

Study on Soil Macrofauna Diversity and Its Role in Litter Decomposition in Coffee-Based Agroforestry

Melda Lely Marthalina¹, Maroeto^{1,✉}, Rossyda Priyadarshini¹

¹ Universitas Pembangunan Nasional “Veteran” Jawa Timur, Surabaya, INDONESIA.

Article History:

Received : 24 July 2024
Revised : 27 November 2024
Accepted : 09 December 2024

Keywords:

Agroforestry,
Biodiversity,
Coffee,
Decomposition rate,
Macrofauna.

Corresponding Author:

✉ maroeto@upnjatim.ac.id
(Maroeto)

ABSTRACT

The biodiversity or diversity of macrofauna depends on abiotic environmental factors and biotic environmental factors. Macrofauna plays a role in decomposing organic matter so that it can restore and maintain soil productivity. The study aims to determine the diversity of soil macrofauna in the Complex Agroforestry system and its effect on the decomposition of coffee litter. The research was carried out by observation of soil macrofauna and observation of litter decomposition rate using RAK which was composed of 2 factors, namely the type of agroforestry and the difference in the age of coffee plants. The results showed that the macrofauna diversity of soil in Complex Agroforestry and Simple Agroforestry was not different because the amount of shade and diversity were almost the same. The Soil Macrofauna Diversity Index showed a low category ($H' < 2$) with an average INP value of 40 – 48%. Biotic factors (litter production) and abiotic factors (temperature and humidity) affect the diversity of good macrofauna. A high macrofauna population will affect the rate of decomposition of debris where macrofauna plays a role in remodeling organic matter.

1. INTRODUCTION

The agroforestry system is a form of land use that influences the physical, chemical and biological characteristics of the soil. Agroforestry is a form of resource management by combining forest management activities (timber) with planting commodities (short-term crops) such as agricultural crops. The agroforestry model that has developed in Indonesia is coffee agroforestry. Agroforestry utilizes a combination of planting patterns between forestry plants and agricultural crops to maintain sustainability and provide ecological, social and economic benefits (Winara, 2018).

Biodiversity is the diversity of living things both on land, water and other ecosystems. One part of soil biodiversity is the soil fauna group that plays a role in improving the physical, chemical and biological properties of the soil (Saputra & Agustina, 2019). Macrofauna is a group of soil organisms that play a role in the decomposition process of soil organic matter. Soil macrofauna play a role in the decomposition of dead plant and fauna material, transporting organic matter from the surface to the soil, improving soil structure and the soil formation process (Hanna, 2022). In the decomposition of organic matter, the role of macrofauna is more in the fragmentation process and providing good environmental facilities (microhabitats) for the further decomposition process carried out by mesofauna and soil macrofauna as well as various types of fungi and bacteria (Anugerah *et al.*, 2022). The existence of soil macrofauna is determined by several environmental factors, namely the biotic environment and the abiotic environment. Environmental factors that can affect the activity of organisms in the soil such as climate (rainfall, temperature), soil (acidity, humidity, soil temperature, nutrients) and vegetation (forests, grasslands), sunlight and food availability (Wibowo & Slamet, 2017).

Research on macrofauna diversity has been widely conducted, including in teak and *jalawure* agroforestry (Winara, 2018) and in three different forest stands, namely the damar (*Agathis loranthifolia*) tree ecosystem, pine (*Pinus merkusii*) and puspa (*Schima walichi*) (Wibowo & Alby, 2020). However, studies on macrofauna diversity with different coffee ages and types of agroforestry and different microclimates and their roles in decomposition rates have not been widely conducted. Based on these reasons, it is necessary to conduct research on macrofauna diversity and its role in processes such as organic matter decomposition, especially litter decomposition in simple and complex agroforestry.

2. MATERIALS AND METHODS

This research was conducted from September to November 2023. The activities took place in Bangelan Village, Wonosari District, Malang Regency, East Java. The activities were carried out in two different plantations: a Simple Agroforestry Plantation (AGS) with coffee and lamtoro (*Leucaena leucocephala*) plants, and a Complex Agroforestry Plantation (AGK) with coffee, lamtoro, and durian plants.

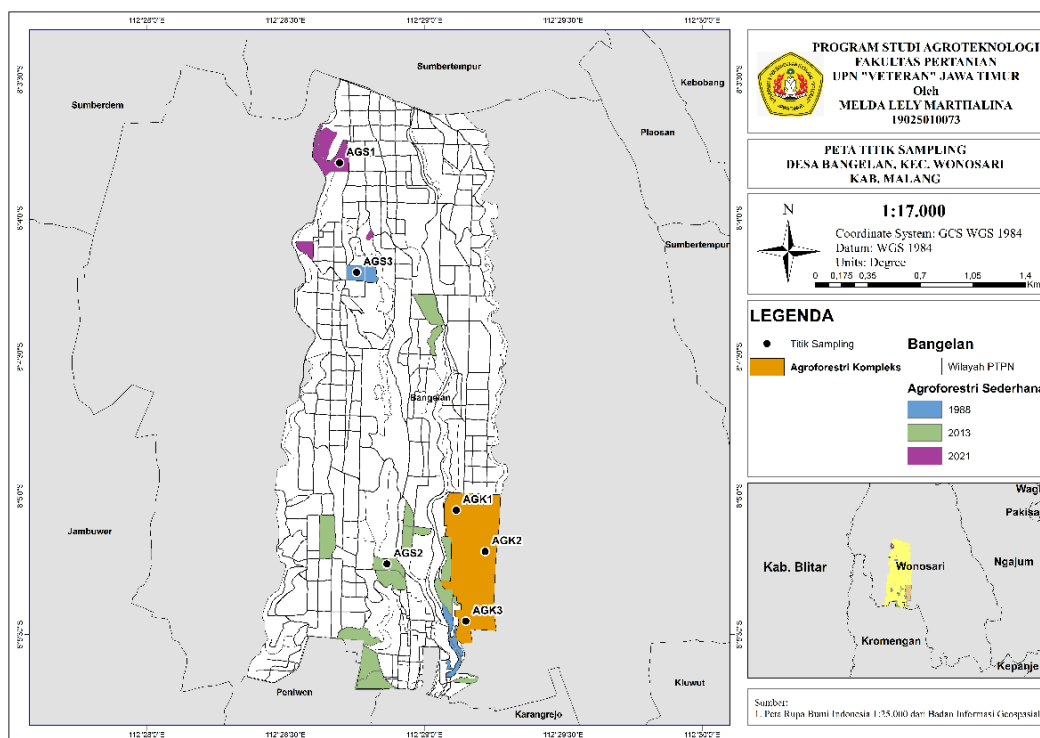


Figure 1. Map of research location with six sampling points

The research is a factorial experiment with treatments arranged according to a Randomized Factorial Design (RAKF) with 2 factors. Factor 1 is the difference in litter types, namely coffee and lamtoro litter and coffee, lamtoro and durian litter. While factor 2 is the difference in microclimate conditions based on variations in 3 different coffee age groups, namely 3-4 year old coffee, 9-10 year old coffee and >25 year old coffee. Data analysis was carried out by calculating the density index, calculating the estimated decomposition rate, and the diversity index using the Shannon-Weaver formula. The following equations are used, among others:

a) Density

Density is the number of individuals of a species per unit of space (Suin, 2005). The equations used to determine the density value include:

$$\text{Density (D) Type A} = \frac{\text{number of type A plots}}{\text{total number of plots}} \quad (1)$$

$$\text{Relative Density of Type A} = \frac{\text{density (D) type A}}{\text{sum of densities of all types}} \times 100\% \quad (2)$$

b) Frequency

Frequency is the number of species found during sampling during research. This variable shows the distribution pattern of soil macrofauna in the research area. The equations used to determine the frequency value include (Suin, 2005):

$$\text{Frequency of species A} = \frac{\text{number of plots where type A was found}}{\text{total number of plots}} \quad (3)$$

$$\text{Relative frequency of species A} = \frac{\text{frequency of type A}}{\text{sum of frequencies of all types}} \times 100\% \quad (4)$$

c) Importance Value Index (IVI)

Importance value is the relative value of the function, role and level of adaptability of a population compared to other populations in a community. Important values are expressed as cumulative values of relative density and relative frequency variables, with the equation (Warda et al., 2024):

$$\text{Important value} = \text{Relative density} + \text{Relative frequency} \quad (5)$$

d) Estimation of Decomposition Rate

The decomposition rate (D) was calculated from weight loss (W) using the following approach (Andrianto et al., 2015):

$$D = \frac{W}{t} \quad (6)$$

$$W = \frac{W_0 - W_t}{W_0} \times 100\% \quad (7)$$

where W_0 is initial litter weight (g), W_t is final dry litter weight (g), and t is observation period.

e) Shannon-Weaver Diversity Index

The diversity index (H') was calculated using the Shannon-Wiener (1949) formula, as the following:

$$H' = - \sum \left(\frac{n_i}{N} \ln \frac{n_i}{N} \right) \quad (8)$$

where H' is Shannon-Wiener diversity index, n_i is number of individual of species i , and N is total number of individuals. The diversity was categorized based on H' values, namely low ($H' \leq 2$), medium ($2 \leq H' \leq 3$), and high ($H' \geq 3$).

3. RESULTS AND DISCUSSION

3.1. Environmental Conditions

Temperature and Humidity

Temperature plays an important role in regulating soil fauna activities because temperature affects the speed of chemical reactions in the body and determines metabolic activities. Based on the results of the t -test analysis, it shows that there is no significant difference in soil temperature between Simple Agroforestry (AGS) and Complex Agroforestry (AGK). The temperature that is not different between AGS and AGK is influenced by the almost the same land conditions due to pruning of coffee plants, resulting in almost the same plant conditions. The temperature of the topsoil fluctuates in one day and one night and depends on the season. Temperature fluctuations depend on weather conditions, area topography and soil conditions (Nurrohman et al., 2015).

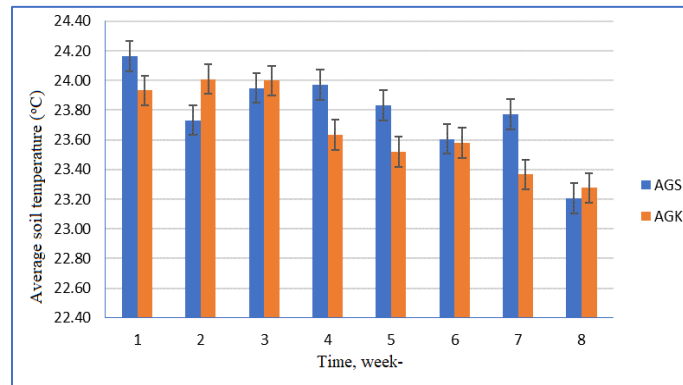


Figure 2. Average morning soil temperature during 8 weeks observation (AGS: Simple Agroforestry; AGK: Complex Agroforestry)

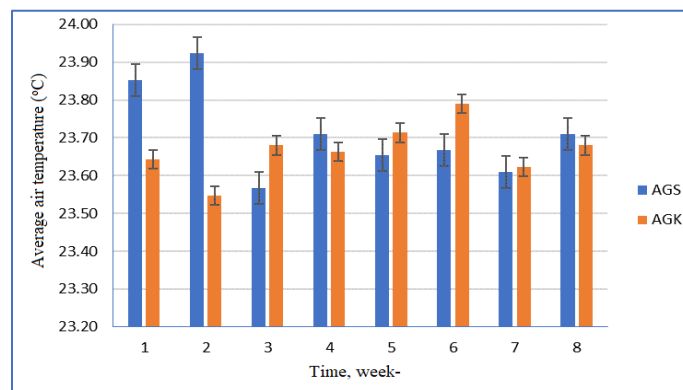


Figure 3 Average morning air temperature during 8 weeks observation (AGS: Simple Agroforestry; AGK: Complex Agroforestry)

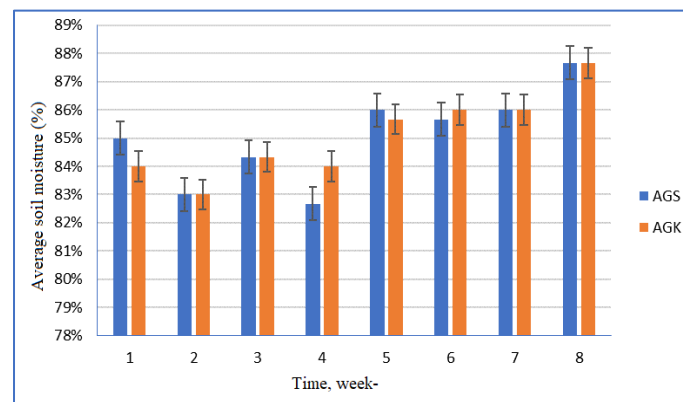


Figure 4. Average soil moisture during 8 weeks observation (AGS: Simple Agroforestry; AGK: Complex Agroforestry)

High air temperatures can accelerate the evaporation of water from the soil, which in turn can affect soil moisture (Maftu'ah *et al.*, 2018). High air temperatures in AGS2 are influenced by several factors such as altitude and canopy cover which affect light intensity. The average temperature variance that is not significantly different is influenced by several factors such as altitude and canopy cover which affect light intensity. Land cover in the form of trees functions to control temperature at a location. Research by Rushayati *et al.* (2011) in Yenri *et al.* (2023), concluded that the higher the percentage of green open space, the lower the air temperature and vice versa. Temperature fluctuations depend on weather conditions, area topography and soil conditions (Nurrohman *et al.*, 2015).

Soil moisture or humidity also plays an important role in plant growth because plants need appropriate soil moisture to absorb nutrients properly and grow optimally. In addition, soil moisture also affects the activity of soil organisms, such as macrofauna and mesofauna, which play a role in the decomposition process, carbon flow, nutrient redistribution, and soil formation (Wibowo *et al.*, 2017). Rainfall is one of the causes of high soil moisture in an area where high rainfall can increase soil moisture, while low rainfall can decrease soil moisture (Pradiko *et al.*, 2020).

3.2. Soil Conditions

Physical Properties of Soil

Physical properties of soil are soil properties related to soil fertility and affect plant growth and production. Soil texture is an important physical property because it affects plant growth and can indirectly improve the circulation of water, air and heat, the activity of soil organisms, the availability of nutrients for plants, the decomposition of organic matter, and the ease with which roots can penetrate deeper into the soil (Mustawa *et al.*, 2017). In general, the proportion of sand at the research location has a relatively low range, which is between 17.9-21.6%, while the proportion of dust has a range of between 20.3-28% and clay has the highest range between 50.4%-61.8%. Soil with high clay content tends to have higher water content and cation exchange capacity because the clay fraction has a large specific surface area of around 800 m² so that it is able to adsorb water molecules and cations (Nurhartanto *et al.*, 2022). Clay particles are the smallest soil fractions so that they have high total porosity but are dominated by micropores or capillary pores so that the infiltration rate is low (Haghnazari *et al.*, 2015). Other parameters of soil physical properties are soil bulk density and soil specific gravity.

The average soil bulk density at the AGS location was 1.27 g/cm³, while at the AGK location the average soil bulk density was around 1.35 g/cm³. This figure has slightly exceeded the density at all research locations ranged from 2.19 to 2.38 g/cm³. Soil with a density of more than 2 g/cm³ generally has high density and low porosity, so it can affect the physical properties of the soil and the availability of water for plants and soil macrofauna. The bulk density of soil is used to assess the density of the soil, where the smaller the bulk weight of the soil, the more loose the soil and vice versa, the greater the bulk density of the soil, the denser the soil (Nurhartanto *et al.*, 2022).

Table 2. Soil Physical Properties Measurement Results in Simple and Complex Agroforestry

Agroforestry Type	Soil Physical Properties	
	Soil Bulk Density (g/cm ³)	Soil Particle Density (g/cm ³)
AGS1	1.27	2.36
AGS2	1.35	2.38
AGS3	1.30	2.26
AGK1	1.27	2.19
AGK2	1.36	2.22
AGK3	1.40	2.26

Note: AGS = Simple Agroforestry; AGK = Complex Agroforestry

Soil Chemical Properties

Soil chemical components, such as pH, organic matter content, and nutrient availability, affect the balance of plant nutrients and the activity of microorganisms in the soil. Sufficient organic matter content can support the existence of soil macrofauna, while extreme soil pH or low nutrient availability can affect the diversity and abundance of soil macrofauna (Nurhartanto, *et al.*, 2022).

The results of the study of soil chemical properties showed that the highest C-organic content was in AGS3 (2.12%) and the low C-organic content was 1.53% in AGK3. The average C-organic content in AGS was 1.89% while the average C-organic content in AGK was 1.60%. This shows that in AGS the C-organic content is higher than in AGK. This can be influenced by the very passive land management so that the C-organic content in the soil decreases. The organic matter content of the soil that is considered good ranges from 1–4% to support healthy and productive plant growth. The organic matter content in the range of 4–8% is included in the criteria for excessive organic matter (Supriyantini *et al.*, 2017). The pH content of the soil at the research location ranged from 4.43–5.16 which means it is included in the very

acidic to acidic category. The optimal pH value for plant growth is 5.5–6.5 (Balitri, 2017). An inappropriate pH level will inhibit the growth of plants, microorganisms, and other organisms and then reduce the food sources available for soil macrofauna (Li *et al.*, 2014). One of them is ants, if the pH is not appropriate, the ants are unlikely to survive long, so pH is one of the factors that determines the level of decomposition of organic matter. The total N content of the soil at the research location showed that the highest N content was in AGS3 (1.60%) and the lowest N content was in AGK3 (1.17%). The higher the organic matter contained in the soil, the higher the N content in the soil so that the ability of the soil to provide nitrogen is highly determined by the condition of the amount of organic matter in the soil (Bakri *et al.*, 2016). The total N content of the soil is highly dependent on the availability of organic matter in the soil. Organic matter in the soil is a source of nutrients that are very much needed by plants (Sari *et al.*, 2022).

Table 3. Soil chemical properties measurement results in simple and complex agroforestry

Agroforestry Type	Soil Chemical Properties		
	Organic Carbon (C-organic) (%)	Total Nitrogen (N-Total) (%)	pH
AGS1	1.76	1.23	4.43
AGS2	1.80	1.29	4.46
AGS3	2.12	1.17	4.50
AGK1	1.68	1.19	4.61
AGK2	1.60	1.32	4.83
AGK3	1.53	1.60	5.16

Note: AGS = Simple Agroforestry; AGK = Complex Agroforestry

3.3. Land Conditions

Vegetation Diversity

Coffee plants have a high relative density (DR) value in each Agroforestry with the highest value in AGK3, which is 64.29%, then the highest relative density value of lamtoro plants in AGS1, which is 49.09% and the highest relative density value of durian in AGK with 13.21%. Overall, coffee plants have a high density level because they are the main crop so that they almost dominate the entire agroforestry. The Importance Value Index (IVI) is used to describe the ecological position of a type in the vegetation community. If the IVI of a type of vegetation has a high value, then that type greatly affects stability. The results of the analysis of the IVI show that coffee and lamtoro from both types of agroforestry are included in the high category while the IVI value of durian in Complex Agroforestry is classified as moderate. According to Handayani & Ahmed (2022), the categorization of IVI values if the IVI value > 42.66 is categorized as high; IVI value is 21.96 – 42.66 in the medium category and IVI < 21.96 in the low category.

Table 4. Vegetation Diversity Index (H') in Simple and Complex Agroforestry

Agroforestry Type	Number of Individuals	Number of Species	Diversity Index (H')	Category
AGS1	55	2	0.69	Low
AGS2	49	2	0.68	Low
AGS3	68	2	0.68	Low
AGK1	53	3	0.95	Low
AGK2	48	3	0.93	Low
AGK3	42	3	0.86	Low

Note: AGS = Simple Agroforestry; AGK = Complex Agroforestry; 1: coffee plant 3-4 years; 2: coffee plant 9-10 years; 3: coffee plant > 25 years.

The diversity of stand species (H') is one of the vegetation parameters that can determine community stability, namely the ability of a community to maintain itself stable from disturbances to its components (Anggara *et al.*, 2020). In this study, the diversity index was calculated on two types of agroforestry, namely Simple Agroforestry and Complex Agroforestry. Based on Table 4, the calculation results for the Complex Agroforestry (AGK) type have a higher diversity index compared to the Simple Agroforestry (AGS) type. The average H' index value in AGS is 0.68 while the H' index value in AGK is 0.91. However, it is known that from both types of agroforestry, the diversity index is still classified as

low with an H' value <2 , where the value with the H' category <2 has a low criterion. The low H' value is due to the type of vegetation that dominates at the location, namely Robusta coffee (*Coffea canephora*) so that the higher the level of dominance of a type, the less its diversity. However, it is known that from both types of agroforestry, the diversity index is still classified as low with a value of $H' < 2$, where the value with the category $H' < 2$ has a low criterion. The low value of H' is due to the type of vegetation that dominates the location, namely Robusta coffee so that the higher the level of dominance of a type, the less diversity it has. The high or low diversity index of a plant community depends on the number of species and the number of individuals (Hidayat, 2017).

Litter Production

Litter production is the amount of litter that falls to the forest floor in a certain period per unit area. The difference in the age of coffee plants in agroforestry land, both simple and complex, also affects litter production. The results of the t -test showed a t -count value (3.7172) $>$ t -table (1.7138) which means there is a significant difference in the average litter production between Simple Agroforestry (AGS) and Complex Agroforestry (AGK). The difference in litter input obtained for each location point is due to temperature factors, differences in plant species density and plant age which indirectly affect it. The decrease in litter production is influenced by environmental conditions, namely microclimate. When the dry season and temperatures become high, the plants will shed their leaves so that litter production increases. When entering the rainy season, litter production will decrease. Research by Mitha et al. (2019), states that the dynamics of litter loss of coffee plants and their shade trees are caused by the dry season and litter production is also caused by the type of shade tree. Total litter input consists of branch, twig, and leaf litter. Each agroforestry area has a different ability to produce litter input.

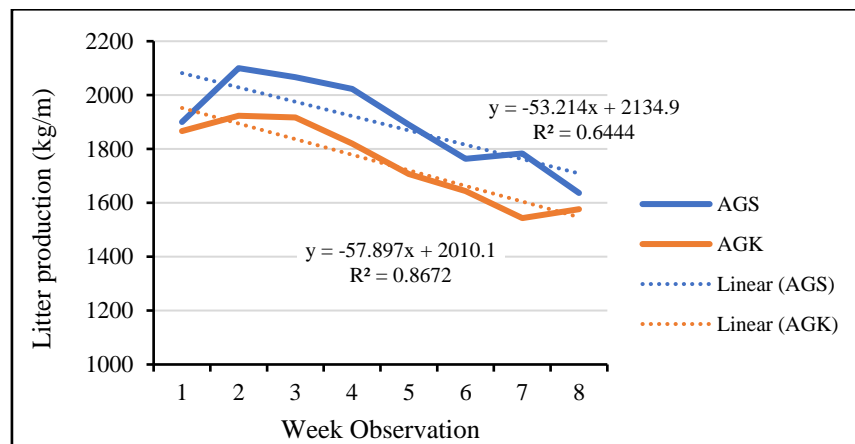


Figure 5. Average litter production in coffee-based agroforestry during 8 weeks observation

Litter Quality

The content of soil organic matter is influenced by the amount of organic matter and carbon input from plants growing on it. The quality of soil organic matter is determined by its chemical properties and characteristics, including C-organic, N-total, polyphenols, and lignin. Lignin plays an important role in determining the rate of litter decomposition (Jayanthi & Arico, 2017). The chemical composition of soil organic matter used for the litter decomposition study can be seen in Table 5.

Table 5. Chemical Composition of Plant Biomass Organic Material in Agroforestry Land

Biomass	Total C (%)	Total N (%)	Lignin (L) (%)	Polyphenol (P) (%)	C/N	L/N	(L+P)/N
Coffee	26.1	1.44	24.76	5.56	18.12	17.19	21.06
Lamtoro	3.26	0.77	20.00	3.20	4.23	25.97	30.13
Durian	7.55	1.65	15.45	6.70	4.57	9.36	13.42

Note: AGS = Simple Agroforestry; AGK = Complex Agroforestry

According to Hairiah *et al.* (2004), litter is categorized as rapidly decomposing if it has a C/N ratio <25, lignin content <15, and polyphenols <3. Based on the analysis results, the organic material used for this study has a relatively low quality. This is indicated by the lignin content value with a range of around 15.45% to 24.76% and polyphenol content of around 3.2% to 6.7%. Polyphenols generally have a negative effect on the litter decomposition process because they interfere with enzymes and proteins. However, several functions in the soil and litter layers are influenced by different polyphenols (Adamczyk *et al.*, 2017). Litter containing polyphenols can reduce the number of important organisms during decomposition. Based on the results of the C/N ratio calculation, overall the coffee biomass content used has a high C/N value of around 18.12 while the lamtoro and durian biomass ranges between 4.23 and 4.57 respectively so that of the three types of litter, coffee litter will take longer to decompose than lamtoro and durian litter. According to Krismawati & Hardini (2014), litter with a high C/N value will decompose more slowly. The nitrogen content in leaves can increase the rate of decomposition, while the carbon content in leaves tends to reduce the rate of decomposition (Ristok *et al.*, 2019). Thus, the high carbon content in leaves will slow down the rate of litter decomposition (Eichenberg *et al.*, 2015).

3.4. Macrofauna Diversity

The diversity of soil macrofauna plays a role in improving the physical, chemical, and biological properties of the soil. Macrofauna at soil depths reaching 0–20 cm and 20–40 cm found in AGS and AGK in Bangelan Village, Wonosari District, Malang Regency amounted to 5 species, including earthworms (*Lumbricus terrestris*), red ants (*Solenopsis invicta*), black ants (*Dolichoderus thoracicus*), centipedes (*Chilopoda*) and subterranean termites (*Macrotermes* sp.).

The diversity index (H') aims to determine the number of species in a region in a particular community (Nasirudin & Susanti, 2018). Based on the results of the Index calculation, it is known that the diversity of macrofauna found is relatively low ($H' < 2$). The low macrofauna diversity index is inseparable from the limited supporting factors for macrofauna diversity, one of which is environmental factors. The Diversity Index is used to determine the level of plant species diversity at all growth phases in a community. The types of macrofauna that dominate the research location include termites with an IVI value of 48.41% in AGS and 47.78% in AGK. The average value of the IVI between AGS and AGK is 40% so that descriptively there is no significant difference in IVI values between the two observation plots based on the results of the *t*-test. The results of the analysis show a *t*-count value (-1.154) < *t*-table (2.132) which means there is no difference in the average between the AGS IVI value and the AGK IVI value. If seen in Table 6, termites are said to dominate with a fairly high Relative Density (DR) value in each type of agroforestry. This is influenced by the availability of organic matter as black food at the research location, possibly as well as temperature and humidity factors.

Table 6. Density and Abundance of Soil Macrofauna Population in Agroforestry Land

Plot	Macrofauna Species	N	D	DR (%)	F	FR (%)	INP (%)	H' Index
AGS	<i>Lumbricus terrestris</i>	431	32.4	24.50	1	20	44.49	1.41
	<i>Solenopsis invicta</i>	407	30.6	23.12	1	20	43.13	
	<i>Dolichoderus thoracicus</i>	410	30.2	23.30	1	20	43.30	
	<i>Macrotermes</i> sp.	500	31.8	28.40	1	20	48.41	
	<i>Chilopoda</i>	12	0.8	0.70	1	20	20.68	
AGK	<i>Lumbricus terrestris</i>	412	24.2	24.08	1	20	46.89	1.42
	<i>Solenopsis invicta</i>	419	20.6	24.49	1	20	42.89	
	<i>Dolichoderus thoracicus</i>	420	20.0	24.54	1	20	42.22	
	<i>Macrotermes</i> sp.	445	25.0	26.01	1	20	47.78	
	<i>Chilopoda</i>	15	0.2	0.88	1	20	20.22	

Note: C = earthworm (*Lumbricus terrestris*); SM = red ant (*Solenopsis invicta*); SH = black ant (*Dolichoderus thoracicus*); K = centipede (*Chilopoda*); R = subterranean termite (*Macrotermes* sp.); AGS = Simple Agroforestry; AGK = Complex Agroforestry.

Several factors that influence the abundance of soil macrofauna include: (1) Physical properties of the soil (bulk weight and specific gravity) (2) Chemical properties of the soil (soil pH, C-organic and N-Total soil); (3) Litter Production; (4) Temperature and (5) Soil humidity. Soil C-organic greatly influences macrofauna. The high and low C-organic in the soil is related to organic matter. The higher the C-organic, the higher the population of macrofauna in the soil. High organic matter content in the soil causes the activity and population of soil fauna to increase in relation to the

activity of soil fauna as decomposing organisms and the mineralization process of organic matter (Nasirudin & Susanti, 2018). The high total N content is due to the high organic matter content of the soil. Sufficient organic matter content will increase the activity of soil organisms so that this also affects the increase in the value of N-total soil. The content of N-total soil has an effect on the abundance of termites (Fitri & Ulfa, 2012).

Relationship of Litter Production to Macrofauna

Organic material from plant and fauna remains of soil organisms, both decomposed and decomposed, determines the type and abundance of soil fauna. Soil organic matter is a source of energy for soil macrofauna to maintain their sustainability. The composition and type of leaf litter determine the type of fauna on a plot of land and the amount of litter determines the density of soil fauna (Nurrohman *et al.*, 2018). The results of the F test show that litter production affects the population of soil macrofauna because the *F* values (16.412) > *F* sig 5% (3.9519). Organic matter is a food source for microorganisms that live in the soil. The more organic matter, the greater the population of macrofauna in the soil (Risman & Ikhsan, 2017). This relationship is also shown. There is a strong relationship between litter production and soil macrofauna (Figure 6a) with a high correlation coefficient value, namely $R^2 = 0.6212$.

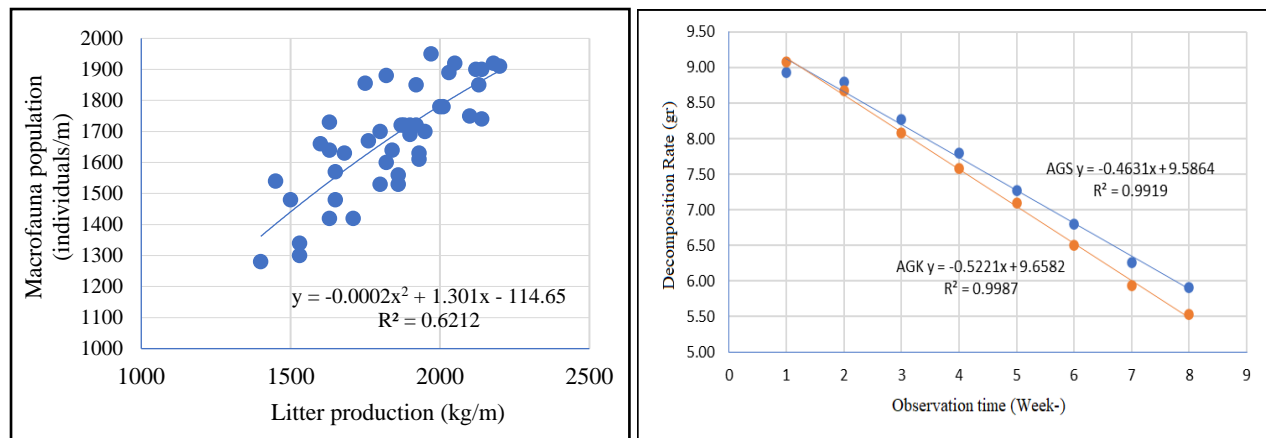


Figure 6. (a) Relationship of litter production and soil macrofauna population, (b) Decomposition rate during 8 weeks observation

3.5. Litter Decomposition Rate

The rate of litter decomposition at the research location was calculated from the change in dry weight of the litter during the decomposition process. The results are presented in Figure 6b. Rapid weight loss is caused by organic matter utilized by soil macrofauna to obtain energy and cell components. Slower weight loss is caused by the decreasing carbon source from organic matter (Mali *et al.*, 2021). Based on the results of the analysis of variance test, it is known that there is no difference in the average decomposition rate in each plot during 8 weeks of observation, indicated by the *F* value (0.6220) < *F* sig 5% (4.0517). The decomposition process occurs due to several abiotic factors including canopy density, air temperature, humidity, and soil temperature. High canopy density increases litter input and humidity, and lowers soil and air temperatures, which stimulates the activity of decomposing organisms. Devianti & Tjahjaningrum (2017), showed that the rate of litter decomposition is usually high at first and then decreases, along with the reduction in organic matter available for decomposition by microbes. The rate of decomposition can reflect the quality of litter and the availability of materials needed by soil microorganisms.

Relationship of Abiotic Factors to Macrofauna

Microclimate is an important factor that influences the activity of soil organisms, including soil macrofauna. Soil temperature has a strong relationship with the abundance of macrofauna with a high correlation coefficient value of $R^2 = 0.7103$. Each type of soil fauna has an optimum temperature range so that high temperatures will affect soil microbial activity. As explained by Robinso *et al.* (2018), that fluctuations of 10-20°C with an average of 15°C do not have the same effect on soil fauna when compared to an environment with a constant temperature of 15°C. Soil temperature is a

soil physical factor that greatly determines the level of diversity of soil macrofauna species. Soil temperature greatly determines the process of decomposition of soil organic matter (Sierra *et al.*, 2017).

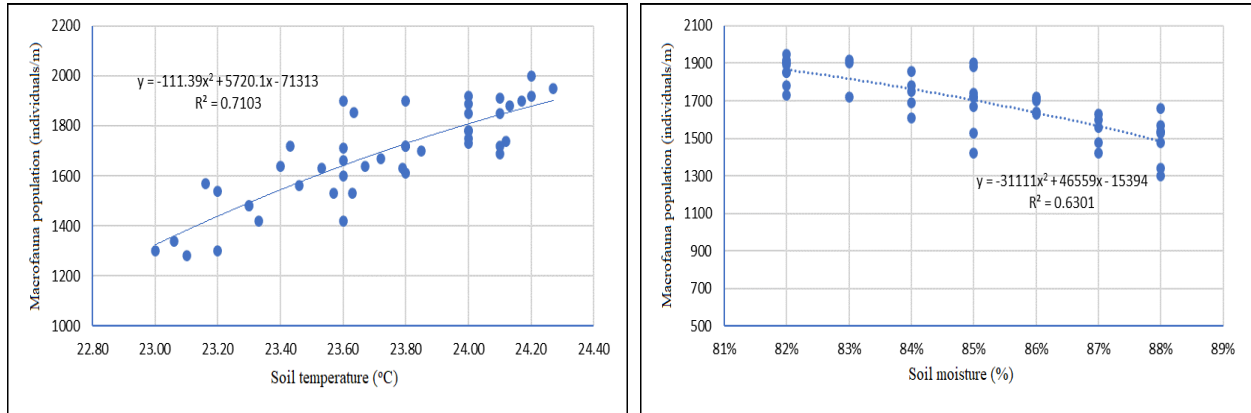


Figure 7. Relationship of abiotic factors to macrofauna: (a) soil temperature, and (b) soil moisture

The effect of soil moisture on macrofauna is shown by the R^2 value of 0.6301 (Figure 7b). High humidity can affect the diversity of soil organisms because it can cause soil fauna to die and migrate to other vegetation, thus affecting the macrofauna population in that vegetation (Rhengi *et al.*, 2022). Temperature also has a limiting effect on the growth of organisms when the humidity is extremely high or low, but humidity has a more critical effect on organisms at extremely high or extremely low temperatures, in addition, soil humidity also greatly affects nitrification, high humidity is better for soil fauna than low humidity (Utami *et al.*, 2019).

Relationship of Abiotic Factors to Decomposition Rate

A hot and humid environment can encourage high levels of macrofauna and microorganism activity where the activity of macrofauna and microorganisms increases, along with increasing soil moisture. Based on the results of the analysis between soil temperature and the decomposition rate in the graph below, it is known that there is a strong relationship with a correlation coefficient value of R^2 , which is 0.6304 (Figure 8). This means that soil temperature has an effect on the litter decomposition process. Meanwhile, air temperature does not affect the litter decomposition rate because the correlation coefficient value is low. An increase in temperature in a land area may reduce litter decomposition rate under dry conditions; litter decomposes more rapidly during the wet season when moisture is ample (Sierra *et al.*, 2017).

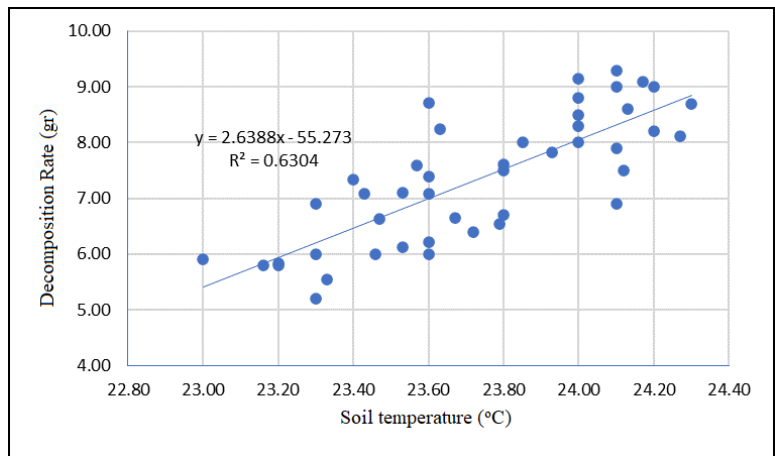


Figure 8. Graph of the relationship between soil temperature and decomposition rate

Relationship of Soil Macrofauna to Decomposition Rate

Based on the graph in Figure 9a, it is known that the population of soil macrofauna to the rate of decomposition has a strong relationship with a high R^2 correlation coefficient value of 0.6551, which means that there is a positive correlation between the abundance of soil macrofauna found to have a significant effect on the rate of decomposition. The higher the decomposition rate, the greater the macrofauna population because of the role of macrofauna in breaking down litter into small pieces (Anggraeny *et al.*, 2017). The results of observations showed that the dominant soil macrofauna were from the Insecta class, namely black ants, termites and red ants. Soil insects that act as decomposers of organic matter turned out to dominate the population. Soil insects have the ability to break down litter and organic matter.

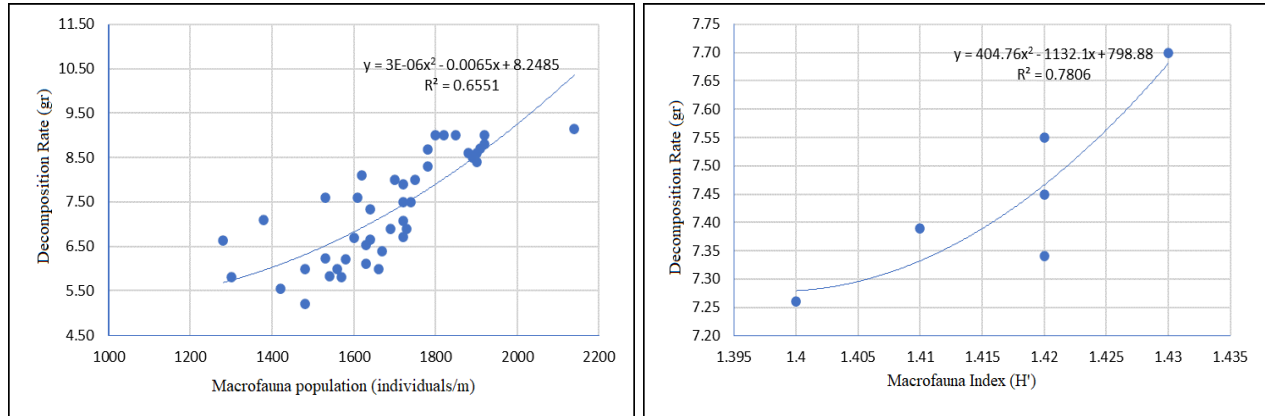


Figure 9. Decomposition rate as affected by: (a) Macrofauna population, and (b) H' Macrofauna index

It is known that the soil macrofauna diversity index and the decomposition rate have a strong relationship with a high correlation coefficient R^2 value 0.7806 with the equation $y = 404.76x^2 - 1132.1x + 798.88$ (Figure 9b), means that the diversity of soil macrofauna found significantly affects the decomposition rate. The higher the decomposition rate, the greater the diversity of macrofauna because of the role of macrofauna in breaking down litter into small pieces (Anggraeny *et al.*, 2017). The results of observations showed that the dominant soil macrofauna were from the Insecta class (insects), namely black ants, termites and red ants. According to Meilin & Nasamsir (2016), soil insects that act as decomposers of organic matter actually dominate the population. Soil insects have the ability to break down litter and organic matter. Black ants, red ants, termites and worms can help create larger spaces for other organic materials, such as litter, by breaking them down into smaller pieces. Earthworms in their life cycle can make burrows in the soil by eating soil mass and organic matter. Earthworm burrows increase infiltration and aeration, reduce surface flow, support earthworm movement to avoid environmental stress, and serve as a place to store and digest food (Riana, 2020).

4. CONCLUSION

Based on the research that has been carried out, it can be concluded that the diversity of soil macrofauna in Complex Agroforestry and Simple Agroforestry is not different because the amount of shade and diversity are almost the same. Biotic factors (litter production) and Abiotic Factors (soil temperature, soil moisture) affect the diversity of macrofauna in both Complex Agroforestry and Simple Agroforestry, and the abundance of macrofauna affects the acceleration of the rate of litter decomposition where macrofauna play a role in breaking down organic matter so that the increase in the macrofauna population accelerates the litter decomposition process.

REFERENCES

Anugerah, D., Indriani, D., & Pariyanto. (2022). Keanekaragaman makrofauna tanah pada perkebunan kelapa sawit di Kecamatan Karang Tinggi Kabupaten Bengkulu Tengah. *Jurnal Riset dan Inovasi Pendidikan Sains (JRIPS)*, 1(2), 81–95. <https://doi.org/10.36085/jrips.v1i2.3599>

- Adamczyk, B., Karonen, M., Adamczyk, S., Engström, M.T., Laakso, T., Saranpää, P., Kitunen, V., Smolander, A., & Simon, J. (2017). Tannins can slow-down but also speed-up soil enzymatic activity in boreal forest. *Soil Biology and Biochemistry*, **107**, 60–67. <https://doi.org/10.1016/j.soilbio.2016.12.027>
- Andrianto, F., Bintoro, A., & Yuwono, S.B. (2015). Produksi dan laju dekomposisi serasah mangrove (*Rhizophora* sp.) di Desa Durian dan Desa Batu Menyan Kecamatan Padang Cermin Kabupaten Pesawaran. *Jurnal Sylva Lestari*, **3**(1), 9–20. <https://doi.org/10.23960/jsl139-20>
- Anggara, F.T., Ardiyansyah, F., Sufajari, A., & Nurchayati, N. (2020). Analisis struktur komunitas rumput (*Poaceae*) di Savana Bekol Taman Nasional Baluran. *Jurnal Biosense*, **3**(1), 16-30.
- Anggraeny, L.W., Wahyuni, S., & Purwanti, E. (2017). Analisis laju dekomposisi serasah tanaman belimbing (*Averrhoa carambola* L.) terhadap keanekaragaman fauna tanah sebagai sumber belajar biologi. *The Annual Research Report*. <https://api.semanticscholar.org/CorpusID:127348317>
- Bakri, I., Thaha, A.R., & Isrun, I. (2016). Status beberapa sifat kimia tanah pada berbagai penggunaan lahan di DAS Poboya Kecamatan Palu Selatan. *Agrotekbis: E-Jurnal Ilmu Pertanian*, **4**(5), 512–520.
- Balitri (Balai Penelitian Tanaman Industri dan Penyegar). (2017). *Persiapan dan kesesuaian lahan tanaman kopi*. Puslitbang Perkebunan Badan Litbang Pertanian, Kementerian Pertanian.
- Ristok, C., Leppert, K.N., Scherer-Lorenzen, M., Niklaus, P.A., & Bruehlheide, H. (2019). Soil macrofauna and leaf functional traits drive the decomposition of secondary metabolites in leaf litter. *Soil Biology and Biochemistry*, **135**, 429–437. <https://doi.org/10.1016/j.soilbio.2019.06.007>
- Devianti, O.K.A., & Tjahjaningrum, I.T.D. (2017). Studi laju dekomposisi serasah pada hutan pinus di kawasan wisata Taman Safari Indonesia II Jawa Timur. *Jurnal Sains dan Seni*, **6**(2), 2337–3520. <http://dx.doi.org/10.12962/j23373520.v6i2.27535>
- Eichenberg, D., Trogisch, S., Huang, Y., He, J.-S., & Bruehlheide, H. (2015). Shifts in community leaf functional traits are related to litter decomposition along a secondary forest succession series in subtropical China. *Journal of Plant Ecology*, **8**, 401–410. <https://doi.org/10.1093/jpe/rtu021>
- Yenri, E., Suhesti, E., & Said, A. (2023). Peranan pohon dalam membentuk iklim mikro. *Jurnal Karya Ilmiah Multidisiplin (JURKIM)*, **3**(1), 95–101. <https://doi.org/10.31849/jurkim.v3i1.12752>
- Fitri, A., & Ulfa, A. (2015). Perencanaan penerapan konsep zero run-off dan agroforestri berdasarkan kajian debit sungai di Sub DAS Belik, Sleman, Daerah Istimewa Yogyakarta. *Jurnal Perencanaan Wilayah dan Kota*, **26**(3), 192-207. <http://dx.doi.org/10.5614/jpwk.2015.26.3.4>
- Haghnazari, F., Shahgholi, H., & Feizi, M. (2015). Factors affecting the infiltration of agricultural soils. *International Journal of Agronomy and Agricultural Research*, **6**(5), 21–35.
- Hairiah, K., Suprayogo, D., Widiyanto, B., Suhara, E., Mardiasuning, A., Widodo, R.H., & Rahayu, S. (2004). Alih guna lahan hutan menjadi lahan agroforestri berbasis kopi: Ketebalan serasah, populasi cacing tanah dan makroporositas tanah. *Agrivita*, **26**(1), 68–80.
- Handayani, H., & Ahmed, Y. (2022). Studi analisis struktur dan komposisi vegetasi Hutan Kota Cibubur dan Hutan Kota Patriot. *Metrik Serial Teknologi dan Sains*, **3**(2), 109-114. <https://doi.org/10.51616/teksi.v3i2.356>
- Hanna, S. (2022). Kepadatan cacing tanah pada agroforestri kopi Kecamatan Wonosalam Jombang. [Undergraduate thesis]. UIN Maulana Malik Ibrahim-Malang. Retrieved from <http://etheses.uin-malang.ac.id/id/eprint/41106>
- Hidayat, M. (2023). Herbaceous plant diversity in the restoration area of Soraya Research Station in Leuser ecosystem. *IJES : Indonesian Journal of Environmental Sustainability*, <https://journal.ar-raniry.ac.id/index.php/IJES> DOI : <https://doi.org/10.22373/ijes.v1i1.4144>
- Jayanthi, S., & Arico, Z. (2017). Laju dekomposisi serasah hutan Taman Nasional Gunung Leuser Resort Tenggulun. *Prosiding Seminar Nasional MIPA III*, 312-317.
- Krismawati, A., & Hardini, D. (2014). Kajian beberapa dekomposer terhadap kecepatan dekomposisi sampah rumah tangga. *Buana Sains*, **14**(2), 79-89.
- Li, J., Pu, L.J., Zhu, M., Zhang, J., Li, P., Dai, X., Xu, Y., & Liu, L. (2014). Evolution of soil properties following reclamation in coastal areas: A review. *Geoderma*, **226-227**, 130–139. <https://doi.org/10.1016/j.geoderma.2014.02.003>

- Maftu'ah, E., Alwi, M., & Willis, M. (2018). Potensi makrofauna tanah sebagai bioindikator kualitas tanah gambut. *Bioscientiae*, *2*(1), 17–25.
- Mali, M.I., Purnama, M.M., & Mau, A.E. (2021). Dekomposisi serasah daun akasia (*Acacia auriculiformis*) di KHDTK LITBANG Kehutanan Oelsoibai Kota Kupang. *Wana Lestari*, *4*(1), 98–106.
- Meilin, A., & Nasamsir. (2016). Serangga dan peranannya dalam bidang pertanian dan kehidupan. *Jurnal Media Pertanian*, *1*(1), 18–28. <http://dx.doi.org/10.33087/jagro.v1i1.12>
- Mitha, R.T., Nurahmi, E., & Anhar, A. (2019). Pengaruh dosis kompos limbah kulit kopi terhadap pertumbuhan beberapa varietas bibit kopi arabika (*Coffea arabica* L.). *Jurnal Ilmiah Mahasiswa Pertanian*, *4*(2), 141–150.
- Mustawa, M., Abdullah, S.H., Mahardhian, G., & Putra, D. (2017). Analisis efisiensi irigasi tetes pada berbagai tekstur tanah untuk tanaman sawi (*Brassica juncea*). *Jurnal Ilmiah Rekayasa Pertanian dan Biosistem*, *5*(2), 408–421
- Nasirudin, M., & Susanti, A. (2018). Hubungan kandungan kimia tanah terhadap keanekaragaman makrofauna tanah pada perkebunan apel semi organik dan anorganik. *Edubiotik : Jurnal Pendidikan, Biologi dan Terapan*, *3*(02), 5–11.
- Nurhartanto, N., Zulkarnain, Z., & Wicaksono, A.A. (2022). Analisis beberapa sifat fisik tanah sebagai indikator kerusakan tanah pada lahan kering. *Jurnal Agroteknologi Tropika Lembab*, *4*(2), 107–112. <http://dx.doi.org/10.35941/jatl.4.2.2022.7001.107-112>
- Nurrohman, E., Rahardjanto, A., & Wahyuni, S. (2015). Keanekaragaman makrofauna tanah di kawasan perkebunan coklat (*Theobroma cacao* L.) sebagai bioindikator kesuburan tanah dan sumber belajar biologi. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *1*(2), 2–12. <http://dx.doi.org/10.22219/jpbi.v1i2.3331>
- Nurrohman, E., Rahardjanto, A., & Wahyuni, S. (2018). Studi hubungan keanekaragaman makrofauna tanah dengan kandungan C-organik dan organofosfat tanah di perkebunan coklat (*Theobroma cacao* L.) Kalibaru Banyuwangi. *Bioeksperimen*, *4*(1), 1–10. <https://doi.org/10.23917/bioeksperimen.v4i1.5923>
- Pradiko, I., Farrasati, R., Rahutomo, S., Ginting, E.N., Candra, D.A.A., Krissetya, Y.A., & Mahendra, Y.S. (2020). Pengaruh iklim terhadap dinamika kelembapan tanah di piringan pohon tanaman kelapa sawit. *WARTA Pusat Penelitian Kelapa Sawit*, *25*(1), 39–51. <https://doi.org/10.22302/iopri.war.warta.v25i1.10>
- Rhengi, F.I.N., Ana Saga, A.J.P., & Supardi, P.N. (2022). Identifikasi diversitas makrofauna tanah di area tambang panas bumi Mutubusa Desa Sokoria Kecamatan Ndona Timur. *Agrica*, *15*(1), 63–77. <https://doi.org/10.37478/agr.v15i1.1967>
- Riana. (2020). Pengaruh mulsa organik dan kepadatan cacing tanah terhadap sifat fisik *Dystrudepts* pada pertanaman kelapa sawit (*Elaeis guineensis* Jacq.). *Jurnal Agroteknologi Tropika*, *9*(1), 1–10.
- Risman, & Ikhsan, A. (2017). Penggambaran makrofauna dan mesofauna tanah di bawah tegakan karet (*Hevea brazilliensis*) di lahan gambut. *Jurnal Agroteknologi Tropika*, *4*(2), 1-15.
- Robinson, S.I., McLaughlin, Ó.B., Marteinsdóttir, B., & O'Gorman, E.J. (2018). Soil temperature effects on the structure and diversity of plant and invertebrate communities. *Journal of Animal Ecology*, *87*(3), 634–646. <https://doi.org/10.1111/1365-2656.12798>
- Rushayati, S.B., Alikodra, H.S., Dahlan, E.N., & Purnomo, H. (2011). Pengembangan ruang terbuka hijau berdasarkan distribusi suhu permukaan di Kabupaten Bandung. *Forum Geografi*, *25*(1), 17. <https://doi.org/10.23917/forgeo.v25i1.5027>
- Saputra, A., & Agustina, P. (2019). Keanekaragaman makrofauna tanah di Universitas Sebelas Maret. *Prosiding SNPBS (Seminar Nasional Pendidikan Biologi dan Saintek)*. Department of Biologi Education, Universitas Muhammadiyah Surakarta: 323-327.
- Sari, A.N., Muliana, M., Yusra, Y., Khusrizal, K., & Akbar, H. (2022). Evaluasi status kesuburan tanah sawah tadah hujan dan irigasi di Kecamatan Nisam Kabupaten Aceh Utara. *Jurnal Ilmiah Mahasiswa Agroekoteknologi*, *1*(2), 49–57. <https://doi.org/10.29103/jimatek.v1i2.8467>
- Shannon, C., & Weaver, W. (1949). *The mathematical theory of communication*. University of Illinois Press.
- Sierra, C.A., Malghani, S., & Loescher, H.W. (2017). Interactions among temperature, moisture, and oxygen in determining decomposition rates at the soil core scale. *Biogeosciences*, *14*(3), 703–720. <https://doi.org/10.5194/bg-14-703-2017>
- Suin, N.M. (2005). *Ekologi hewan tanah*. Jakarta: Bumi Aksara.
- Supriyantini, E., Nuraini, R.A.T., & Fadmawati, A.P. (2017). Studi kandungan bahan organik pada beberapa muara sungai di kawasan ekosistem mangrove, di wilayah pesisir pantai utara Kota Semarang, Jawa Tengah. *Buletin Oseanografi Marina*, *6*(1), 29–38. <https://doi.org/10.14710/buloma.v6i1.15739>

- Utami, K., Hanudin, E., & Nurudin, N. (2020). The kinetics curve of nitrogen mineralization from perennial leaves litter decomposed by earthworm (*Phretima californica*). *Sains Tanah – Journal of Soil Science and Agroclimatology*, *17*(2), 152-160. <https://dx.doi.org/10.20961/stjssa.v17i2.46928>
- Warda, Ponisri, Farida, A., & Saeni, F. (2024). Komposisi vegetasi tingkat tiang dan pancang pada area hutan produksi KPHP Makbon Kabupaten Sorong. *Agriva Jurnal*, *2*(2), 1–7.
- Wibowo, A., Semedi, J.M., & Salleh, K.O. (2017). Spatial temporal analysis of urban heat hazard on education area (University of Indonesia). *The Indonesian Journal of Geography*, *49*(1), 1. <https://doi.org/10.22146/ijg.11821>
- Wibowo, C., & Slamet, S.A. (2017). Keanekaragaman makrofauna tanah pada berbagai tipe tegakan di areal bekas tambang silika di Holcim Educational Forest, Sukabumi, Jawa Barat. *Jurnal Silvikultur Tropika*, *8*(1), 26–34. <https://doi.org/10.29244/j-siltrop.8.1.26-34>
- Wibowo, C., & Alby, M.F. (2020). The diversity and frequency of soil macrofauna on three different trees at Educational Forest of Gunung Walat. *Jurnal Silvikultur Tropika*, *11*(1), 25–31.
- Winara, A. (2018). Keragaman makrofauna tanah pada agroforestri jati (*Tectona grandis*) dan jalawure (*Tacca leontopetaloides*). *Jurnal Agroforestri Indonesia*, *1*(1), 47–55.
- Winara, A. (2020). Keragaman makrofauna tanah pada agroforestri jati (*Tectona grandis*) dan kimpul (*Xanthosoma sangittifolium*). *Jurnal Agroforestri Indonesia*, *3*(1), 9–18