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Ecology of soil macrofauna on palm oil (*Elaeis Guineensis Jacq.*) and cocoa (*Theobroma Cacao L.*) plantations in Serbajadi District, Serdang Bedagai Regency

Agnes Monika Simamora, Binari Manurung*
Faculty of Mathematics and Natural Sciences, State University of Medan, Medan, Indonesia
Coressponding Author: Binari Manurung
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Abstract
Changes in land use and plantation management systems, such as oil palm monoculture and cocoa agroforestry, can affect soil macrofauna communities, which serve as bioindicators of soil quality. This study aimed to analyze the types, richness, diversity, dominance, and evenness of soil macrofauna communities, as well as differences between them, in oil palm and cocoa plantations in Serbajadi District, Serdang Bedagai Regency. This quantitative descriptive study was conducted from March to April 2026. Soil macrofauna samples were collected using the pitfall trap method at five points in the oil palm plantation and five points in the cocoa plantation. Sample identification was performed at the Biology Laboratory of Medan State University. Data were analyzed using the Margalef index for richness, Shannon-Wiener index for diversity, Simpson index for dominance, and Evenness index; a t-test was used to compare diversity and richness between the two plantations. Soil physicochemical factors (temperature, pH, and moisture content) were also measured. Nine types of soil macrofauna were found in the oil palm plantation, and eight types were found in the cocoa plantation. The total number of individuals was higher in the oil palm plantation (413) than in the cocoa plantation (235). Both plantation areas exhibited low richness and dominance, moderate diversity, and high evenness. The t-test revealed a significant difference between the soil macrofauna communities in the oil palm and cocoa plantations (calculated t-value 5.00 > t-table 2.58). Soil physicochemical conditions remained conducive to soil macrofauna life in both plantations.

Keywords: Cocoa, biodiversity, oil palm, soil macrofauna, pitfall trap

Introduction

The plantation sector in Indonesia, particularly oil palm (*Elaeis guineensis* Jacq.) and cocoa (*Theobroma cacao* L.), plays a strategic role in the national economy. However, the expansion and intensification of these two types of plantations pose challenges to environmental sustainability, particularly related to declining soil fertility and the loss of soil biodiversity (Dislich *et al*., 2017) [5]. Soil is a complex biological system in which living organisms, including soil macrofauna, interact and perform important ecological functions.

Soil macrofauna (organisms >2 mm) act as organic matter decomposers, ecosystem engineers, and bioindicators of soil quality because their structure reflects environmental conditions (Lavelle *et al*., 2020 Mamabolo *et al*., 2024) [9, 11]. Differences in cultivation systems, such as homogeneous, intensive oil palm monocultures and more diverse cocoa agroforestry, have direct implications for soil macrofauna diversity. Monoculture systems tend to reduce the number of taxa and density of macrofauna compared to systems with more complex vegetation (Susanti *et al*., 2021) [16].

Several previous studies have documented soil macrofauna communities in oil palm and cocoa plantations. In oil palm areas, research by Asrina *et al*. (2024) [1] in Konawe identified 18 species across 9 orders, revealing a moderate diversity index (H' = 1.8–2.1). A study by Susanti *et al*. (2021) [16] in Jambi also demonstrated that the conversion of forest cover to oil palm plantations impacts Collembola composition a factor closely linked to soil moisture, acidity levels, and organic matter supply. Meanwhile, a study on cocoa plantations by Dergong *et al*. (2025) [4] in East Manggarai reported diversity indices ranging from 1.76 to 2.20, identifying pH and organic carbon as influential variables. Similarly, Utami *et al*. (2025) [17] found a dominance of Formicidae (ants) within cocoa agroforestry systems in North Lombok, alongside moderate diversity levels. However, despite extensive separate research on both commodities, comparative studies directly contrasting oil palm and cocoa ecosystems in North Sumatra, specifically in Serbajadi remain scarce. Consequently, such research is essential to support sustainable plantation land management in the region.

Serbajadi District, Serdang Bedagai Regency, is a region with a fairly large oil palm and cocoa plantation area, but data on the ecology of soil macrofauna in this area is still limited. Although research on soil macrofauna in both plantation commodities has been widely conducted, direct comparative studies between oil palm and cocoa plantations in North Sumatra, particularly in Serbajadi District, are still limited and need to be conducted. Comparative studies comparing these two plantation systems are important to support sustainable land management strategies. This study aims to analyze the types, abundance, diversity, dominance, evenness, and differences in soil macrofauna communities in oil palm and cocoa plantations in Serbajadi District.

Materials and methods

This research used a quantitative descriptive method and was conducted from March to April 2026 in oil palm and cocoa plantations in Serbajadi District, Serdang Bedagai Regency, North Sumatra Province. Sample identification was conducted at the Biology Laboratory, Faculty of Mathematics and Natural Sciences, Medan State University. The study population comprised all soil macrofauna in both plantation areas. Samples consisted of soil macrofauna trapped in pitfall traps. Sampling was conducted using a purposive sampling technique, with five trap placement

points in each plantation area. Pitfall traps consisted of plastic cups buried parallel to the soil surface, filled with detergent solution, and fitted with protective roofs. Sampling was conducted six times with one-week intervals between each sampling. Traps were set for 24 hours.
Captured macrofauna were cleaned, preserved in 70% alcohol, and identified in the laboratory using a stereo microscope, the Suin (2012) [15] identification book, and supporting literature. Physicochemical soil parameters (soil temperature, pH, and water content) were measured at each trap setting using a thermometer and soil tester. The data obtained were analyzed using:

a. Abundance index

The abundance index used in this study is the Margalef index, which describes the number of species present in a community (Indrayani, 2022) [8]. The formula is written as follows :

$$Dmg = \frac{(S-1)}{\ln N}$$

Description
S = Number of species observed
N = Number of individuals of all species

The Abundance Index assessment criteria are
Dmg ≤ 2.5: Low abundance.
2.5 < Dmg < 4: Medium abundance.
Dmg ≥ 4: High abundance.

b. Diversity index

To calculate the diversity index value, the Shannon-Wiener formula can be used. To calculate diversity, the following formula can be used :

$$H' = -\sum_{r=t}^{s} pi\,(\ln pi)\;; pi = \frac{ni}{N}$$

Description
S = Number of species
ni = Number of individuals of one species
N = Number of individuals of all species
pi = Proportion of the number of individuals to the total number of individuals of all species

The diversity index criteria are divided into three categories:
1. Low, if the diversity index H' < 1.
2. Medium, if the diversity index 1 < H' < 3.
3. High, if the diversity index H' > 3

c. Dominance index

Dominance index calculation to determine the level of dominance in a community. Dominance can be calculated using the following formula :

$$D = \sum \left(\frac{ni}{N}\right)_2$$

Description
D = Dominance index
ni = Number of individuals of one species
N = Number of individuals of all species

The Dominance Index assessment criteria are
0 < D ≤ 0.4: Low dominance, no ecological pressure.
0.4 < D ≤ 0.6: Medium dominance, fairly stable environmental conditions.
0.6 < D ≤ 1: High dominance, ecological press

d. Evenness index

According to Habibi & Yudha (2022) [7], to find out evenness, it can be calculated using the following formula :

$$E = \frac{H'}{\ln S}$$

Description
H' = Shannon-Wiener Species Diversity Index
S = Number of Soil Macrofauna Species

The evenness index assessment criteria range from 0 to 1, where:
0 < E ≤ 0.4: The evenness of the soil macrofauna is low, and the community is stressed.
0.4 < E ≤ 0.6: The evenness of the soil macrofauna is moderate, and the community is unstable.
0.6 < E ≤ 1: The evenness of the soil macrofauna is high, and the community is stable.

e. Test of differences in diversity and abundance

According to Zar (1984) [18], the t-test is used to test whether the diversity and abundance between two communities differ significantly or not. The formula used is:

$$t_{hitung} = \frac{H'1 - H'2}{S_{H_1 - H_2}}$$

With

$$S_{H1-H2} = \sqrt{S^2H'1 + S^2H'2}$$

The varians of H' can be estimated using the following equation

$$S^2H' = \frac{\sum n_i(log^2 n_i) - (\sum n_i \log n_i)^2 / N}{N^2}$$

The degrees of freedom used to find the t table can be found using the following formula :

$$df = \frac{(S^2H'1 + S^2H'2)^2}{\frac{(S^2H'1)^2}{N_1} + \frac{(S^2H'2)^2}{N_2}}$$

Description
H'1= Soil macrofauna diversity index in oil palm plantations
H'2= Soil macrofauna diversity index in cocoa plantations
$SH1{-}H2$ = Variance of soil macrofauna diversity in oil palm plantations and cocoa plantations
S2H'1= Variance of soil macrofauna diversity in oil palm plantations
S2H'2= Variance of soil macrofauna diversity in cocoa plantations
$N1$= Total number of soil macrofauna individuals in oil palm plantations
$N2$= Total number of soil macrofauna individuals in cocoa plantations

df = Degrees of freedom

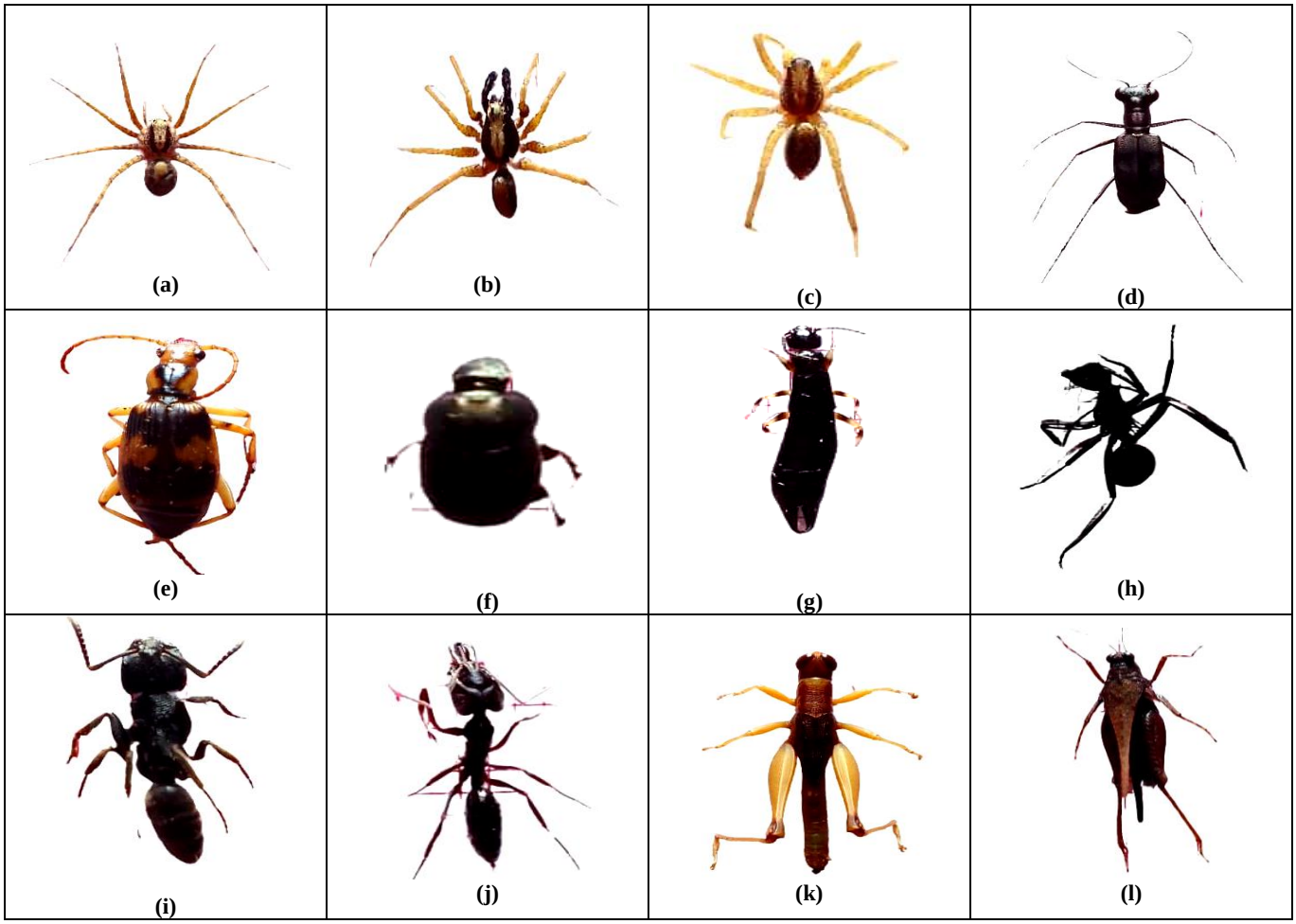
The classification criteria are:
If the calculated t < t table (α = 0.05), then there is no significant difference.
If the calculated t > t table (α = 0.05), then there is a significant difference.

Results
Types and amounts of soil macrofauna

The study in oil palm and cocoa plantations in Serbajadi District (March–April 2026) found 648 soil macrofauna individuals from 6 orders (Araneae, Coleoptera, Dermaptera, Hymenoptera, Orthoptera, Spirobolida), 10 families, and 14 species. Oil palm had more individuals (413) than cocoa (235). The most abundant species were *Pardosa laura* and *Odontoponera denticulata* (128 each), while *Criotettix bispinosus* (100 individuals) was found only in oil palm.

Table 1: Types and quantities of soil macrofauna found in *oil* palm and cocoa plantation areas

No	Order	Family	Species	Number of Individuals Trapped		Amount
				Palm oil	Cocoa	
1.	Araneae	Lycosidae	*Anoteropsis hilaris*	49	0	49
			Pardosa laura	48	80	128
			Pardosa pseudoannulata	0	85	85
2.	Coleoptera	Cicindelidae	*Cicindela punctulata*	0	9	9
		Carabidae	*Dromius quadrimaculatus*	7	0	7
		Scarabaeidae	*Onthophagus taurus*	5	0	5
3.	Dermaptera	Anisolabididae	*Euborellia annulipes*	0	7	7
4.	Hymenoptera	Formicidae	*Polyrhachis armata*	4	0	4
			Odontoponera denticulata	99	29	128
			Odontomachus monticola	69	0	69
5.	Orthoptera	Acrididae	*Caryanda spuria*	0	3	3
		Tetrigidae	*Criotettix bispinosus*	100	0	100
		Gryllidae	*Gryllodes sigillatus*	32	19	51
6.	Spirobolida	Trigoniulidae	*Trigoniulus corallinus*	0	3	3
Amount				413	235	648



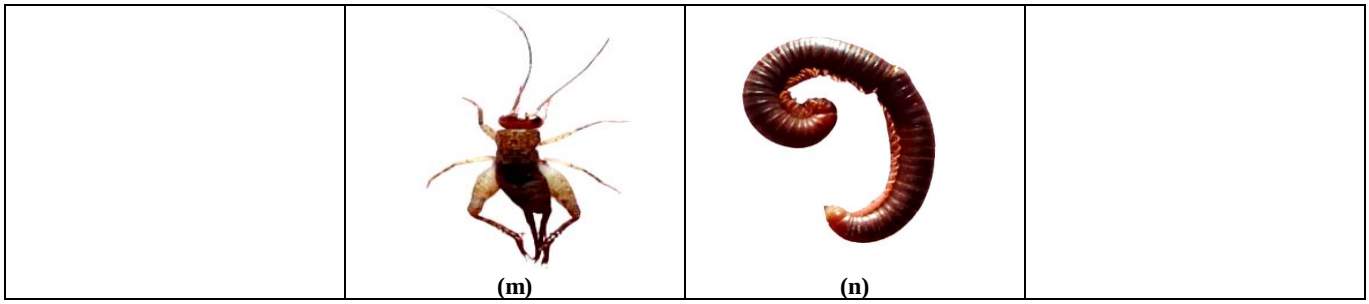


Fig 1: The diversity of types of macrofauna that are caught includes: (a) *Anoteropsis hilaris*, (b) *Pardosa laura*, (c) *Pardosa pseudoannulata*, (d) *Cicindela punctulata*, (e) *Dromius quadrimaculatus*, (f) *Onthophagus taurus*, (g) *Euborellia annulipes*, (h) *Polyrhachis armata*, (i) *Odontoponera denticulata*, (j) *Odontomachus monticola*, (k) *Caryanda spuria*, (l) *Criotettix bispinosus*, (m) *Gryllodes sigillatus* and (n) *Trigoniulus corallinus*

Soil macrofauna abundance and diversity index

The abundance index is used to determine the level of species richness in a community based on the number of species and the total number of individuals found. The soil macrofauna abundance index in oil palm (*Elaeis guineensis* Jacq.) and cocoa (*Theobroma cacao* L.) plantations in Serbajadi District, Serdang Bedagai Regency is presented in Table 2.

Table 2: Soil macrofauna abundance index found in oil palm and cocoa plantation areas

No.	Plantation Area	Abundance Index	Category
1.	Palm oil	1.32	Low
2.	Cocoa	1.28	Low

Based on Table 2, it can be seen that the soil macrofauna abundance index in the oil palm (*Elaeis guineensis* Jacq.) plantation area has a value of 1.32 and in the cocoa (*Theobroma cacao* L.) plantation area is 1.28. Based on the Margalef abundance index criteria, both plantation areas are included in the low category.

The diversity index is used to describe the level of species diversity based on the number of species and the number of individuals found at a location. The diversity index of soil macrofauna in oil palm (*Elaeis guineensis* Jacq.) and cocoa (*Theobroma cacao* L.) plantation areas in Serbajadi District, Serdang Bedagai Regency is presented in Table 3.

Table 3: Soil macrofauna diversity index found in oil palm and cocoa plantation areas

No.	Plantation Area	Diversity Index	Category
1.	Palm oil	1.85	Medium
2.	Cocoa	1.53	Medium

Based on Table 3, it is known that the soil macrofauna diversity index in the oil palm (*Elaeis guineensis* Jacq.) plantation area has a value of 1.85 and in the cocoa (*Theobroma cacao* L.) plantation area is 1.53. Based on the Shannon-Wiener diversity index criteria, both plantation areas are included in the medium category.

Soil macrofauna dominance and evenness index

The dominance index is used to determine whether or not certain species dominate a community in an ecosystem. The dominance index of soil macrofauna in the plantation area of Palm oil (*Elaeis guineensis* Jacq.) and Cocoa (*Theobroma cacao* L.) in Serbajadi District, Serdang Bedagai Regency is presented in Table 4.

Table 4: Soil macrofauna dominance index found in palm oil and cocoa plantation areas

No.	Plantation Area	Dominance Index	Kategory
1.	Palm oil	0.17	Low
2.	Cocoa	0.27	Low

Based on table 4, it is known that the soil macrofauna dominance index in the Palm oil (*Elaeis guineensis* Jacq.) plantation area has a value of 0.17 and in the Cocoa (*Theobroma cacao* L.) plantation area is 0.27. Based on the Simpson dominance index criteria, both plantation areas are included in the low dominance category, there is no ecological pressure.

The evenness index is used to determine the distribution level of individuals of each species in a soil macrofauna community. The evenness index value describes the balance in the number of individuals between species found at the research location. The evenness index of soil macrofauna in the Palm oil (*Elaeis guineensis* Jacq.) and Cocoa (*Theobroma cacao* L.) plantation areas in Serbajadi District, Serdang Bedagai Regency is presented in Table 5.

Table 5: Evenness index of soil macrofauna found in palm oil and cocoa plantation areas

No.	Plantation Area	Evenness Index	Kategori
1.	Palm oil	0,84	High
2.	Cocoa	0,73	High

Based on Table 5, it is known that the evenness index value of soil macrofauna in the Palm oil (*Elaeis guineensis* Jacq.) plantation area has a value of 0.84 and in the Cocoa (*Theobroma cacao* L.) plantation area is 0.73. These values indicate that both plantation areas have a relatively high level of evenness.

Differences in the diversity and abundance of soil macrofauna in palm oil and cocoa plantation areas

Based on the results of the t-test, there are significant differences in the diversity of soil macrofauna in the plantation areas of Palm oil (*Elaeis guineensis* Jacq.) and Cocoa (*Theobroma cacao* L.) in Serbajadi District, Serdang Bedagai Regency. The results of the t-test of soil macrofauna diversity in the plantation areas of Palm oil (*Elaeis guineensis* Jacq.) and Cocoa (*Theobroma cacao* L.) in Serbajadi District, Serdang Bedagai Regency are presented in Table 6.

Table 6: T-test of diversity and abundance of soil macrofauna found in palm oil plantation areas dan cocoa

Test Statistics	Score
H' Palm oil plantations	1.85
H' Cocoa plantations	1.53
T-value	5
Degrees of freedom (db)	380.31
Table t values (α)	2.58
Signification	Highly significant

Based on the data in Table 4.6, the diversity index (H') value of soil macrofauna in the oil palm plantation area is 1.85 and in the cocoa plantation area is 1.53. The t-test results indicate a highly significant difference between the two plantation areas, with the calculated t-value exceeding the t-table value (calculated t = 5 > t-table = 2.58).

Physico-chemical conditions of soil in oil palm and cocoa plantation areas

Soil physicochemical properties were measured to describe environmental conditions during the study. The recorded environmental conditions were the result of direct measurements at the study site. The parameters observed were soil temperature, soil water content, and pH. Measurements of soil physicochemical properties in oil palm (*Elaeis guineensis* Jacq.) and cocoa (*Theobroma cacao* L.) plantations in Serbajadi District, Serdang Bedagai Regency are presented in Table 7.

Tabel 7: Results of soil physico-chemical measurements in oil palm and cocoa plantation areas

No	Parameter	n	Palm Oil		Cocoa	
			R	$\bar{x}$ ± SD	R	$\bar{x}$ ± SD
1.	Soil temperature (°C)	6	26.0 –30.0	28.3 ± 1.5	27.0 –30.0	28.6 ± 1.1
2.	Soil water content (%)	6	20.0 –34.0	25.1 ± 5.1	14.0 –39.0	23.0 ± 9.3
3.	pH	6	8.4 – 9.1	8.7 ± 0.3	7.9 – 9.1	8.4 ± 0.5

The results of soil physicochemical properties measurements at both plantation locations are presented in Table 7. The soil physicochemical conditions at both plantation areas showed relatively similar characteristics. In the oil palm plantation, soil temperature ranged from 26.0–30.0°C (28.3±1.5°C), water content 20.0–34.0% (25.1±5.1%), and pH 8.4–9.1 (8.7±0.3). Meanwhile, in the cocoa plantation, soil temperature was recorded at 27.0–30.0°C (28.6±1.1°C), water content 14.0–39.0% (23.0±9.3%), and pH 7.9–9.1 (8.4±0.5). Both locations had a relatively alkaline soil pH with higher variations in water content in the cocoa area. These environmental conditions still support the existence of soil macrofauna, as found in various macrofauna groups from the Arthropoda phylum in both plantation areas, although the composition differs between locations.

Discussion

Types and amounts of soil macrofauna

The number of soils macrofauna individuals found in oil palm plantations (413 individuals) was higher than in cocoa plantations (235 individuals). This difference is thought to be related to the characteristics of the litter produced by each plant. The homogenous and slowly decomposing oil palm litter creates stable microhabitat conditions, allowing for population explosions in certain species, such as Criotettix bispinosus, which was only found in oil palm plantations with 100 individuals. Conversely, cocoa agroforestry systems with higher vegetation diversity actually produced a lower total number of individuals, thought to be due to more complex competition between ecological functions and more variable soil water conditions (Awazi *et al*., 2025) [2]. Thus, vegetation complexity does not always correlate positively with individual abundance, but rather influences a more even distribution of species across species.

Soil macrofauna abundance and diversity index

The Margalef abundance index values at both locations were low (oil palm: 1.32; cocoa: 1.28), indicating that the number of species found was relatively small compared to the total number of individuals. This low abundance is thought to be due to intensified land management, which simplifies habitat structure and limits the availability of ecological niches for soil macrofauna (Phillips *et al*., 2021) [13]. However, the Shannon-Wiener diversity index was moderate at both locations (oil palm: 1.85; cocoa: 1.53), indicating that the soil macrofauna community is still composed of several species that are able to adapt to local environmental conditions. The higher diversity in oil palm plantations, despite being managed as monocultures, indicates that the habitat conditions, particularly stable water content (SD = 5.1) and relatively uniform temperature, are more supportive of the presence of a variety of macrofauna species compared to cocoa plantations, which have higher water content variation (SD = 9.3). The diversity of organic matter quality and differences in microhabitats at each location also contribute to the differences in diversity values (Njoroge *et al*., 2023) [12].

Soil macrofauna dominance and evenness index

Simpson's dominance index values at both locations were low (oil palm: 0.17; cocoa: 0.27), indicating that no species dominated the community excessively. This reflects a relatively balanced distribution of individuals between species, resulting in stable competition for resources and no significant ecological pressure (Lisner *et al*., 2024) [10]. The evenness index for oil palm (0.84) and cocoa (0.73) was high, confirming that individuals were evenly distributed across each species and indicating a stable community with balanced resource utilization (Srednick & Swearer, 2024) [14]. However, the higher evenness value for oil palm indicates a more balanced distribution of individuals between species at the location than for cocoa, which is consistent with its higher diversity value.

Differences in the diversity and abundance of soil macrofauna in oil palm and cocoa plantation areas

The t-test results showed a significant difference between the diversity of soil macrofauna in oil palm and cocoa plantations (t-count = 5 > t-table = 2.58; $p < 0.01$). This

difference indicates that the unique habitat characteristics of each plantation system—particularly vegetation composition, canopy structure, and litter and organic matter management—have a significant impact on the structure of soil macrofauna communities. In oil palm plantations, monoculture systems with relatively homogeneous litter from a single plant species were still able to support higher diversity (H' = 1.85) compared to cocoa (H' = 1.53). This is thought to be because the slowly decomposing oil palm litter provides a stable microhabitat for soil macrofauna (Susanti *et al*., 2021) [16]. Conversely, in cocoa plantations with agroforestry systems, despite greater vegetation diversity, highly variable soil water content (SD = 9.3) and a slightly lower pH (8.4) are thought to be limiting factors for some macrofauna groups. This finding is in line with Eisenhauer *et al*. (2019) [6] who stated that soil fauna diversity is not only determined by vegetation complexity, but also by the stability of microenvironmental conditions at the soil level.

Physico-chemical conditions of soil in oil palm and cocoa plantation areas

Abiotic soil factors, including temperature, water content, and pH, play a significant role in determining the structure and composition of soil macrofauna communities (Burton *et al*., 2022) [3]. Measurement results showed that soil temperature at both locations was within the optimal range for macrofauna activity (26–30°C). However, soil water content showed higher variations in cocoa plantations (14–39%; average 23.0 ± 9.3%) compared to oil palm plantations (20–34%; average 25.1 ± 5.1%). The high variation in water content in cocoa is suspected to be a limiting factor causing lower macrofauna diversity, considering that soil water content directly affects the mobility, respiration, and reproduction of soil organisms (Xie *et al*., 2022). Meanwhile, soil pH at both locations was classified as alkaline (oil palm: 8.7 ± 0.3; cocoa: 8.4 ± 0.5), which is strongly suspected to originate from the liming practices of farmers. These alkaline conditions can alter litter quality and slow decomposition rates, thus impacting the availability of food sources for soil macrofauna (Zhang *et al*., 2023) [19]. Overall, variations in water content and alkaline pH conditions at both locations are suspected to be limiting factors that contribute to differences in soil macrofauna diversity and composition, in line with the findings of Burton *et al*. (2022) [3] and Xie *et al*. (2022) that abiotic soil factors play a dominant role in shaping soil fauna communities at the local scale.

Overall, the results of this study indicate that the soil macrofauna communities in both plantation areas have a moderate level of diversity with low dominance and high evenness, reflecting a relatively stable community condition. Significant differences between the two locations, particularly in the number of individuals and diversity indices, are more influenced by abiotic soil factors particularly water content and pH and the characteristics of each plant's litter, rather than the complexity of the aboveground vegetation. These findings underscore the importance of sustainable management of organic matter and litter to maintain the stability of soil macrofauna habitats, given that this group of organisms plays a crucial role as bioindicators of soil quality and supports the function of plantation ecosystems.

Conclusion

This study identified 14 species of soil macrofauna from 6 orders with a total of 648 individuals in oil palm and cocoa plantations in Serbajadi District. The soil macrofauna communities at both locations showed low abundance, moderate diversity, low dominance, and high evenness, reflecting relatively stable community conditions despite significant differences between the two areas ($p < 0.01$). Abiotic soil factors, particularly variations in water content and alkaline pH, are suspected to be the main limiting factors influencing differences in macrofauna diversity between locations, in addition to litter characteristics and land management systems. Therefore, litter and organic matter management needs to be maintained sustainably to support the role of soil macrofauna as bioindicators of soil fertility and as a basis for consideration in environmentally friendly plantation management.

References

1. Asrina A, Ahmad S W, Jamilil, Mukhsar, Rudia L O A P. Keanekaragaman makrofauna tanah pada areal perkebunan Kelapa Sawit di Kecamatan Besulutu, Kabupaten Konawe, Sulawesi Tenggara. BioWallacea: Jurnal Penelitian Biologi,2024:11(1):136-146.
2. Awazi N P, Tsufac A R, Ambebe T F. The tree species diversity–Soil macrofauna nexus in cocoa based agroforests in Cameroon: A biophysical as sessment. Soil Advances,2025:3:100042.
3. Burton V J, Contu S, De Palma A, Hill S L L, Albrecht H, Bone J S, *et al*. Land use and soil characteristics affect soil organisms differently from above-ground assemblages. BMC Ecology and Evolution,2022:22(135):1-14.
4. Dergong S D, Kesumadewi A A, Kartini N L. Soil macrofauna as bioindicators of soil fertility in cocoa plantations (*Theobroma cacao* L.) at different elevations in Kota Komba Subdistrict, East Manggarai Regency. International Journal of Multidisciplinary Research and Analysis,2025:8(8):4468-4476.
5. Dislich C, Keyel A C, Salecker J, Kisel Y, Meyer K M, Auliya M, *et al*. A review of the ecosystem functions in oil palm plantations, using forests as a reference system. Biological Reviews,2017:92(3):1539-1569.
6. Eisenhauer N, Bonn A, Guerra CA. Recognizing the quiet extinction of invertebrates. Nature Communications,2019:10(1):50.
7. Habibi I, Yudha GN. Pengaruh tanaman refugia terhadap serangga aerial dan hasil panen pada tiga varietas tanaman jagung (Zea mays L.). G Tec h: Jurnal Teknologi Terapan,2022:6(2):100-109.
8. Indrayani Y. Keanekaragaman Jenis Kupu-Kupu di Kawasan Taman Kehati Kabupaten Sekadau. Jurnal Hutan Lestari,2022:10(4):982-991.
9. Lavelle P, Rodríguez N, Arguello O, Bernal J, Botero C, Chaparro P, *et al*. Soil biodiversity and ecosystem functions in tropical systems: A review. Soil Biology and Biochemistry,2020:149:107873.
10. Lisner A, Segrestin J, Konečná M, Lepš J. Why are plant communities stable? Disentangling the role of dominance, asynchrony and averaging effect following realistic species loss scenario. Journal of Ecology,2024:112(8):1832-1841.
11. Mamabolo E, Pryke J S, Gaigher R. Soil macrofauna are important bioindicators of soil

quality in agroecosystems under different management. Ecological Indicators,2024:167:112723.
12. Njoroge DM, Dossa GG, Ye L, Lin X, Schaefer D, Tomlinson K, *et al*. Access to fauna more influential than litter mixing effects during leaf litter decomposition. Science of the Total Environment,2023:860:160190.
13. Phillips HR, Bach EM, Bartz ML, Bennett JM, Beugnon R, Briones MJ, *et al*. Global data on earthworm abundance, biomass, diversity and corresponding environmental properties. Scientific Data,2021:8(1):136.
14. Srednick G, Swearer SE. Understanding diversity synch rony stability relationships in multitrophic communities . Nature Ecology & Evolution,2024:8:1259-1269.
15. Suin N M. Ekologi Hewan Tanah. Jakarta: Bumi Aksara, 2012.
16. Susanti N, Hairiah K, Purnomosidhi P. Pengaruh sistem penggunaan lahan terhadap keanekaragaman fauna tan ah di lahan perkebunan tropis. Jurnal Tanah dan Iklim,2 021:45(2):103-114.
17. Utami A A, Susilowati L E, Jaya D K, Azizah I R. Mak rofauna permukaan tanah di bawah satuan pohon campuran alpukat, kakao, dan kopi di Desa Senaru Lombok Utara. Jurnal Sains Teknologi & Lingkungan,2025:11(1):198-207.
18. Zar J. H. Biostatistical analysis. 2nd ed. Prentice-Hall, Inc., 1984.
19. Zhang L, Liu J, Yin R, Xu Z, You C, Li H, *et al*. Soil fauna accelerated litter C and N release by improving litter quality across an elevational gradien t. Ecological Processes,2023:12(47):1-12.