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Original Research Article

Soil Fertility Analysis using Microarthropod Diversity Index in Coffee-Based Agroforestry in Mount Ungaran, Indonesia

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ABSTRACT

The conversion of forest functions to plantation land results in decreased land function and ecosystem disruption. Coffee-based agroforestry is a management system that is considered capable of maintaining land functions and reducing the level of leaching of nutrients. This study uses the soil microarthropod diversity index to evaluate the soil fertility level in 2 types of coffee-based agroforestry in Mount Ungaran. Sampling was conducted in Banyuwindu to represent intensive land and Gonoharjo as non-intensive land. Microarthropod samples in the soil were analyzed using Pitfall traps and extracted using the Tullgren-Funnel method. Soil microarthropods from the sampling were identified in family-level taxa. The species diversity index was analyzed using the Hutcheson t-test and the Sorensen similarity index. Characteristics of organic composition showed that intensive land had a value of 17% lower than non-intensive land. Environmental characteristics of intensive land types tend to have lower pH and soil moisture values than non-intensive land. The Shanon-Wiener diversity index analysis showed that soil microarthropods on the Intensive land type were H'= 2.08 and the Non-Intensive was H'= 2.30. Hutcheson's t-test showed that the diversity of soil microarthropods was significantly different with a significant value (p-value < 0.05), and the Sorensen similarity index value showed a similarity level of 52.17%. Based on the results of various analyses, it can be concluded that the intensive type of land has lower soil fertility than non-intensive land in the coffee agroforestry system in Mount Ungaran.

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1. INTRODUCTION

In the last decade, the conversion of forest functions into plantations has been massively carried out worldwide. Land conversion results in various impacts, such as environmental, ecological, and economic impacts (Rondhi, 2018). The conversion of forest functions to plantations has significantly disrupted ecosystem stability and damaged structure, composition, and soil fertility (Kimberly, 2013). A land management system is needed to maintain the function of the land ecosystem and its productivity, such as an agroforestry system (Utami, 2011; Firdaus, 2013).

One example of an agroforestry system in Central Java that is being developed is coffee-based agroforestry in the Mount Ungaran area, Semarang. This agroforestry model can provide ecosystem services that are almost the same as forests while simultaneously meeting social, economic, and ecological interests. Using coffee-based agroforestry is a safe method of reducing runoff and erosion rates. If the surface runoff is low, then the leaching of nutrients will be lower so that soil fertility is maintained (Cannavo, 2011).

Coffee-based agroforestry has several types of land management, including intensive and non-intensive. Intensive processing type is a type of land cultivation that resembles a monoculture plantation where the land is cleared of canopies or other plants besides coffee, and pruning and fertilization are carried out. The non-intensive type of processing is a simple type of processing in which coffee plants are only allowed to grow to intercrop with native forest trees. Only a few studies have been found that specifically analyze differences in soil fertility levels from the type of land cultivation. The difference in land management systems certainly continuously causes changes in soil fertility.

Several methods of soil fertility analysis have been developed by researchers, such as methods based on chemistry, physics, and biology. Soil fertility analysis methods based on chemical methods require laboratory measurements of several soil properties, such as soil pH, C-Organic, CEC, KB, P2O5, K2O, and other tests that are complex and increase costs (Firdaus 2018). Physics-based soil fertility analysis methods using visible and infrared spectra offer an opportunity to assess soil properties quickly but require high-energy devices (Yang, 2020). Biological-based soil fertility analysis method is believed to be the most appropriate alternative because it is directly related to the structure of the community and its ecosystem. This is based on the fact that the conversion of land from forest to plantation will disrupt the stability of the ecosystem in it.

Determination of soil fertility based on biology usually utilizes the activity of macro-organisms as an indicator because their activities are easy to observe. However, macro-organisms in coffee agroforestry are relatively few and uniform so they cannot be used as indicators. Microorganisms are believed to be an accurate indicator of soil fertility because soil organisms are susceptible to the conditions and composition of the soil in which they live (Rahardian et al, 2020; Shidiq, 2020). Soil organisms have diverse roles, such as controlling plant diseases due to fungi, reorganizing organic matter, balancing ecosystems, biological indicators of fertility levels or soil conditions and decomposing toxic materials (Selvany, 2018).

One soil organism that can be developed as an indicator of fertility is soil microarthropods. Microartopods are soil fauna that play an essential role in various processes in the soil, such as the distribution of organic matter, rate of decomposition, nutrient cycling, soil structure formation, determination of porosity, aeration and infiltration. Therefore, soil microarthropods are very suitable to be used for monitoring the level of soil fertility in coffee-based agroforestry. This study aims to evaluate the level of soil fertility using the soil microarthropod diversity index in 2 types of land management in the agroforestry area of Mount Ungaran, Semarang.

2. METHODS

The methods used include soil sampling (PCT) and *pitfall traps*. Soil samples were taken using a shovel with a depth of 10 cm and a diameter of 7 cm. Each hole is given a container of the same size that contains the soap solution. The container is left for 8 hours, and then taken to the laboratory for sorting. Soil samples were extracted using a *Berlese-Tullgren funnel* extractor and identified under a stereo microscope (Nikon SMZ 745). An additional 300 grams of soil samples were taken from each research station to analyze soil organic matter. Specimens were collected in 70% alcohol solution and identified at least to a familial level. The identified microarthropods were counted based on taxa groupings to obtain the values of density, diversity, and evenness. The analysis of the three components of the community structure is assisted by using PAST software version 4.4. (Shidiq, 2020).

3. RESULTS AND DISCUSSIONS

3.1. Locus of Research

This research is located on the slopes of Mount Ungaran, an agroforestry area based on coffee plants. Based on the type of coffee processing, there are 2 types of agroforestry, namely Intensive - Banyuwindu, Kec. Fern 7°10'07.6"S 110°18'26.8"E (Monoculture = Pruning coffee trees, removing other plants and applying fertilizer); and Gonoharjo Non-Intensive, 7°9'105"S 110°20'128"E (Simple = Allowing coffee plants to grow overlapping (intercropping) with native forest plants).

Figure 1. Landscape of (a) Intensive Land (b) Non-Intensive Land

3.2. Microarthropod sampling

The sampling results on coffee-based agroforestry areas on intensively cultivated land have a density value of 1160 individuals/m2, while on non-intensive land, it is 1200 individuals/m2. The high density of microarthropods in each field consisted of 11-12 types of microarthropod species consisting of 10 families in 6 different orders. Dominance is found in the orders Hymenoptera, Coleoptera and Collembola. The dominant species in the Intensive Area include Pseudisotoma sp (Di 29.91%), family Isotomidae; Chyphoderopsis sp (Di 32.08%), from the family Cyphoderidae order Collembola and species Oecophylla sp (Di 15.09%), from family Formicidae order Hymenoptera. The type of non-intensive land is dominated by the order Collembola with the same family and species as the intensive land, namely the type Chyphoderopsis sp (Di 18.33%) and Pseudisotoma sp (Di 21.67%) and the order Coleoptera family Staphylinidae Type Paederus sp (Di 10 %).

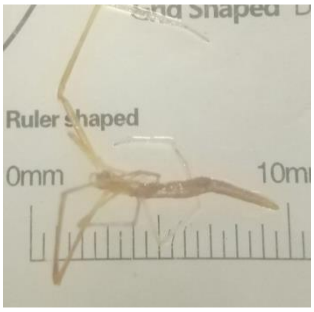
The Collembola found in both land types indicated that the two types of land were still in good condition because of the function of the Collembola. Collembola is an essential and abundant soil microarthropod because it interacts with ecosystem physiochemical processes, decomposition, and mineralization of organic matter through litter fragmentation. In addition, the presence of Collembola in the soil is used to predict and control the action of decomposers and is sensitive to changes in soil physical and chemical properties and characteristics of natural microhabitats after agricultural and forestry activities (Machado, 2019). Meanwhile, the Intensive area is dominated by another order in the form of Hymenoptera, which has more predatory characteristics than several other microarthropod species, thus affecting species diversity (Putra, 2017).

The difference in soil conditions or soil biological quality observed with the value of soil microarthropod density in the two types of cultivation observed showed that land with non-intensive cultivation had a much higher microarthropod density than the intensive cultivation type. This shows that the soil on land with non-intensive treatment is considered better in providing the necessities of life for soil microarthropods. Acari and Colembolla in Non-Intensive Land is often found in various lands/soils with ecosystem conditions with high fertility levels. Therefore, the absence of Acari in intensive land indicates a change in the ecosystem in that land whose fertility is decreasing (Rahardian, 2021).

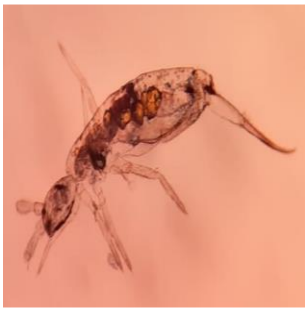
The diversity in both fields was analyzed quantitatively using the Shannon-Wiener index with the result that microarthropod diversity in intensive land (H'=2.08) was lower than in non-intensive land (H'=2,3). Further analysis of the Shannon index value in each field used the Hutcheson diversity t-test which showed that the diversity of microarthropods in the two types of cultivated land showed a significant difference (p-value <0.05). The diversity pattern is in line with the evenness pattern, which shows that the graded evenness index of Intensive land (0.73) is lower than that of Non-Intensive land (0.83).

Aphis sp

drassodes sp



Oxyopes sp



Oxyopes sp

Ascocyrtus sp

cryptopygus sp

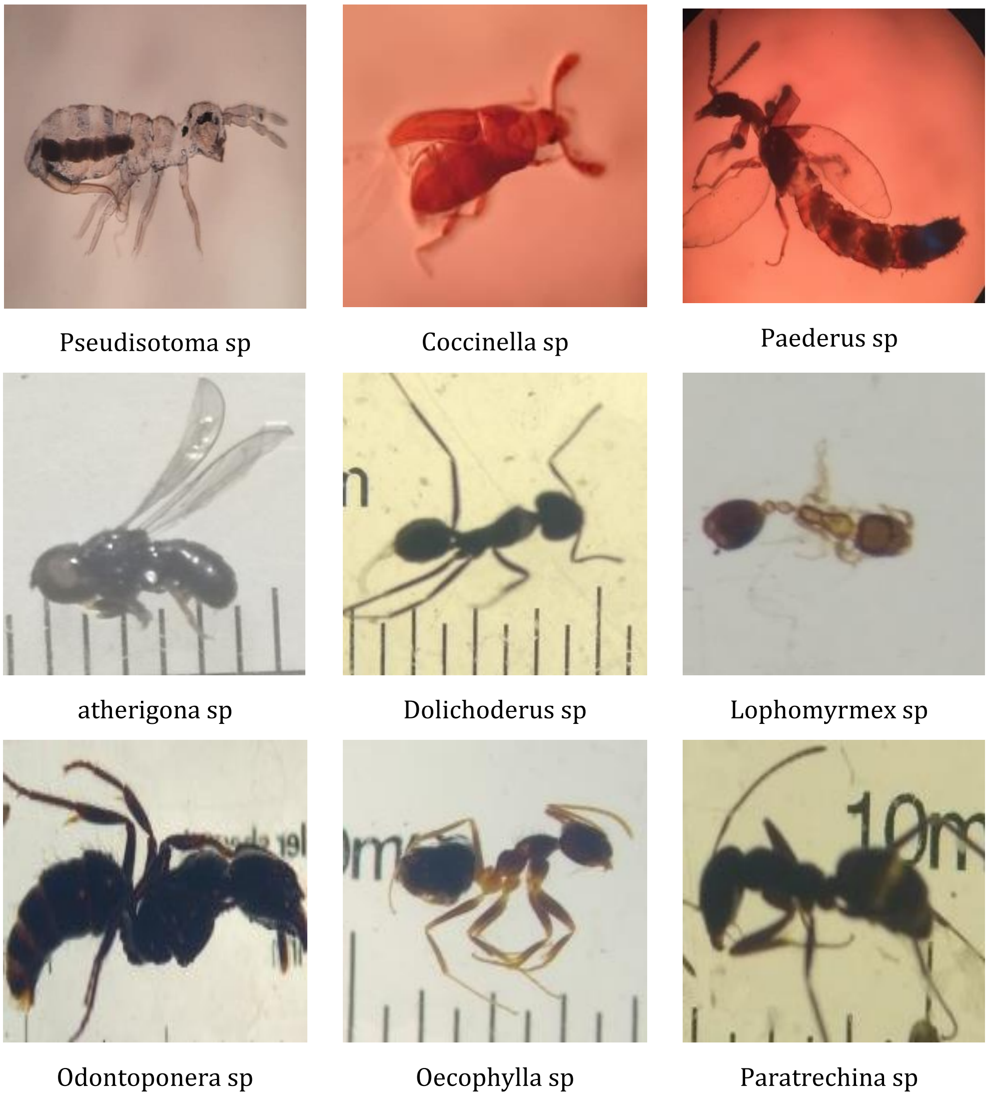


Figure 2. Soil microarthropods in coffee agroforestry in Mount Ungaran

Table 1. Microarthropod density (eng/m2), dominance (%), Shannon diversity index (H'), and evenness index (e) in coffee agroforestry in Mount Ungaran.

TAXA	Species	Intensive		Non-Intensive	
		K (m^2)	Di (%)	K (m^2)	Di (%)
Acari					
Aphidoidea	Aphis sp	0	0	80	6,67^{sd}
Araneae					
Gnaphosidae	drassodes sp	0	0	80	6,67^{sd}
Oxyopidae.	Oxyopes sp	100	9,43^{sd}	80	6,67^{sd}
Colembola					
Cyphoderidae	Chyphoderopsis sp	340	32,08^{d}	220	18,33^{d}
Entomobryidae	Ascocyrtus sp	0	0	40	3,33^{sd}
Isotomidae	cryptopygus sp	60	5,66^{sd}	60	5^{sd}
	Pseudisotoma sp	180	16,98^{d}	260	21,67^{d}

TAXA	Species	Intensive		Non-Intensive	
		K (m^2)	Di (%)	K (m^2)	Di (%)
Coleoptera					
Coccinellidae	Coccinella sp	20	1,89[r]	80	6,67[sd]
Staphylinidae	Paederus sp	0	0	120	10[d]
Diptera					
Muscidae	atherigona sp	0	0	80	6,67[sd]
Hymenoptera					
Formicidae	Dolichoderus sp	80	7,55[sd]	0	0
	Lophomyrmex sp	40	3,77[sd]	0	0
	Odontoponera sp	60	5,66[sd]	60	5[sd]
	Oecophylla sp	160	15,09[d]	0	0
	Paratrechina sp	20	1,89[r]	40	3,33[sd]
Number of Individuals, n		1060		1200	
Number of Species, S		11		12	
Shannon-Wiener Index, H'		2,08		2,30	
Similarity, e		0,73		0,83	

Criteria Di; dominant, > 10%; sub dominant, 3.2%–9.9%; 1.0% – 3.1% respondents; sub-resendent,0.32% - 0.99%; sporadic, 0.99%

The pattern of soil microarthropod diversity in each observed land type matched the hypothesis because the diversity index in Non-Intensive land was higher than In Intensive land. The high index of soil microarthropod diversity in the non-intensive land type was caused by the high number of species and evenness values in the land compared to the intensive land. The level of similarity between land types has quite the same similarity criteria. This was due to the relatively even distribution of the abundance of each taxa making up the microarthropod soil community in the two land types. The number of species in the Hymenoptera taxa in the Intensive land type affects the level of diversity at that location (Ari, Rahardian & Tarwotjo 2019).

Table 2 Sorensen similarity index of soil microarthropods in coffee plantation agroforestry in Mount Ungaran.

Criteria	Intensive x Non Intensive
t Hutcheson	0,02
ISS	52,17%

Hutchenson t criteria: p value <0.05 significantly different
ISS criteria (%): (51-75%) quite the same;

The Sorensen similarity index of soil microarthropods calculates the results of the similarity value between 52.17%. The level of similarity shows the criteria is quite the same with a value above 50%. Due to the similar composition formed and the type of land used as a sampling station, it is quite similar. The community similarity index describes the level of similarity in structure, composition, and species richness from which to compare. The similarity index value ranges from 0-100%. The index value close to 100% indicates a higher level of similarity between the two communities being compared (Putra, 2017).

Table 3. Environmental characteristics of coffee agroforestry in Mount Ungaran

Parameter	Intensive	Non Intensive
soil moisture	80	80
soil temperature	24	24
humidity	70	68
air temperature	26	28
soil ph	6	6,4
Organic Ingredients	14,6	17,8

Environmental characteristics that are seen show differences in organic matter where Intensive land has a value of 17% lower than Non-Intensive land, (Table 2). The other environmental parameters in each location have values that are not much different. Environmental characteristics in terms of physical and chemical factors showed not too significant differences. However, soils in intensive land types tend to have lower pH, organic matter content, and soil moisture values. This is because the greater soil moisture is influenced by soil temperature in the area where the higher the temperature, the lower the soil moisture level. 2020). The characteristics of soil organic matter show criteria that are in line with the level of species diversity that exists in both types of land, so that it can be said that non-intensive land is considered more fertile than intensive land, both physically and biologically.

4. CONCLUSION

Soil fertility in the Intensive and Non-Intensive tillage types can be observed based on the composition of the soil microarthropod community structure. The diversity value of the Intensive land type (H'=2.08) is lower than that of the Non-Intensive land type (H'=2.3). The diversity of soil microarthropod species in various types of coffee agroforestry land management shows results in line with soil chemical and physical factors (organic matter), which show that non-intensive land is considered more fertile than intensive land.

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