Research Article

Soil-Dwelling Artropods Diversity Across Three Different Types of Land Use in Bogor, Jawa Barat

Keanekaragaman Arthropoda Permukaan Tanah di Tiga Jenis Tata Guna Lahan yang Berbeda di Bogor, Jawa Barat

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Received: April, 2026
Accepted: June, 2026
Published: July, 2026

p-ISSN: 2723-7974
e-ISSN: 2723-7966
doi: 10.52045/jca.v6i2.1361

Website: https://ojs.untika.ac.id/index.php/faperta

Abstract: Studies of soil-dwelling arthropods can reveal how ecosystems respond to various land management methods. This study aims to compare the diversity of soil-dwelling arthropods and their community composition across three land-use types in Bogor: planted forests, semi-intensive oil palm plantations, and intensive corn fields. The study was conducted from February to August 2016. Pitfall traps were used for sampling. Ground-dwelling arthropods were observed nine times across the three different agricultural ecosystems. Each has distinct abiotic conditions, where the corn field has the highest light intensity and temperature. A total of 90 plots and 450 pitfall traps across all land use types, 12377 arthropods were collected from 12 orders and 25 families, with Collembola as the dominant order. Formicidae dominated in the forest (51%) and oil palm plantation (37%), while Isotomidae dominated the corn field (34.9%). The number of orders and families in the three ecosystems did not differ significantly, whereas the number of individuals in the three ecosystems differed significantly. The Shannon-Wiener diversity index fell within the moderate to low range for all habitats. Evenness's index remained low across all studied habitats, and non-asymptotic rarefaction curves indicated that further sampling would likely capture additional taxa. These findings underscore that land-use types strongly influence soil arthropod activity density.

Keywords: soil-dwelling arthropod, land uses, diversity

Abstrak: Studi arthropoda penghuni tanah dapat mengungkap bagaimana ekosistem merespons berbagai metode pengelolaan lahan. Penelitian ini bertujuan untuk membandingkan keanekaragaman arthropoda penghuni tanah dan komposisi komunitasnya di tiga tipe penggunaan lahan di Bogor: hutan tanaman, perkebunan kelapa sawit semi-intensif, dan ladang jagung intensif. Penelitian ini dilakukan pada Februari hingga Agustus 2016. Perangkap lubang (pitfall traps) digunakan untuk pengambilan sampel. Arthropoda yang hidup di tanah diamati sebanyak sembilan kali di tiga tata guna lahan pertanian yang berbeda. Masing-masing memiliki kondisi abiotik yang berbeda, di mana ladang jagung memiliki intensitas cahaya dan suhu tertinggi. Sebanyak 90 plot dan 450 perangkap lubang di seluruh jenis penggunaan lahan, terkumpul 12.377 arthropoda dari 12 ordo dan 25 famili, dengan Collembola sebagai ordo yang dominan. Formicidae mendominasi di hutan (51%) dan perkebunan kelapa sawit (37%), sedangkan Isotomidae mendominasi di ladang jagung (34,9%). Jumlah ordo dan famili di ketiga ekosistem tersebut tidak berbeda secara signifikan, sedangkan jumlah individu di ketiga ekosistem tersebut berbeda secara signifikan. Indeks keragaman Shannon-Wiener berada dalam kisaran sedang mendekati rendah untuk semua habitat. Indeks evenness rendah di seluruh habitat yang diteliti, dan kurva rarefaction non-asimptotik menunjukkan bahwa pengambilan sampel lebih lanjut kemungkinan akan menangkap taksa tambahan. Temuan ini menegaskan bahwa jenis penggunaan lahan sangat memengaruhi kepadatan aktivitas arthropoda tanah.

Kata kunci: serangga permukaan tanah, tata guna lahan, keanekaragaman

Citation:
Lia M, Apriliani, Mirna. 2026. Soil-Dwelling Artropods Diversity Across Three Different Types of Land Use in Bogor, Jawa Barat. *CELEBES Agricultural*. 6(2): 103-116. doi: 10.52045/jca.v6i2.1361

INTRODUCTION

Arthropods constitute a fundamental biological component that helps maintain the function and long-term stability of ecosystems. Their sensitivity to environmental change and habitat disturbance makes them reliable bioindicators for assessing ecosystem health (Ramola *et al.*, 2024). Tropical land-use change is one of the most important drivers of biodiversity loss and ecosystem alteration in the world's humid forests. As natural forests are converted into plantations, croplands, pasture, or other managed landscapes, the structure of vegetation, litter input, microclimate, and soil conditions changes rapidly, often reducing habitat complexity and disrupting belowground processes. These changes are especially significant in tropical regions, where high productivity and intense human pressure make soil ecosystems highly sensitive to disturbance (Zhou *et al.*, 2022). In tropical regions, soil-dwelling arthropods are particularly susceptible to habitat modification, including shifts in vegetation structure, moisture levels, and light intensity. Soil arthropod communities play a central role in tropical ecosystems by contributing to decomposition, nutrient cycling, soil aggregation, and energy transfer within food webs. When forests are replaced by simplified land uses, soil arthropod abundance, diversity, and community composition often change, reflecting altered resource pathways and reduced environmental heterogeneity (Li *et al.*, 2024). These groups also contribute directly to nutrient cycling and natural pest regulation, which underscores the importance of soil-arthropod studies for evaluating ecosystem quality (Rahayu *et al.*, 2021). Understanding their presence not only reflects biodiversity levels but also provides insight into how ecosystems respond to environmental pressures.

Variations in land use and management intensity are widely recognized as major factors influencing arthropod diversity (Mhlanga *et al.*, 2022). Land-use types with different vegetation structures and management intensities are expected to differ in soil-dweller composition, relative abundance, and diversity indices. The three ecosystems selected for this study represent a clear gradient of land-management practices, ranging from natural conditions to semi-intensive and intensive agricultural systems. Comparative evidence on soil-surface arthropod community structure across artificial forest, oil palm plantation, and cornfield systems in Bogor remains limited. As a result, it is still unclear how these land-use types differ in shaping arthropod composition, abundance, and diversity, creating a clear gap in understanding land-use effects on soil surface biodiversity.

The primary objective of this study is to analyze and compare the diversity, abundance, and composition of soil surface arthropods in various ecosystems, including planted forests, oil palm plantations, and cornfields in Bogor. By identifying the present families and examining how different management intensities influence community dominance, this study aims to provide a clearer understanding of how land-use types shape soil arthropod assemblages. Based on this, the study tests the hypothesis that land-use types with different vegetation structures and management intensities are expected to exhibit differences in diversity, relative abundance, and diversity indices of soil surface arthropods.

MATERIALS AND METHODS

Study Area

The sampling sites were located in Bogor City, West Java (6˚35'42.1368"S; 106˚48'59.8860"E), with elevations ranging from 190 to 330 m above sea level and an average height of around 265 m. The three ecosystems selected represent different management spectrums of land uses: Forest (representing natural conditions), Oil Palm Plantation (representing semi-intensive land use), and Corn Field (representing intensive land use). The first study site was the Dramaga Research Forest in Situ Gede Village, West Bogor at 60˚ 33’38” LS and 106˚ 105’19” BT, which represented the forest ecosystem. This area contains 88 genera and 43 tree families with dense canopies reaching 45–50 m, dominated by species such as Hymenaea courbaril, Agathis loranthifolia, several Hopea species, and others (Haryadi, 2016). The forest floor is characterized by thick leaf litter and varied understory plants. The second site, an oil palm plantation in Cimulang and Bantarsari (Rancabungur District, managed by PTPN VIII at 6˚ 31 '33.5" LS and 106˚ 42' 58.4" BT, spans 1000 ha and was established in 2005. Cornfields is located at 6° 32’ 12.6’’ LS and 106° 44’ 49.8’’ BT in South Bogor, and Bojong Gede were selected to represent seasonal crop habitats (Figure 1). The three sites are separated by at least 5 km, and their average abiotic conditions were measured directly during this study. The measurement of abiotic parameters aims to describe differences in physical environmental conditions by measuring air temperature and humidity, soil moisture and pH, and sunlight intensity, as presented in Table 1.

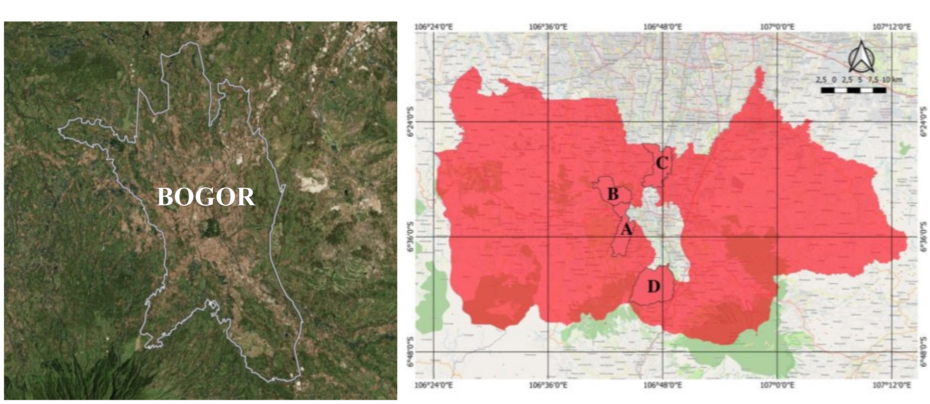

Figure 1. Sampling map illustrating the specific locations of the forest in Dramaga (A), the oil palm plantation in Rancabungur (B), and the cornfields in Bojonggede (C) and Cijeruk (D), Bogor District, West Java, Indonesia.

Table 1. Abiotic features characterizing the three vegetation habitats

	Forest	Oil palm	Corn
Light intensity (lux)	533.24	2650.28	6768.60
Temperature (°C)	28.09	29.06	34.16
RG (%)	86.40	80.46	65.58
Soil pH	5.91	6.01	6.11
Soil moisture (%)	78.90	79.14	81.90

Activity-density and diversity of soil-dwelling arthropods

Sampling was conducted in three different ecosystems using the pitfall trap method (Figure 2b). The pitfall traps were made using 450-ml plastic cups, with a surface diameter of 8 cm and a height of 9 cm. Each cup was carefully buried in the ground so that the rim was level with the surrounding ground surface, thereby not obstructing the movement of arthropods. Two hundred milliliters of a 2% formalin solution, serving as a preservative, was poured into each trap. The solution was mixed with a 1% concentration of liquid detergent to reduce surface tension, ensuring that trapped insects would sink immediately.

As a precaution against the risk of flooding from rainwater, contamination from leaf litter, and disturbance from small vertebrates, each trap was protected with a 20 cm × 20 cm tin plate canopy. This canopy is installed like a roof over the hole using support wires 10 cm above the ground surface. The traps are then left active in the field for 3 × 24 hours. Sampling is conducted twice a month using a plot. A total of 5 pitfall traps were set up in 10 m x 10 m plots, which were repeated 5 times each with a distance of ±200 meters between plots in every land-use type (Figure 2). There were a total of 90 plots and 450 pitfall traps across all ecosystems during the sampling period from March to May. In the laboratory, the soil arthropod samples obtained were observed and grouped into families and orders.

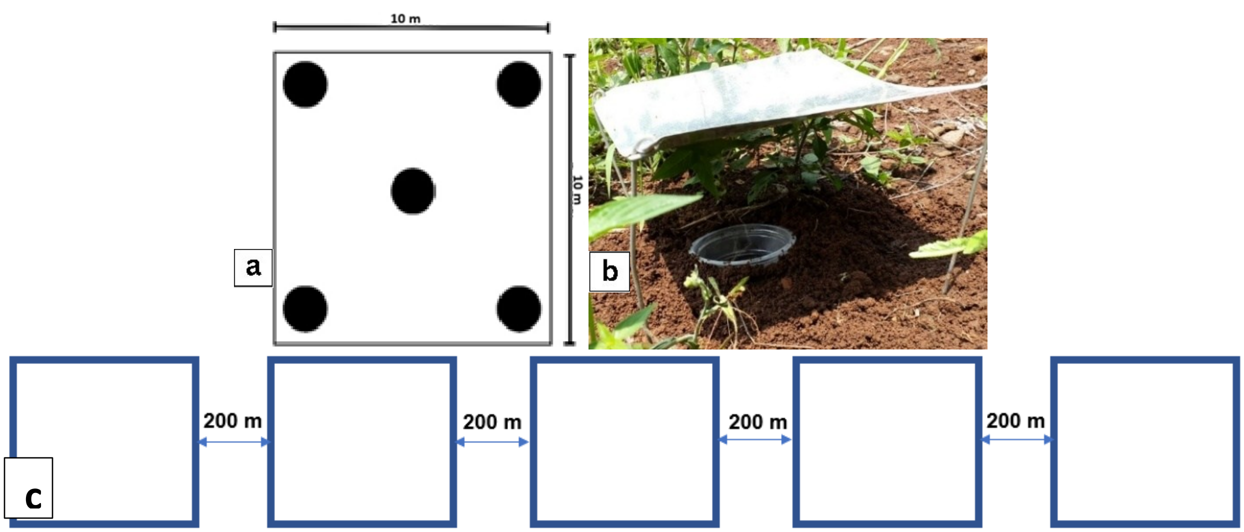

Figure 2. (a) Scheme of pitfall trap placement, (b) Pitfall Trap, (c) Distance between plots

Soil-dweller specimens were examined morphologically, documented, and subsequently identified in the laboratory. A stereoscopic dissecting microscope was employed to observe key diagnostic features. Classification was performed to the lowest possible taxonomic level, Order and Family, by referencing established taxonomic keys and comparing observed characteristics against standard descriptions provided in the reference text: Borror and DeLong's Introduction to the Study of Insects (Triplehorn & Johnson, 2005). In addition to books, identification is done using Google Lens and websites run by arthropod enthusiasts such as BugGuide . Identification data were recorded using Microsoft Excel. Shannon-Wiener diversity indices, Simpson and evenness were calculated using PAST version 5.1. Graphs were generated using Microsoft Excel.

RESULTS AND DISCUSSION

Assemblage composition

A total of 14.629 soil-arthropod specimens from 12 orders and 25 families were collected during the sampling period across various land-use typesBased on the 12 orders found in the three ecosystems, the six orders with the highest number of individuals, in descending order, are Orthoptera, Hymenoptera, Coleoptera, Collembola, Dermaptera, and Araneae. Collembola and Hymenoptera were the most dominant orders. The higher representation of Collembola in various types of land use was associated with soil fertility (Husamah *et al.*, 2012) across various land use types and experienced relatively rapid colonization (Widrializa *et al.*, 2015). Hymenoptera are common because they belong to a widespread order of insects that includes pollinators, predators, and parasitoids, allowing this group to play an important role in almost all terrestrial ecosystems (Peters *et al.*, 2017). Collembola and Hymenoptera are thus able to colonize and inhabit various habitats (Remelli *et al.*, 2025).

Table 2. Order of species collection from all samples in the three types of land uses

Orders	Forest	Corn	Palm Oil
Acari	✓	✓	✓
Aranae	✓	✓	✓
Coleoptera	✓	✓	✓
Collembola	✓	✓	✓
Dermaptera	✓	✓	✓
Embiidina	–	✓	–
Geophilimorpha	✓	–	–
Hemiptera	✓	✓	✓
Hymenoptera	✓	✓	✓
Isopoda	✓	✓	✓
Isoptera	✓	✓	✓
Orthoptera	✓	✓	✓

The rarefaction curve (Figure 3) is used to estimate the total family richness in an ecosystem by showing how species accumulate as sampling effort increases. Its pattern helps determine whether the number of samples taken is sufficient to represent the true diversity of a community (Willis, 2019). In this study, the rarefaction curves (Figure 3) of all three ecosystems have not yet reached an asymptote point, indicating that sampling effort did not fully capture the total taxon richness and that additional plots or complementary collection methods would likely record additional taxa. This suggests that the observed diversity is likely the actual richness, and additional sampling would continue to reveal more taxa. This means that it is necessary to increase the number of sample plots and use other soil-arthropod collection methods such as Tullgren funnels or Macfadyen extractors. The use of pitfall traps can also be combined with the soil flotation technique (Junod *et al.,* 2023).

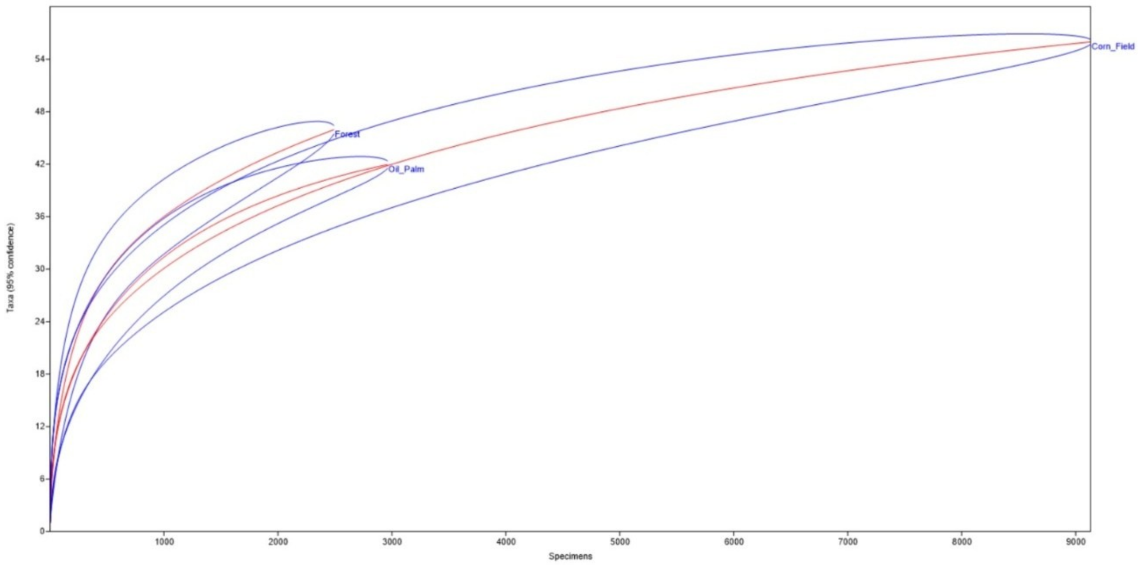

Figure 3. The rarefaction curves of the soil-dwelling arthropod were sampled from the three vegetation habitats

Individual richness in the three types of ecosystems shows that the highest to lowest relative frequencies are found in oil palm plantations (36%), forests (33%), and corn fields (31%). The highest individual wealth is found in oil palm plantations (Figure 4), indicating that the microhabitat conditions where food sources are concentrated, and nests are available in the canopy and on the ground surface (Stone *et al.,* 2025). The families Formicidae and Entomobryidae belong to a family of insects inhabiting three different ecosystems. The Formicidae family is the most dominant in forest and oil palm plantations, while being the second-most dominant family in the cornfield. Species belonging to this family are ants, which are social insects with substantial intraspecific variation and worker caste polymorphism. Dominant species within the Formicidae family serve as sensitive bioindicators of habitat quality and disturbance levels, with all dominant species showing a strong correlation with environmental factors such as humidity (r=0.989) and temperature; forest habitats are more conducive to specialized species, whereas oil palm and agricultural lands serve as suitable habitats for opportunistic species that thrive in both open and disturbed habitats (Budiaman *et al.,* 2025). Given the numerous species involved, the rarity of many of them, and the primary emphasis in ant systematics on the non-reproductive, or worker, caste, this is not surprising (Ward, 2007). Entomobryidae are found in three different ecosystems in terms of both environment and use. This shows that the occurrence of Entomobryidae in all three land-use types suggests that this family may have relatively broad habitat tolerance within the study area. In line with the statement by Vegter *et al.* (1997), the degree of spatial aggregation of a collembola species does not appear to be related to drought sensitivity or spatial heterogeneity in the humidity regime of the habitat.

Relative abundance

The number of orders and families in the three ecosystems did not differ significantly based on the chi-square test, whereas the number of individuals in the three ecosystems differed significantly. The dominant families and their activity-density percentages in the three ecosystems were Formicidae (30.6%), Isotomidae (24%), Entomobryidae (21%), Gryllidae (6.8%), and Lycosidae (5%) (Table 2). Formicidae are commonly found in open habitats such as oil palm plantations (Roza *et al.*, 2022), and they are among the most abundant Hymenoptera bioindicators and can therefore indicate soil health (Mhlanga *et al.*, 2022). Meanwhile, the families Entomobryidae, Phoridae, and Scolytidae are influenced by the availability of specific substrates (dead wood and carcasses) and are therefore highly dependent on vegetation structure (Rojas-Castillo *et al.*, 2023)

Table 2. Chi-square test results based on the number of orders, families, and individuals and dominant soil-dwelling arthropods found in three ecosystem types

Ekosistem	Jumlah yang ditemukan		
	Ordo	Famili	Individu
Jagung	10	19	7933
Kelapa Sawit	9	16	2526
Hutan Buatan	11	20	1918
χ^2	0.229	0.301	32448
P	0.892	0.86	< 0.001

Order	**Family**	**Number of individuals**			χ^2	**p**
		Corn Field	**Oil Palm**	**Forest**		
Ortophtera	Gryllidae	603	293	25	545.07	< 0.001
Hymenoptera	Formicidae	1956	1138	1012	383.86	< 0.001
Coleoptera	Carabidae	76	2	3	133.41	< 0.001
	Scarabaeidae	17	20	14	1.06	= 0.589
	Staphylinidae	66	91	95	5.88	=0.052
Collembola	Entomobryidae	1608	636	622	668.94	< 0.001
	Isotomidae	3192	13	47	6149.51	< 0.001
Dermaptera	Forficulidae	3	5	9	3.29	= 0.192
	Carcinophoridae	6	5	17	9.50	=0.008
Araneae	Lycosidae	115	114	1	112.03	< 0.001
	Salticidae	12	5	11	3.07	= 0.215

Based on the results of the chi-square test, the abundance of the families Forficulidae, Salticidae, Scarabaeidae, Staphylinidae, and Carcinophoridae did not differ significantly across the ecosystems ($p > 0.001$). The abundance values for each family were not significantly different. The abundance of other families in the three ecosystems differed significantly ($p < 0.001$). Differences in individual abundance across ecosystems were influenced by plant biomass (Schindler *et al.* 2011). According to Hooper *et al.* (2000), arthropod abundance depends on the extent of agricultural land cover, as the survival of most arthropods depends on nutrients for their growth. Land-use practices influence the diversity and presence of macrofauna both within and on the soil surface (Baker 1998).

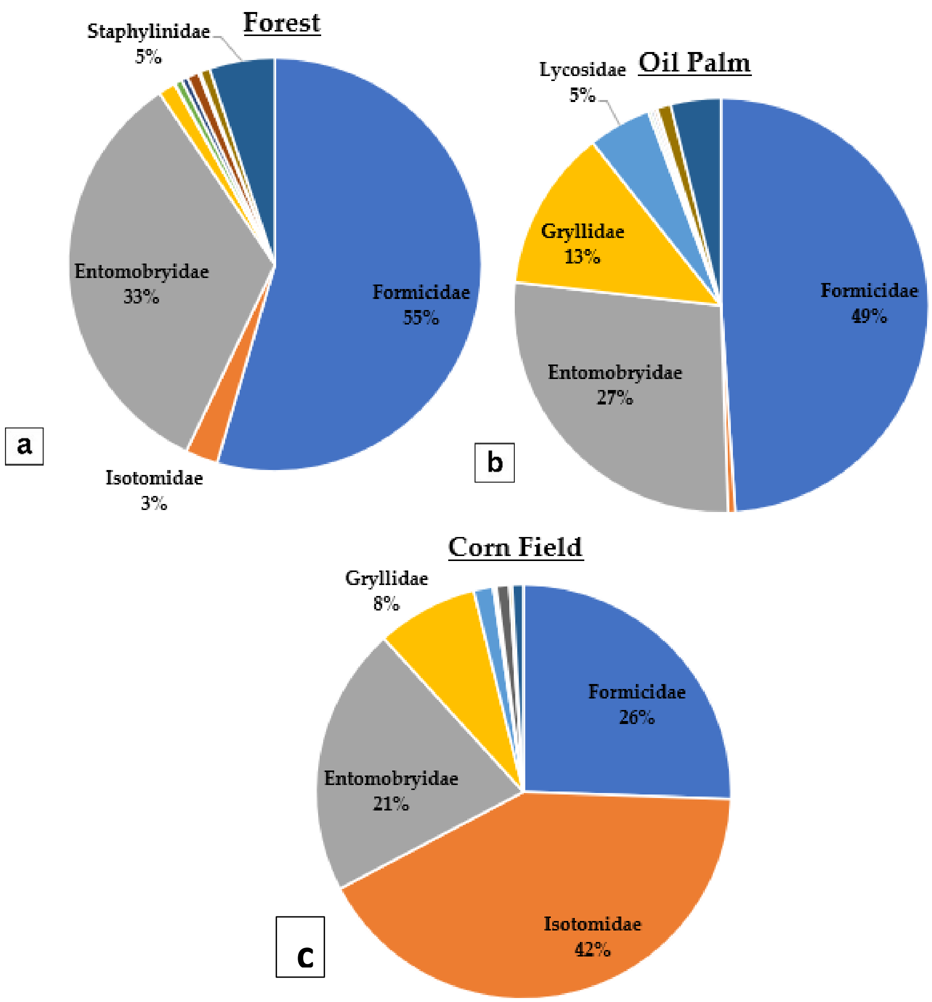

Figure 4. Variation of soil-arthropods relative abundance by family across different land use types.

In the forest ecosystem, Formicidae dominates with the highest relative abundance (55%), followed by Entomobryidae (33%) (Figure 4a). Species belonging to the Formicidae family are ants, which are social insects with substantial intraspecific variation and worker caste polymorphism. In this case, the Formicidae family includes soil macrofauna in forest habitats as bioindicators in the soil. This group of ants can contribute around 10% of the total biomass as the main predators of plant-damaging pests and soil bioturbation processes (Zhou *et al.*, 2026). The presence of Entomobryidae in the forest ecosystem is related to the availability of organic matter such as abundant leaf litter. In line with research (Susanti *et al.*, 2024), it shows that fluctuations in soil-surface arthropods in the Collembola community, including Entomobryidae, have a higher abundance of individuals compared to plantations, which is influenced by abundant organic matter. Staphylinidae family, is found in practically every kind of environment. Based on activity-density data in the three different ecosystems, the highest number of individuals was found in forests, followed by oil palm plantations, and the lowest in corn fields. These data results are supported by Bohac's (1999) statement that knowledge of the broad habitat requirements of common Staphylinid species and the fact that this family is distributed in almost all semi-natural and man-made habitats are two features that make staphylinids attractive as potential bioindicators

In oil palm plantations, Formicidae again became the dominant group (49%), followed by Entomobryidae (27%), Gryllidae (13%), and Lycosidae (5%) (Figure 4b). The dominance pattern of the Formicidae and Entomobryidae families is thought to be related to the vegetation structure in oil palm plantations, which still provides habitat for individuals. In oil palm replanting conditions in Riau Province, the relative abundance of Formicidae increased during rejuvenation, resulting in denser intervegetation structures (Ashton-Butt *et al.*, 2019). The family with the highest activity density in oil palm plantations is Gryllidae, which are insects that inhabit the understory vegetation, which provides both habitat and foraging space. Gryllidae are among the most adaptable insects across various habitat types, particularly those undergoing internal changes (Lestari *et al.*, 2022). The Lycosidae are ground-dwelling hunting spiders that are highly abundant at all times. These spiders hunt in the understory vegetation, which is dominated by weeds in oil palm plantations. This is consistent with a study by Lia *et al.* (2022), which found high spider diversity and abundance in oil palm plantations. Some of the spiders found include *Lysania* sp., as well as *Pardosa* sp., species belonging to the Lycosidae family, which were dominant in oil palm.

A significantly different relative abundance of individuals was found in corn fields, where Isotomidae dominated (42%), followed by Formicidae (26%), and Entomobryidae (21%) (Figure 4c). The relative abundance of Isotomidae is dominant in corn fields, so it is suspected that there is a relationship with tolerance to anthropogenic disturbances and the ability to utilize soil organic matter from environmental residues. The response of this family is very sensitive to changes in the soil environment as the intensity of agricultural disturbances increases (Ma *et al.*, 2023). Meanwhile, the presence of Gryllidae as a phytophagous pest is suspected to have a wide host range in agricultural land areas. In line with research Talpur *et al.*, (2023), in Pakistani agricultural land, the presence of soil-surface arthropods from the Gryllidae family attacks crops such as corn, wheat, cotton, and grass.

The use of pitfall traps is one of the factors influencing the activity density of soil-dwelling arthropods. This is due to the limitations of the pitfall trap method for catching surface-moving creatures. Instead of suggesting a big real population size, a high catch count may just indicate that the arthropods are very active. In addition, the microclimate of the habitat influences several soil-dwelling arthropods, such as springtails and mites, that live in the lower leaf litter (hemiedaphic) or deep within the soil profile (euedaphic), which will significantly underestimate their number and richness since they seldom surface. Another reason why springtails (Isotomidae and Entomobryidae) are so abundant in cornfields may be that excavating the soil to set the trap causes a temporary disturbance that alters local conditions and CO_2 levels. This can artificially stimulate the movement of Collembola or mites into the trap, leading to skewed initial findings (Schirmel *et al.*, 2010).

Biodiversity indices

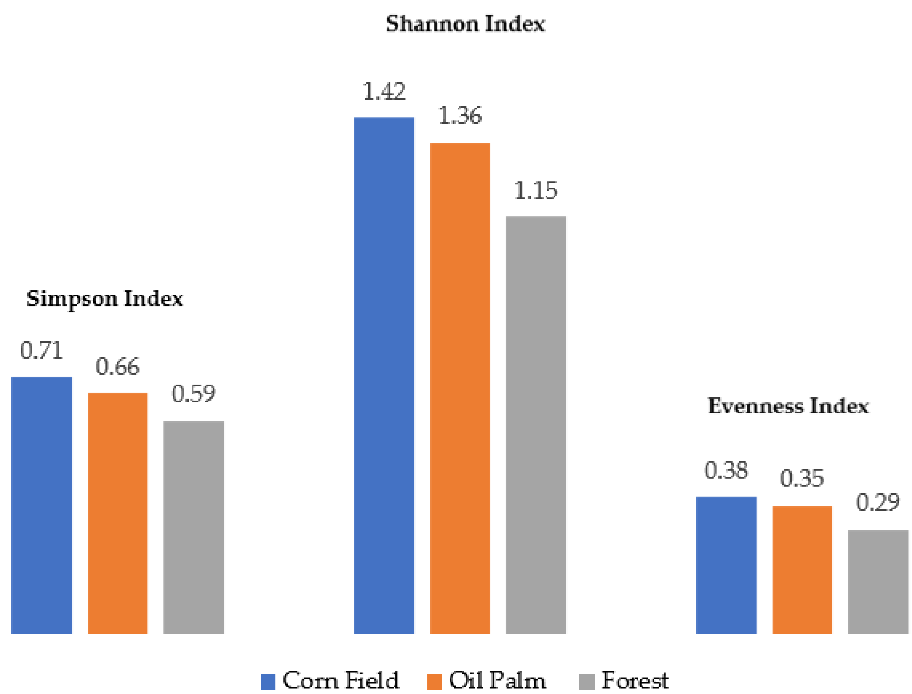

Figure 5. Shannon diversity index, Simpson index, and Evenness index for each different land use type. Note: Shannon diversity index (high (H^'>3), medium (1≤H^'≤3), low (H^'<1)), Simpson index (low (1-D<0.3) medium 0.3≤1-D≤0.6 to high (1-D>0.6)) and Evenness index (high (E>0.6), medium (0.3≤E≤0.6), low (E<0.3))

Variable diversity can be identified from Shannon's diversity index, Simpson's index, and evenness index for each different land use type. Diversity in the three types of land use shows that Shannon's diversity index is in the moderate to low category, the Simpson index is in the moderate to high category, and the evenness index is in the low category (Figure 5). The highest Shannon's diversity index was found in oil palm plantations due to the diversity of soil-arthropods, and the oil palm plantation had the highest relative evenness value, but all habitats showed low evenness. Meanwhile, in the forest, Shannon's diversity index is lower than in corn fields due to the use of land for crop rotation, which allows for a diverse insect community, so that the diversity in corn fields can exceed that in forest land (Weisner, 2018). The Simpson index and evenness index are lowest in forest land compared to oil palm plantation land and corn farmland because the composition of agricultural tends to be more cultivation practices and structurally homogeneous, so that only a few highly competitive and adaptive species are able to dominate the available ecological niche. Conversely, oil palm plantations and corn fields experience more intense disturbances and have higher habitat diversity, resulting in more dynamic competition and allowing opportunities for many beneficial species to coexist. Consequently, no single species dominates conspicuously, and the level of single dominance is lower (Maharani *et al.*, 2024; Sumah & Kusumadinata, 2023).

CONCLUSIONS

This study concludes that different land management practices influence the composition and diversity of soil arthropods in Bogor, West Java. All three ecosystems exhibited moderate to low levels of Shannon diversity (H') because the orders Orthoptera, Hymenoptera, Coleoptera, and Collembola had the highest number of individuals found in most land use. The Entomobryidae and Formicidae are families of soil-dwelling arthropods that have the highest relative abundance across the three land-use types. The number of individuals in each of the three types of agricultural ecosystems has the highest abundance compared to oil palm plantations and artificial forests, although the number of orders and families of soil arthropods has values that are not significantly different.

ACKNOWLEDGMENT

The author is greatly thankful to Dyah Rini Puspitasari as technical assistance and to the anonymous reviewers for providing valuable comments and suggestions that improve this article.

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