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Diversity and Abundance of Soil Arthropods in Terrestrial Area of Situ Lengkong Panjalu, West Java, Indonesia

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Abstract. *Soil arthropods play an important role in nutrient cycling and maintenance of soil structure. Thus, their abundance and diversity can indicate the biological quality of the soil. Due to different soil management practices, arthropods are also very sensitive to environmental changes. This study aims to analyze the abundance and diversity of soil arthropods and the environmental factors that support the abundance of soil arthropods in terrestrial of Situ Lengkong Panjalu, West Java, Indonesia. The methods used to obtain samples of soil arthropods are pitfall trap. Soil arthropod data were analyzed to determine the Shannon diversity index (H'), Margalef richness index (R), and Evenness index (E). The effect of abiotic environmental factors was analyzed using Principal Component Analysis (PCA). A total of 1263 arthropods were found in Situ Lengkong Panjalu, belonging to 11 orders, 24 families, and 32 morphospecies. The current work determined the scores of H'= 2.08, R = 3,08, and E = 0.72 of soil arthropods in Situ Lengkong Panjalu, West Java, Indonesia. Results revealed that humidity is one such environmental parameter affecting the presence of soil arthropods in Situ Lengkong Panjalu, West Java, Indonesia. This research can be used as a guide in validating and conservation of the habitat of soil arthropod species on West Java.*

Keywords: *abundance, arthropods, diversity, Situ Lengkong, soil*

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INTRODUCTION

Soil provides the basics for human livelihood and well-being, including food supply, freshwater, many other ecosystem services, and biodiversity (Bach et al., 2020). This is especially the case with the soils of agricultural areas, which account for 13% of the total ice-free land cover globally and are among the most important resources for ecosystem functioning, often compromised by mismanagement (Menta et al., 2020). Biodiversity plays a crucial role in ecosystem functioning and services nevertheless, many authors have highlighted the negative effects of conventional management on soil biodiversity multifunctionality (Schuster et al., 2019). Practices such as tillage, overfertilization, monoculture, and pesticide application often give rise to increased soil erosion, decay of organic matter content, salinization, and compaction, which may lead to a reduction in crop productivity and soil biodiversity, and subsequent socioeconomic losses (Smith et al., 2015; Menta et al., 2020).

Loss of forest cover is a direct cause of habitat loss, which in turn results in a decline in biodiversity. Human activities convert natural habitats into agricultural land, plantations, and pastures, which poses a significant threat to the stability of ecosystems and species diversity (Perry et al., 2021). Terrestrial ecosystems are habitats for a wide range of arthropods, including insects, spiders, mites, and their relatives, making them the most diverse group of organisms, accounting for approximately 66% of the world's known biodiversity (Zhang, 2011). Biological data for environmental monitoring and management are generally obtained from large living organisms such as vascular plants and vertebrates comprising between 2 and 6% of the estimated global biodiversity. The invertebrates, including arthropod fauna, micro-flora, and micro-fauna (bacteria, algae, fungi, protozoa, etc.), account for most of the biodiversity and collectively form the invisible infrastructure that drives ecosystem dynamics (Wale & Yesuf, 2022).

Soil arthropods are a critical element in the ecosystem's decomposition and nutrient cycling processes. In forest ecosystems, soil arthropods facilitate soil fertility by accelerating litter and soil organic matter decomposition (Carrillo et al., 2011; Wang et al., 2017). Arthropods are essential for ecosystem functions and have received much attention in biodiversity, conservation, and ecological studies (Meidalima et al., 2017). Soil arthropod communities can be used as soil health indicators, including appropriate land management, abundance and diversity, network structure, and community stability (Zayadi et al., 2013). Previous research has indicated that they may be used to inform agricultural land management to promote crop growth and ecosystem services, since arthropods respond in predictable ways to land changes, their abundance and species richness may predict soil conditions. However, this might be challenged by a lack of their taxonomy to species level and the study of relationships between species of arthropods with soil physicochemical parameters (Truter et al., 2014; Sari et al., 2022).

Situ Lengkong Panjalu is an ecotourism area (57.95 hectares) in the form of a lake, and there is an island in the middle, which is included in a Nature Reserve (Adnan et al., 2023). This area is located in Panjalu Village, which has an area of 1,084 hectares and a population of 12,575. There are several ecosystems around Situ Lengkong Panjalu, one of which is an artificial ecosystem. The artificial ecosystem consists of rice fields, plantations, ponds, and settlements. The ecosystem is an artificial ecosystem to utilize it to benefit the community. Human intervention has caused differences in the composition of the environment, which impacts the diversity of fauna in the area, one of which is arthropods. Soil recycling, vegetation pruning, and the harvesting process are disturbance factors that can affect the ecosystem. Soil fertility evaluation is urgently needed to understand soil fertility levels and prevent soil degradation. This can affect the arthropod niche, which will impact the diversity and abundance of arthropods.

Therefore, this study aimed to learn the diversity and abundance of soil arthropod communities and their relation with environmental factors in various ecosystems in the Situ Lengkong Panjalu area.

MATERIALS AND METHODS

Study area

This research was conducted in January 2024 on four types of ecosystems in the Situ Lengkong Panjalu Area, Ciamis District, West Java, namely rice fields, plantations, ponds/ water sources, and settlements (see Figure 1; Table 1).

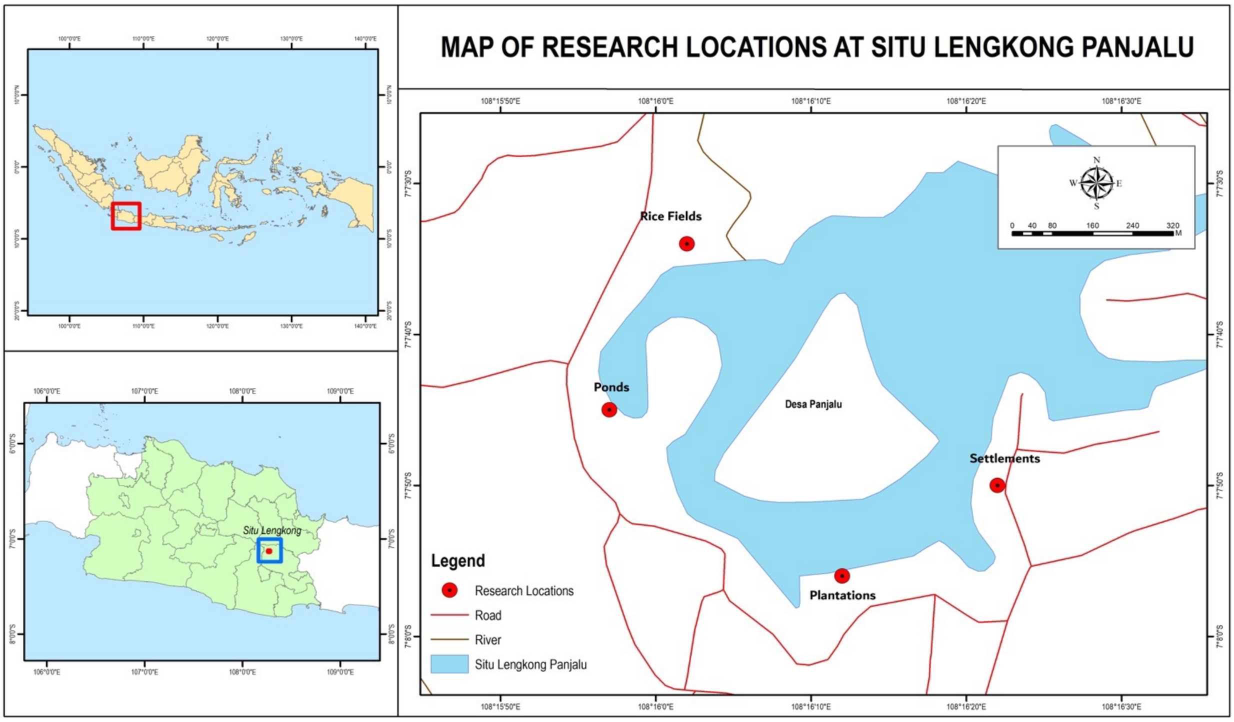

Figure 1. Research Location in the Situ Lengkong Panjalu, Ciamis Regency, West Java, Indone-

Table 1. Coordinates of ecosystem locations

Locations	Coordinates		Description
	Lattitude	Longitude	
Rice fields	7°07’34”S	108°16’02”E	Rice farming land
Ponds/Water sources	7°07’45”S	108°15’57”E	Mixed gardens near several ponds
Plantations	7°07’56”S	108°16’12”E	Mixed garden with dominant vegetable crops
Settlements	7°07’50”S	108°16’22”E	Urban green space surrounded by building

Arthropod sampling

The research used a survey method. Determination of the research location is done by using a purposive sampling technique. Soil arthropod was collected using pitfall traps (Triyogo et al., 2020; Knapp et al., 2022). At each site, a total of 10 traps (5 by 2 plot) were placed systematically at 2 m intervals. Glass cups (10 cm in diameter and 30 cm deep) were buried in the ground. The traps were filled with 100 mL alcohol solution (70%) mixed with a few drops of detergent to immobilize the trapped arthropods. Approximately one-third of the cup's height was filled with the water-detergent mixture, and a zinc sheet was used as a pitfall trap cover to prevent rainwater from entering the trap (Gonçalves et al., 2020). The traps were set for 24 hours, and then the captured soil arthropods were collected in sample bottles and taken to the laboratory. The arthropods collected from each sampling unit were then sorted and identified for their families based on several identification books' morphological characters of soil insects. To identify soil arthropod samples, soil arthropod identification references were used (Borror et al., 1981; Gibb & Oseto, 2006; Decker, 2013), online identification keys (official website https://www.bugguide.net; and http://www.antwiki.org).

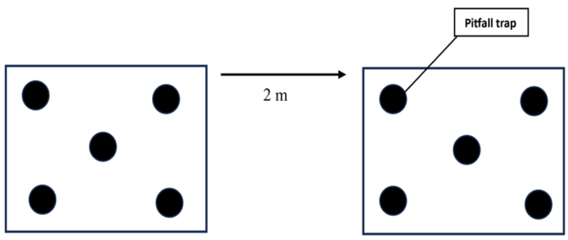

Figure 2. Plot design on each ecosystem for observation

Environmental parameters measurement

The environmental factors measured in this study were temperature using a thermometer, humidity using a hygrometer, light intensity using a lux meter, and pH using a soil tester. Furthermore, the results obtained will be analyzed using the PCA method using PAST3 software (Trianto & Purwanto, 2022).

Data analysis

The number of species and the number of individuals in each species (the abundance) from each location were used to analyze the abundance and species diversity using several ecological indices. The Shannon-Wiener index (H') and Evenness (E) were calculated according to Magurran (2004).

Shannon-Wiener index (H)

$$H' = \Sigma\, Pi \ln Pi, \text{ whereas } Pi = ni / N$$

Margalef Richness Index (R)

$$R = (S-1) / \ln N$$

Evenness index (E)

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

In above formula, ni is number of individuals of the *i*-th species, *N* is number of individuals of all species, *Pi* is the relative abundance of each species, calculated as the proportion of individuals of the *i*-th species to the total number of individuals in the community, and S is the total number of species found in the quadrat.

Principal Component Analysis (PCA)

The environmental parameters here in included temperature, humidity, pH, and light intensity and were analyzed using the PCA method in PAST3 software. The data analysis aimed to determine the dominant characteristics affecting the diversity and abundance of soil arthropods in the several ecosystems in the Situ Lengkong Panjalu. Interpreting PCA results involves understanding the variance explained by each principal component. High variance components capture significant information, aiding in dimensionality reduction. Analyze the cumulative explained variance to determine how many components retain most of the data's information (Trianto & Purwanto, 2022).

RESULTS AND DISCUSSION

Soil arthropod diversity and abundance

Soil management may differentially affect arthropod functional groups due to differences in resource needs or dispersal among taxa. Because many of these arthropods provide ecosystem services or are pests, biodiversity can affect crop yield (Lichtenberg et al., 2023). The field study of four different ecosystems showed various soil arthropod populations belonging to Araneae, Blattodea, Coleoptera, Dermaptera, Diptera, Hemiptera, Hymenoptera, Isopoda, Lepidoptera, Odonata, and Orthoptera (Table 2). A total of 1.263 individuals of soil arthropods were recorded during the study. The highest abundance of soil arthropods was found at rice fields (435 individuals) compared to other sites, ponds (168 individuals), plantations (394 individuals), and settlements (266 individuals).

The high population of arthropods in the rice field ecosystem is due to the wild vegetation that grows there. The research results of Jauharlina et al. (2019) showed that wild vegetation that grows naturally can act as a habitat for the development of arthropods. The result of the study revealed the presence of 32 morphospecies under 11 taxa of soil arthropods in the area of Situ Lengkong Panjalu. Among all the groups of arthropods, Araneae, Hymenoptera, and Orthoptera were the predominant group in all research sites, with a total composition of more than 50% in each ecosystem type (Table 2).

Table 2. Relative abundance of the orders of soil arthropods at several ecosystems

Taxa	Relative abundance of arthropods (% / individual per research area)			
	Rice fields	Ponds/Water sources	Plantations	Settlements
Araneae	26.67% (116)	25.60% (43)	35.28% (139)	11.65% (31)
Blattodea	0% (0)	2.98% (5)	0% (0)	3.01% (8)
Coleoptera	5.29 % (23)	2.38% (4)	4.06% (16)	3.38% (9)
Dermaptera	0.23% (1)	0% (0)	0% (0)	0% (0)
Diptera	0% (0)	9.52% (16)	2.03% (8)	10.53% (28)
Hemiptera	1.84% (8)	1.19% (2)	1.78% (7)	0.75% (2)
Hymenoptera	50.34% (219)	43.45% (73)	45.18% (178)	58.65% (156)
Isopoda	0.92% (4)	0% (0)	0.76% (3)	3.38% (9)
Lepidoptera	0.23% (1)	0% (0)	0% (0)	0% (0)
Odonata	0.23% (1)	0% (0)	0% (0)	0% (0)
Orthoptera	14.25% (62)	14.88% (25)	10.91% (43)	8.65% (23)
Total	435	168	394	266

Hymenoptera is the most common order found in the study area, the most dominant family being *Formicidae*. In the study area, many of the bases of woody plants were found to have been cut down, making *Formicidae* abundant. According to Fauzi et al. (2023), *Formicidae* make nests in areas where there are woody plants or former woody plants. Ant nests are found in soil areas, whether covered or not, between rocks, wood, plant roots, and twigs on bushes or trees. Ants are widely distributed geographically and sensitive to various factors, including soil physical and chemical properties. Santos et al. (2007) reported that *Formicidae* catch is dominant in pitfall traps in olive groves. The order Hymenoptera is distributed in all vegetation, forests, or other places that provide food, such as flowering plants and horticultural crops. Most Hymenoptera are active on sunny days in search of food, such as insects, pollen, and nectar, or nesting material, an insect that is often found on the surface of the land in both the dry and rainy seasons (Haneda et al., 2019; Sari et al., 2022).

Of all terrestrial arthropods, ants are perhaps the most important regarding ecosystem impacts, sometimes acting as ecosystem engineers. Ants can affect soil physical structure, nutrient dynamics, and biological properties of the soil environment by building mounds or nests (Nooten et al., 2019; Batzer & Wu, 2020). Furthermore, ants play an important role in belowground processes by altering the physical and chemical environment and their effects on plants, microorganisms, and other soil organisms. They are important seed dispersers and can influence soil's carbon and nutrient cycles (Tausan et al., 2017). Ant communities play a crucial role in the mineralization process due to the continuous soil excavation activities performed. The presence of ants in agricultural habitats is influenced by food availability and the suitability of environmental factors for nesting. Ant diversity can be a bioindicator of agroecosystem health (Widhiono et al., 2017). Ants are often used as bioindicators in many fields (Lawes et al., 2017; Sujak et al., 2023). According to Melliger et al. (2018), variations in land conditions significantly influence the diversity of ants in a specific location. Environmental changes greatly affect the abundance of ant species in a particular area, and ants respond to disturbances or disruptions in the soil as these serve as their habitats (Andersen, 2019). Additionally, Kelly et al. (2020) reported that soil tillage practices can influence the diversity and abundance of ants in dryland agriculture.

The result of the soil arthropod community's diversity, richness, and evenness indices calculation shows various values (Table 3). The richness and evenness indices have been combined mathematically in various ways to calculate diversity indices based on proportional abundance.

Table 3. Diversity indicators of soil arthropods in four different ecosystems

Ecological Indices	Rice fields	Ponds/water sources	Plantations	Settlements
Shannon-Wiener (H')	2.13	2.04	1.92	2.21
Margalef (R)	3.95	2.15	3.18	3.04
Pielou’s Evenness (E)	0.66	0.82	0.64	0.76

The Shannon-Wiener diversity index (H') showed that the soil arthropod at each location has a moderate level of diversity because the H' values obtained ranged from 1 to 3. This indicates that the Situ Lengkong area has moderate ecosystem stability. This means that the ecosystem in the area still provides sufficient food that supports the life of soil arthropods (Gonçalves et al., 2021). The highest diversity index was found in the settlement site (H': 2.21), while the lowest value of H′ soil arthropods was 1.92, and it was caught from the Plantations site. The difference in species diversity index is caused by differences in species richness in each ecosystem type. Mathematically, species richness is directly proportional to the species diversity index (Sari et al., 2022).

The number of species richness in this study varied between 2.15 to 3.95, according to Rodríguez et al. (2020) indicating a moderate species richness value. The highest species richness value was found in the rice field site (R: 3.95) compared to another site. Margalef species richness index indicates the number of species in a community and expresses the simplest biological concept. It indicates the suitability of the habitat for different species. The numerical value of this index decreases in adverse biological factors or environmental stresses and increases with an increasing number of species and density of each species, as well as higher human intervention causing a constant disturbance, and affecting the richness (Yahyapour et al., 2022).

Evenness index analysis shows that the evenness value of the soil arthropod family in the Situ Lengkong Panjalu area is considered high evenness because it has a value of >0.6. The evenness index value usually appears between E=0-1. The higher the evenness index value, the more even the distribution of taxa and individuals is (Li et al., 2018). The evenness of the number of individuals in each taxa in Situ Lengkong shows that the ecosystem provides food for arthropods fairly evenly. The evenness index value measures the balance between one community and another. Differences in diversity and evenness values can be caused by many factors, such as habitat type, vegetation, and abiotic factors, such as weather, light intensity, and humidity.

Many ground surface arthropods spend part or all of their life aboveground. The more abundance, distribution, and diversity of ground-surface insect species, the more species, and individuals area reflect, and the more stable the ecosystem (Magurran, 2004). Insects in an ecosystem are a group of biota that have an essential role in maintaining the balance or stability of the ecosystem because they have an even distribution in trophic levels (Fauzi et al., 2023). According to Yanuwiadi et al. (2023), the diversity of soil arthropods shows a variety of ecological roles in positioning themselves in food webs in terrestrial ecosystems. Natural ecosystems without any disturbance from humans lead to stability in abundance, and the richness of taxa, composition, and functional traits are more maintained. The size of the role needed to fill the availability of niches is also a determining factor in forming an ecosystem balance.

Environmental parameters

Environmental factors also greatly affect the existence of soil arthropod species. An individual's success rate in living (grow and reproduce) is influenced by physical or abiotic environmental factors. The results showed that the average air temperature at the location where soil arthropod was found in the Situ Lengkong Panjalu area was in the range of 28.6-30.2°C, humidity 79.2-85.2%, Soil temperature 26.4-29.8°C, soil pH equal to 5.0-6.2, and light intensity of 1778-5319.6 lux (Table 4). Furthermore, the environmental parameter data obtained were analyzed using the PCA method with PAST3 software. This analysis aims to see the dominant characteristics that affect the diversity and abundance of soil arthropods (Trianto et al., 2020).

Principal Component Analysis (PCA) was conducted from the data collected. The correlation analysis between-group results in eigenvalues and percent variances shown in Table 5, while the scatter plot can be seen in Figure 3. The principal components analysis shows the pattern of sample clustering based on each character's role in the clustering process. The loading plot of component 1 can be seen in Figure 4.

Table 4. Average measurement of environmental factors at several ecosystems

Locations	Environmental parameters				
	Air temperature (°C)	Humidity (%)	Soil temperature (°C)	pH	Light intensity (lux)
Rice fields	30.2	82.8	29.8	5.2	5319.6
Ponds/Water sources	28.6	85.2	27.6	5.0	1455.4
Plantations	29.7	80.6	27.4	60.2	1554
Settlements	29.8	79.2	26.4	5.8	1778

Table 5. Eigenvalue and % Variance

Principal Component (PC)	Eigenvalue	% Variance
1	276.679	97.87
2	5.85035	2.069
3	0.16831	0.059
4	0.00136	0.004
5	0.00041	0.001

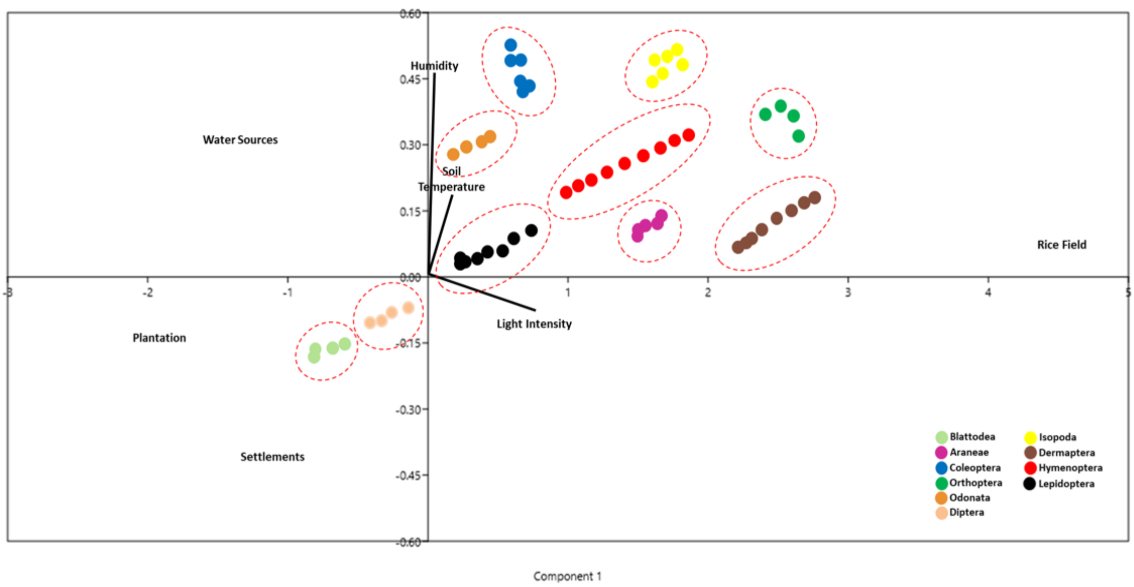

Figure 3. The visualization of PCA

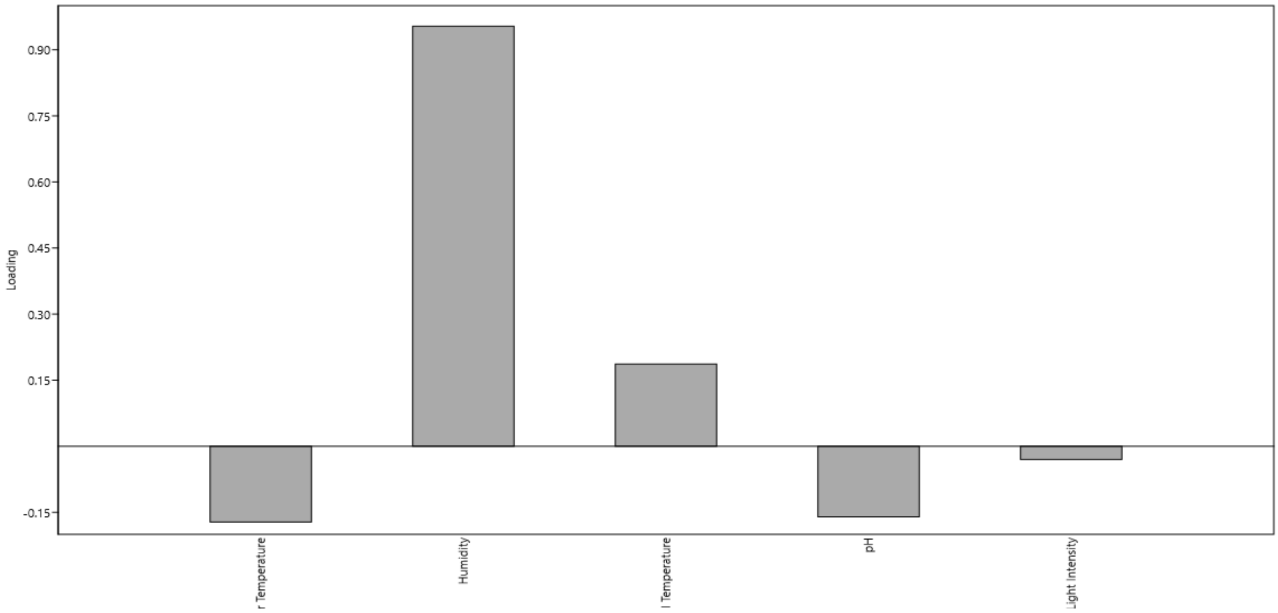

Figure 4. The loading plot of component

The most dominant characteristic for forming four clusters that determine to cluster of the species is humidity. This can be seen from the length of the resulting line (Figure 3), and the picture of the Loading Plot of Component (Figure 4) produced. Trianto & Purwanto (2022) stated that the longer the arrow and the higher the graph formed, hence the characters' role in group formation is also high. The influence of air humidity slightly affects the soil's pH intensity. High humidity in a location can initiate wetting of the forest floor. In this way, the nutrients resulting from the decomposition and humification of the detritivore arthropod soil along with the microbes can also be absorbed through the soil porosity. Soil porosity is carried out by soil-digging arthropods, for example, termites (Termitidae) to facilitate aeration and root penetration and prevent surface crust and erosion of the topsoil (Culliney, 2013; Yanuwiadi et al., 2023)

Each ecosystem has different environmental characteristics, such as temperature, humidity, and light intensity (Adnan & Dadi, 2023). Each combination of factors has a different influence on the type or group of soil arthropods, both beneficial and detrimental. Geographical regions with different climate patterns, vegetation, and other factors are inhabited by different groups and have different compositions of diversity. Habitat preference also depends on the absence of their predators and competitors (Leksono et al., 2019). Our study showed a substantial difference between arthropod communities in four research sites; we could relate these variabilities of sites with the abiotic factors. As Kurnianto et al. (2022) also stated, environmental gradients profoundly distributed faunal communities in different ecological regions. The previous study by Nargis et al. (2021) reported that climatic factors and humidity alter the arthropod community's distribution in an ecosystem.

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CONCLUSION

The different types of ecosystems have various impacts on soil arthropods. Furthermore, the intensity of land management affected the soil arthropods mentioned in this research, including Araneae, Blattodea, Coleoptera, Dermaptera, Diptera, Hemiptera, Hymenoptera, Isopoda, Lepidoptera, Odonata, and Orthoptera, which are commonly used to illustrate field conditions. Arthropods taxa were found as dominant is Hymenoptera and among the research stations, rice fields station has the highest arthropod diversity. This research can be used as a guide in the validation and conservation of the habitat of soil arthropod species on West Java.

AUTHOR CONTRIBUTION

B.A.A. developed and designed the research. B.A.A. and T.K. conducted the fieldwork and sample collection. B.A.A. run the laboratory works. B.A.A., T.K., and M.T. analyzed the data. B.A.A., T.K., and M.T. wrote the manuscript. B.A.A. is the main contributor. All authors have read and approved the final manuscript.

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CONFLICT OF INTEREST

The authors state there is no conflict of interest.

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