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Research Article

Composition and Structure of Soil Macrofauna Communities in Three Land Use Types in Koto Perambahan Village, Kampar Regency, Riau

Komposisi dan Struktur Komunitas Makrofauna Tanah pada Tiga Tipe Penggunaan Lahan di Desa Koto Perambahan, Kabupaten Kampar, Riau

Hidayatul Annisa[1]*, Andi Saputra[1], Syamsul Bachry. H[2], Delfi Trisnawati[3], Vebrita Sari[4]

[1] Department of Biology, Faculty of Life Sciences, Pahlawan Tuanku Tambusai University, Kampar, 28412, Riau, Indonesia

[2]Department of Biology, Faculty of Life Sciences, Pahlawan Tuanku Tambusai University, Kampar, 28412, Riau, Indonesia

[3]Department of Biology, Faculty of Life Sciences, Pahlawan Tuanku Tambusai University, Kampar, 28412, Riau, Indonesia

[4]Department of Biology, Faculty of Life Sciences, Pahlawan Tuanku Tambusai University, Kampar, 28412, Riau, Indonesia

[5]Department of Biology, Faculty of Life Sciences, Pahlawan Tuanku Tambusai University, Kampar, 28412, Riau, Indonesia

*email:
hidayatulannisa94@gmail.com

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Abstract: Microfauna play an important role as primary bioindicators of soil health, responding rapidly to changes in land use. This study aimed to analyze the community structure of macrofauna at secondary forest, riparian area, and oil palm plantation, in Koto Prambahan Village, Kampar. Field sampling was conducted in may 2026 using the hand sorting method within quadrat plots. A total of 13 genera representing 12 families were recorded. The secondary forest exhibited the highest density and diversity, with a Shannon Wiener diversity index of 2.41, followed by the riparian area (2.28) and the oil palm plantation (2.07). The evenness index suggested a relatively balanced distribution of individuals among genera across all habitats, whereas the highest dominance was recorded in the oil palm plantation. Overall, the findings demonstrate that natural and semi-natural habitats maintain a richer and more stable soil macrofauna community than intensively managed plantations. Preserving forest and riparian ecosystems is therefore essential for sustaining soil biodiversity and ecological processes within tropical landscapes.

Keywords: Agroforestry, Biodiversity, Bioindicators, Macrofauna, Organic Matter, Riparian

Abstrak: Makrofauna tanah berperan penting dalam menjaga kesuburan tanah dan mendukung berbagai fungsi ekosistem, namun struktur komunitasnya sangat dipengaruhi oleh perubahan penggunaan lahan. Penelitian ini bertujuan untuk menganalisis struktur komunitas makrofauna tanah pada tiga tipe penggunaan lahan, yaitu hutan, kawasan riparian, dan perkebunan kelapa sawit di Desa Koto Prambahan, Kabupaten Kampar, Provinsi Riau. Penelitian dilaksanakan pada bulan Februari hingga Juli 2023 menggunakan metode *hand sorting* pada plot kuadrat. Struktur komunitas dianalisis berdasarkan komposisi genus, kelimpahan, kepadatan, keanekaragaman, kemerataan, dan dominansi, serta didukung oleh pengukuran beberapa faktor lingkungan. Hasil penelitian menunjukkan bahwa ditemukan 13 genus yang termasuk ke dalam 12 famili dengan total 144 individu, yang terdiri atas 58 individu pada habitat hutan, 47 individu pada habitat riparian, dan 39 individu pada habitat kebun kelapa sawit. Habitat hutan memiliki kepadatan dan keanekaragaman tertinggi dengan nilai indeks keanekaragaman Shannon Wiener (H' = 2,41), diikuti habitat riparian (H' = 2,28) dan habitat kebun kelapa sawit (H' = 2,07). Nilai kemerataan menunjukkan penyebaran individu antar genus yang relatif merata pada ketiga habitat, sedangkan nilai dominansi tertinggi ditemukan pada habitat kebun kelapa sawit. Hasil penelitian menunjukkan bahwa habitat hutan menyediakan kondisi lingkungan yang lebih mendukung bagi keberlangsungan komunitas makrofauna tanah dibandingkan habitat riparian dan perkebunan kelapa sawit. Oleh karena itu, pelestarian habitat hutan dan kawasan riparian perlu diprioritaskan sebagai upaya mempertahankan keanekaragaman hayati tanah dan fungsi ekologis ekosistem daratan tropis.

Kata Kunci : Agroforestri, Biodiversitas, Bioindikator, Makrofauna, Materi Organik, Riparian

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INTRODUCTION

Soil is a vital component of terrestrial ecosystems that plays a role in supporting various ecological processes, such as the decomposition of organic matter, the nutrient cycle, and soil structure formation. Soil macrofauna play a crucial role in decomposing litter and forming soil aggregates, thereby enhancing soil fertility and sustaining ecosystem functions (Lavelle, 1997; Jouquet et al., 2014; Naemah et al., 2025). Furthermore, soil macrofauna are highly sensitive to environmental changes, making them widely used as bioindicators of soil quality (De Bruyn, 1997; Lavelle et al., 2006).

Land use change is one of the factors influencing the structure of soil macrofauna communities. The conversion of forests into agricultural land or plantations leads to changes in vegetation cover, organic matter content, soil temperature, and moisture, which in turn affect the composition, abundance, and diversity of soil macrofauna (Lavelle & Spain, 2001; Brussaard et al., 2007; Tsiafouli et al., 2015). Natural habitats generally have more diverse macrofauna communities than intensively managed lands. Increasing land-use change poses a significant threat to soil biodiversity and ecosystem functioning in tropical ecosystems. Soil organisms are essential for sustaining nutrient cycling, promoting soil aggregation, and enhancing ecosystem resilience to environmental change

In Riau Province, land use changes are occurring quite rapidly due to the expansion of the plantation sector, particularly oil palm plantations. These changes have the potential to affect the diversity of soil organisms, including macrofauna. Information on soil fauna communities in tropical ecosystems of Indonesia, particularly in landscapes consisting of natural forests, riparian areas, and oil palm plantations, is still limited. Differences in habitat characteristics among these ecosystems may influence soil fauna diversity and abundance, highlighting the need for comparative studies to better understand the ecological impacts of land-use change. Such information is important for supporting biodiversity conservation and sustainable land management.

MATERIALS AND METHODS

2.1 Study Area

The research was conducted in May 2026 in Koto Prambahan Village, Kampar Subdistrict, Kampar Regency, Riau Province. The study area encompassed three land-use types: forest, the Kampar River riparian zone, and oil palm plantations. These three habitats were selected through purposive sampling because they represent distinct land-use conditions and exhibit varying characteristics in terms of vegetation, soil conditions, and levels of anthropogenic disturbance.
The forest habitat is characterized by natural vegetation cover with a relatively low level of disturbance, while the riparian zone is a transitional area along the banks of the Kampar River that has relatively high soil moisture due to the influence of river flow. The oil palm plantation habitat is dominated by *Elaeis guineensis* Jacq. and is intensively managed, resulting in environmental conditions that differ from those of natural habitats.

2.2 Sampling

Sampling was conducted using the hand-sorting method on three 1 × 1 m plots in each habitat. Soil macrofauna were collected from the litter and soil layers to a depth of approximately 20 cm and then identified based on morphological characteristics to the highest possible taxonomic level. Soil temperature, soil pH, soil moisture, and light intensity were measured as environmental parameters.

2.3 Data Analysis

The observational data were analyzed descriptively and quantitatively. Soil macrofauna abundance was calculated based on the number of individuals found at each research station. The structure of the soil macrofauna community was analyzed using the Shannon–Wiener diversity index (H'), the Pielou evenness index (E), and the Simpson dominance index (C). The diversity index values were calculated using the following equation:

$$H' = -\Sigma (Pi \ln Pi)$$

The Shannon–Wiener diversity index (H′) was classified into three categories: low diversity (H′ < 1), moderate diversity (1 ≤ H′ ≤ 3), and high diversity (H′ > 3).

The evenness index (E) was calculated using the following equation:

$$E = H'/\ln S$$

The evenness values were interpreted as follows: low evenness (E < 0.50), moderate evenness (0.50 ≤ E ≤ 0.75), and high evenness (E > 0.75), where H' is the Shannon–Wiener diversity index and S is the total number of species recorded.

The Simpson dominance index (C) was calculated using the following equation:

$$C = \Sigma Pi^2$$

A dominance index value approaching 1 indicates that one or a few species dominate the community.

RESULTS AND DISCUSSION

3.1 Environmental Conditions

Environmental variables were measured across the three habitat types, namely secondary forest, riparian zone, and oil palm plantation. The parameters assessed included soil temperature,

soil moisture, soil pH, and light intensity. Overall, the measured environmental conditions showed relatively small differences among habitats because all sampling sites were located within the same geographical region and experienced similar climatic conditions. Nevertheless, variations in the recorded values reflected differences in vegetation structure and canopy openness among habitat types (Tabel 1)

Tabel 1. Environmental conditions recorded in the forest, riparian and oil palm plantation habitats

Parameter	Forest	Riparian	Oil Palm Plantation
Soil temperature (˚C)	26.1	27.4	28.3
Soil moisture (%)	72.5	70.8	64.9
Soil pH	6.3	6.5	5.9
Light intensity (lux)	3,250	6,850	8,420

The forest habitat exhibited the lowest soil temperature (26.1 ˚C) and the highest soil moisture (72.5%). These conditions are likely associated with the dense forest canopy, which limits direct solar radiation reaching the soil surface and enhances moisture retention. The soil pH in the forest was 6.3, indicating slightly acidic conditions approaching neutrality. In addition, the forest received the lowest light intensity (3,250 lux), reflecting the high canopy cover that effectively reduced solar radiation penetrating the forest floor. Similar observations have been reported by Wong et al. (2016), who demonstrated that dense forest canopies moderate microclimatic conditions by lowering soil temperature and maintaining higher soil moisture.

The riparian habitat showed intermediate environmental conditions, with a soil temperature of 27.4 ˚C and soil moisture of 70.8%. These values indicate a slightly warmer microclimate than the forest habitat, which may be attributed to the relatively lower canopy density in certain sections of the riparian zone. According to Williamson et al. (2021), vegetation structure and canopy cover are key determinants of riparian microclimate, where denser vegetation generally contributes to lower temperatures and higher humidity. Despite the more open vegetation, the presence of the adjacent stream likely contributed to maintaining relatively high soil moisture within this habitat.

The oil palm plantation recorded the highest soil temperature (28.3 ˚C) and the lowest soil moisture (64.9%). These conditions are probably related to the more open canopy resulting from wider planting distances, allowing greater solar radiation to reach the soil surface. The plantation also exhibited the most acidic soil (pH 5.9) and the highest light intensity (8,420 lux). Reduced canopy cover in oil palm plantations increases solar exposure, leading to higher soil temperatures and lower moisture content compared with tropical forest ecosystems, as reported by Hardwick et al. (2015).

The measured environmental conditions across all habitats remained within ranges that can support soil macrofauna communities. However, variations in soil temperature, moisture, pH, and light availability among habitats are likely to influence differences in the composition and community structure of soil macrofauna. Soil macrofauna generally thrive under moderate temperatures ranging from 15 to 45 ˚C (Asrina et al., 2024), near-neutral soil pH (Suin, 2012), and environments with adequate soil moisture (Sugiyarto et al., 2007). These environmental factors play an important role in determining habitat suitability and regulating the distribution and abundance of soil macrofauna across different land-use types.

3.2 Composition of Soil Macrofauna

A total of 13 genera of soil macrofauna belonging to 12 families were identified, namely Megascolecidae (Pheretima sp.), Formicidae (Diacamma sp. and Polyrhachis sp.), Termitidae (Macrotermes sp.), Gryllidae (Teleogryllus sp.), Acrididae (Atractomorpha sp.), Tetrigidae (Eucriotettix sp.), Carabidae (Chlaenius sp.), Scarabaeidae (Onthophagus sp.), Paradoxosomatidae (Orthomorpha sp.), Scolopendridae (Scolopendra sp.), Lycosidae (Pardosa sp.), and Achatinidae (Achatina sp.) were found at the study site (Table 2).

Tabel 2. Composition of Soil Macrofauna in Three Land Use Types

Family	Genus	Forest	Riparian	Oil Palm Plantation	Total
Megascolecidae	*Pheretima* sp.	6	5	3	14
Formicidae	*Diacamma* sp.	8	6	4	18
Formicidae	*Polyrhachis* sp.	7	6	9	22
Termitidae	*Macrotermes* sp.	6	5	4	15
Gryllidae	*Teleogryllus* sp.	5	4	3	12
Acrididae	*Atractomorpha* sp.	2	3	5	10
Tetrigidae	*Eucriotettix* sp.	3	2	2	7
Carabidae	*Chlaenius* sp.	4	3	2	9
Scarabaeidae	*Onthophagus* sp.	3	3	2	8
Paradoxosomatidae	*Orthomorpha* sp.	4	3	1	8
Scolopendridae	*Scolopendra* sp.	3	2	1	6
Lycosidae	*Pardosa* sp.	4	3	2	9
Achatinidae	*Achatina* sp.	3	2	1	6
Total individu		58	47	39	144

Differences in the composition of soil macrofauna across the three land-use types indicate that habitat characteristics play a significant role in determining the presence and distribution of soil organisms. Forest habitats have more diverse communities compared to riparian and oil palm plantation habitats, indicating that environmental conditions in forested areas are still capable of providing more suitable habitats for various groups of soil macrofauna. These conditions are

associated with denser canopy cover, higher litter accumulation, and a relatively stable microclimate, all of which support the activity of soil organisms. These findings align with those of Wibowo and Slamet (2017), who stated that soil macrofauna serve as sensitive bioindicators of changes in habitat quality. Wong et al. (2016) also reported that increased organic matter content and soil moisture can enhance the abundance and diversity of soil macrofauna by providing better food sources and habitats.

The Formicidae family was found across all land-use types with relatively high numbers of individuals. The dominance of this group indicates ants' ability to adapt to varying environmental conditions and their flexibility in utilizing various food sources and microhabitats. Ants are recognized as one of the most adaptable groups of soil fauna due to their high tolerance to environmental and habitat changes, which allows them to inhabit a variety of ecosystem types (Del Toro et al., 2012).

3.3 Soil Macrofauna Density

Soil macrofauna density varied among the three habitat types (Figure 1). The forest habitat supported the highest density (19.33 individuals m^{-2}), followed by the riparian habitat (15.67 individuals m^{-2}), while the oil palm plantation showed the lowest density (13.00 individuals m^{-2}). The observed variation suggests that differences in habitat conditions influence the capacity of each ecosystem to support soil macrofauna populations.

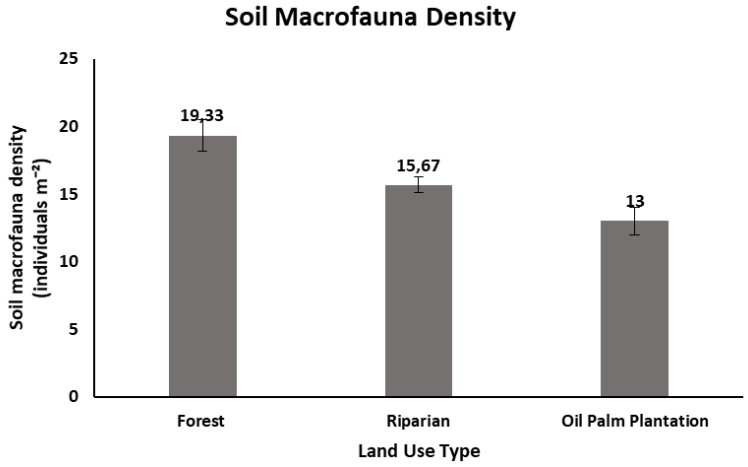


Figure 1. Soil Macrofauna Density in Three Land Use Types

Differences in the abundance and density of soil macrofauna among the investigated habitats indicate that land-use type plays an important role in determining the capacity of ecosystems to support soil-dwelling organisms. The forest habitat provided more favorable environmental conditions, including greater organic matter availability, higher soil moisture, and a more stable thermal regime, which collectively promoted higher macrofauna populations than those observed in the riparian area and oil palm plantation. These findings are in agreement with

Bedano et al. (2016), who reported that natural forest ecosystems generally sustain higher soil macrofauna abundance than intensively managed agricultural lands. Likewise, Suleiman et al. (2024) emphasized that vegetation complexity and habitat characteristics are key drivers shaping the distribution and composition of soil fauna communities.

In contrast, the oil palm plantation presented less suitable conditions for soil macrofauna. Reduced canopy cover increased soil temperature, lowered soil moisture, and limited litter accumulation, thereby decreasing habitat quality for decomposer organisms. Similar observations were reported by Lavelle et al. (2022), who identified land-cover change and management practices as major determinants of soil macrofauna community structure and abundance. Overall, the present study demonstrates that soil macrofauna abundance can serve as a practical ecological indicator for assessing habitat quality and evaluating the effects of different land-use types on soil biodiversity.

3.4 Diversity, Evenness, and Dominance of Soil Macrofauna Communities

Differences in habitat conditions were reflected in the structure of soil macrofauna communities. As presented in Table 3, the diversity (H'), evenness (E), and dominance (C) indices varied among the forest, riparian, and oil palm plantation habitats. The forest habitat recorded the highest diversity and evenness values, indicating a more stable community with a relatively balanced distribution of individuals among taxa. In contrast, the oil palm plantation exhibited the highest dominance index, suggesting that the community was dominated by only a few taxa. These findings indicate that land-use type influences the composition and distribution of soil macrofauna. Because soil macrofauna respond sensitively to changes in environmental conditions, their community structure can serve as a reliable bioindicator of soil quality and ecosystem health (Susanto & Rahayu, 2022).

Tabel 3. Diversity (H'), Evenness (E), and Dominance (C) Indices of Soil Macrofauna Communities in Different Habitats

Habitat	Indeks Keanekaragaman (H')	Indeks Kemerataan (E)	Indeks Dominansi (C)
Forest	2,41	0,94	0,12
Riparian	2,28	0,89	0,15
Oil Palm Plantation	2,07	0,81	0,19

The highest diversity index (H') value was found in forest habitats at 2.41, followed by riparian habitats at 2.28, and oil palm plantations at 2.07. These differences indicate that forest habitats support a more diverse population of soil macrofauna compared to other habitats. These conditions are believed to be influenced by higher soil moisture, lower temperatures, and greater availability of litter, which provide better food sources and habitats for various groups of soil

macrofauna. In contrast, oil palm plantation habitats have more open environmental conditions and undergo soil management practices, resulting in fewer individuals of certain genera and lower diversity. Changes in soil conditions resulting from agricultural activities—such as fertilizer use, pesticide application, and soil tillage—are known to affect the distribution and presence of soil macrofauna by altering the soil's physical, chemical, and biological properties (Sharpley et al., 2011; Pelosi et al., 2014; Crittenden et al., 2014).

The evenness index (E) values for the three habitats ranged from 0.81 to 0.94, indicating that the distribution of individuals across genera was relatively even. The forest habitat had the highest evenness value (0.94), followed by the riparian habitat (0.89) and the oil palm plantation (0.81). The high evenness values indicate that there were no significant differences in the number of individuals among genera, so the soil macrofauna community in this habitat is relatively stable In contrast to the diversity index, the dominance index (C) was lowest in the forest habitat (0.12) and highest in the oil palm plantation (0.19). Nevertheless, dominance values remained low across all habitats, indicating that no genus completely dominated the community. Instead, the soil macrofauna communities consisted of several genera with relatively balanced abundances. Ants and earthworms were consistently found in all habitat types. Earthworms are recognized as ecosystem engineers because they facilitate organic matter decomposition, improve nutrient cycling, and enhance soil structure. Their abundance is generally higher in habitats characterized by high soil moisture and abundant litter (Lavelle et al., 2006).

The forest habitat exhibited a more favorable soil macrofauna community structure than the riparian and oil palm plantation habitats. This was reflected by its higher diversity and evenness indices, together with a lower dominance index. In contrast, the oil palm plantation supported a simpler community structure, which is likely associated with more open environmental conditions, reduced litter input, and lower organic matter availability compared with the forest and riparian habitats.

CONCLUSIONS

This study demonstrated that land-use type significantly influences the community structure of soil macrofauna. The secondary forest supported the highest abundance, density, and diversity of soil macrofauna, whereas the oil palm plantation exhibited lower diversity and higher dominance. Differences in canopy cover and soil environmental conditions, particularly soil moisture, temperature, pH, and light intensity, likely contributed to these variations. These findings highlight the ecological importance of maintaining forest and riparian habitats to sustain soil biodiversity and ecosystem functioning. The present study was limited to three habitat types within a single study area and a limited number of environmental variables. Future studies should include seasonal sampling, a broader range of soil physicochemical properties, and

additional land-use types to improve understanding of the mechanisms governing soil macrofauna community dynamics.

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