler, 2004). Shade trees also provide income for coffee farmers as a wood, firewood, fruit and others. Coffee and its shade trees contribute to ecosystem preservation, such as creating an environment for the conservation of certain bird species.

Agroforestry provides many important ecosystem services in supporting food security. Some of its roles are reducing run-off and erosion, relatively safer from the risk of harvest failure, and more stable against market fluctuations and the effects of climate change (Noordwijk *et al*., 2016). In East Java, non-forestry plants in agroforestry are very diverse, for example coffee, elephant yam, cocoa, corn, and vegetables. If the income from managing agroforestry is profitable, then the community's opportunity to convert forest land will be smaller. The ability to act as a buffer against biophysical, economic and social changes is

a key requirement for efforts to preserve and sustainably utilize agroforestry (Sulastri *et al*., 2022).

The aim of this research is to evaluate the productivity and environmental condition of pine-coffee agroforestry in UB forests. The four pine-coffee agroforestry management in the UB forest, Karangploso have differences in fertilizer management and shade tree management. In general, assessing ecosystem environmental services in coffee agroforestry can be carried out on 4 main services, namely provision services, regulatory services, supporting services and cultural services. (Abdul *et al*., 2015).

II. MATERIALS AND METHODS

The research was conducted in the UB Forest of Boro Sumbersari Hamlet, Tawangargo Village, Karangploso District, Malang Regency, East Java. Research was conducted on 4 pine-coffee agroforestry management (Low Coffee Management (LC), Medium Coffee Management (MC), High Coffee Management (HC), and Best Management Practice (BMP)). Observations used a nested design by comparing 4 agroforestry managements then tested with LSD (Least Significant Difference). Observation variables include coffee morphology and harvest (provider services) and environmental aspects (supporting services).

2.1 Morphology and Coffee Harvest Observation (Provider Services)

Morphological observations were carried out on plant height, number of leaves, leaf area, number of productive branches, number of unproductive branches, branch length, number of segments each branch, number of clusters each branch, and harvest.

2.2 Environmental Aspects (Support Services)

Observations of understorey plant carried out with determining the area and number of sample plots to be used. Furthermore, observations of understorey plant biodiversity were analyzed using the Sum Dominance Ratio (SDR) (Widaryanto *et al*., 2019) with the formula:

a. Density

- Absolute Density

$$KM = \frac{\text{Number of species discovered}}{\text{Number of plots}}$$

- Relative Density

$$KN = \frac{\text{Absolute density of that type}}{\text{Sum of the absolute densities of all types}} x100\%$$

b. Frequency

- Absolute Frequency

$$FM = \frac{\text{Plots where the species is found}}{\text{Total number of plots}}$$

- Relative Frequency

$$FN = \frac{\text{FM value}}{\text{Number of FM of all species}} x100\%$$

c. Dominance

- Absolute Dominance

$$DM = \frac{\text{Biomass value of the species found}}{\text{Total biomass of the entire sample area}}$$

- Relative Dominance

$$DN = \frac{\text{DM value}}{\text{Number of DM of all species}} x100\%$$

d. Important value index Index

$$IVI = KN+FN+DN$$

e. Summed Dominance Ratio (SDR)

$$SDRs = \frac{IVI}{3}$$

f. Shannon-Wiener diversity index (H ')

$$(H') = -\sum Pi \ln (Pi), \text{ where } Pi = \frac{ni}{N}$$

Information:

H ' = Diversity index

ni = Number of important value indices for each type

N = Total number of important value indices for all types

ln = Natural logarithm (natural number)

The value H ' < 1 indicates low species diversity, H ' = 1 to 3,322 indicates medium species diversity, H ' > 3,322 indicates high species diversity.

g. Simpson dominance index (C)

$$C = \sum \left(\frac{ni}{N}\right)^2$$

Information:

C = Simpson's dominance index

ni = Importance value index of each nth species

N = Total importance index of all species

The dominance index ranges from 0 – 1, if C = 0, it means that there are no species that dominate other species or the community structure is in a stable state. C = 1, meaning there is a species that dominates other species or the community structure is stable due to ecological pressure.

III. RESULTS AND DISCUSSION

3.1 Coffee Morphology and Harvest

Table 1. Arabica coffee morphology and harvest in agroforestry

P	PH	LA	PC	UPC	BL	S	BC	H
LC	381.00b	83.28a	30.83 b	26.09 c	68.68 a	21.73	6.31 a	831.56 a
MC	395.21b	80.07a	36.58 c	8.33 b	88.93 b	18,20	7.51 a	1460.26 b
H.C	405.81b	79.92a	37.04 c	9.88 b	79.82 b	19.09	6.34 a	1804.31 b
BMP	133.97a	100.37b	25.46 a	0.33 a	109.73 c	20.18	9.50 b	3473.39 c
BNT 5%	38.04	9.07	4.77	2.66	10.36	ns	1.53	484.70
KK	11.12	10.15	14.13	22.94	11.48	15.50	19.85	24.63

Information: P (treatment), PH (plant height, cm), LA (leaf area cm^2), PC (number of productive branches), UPC (number of unproductive branches), BL (branch length), S (number of segments per branch), BC (number of branch clusters), H (harvest, g $plant^{-1}$). Numbers accompanied by the same letter in the same column indicate that they are not significantly different based on the BNT test at the 5% level; ns = not significantly different.

The results show that different levels of management in coffee plant cultivation result in different growth and development of coffee plants, thus having an impact on differences in coffee plant production. Differences in management levels have an influence on almost all observed variables, including plant height, leaf area, number of productive branches, number of unproductive branches, and branch length. The influence of branch growth on coffee plants have an impact on the development of coffee plants. Different levels of management in coffee cultivation also have a significant effect on the development of coffee plants. Variables that show the influence of the level of management on the development of coffee plants include the results of the number of clusters each branch and the number of fruit each plant. The influence level of management on the development coffee plants has an impact on harvest yield or coffee fruit production each plant.

Different levels of management have a significant effect on yield each plant. The harvest results in the BMP treatment were able to provide higher yields compared to other treatments. BMP implementation is able to produce high yields each plant because the coffee plants in the BMP treatment are managed according to good coffee plant cultivation. Coffee plants in the BMP treatment were pruned so that coffee plants in the BMP treatment had an average plant height of around 150 cm. Pruning carried out on coffee plants can cause photosynthate results to accumulate in the development of flowers and fruit on coffee plants so that the number of coffee plant fruits in the BMP treatment is higher than in all treatments so that the comparison is straight with the harvest results obtained. Pruning carried out on coffee plants can redistribute the results of photosynthesis in the form of photosynthate leading to a large number of fruit each clusters which has an impact on higher coffee fruit production (Dufour *et al*., 2019).

Pruning coffee plants is useful in regulating the height of coffee plants, making it easier to maintenance and harvesting, forming new production branches for coffee plants, removing unwanted branches such as old branches, facilitating the interception of sunlight, improving air flow in the canopy, making it easier to control pests and diseases, reduce erratic changes in coffee crop yields (fluctuating), as well as reducing excessive fertilization (Hulupi and Martini, 2013). The research from Mulyono *et al*. (2016), shows that pruning coffee plants can produce a higher average percentage of normal beans and has a very significant effect on red fruit weight, green bean weight, normal bean percentage, round bean percentage, empty bean percentage, and coffee bean yield.

3.1 Environmental aspects

Table 2. Understorey biodiversity found on pine-coffee agroforestry

No	Types of Understorey	Plant classification	KM	KN (%)	FM	FN (%)	INP (%)
		LC PLOT					
1	*Ageratina riparia*	Ornamental plant	23.49	79.60	1.00	22.82	102.42
2	*Diplazium esculentum*	Vegetable crop	3.01	10.82	1.00	22.82	33.64
3	*Davallia denticulata*	Ornamental plant	1.03	3.70	0.83	18.84	22.55

4	*Histiopteris incisa*	Vegetable crops	1.03	3.64	0.75	16.85	20.49
5	*Cyperus melanospermus elatus*	Grass	1.24	3.61	0.75	17.92	21.54
		MC PLOT					
1	*Ageratina riparia*	Ornamental plant	14.40	59.60	1.00	24.87	84.48
2	*Rubia cordifolia*	Ornamental plant	9.88	34.36	0.75	17.21	51.58
3	*Diplazium esculentum*	Vegetable crops	1.98	8.49	0.83	20.48	28.97
4	*Histiopteris incisa*	Vegetable crops	0.58	2.48	0.68	17.83	20.32
5	*Cyperus melanospermus elatus*	Grass	2.00	8.23	0.40	10.32	18.56
		HC PLOT					
1	*Ageratina riparia*	Ornamental plant	3.83	29.28	0.83	18.42	47.70
2	*Diplazium esculentum*	Vegetable crops	4.91	40.45	1.00	23.18	63.64
3	*Davallia denticulata*	Ornamental plant	0.51	4.48	0.62	15.47	19.96
4	*Histiopteris incisa*	Vegetable crops	1.91	14.21	0.66	14.21	28.42
5	*Lantana spp.*	Ornamental plant	0.80	6.84	0.58	12.25	19.09
		BMP PLOT					
1	*Ageratina riparia*	Ornamental plant	9.35	52.56	1.00	16.82	69.39
2	*Diplazium esculentum*	Vegetable crops	1.27	7.76	0.91	15.09	22.85
3	*Urtica diocia*	Ornamental plant	1.63	12.87	0.56	9.98	22.95
4	*Centella asiatica*	Herbaceous plants	1.99	9.94	0.62	9.32	19.26
5	*Colocasia esculenta*	Tubers	0.59	3.51	1.00	14.83	18.34

Information: KM= absolute density, KN= relative density, FM= absolute frequency, FN: relative frequency, INP= important value index

Based on biodiversity result, the species that dominates in all agroforestry management plots is *Ageratina riparia* from the *Asteraceae* with an important value index of 102.42% in LC plots. This is also found in all existing management plots. This can be influenced by environmental factors such as temperature, light intensity and humidity of the surrounding air. Moenandir (1990) stated that what influences the number of species living in a community is light, where light greatly influences the type and the number of individuals that can grow in that place.

The other side, this can also be influenced by shading factors that exist on coffee and pine agroforestry and also influenced by the plant species themselves, such as in the process of seed dispersal. This is supported by Zulharman (2017), who gives the opinion that *Ageratina riparia* is a species found in shaded areas. *Ageratina riparia* is also a plant species that is usually found in mountainous areas of secondary forest and open or semi-open areas. Adult *Ageratina riparia* can produce 10,000 to 100,000 seeds each year. Usually species in the *Asteraceae* family are spread via wind and water.

1. Shannon-Wiener Diversity Index

Table 1. Shannon Wiener diversity index value (H')

PLOT	INDEX H'			
	M-1	M-2	M-3	M-4
LC	1.39	1.40	1.40	1.40
MC	1.49	1.52	1.53	1.52
HC	1.70	1.74	1.73	1.75
B MP	1.97	2.03	2.04	2.02

The diversity index values from each plot of LC, MC, HC, and BMP management was 1.4, 1.52, 1.73, and 2.02. From this value shows that the diversity of species on agroforestry is still in the medium category. This is in accordance with Indrawan *et al*. (2013), who explained that if the value of H' = 1-3.322 indicates that species diversity is classified as moderate.

2. Simpson Dominance Index

Table 2. Simpson dominance index value (C)

PLOT	INDEX C			
	M-1	M-2	M-3	M-4
LC	1	1	1	1
MC	1	1	1	1
H.C	1	1	1	1
B MP	1	1	1	1

Based on Table 3, the Simpson dominance index value (C) in all observation plots shows 1. Its mean that there is a dominant species in each plot. This can be seen in the LC, MC, HC and BMP management plots from the first to the last week of observation. This value means that there is species that dominate other species, or the community structure is stable due to ecological pressure (Fachrul *et al*., 2005).

The environmental conditions is the key to building up the understorey plant community that has grown. Environental variables in this research are intensity of sun light. Sun light was received by understorey plants can influence growth and can dominate understorey plant species in sample plots and in each different management plot. The results of the correlation between the Simpson dominance index show that there is no close relationship between understorey dominance and sun light intensity. This is not in accordance with the opinion of Indriyani *et al*. (2017), who explained that one of the environmental conditions that most influences the growth of plants are sunlight and shade.

IV. CONCLUSIONS

Based on the results, it can be concluded that the total diversity index value of understorey plants in UB Forest's coffee and pine agroforestry ranges from 1.4 – 2. Because of the value of H'= 1 – 3.322, its shows that the understorey community at the research location has medium level in vegetation diversity. The results of this study show that there is a diversity of different species in different agroforestry management, but the level of diversity is still the same or moderate.

The differences in cultivation management carried out in each treatment had a real influence on almost all observed variables. Different levels of cultivation management have a significant influence on the variables number of productive branches, number of unproductive branches, branch length, number of clusters each branch, and harvest yield. Different levels of cultivation management do not have a significant effect on the variable number of segments each branch on coffee plants. The results of coffee plant production can be seen in the yield each plant. The yield each plant in the BMP treatment gave higher yields than other treatments. The average harvest yield in BMP treatment was 3473.39 g each plant. BMP treatment is the best treatment that can be used as a recommendation for coffee cultivation management, especially in the UB Forest area.

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