Jurnal Biolokus: Jurnal Penelitian Pendidikan Biologi dan Biologi
Vol. 6, Issue 2, December 2023
Pages : 111-120

p-ISSN: 2621-3702
e-ISSN: 2621-7538

Diversity and community structure of soil microarthrophods of several moorlands in Gumukmas District, Jember Regency, East Java

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ABSTRACT

The effectiveness of soil microarthropods as a bioindicator was studied to evaluate various soils in the conditions of various lands, including moorland in Gumukmas District, Jember Regency. This study focuses on data collection of the diversity and structure of soil microarthropod communities along with the assessment of their ecological parameters. Field observations were carried out in five villages in Gumukmas District from August-September 2022 using the hand sorting method. The data were analyzed using α-diversity parameters (Dominance Index, Simpson Index, Evenness, Shannon-Weiner Index, Brillouin Index, and Margalef Species Richness). Habitat similarities were presented by UPGMA multivariate analysis and the estimation of abiotic factors that influence soil microarthropod composition was estimated by Canonical Component Analysis (CCA). The observations showed a total of 24 families from 13 soil microarthropod orders that spread across Gumukmas District. The abundance of diversity based on the α-diversity is still relatively low to moderate, nevertheless, the correlation of microarthropod orders to environmental factors can reveal conditions of the soil cycle through the study site. The results of the study are expected to assist in efforts to restore the diversity of soil microarthropods to support better soil quality.

Keywords: Diversity and communities, Gumukmas district, moorlands, soil microarthropods

INTRODUCTION

Jember Regency is one of the important areas that play as a fulfiller through food commodities in East Java Province, Indonesia with a production supply of 20% in 2018 (Dinas Ketahanan Pangan Jawa Timur, 2022). By sources, most of the food commodities of Jember Regency has produced from agricultural land which covers 165.058,39 hectares area span (50.11% of the area). It is classified into rice fields (covering 86.685,56 hectares (26.32%), gardens (covering 34.590,46 hectares (10.50%), and moorlands/tegalan (covering 43.782,37 hectares (13.29%) spread across 31 sub-districts, including Gumukmas District (Pemerintah Kabupaten Jember, 2015). Gumukmas District, in this case, has served as a lowland agricultural area (within the land elevation range of 0-2°). Through the records of Gumukmas agricultural area, the rice field reaches 4.767 hectares, the moorlands area covers around 1110 hectares, and 297 hectares are used as gardens (BPS Kabupaten Jember, 2017).

Based on the type of planting pattern, rice fields and gardens tend to apply a monoculture system (Badan Standarisasi Nasional, 2010) as a form of intensification of primary income, while moorlands mostly were inclined to implement a polyculture system, as the reason for flexibility care (Hani & Suryanto, 2014). So far, the polyculture system applied to moorlands could be adopted from agroforestry, silviculture, or even permaculture patterns with a system of structuring and mixing vegetation based on strata and habitus (King & Chandler, 2022: Bidura, 2017). The adaptation of mixing vegetation in moor ecosystems naturally forms biological cycles including food chains and energy flows so that it has the potential to increase land productivity independently (Zahro et al, 2017).

So far, in Jember Regency, especially Gumukmas District, this potential has not been studied in detail which requires preliminary studies.

One of the procedures that can be used to analyze the productivity of moorlands is examined the biological components inside the soil (O'Neill et al., 2005). Soil acts as a microhabitat that serves its climatic conditions, so it could support the life of biotic organisms, including the diversity of soil microarthropods (Garcia-Pallacios et al., 2013). This group also consists of mesofaunas which have similar behavior to terrestrial-fossorial arthropods (Prasetiani et al., 2019). Soil microarthropods hold important niches as detritivores. They broke fragments from the remains of living beings (detritus) before entering the decomposition process which is carried out by fungi and bacteria (Neher & Barbercheck, 2019). Also, they can be used as a bioindicator to determine the condition of the soil (Leksono et al., 2018).

The use of soil microarthropods in analyzing soil quality has so far indeed been widely implemented in various agricultural landscapes such as in Australia, American plains, and Europe as well as various regions in Asia (O'Neil et al., 2010) because it is considered an effective bioindicator (Neher & Barbercheck, 2019; Landi et al., 2020). This reason refers to the character of soil microarthropods that are following the rules of bioindicators including responsive, cheap, analytical, representative, actual, easy to obtain, and identify (O'Neil et al., 2010). Although identification up to the species level is quite limited due to the high morphological variations (Greenslade, 2007), the richness of existing families and orders can describe the ecological conditions of the soil in detail based on an assessment of diversity, community structure, and presence (Menta & Remelli, 2020). In addition to soil microarthropods, other measurements against abiotic factors include physics: (temperature and humidity); chemical (pH and litter thickness); and other supporting biological factors such as the percentage of canopy cover can also complement the detailed discussion of soil conditions (Kazemi et al., 2009; Rohyani, 2021).

The soil microarthropods in this study have been carried out on several moorlands in Gumukmas District, focusing on data collection of diversity, community structure, and assessment of ecological parameters using α-diversity. In addition, we also use habitat similarity and investigate the correlation between soil microarthropods to abiotic factors were evaluated using Canonical Component Analysis. The results of this study are expected to complete basic information to induce ecosystem management in moor management effectively. In addition, the data from the study can also be developed to become an accelerator for composting systems to support soil quality, especially in Jember Regency.

METHOD

Study area

Soil microarthropod studies were carried out on moorland spread across five villages in Gumukmas District, including Menampu, Gumukmas, Tembokrejo, Bagorejo, and Purwoasri. Each of the villages is represented by three site points (Figure 1).

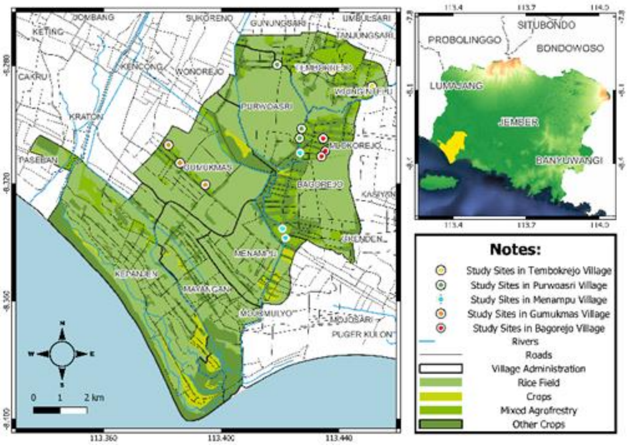

Figure 1. Map of sampling locations in Gumukmas District, Jember Regency, East Java Province.

By the preliminary survey, the moorland at all stations is secondary agricultural land that is managed independently by the surrounding community with variations in vegetation components from various habitus. The represented commodities grown from moorland in Gumukmas District include annual fruits, timbers, coconut, hardwood, cassava, herbal medicine plants, and various other commodities. Based on the type of moor soil, Gumukmas District is classified as an entisol (Mas'udi et al., 2021).

Field observations, sampling techniques & species identification

Field observations were carried out during August – September 2022. Soil microarthropods samples were taken using hand sorting techniques (Blume et al., 2016) by combing litter, weathered wood, and soil on each plot for 30 minutes using a shovel, sickle, and scratch. The soil microarthropods that have been taken are then put in plastic containers containing a mixture of litter, weathered wood, and soil from each plot that is moistened with a little water to maintain moisture. In addition to microarthropod samples, measurements were also made of abiotic factors in each field including Soil temperature, air temperature, Soil humidity, Air humidity, soil pH, litter thickness as well as supporting biological factors such as the percentage of land canopy cover (Table 1).

Table 1. Abiotic factors of moorland in five villages in Gumukmas District.

Location (Villages)	**pH**	**Soil Humidity (%)**	**Soil Temperatures (C °)**	**Air Humidity (%)**	**Air Temperature (C °)**	**Canopy cover (C °)**	**Litter Thickness (cm)**
Menampu	6.73 ± 0.25	96 ± 3.46	28.6 ± 0.26	94 ± 6	30,26 ± 0,64	65,6 ± 1,63	1.63 ± 0.51
Gumukmas	6.5 ± 0.36	34.33 ± 4.04	28.1 ± 0.2	88 ± 1	30,93 ± 0,64	63,93 ± 5,45	1.23 ± 0.25
Tembokrej	6.8 ± 0.2	72.33 ± 2.08	27.23 ± 0.51	83,67 ± 0,28	31,76 ± 0,47	61.46 ± 3.29	1.1 ± 0.1
Bagorejo	6.93 ± 0.11	60.67 ± 8.14	27.3 ± 0.34	70,63 ± 1,87	35.23 ± 0.87	81,36 ± 0,97	0,73 ± 0,25
Purwoasri	6.97 ± 025	58,67 ± 4,04	26.07 ± 0.2	94.33 ± 1.52	28,7 ± 0,62	53,43 ± 2,85	0,5 ± 0,1

Samples in plastic bottles were taken to the Laboratory for extraction using Berlese-Tullgreen funnel (mesh ± 2 mm) (Sapkota et al., 2011). The heating of the sample uses a 25W bulb, while the container is filled with 70% alcohol for specimen preservation. The extraction process is carried out for 72 hours until the sample containing the soil suspension, litter, and wood fragments completely dries out. Specimens in the shelter container are sorted using a tweezer and observed with a stereo microscope, type Leica MZ75. The process of identifying microarthropod specimens is based on the following references (Eisenbeis & Wichard, 1987; Krantz, 1971; Green et al., 1990; Noël & Séchet, 2007; Hidayat et al., 2022). Soil microarthropod samples were quantified and grouped by order and family distinguished at each station.

Data analysis

The diversity of soil microarthropod between sites was statistically described using alpha-diversity parameters. These parameters include taxa diversity (familial and order), Dominance index, Simpson Index, Evenness, Shannon-Wiener Diversity Index, Brillouin Index and Margalef Wealth Index. The index has described below:

1. Simpson's Dominance Index (Brower, 1990)

$$Di = \sum_i \left(\frac{n_i}{N}\right)^2$$

Where: Di = Dominance Index
n_i = number of individuals in each family
N = Total number from all families

2. Simpson's Diversity Index (Brower, 1990)

$$D = 1 - Di$$

3. Buzas-Gibson's Evenness (Buzas & Hayek, 2005)

$$E = e^H / S$$

Where: E = Buzas-Gibson's Evenness
e^H = Logarithm base for Shannon-Wiener index
S = Familiy richness

4. Shannon-Wiener Diversity Index (Odum & Barrett, 1971)

$$H' = -\sum ni.N^{-1}.\ln\,(ni.N^{-1})$$

Where: H' = Shannon-Wiener Index
ni = number of individuals in each family
N = Total number from all families

5. Brillouin's Index (Brillouin, 1956)

$$\dot{H} = 〖(\ln〗 \ (N!) - \ln\sum_i ▒ \ 〖\ln_i (n!))/N〗 \ \hat{}$$

Where: $\dot{H}$ = Brillouin's Index
N! = Total number from all families
n = Total of individual numbers by the sample

6. Margalef's Index (Clifford & Stephenson, 1975)

$$d = \frac{S-1}{\ln(n)}$$

Where: d = Margalef's Index
S = Total number of families
n = Total of individual numbers by the sample

The community structure of soil arthropods is also estimated using the Importance Value Index (IVI) (Misra, 1980). In addition, the composition between soil microarthropods and abiotic factors measured in each village is also analyzed using Canonical Component Analysis (CCA) and habitat similarity characters were also analyzed using multivariate clustering Unweighted Pair Groups Method and Arithmetic Mean (UPGMA) on PAST Application 4.07 (Hammer et al., 2021).

RESULTS AND DISCUSSION

Diversity and community structure of soil microarthropods

The identification of 173 specimens exposed 24 families of 13 orders of soil microarthropods scattered on moorlands from five villages (Figures 3A, 3B). Specimen sorting shows that in Purwosari there are 6 families and 3 orders of 44 individuals, Tembokrejo there are 10 families and 8 orders of 31 individuals, Gumukmas there are 10 families and 5 orders of 34 individuals, Bagorejo there are 10 families and 6 orders of 38 individuals, and Menampu there are. 10 families and 7 orders of 26 individuals. The diversity variations in the order and microarthropod family through villages can reflect that each moorland has a different character, even though there is one order found in all villages, collembola (encompassing the two families Tomoceridae and Entomobridae). These two families collembola are contribute to the nitrogen and carbon cycles that affect the condition of the soil microstructure (Joimel et al., 2021; Eisenbeis & Wichard, 1987). In addition, the magnitude of the contribution of each soil microarthropod family in structuring a community is estimated by the value of the IVI (Figure 3C).

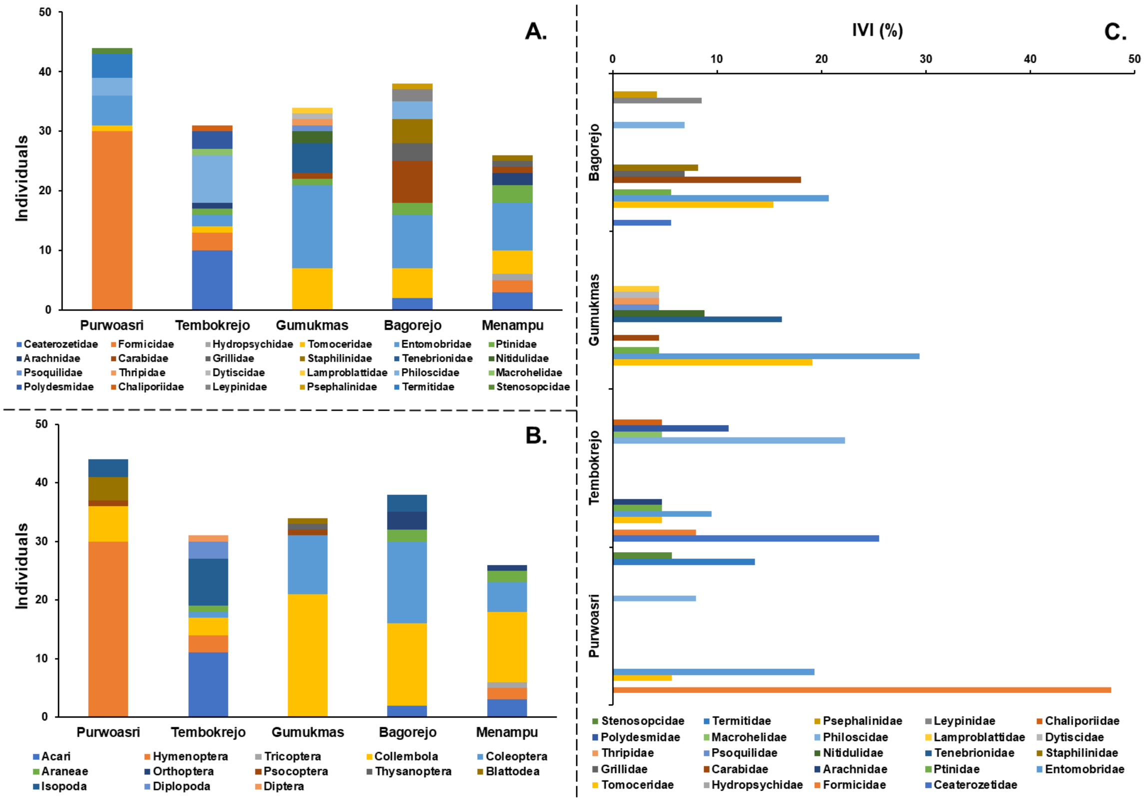

Figure 3. The diversity of soil microarthropods in each village in Gumukmas District: A. Family, B. Ordo, and C. IVI.

Based on the IVI values integrated with the estimated attendance according to the parameters of alpha-diversity (Dominance (Di), Simpson Index (D) and Abundance (E)) (figure 3), the four locations have a relatively low dominance level, but in Purwoasri Village there is almost a predominance of the Formicidae family. Formicidae is known as a family that lives colonially and is widespread in different parts of the world (Austin & Dowtown, 2000). Ecologically, Formicidae generally has a role as a soil architecs by building its nest tunnels in the soil to improve oxygen circulation (Meilina et al., 2017). However, there are species of Formicidae that can also cause diversity damage in the form of invasion using formic acid (Siriyah, 2016), such as *the Anoplolepis gracilipes* found in Purwoasri Village. Therefore, to control the population of *A. gracilipes,* an initiation of biological control is needed to restore the condition of the moor, especially Purwoasri Village in the future.

Table 2. α-diversity parameters from five villages in Gumukmas District.

Parameters	Villages				
	Menampu	**Gumukmas**	**Tembokrejo**	**Bagorejo**	**Purwoasri**
Dominance (Di)	0.13	0.22	0.17	0.12	0.48
Simpson Index (D)	0.87	0.78	0.83	0.88	0.52
Shannon Wiener Index (H')	2.22	1.89	2.04	2.24	1.14
Evenness (E)	0.92	0.66	0.77	0.94	0.52
Brillouin (Ḣ)	1.64	1.45	1.55	1.79	0.93
Margalef (d)	2.76	2.55	2.62	2.47	1.32

Estimation of soil microarthropods in each village based on the assessment of the Shannon-Wiener Index (H'), Brillouin (Ḣ), and Margalef (d) (Table 2), indicated at moderate levels (Bagorejo Village, Menampu Village, and Tembokrejo Village) to low (Gumukmas Village and Purwoasri Village) (Odum & Barrett, 1971; Brillouin, 1956; Clifford & Stephenson, 1975). This refers to the value of each diversity indicator where H' ranges from 2.22-1.14, Ḣ ranges from 1.79-0.93, and d ranges from 2.76-1.32. The abundance of diversity of soil microarthropods is strongly influenced by the presence of causative factors both natural and artificial. Natural factors include soil type, size of dry leaves or litter as the main material for decomposition, diversity of vegetation taxa, the presence of terrestrial macrofauna as biomass-producing agents, and the physical and chemical microclimatic conditions of the area (Kazemi et al., 2009). Artificial factors include various anthropogenic activities, including the use of pesticides and synthetic chemical fertilizers, as well as littering and waste disposal (Joy et al., 2005). Principally, α-diversity has been widely used to measure actual intra-community diversity on the habitat level (Thukral, 2017). In these cases, the character of soil microarthropod communities in each village was compared and visualized based on community assessment e.g., evenness (to detect an effective number on each family abundant from total family measurement), Simpson and dominance index (to quantify the total communities and families contribution on each village), and biodiversity index (Shannon-Wienner, Margalef, and Blirrouin to measure diversity condition qualitatively based on family abundance calculations) (Brower, 1990; Buzas & Hayek, 2005; Odum & Barrett, 1971; Brillouin, 1956; Clifford & Stephenson, 1975). The higher or lower scores simply represent the multitrophic interaction between ecosystem properties that be complemented by field information (Menta & Remelli, 2020).

So far, based on the combined information in Figure 3 and the estimated diversity index in Table 2, three factors are assumed to be the cause of the diverse conditions of all study sites including 1. types of moor soils of the entisol type which naturally have low organic matter content and are hard and dense textured (Mas'udi et al., 2021), 2. the use of synthetic fertilizers on the land so that may influence the condition of the organic components of the soil (Joy et al., 2005), 3. and the relatively close distance of the moorland from non-organic rice fields, allowing residues of inorganic matter to enter the moorland area as adjacent effect (Zermeno-Hernandez et al., 2020). This condition underlies the consensus that efforts to increase natural soil fertility levels are a necessary step to improve the productivity of moorland in the study of sites and related locations further.

Clustering and composition of microarthropod orders towards soil abiotic parameters

The results of clustering by UPGMA reveal five villages of study sites showed two clusters: cluster 1 (covering Bagorejo, Menampu, and Gumukmas) and Cluster 2 (covering Tembokrejo and Purwoasri) (Figure 4). The separation of the two clusters may be caused by the resemblances of moorland types as soil microarthropod habitats. A similar condition such as soil microclimatic might also influence the model of distribution and composition of the microarthropod order in each cluster (Villareal-Rosas et al., 2013).

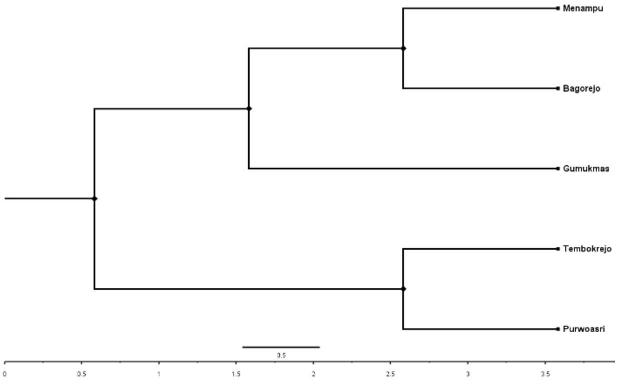

Figure 4. Dendrogram of habitat similarity by UPGMA. Two clusters distinguish the conditions of the five study sites.

The composition of the soil microarthropod order through the seven abiotic parameters (pH, Soil Humidity, Soil Temperatures, Air Temperatures, Air Humidity, Canopy Coverage, and Litter Thickness) of the soil were expressed by a CCA. The result of the analysis reflected 87.83% of the information expressed by the values of CC1 and CC2 (Figure 5). Based on the study site, Gumukmas, Bagorejo and Menampu have similarities in terms of abiotic factors including litter thickness, air temperature, soil temperature, and canopy cover which are strongly correlated with the existence of the order Araneae, Orthoptera, Tricoptera, Collembola, Coleoptera, and Thysanoptera. The order Araneae contributed specifically as predators to control the population of other orders as the main diets. They might use the fallen leaves to hide and ambush their prey (Pereira et al., 2021) The entire family of the order Collembola and some families of Coleoptera contribute to the decomposition of detritus (Ptinidae, and Tenebrionidae) (Joimel et al., 2021; Bell & Phillips, 2012; Cheli et al., 2021), but there are also families of Coleoptera that fill the predator niches such as (Carabidae, Staphilinidae, Nitiduliidae, and Dysticidae) (Holland, 2002; Winasa et al., 2007; Bartelt et al., 1995; Yee, 2014). The order Orthoptera and Thysanoptera, both are known to use soil as a habitat for nesting, although there are differences in their diet niches. Orthoptera represented by the family of Grillidae tend to be omnivorous (Gawałek et al., 2014), while the order Thysanoptera are generally herbivores (Mound and Teulon, 1995). In addition, the existence of the order Tricoptera in this observation requires confirmation, study, and further study because the order is more inclined to be in aquatic habitats (Vasiliu-Oromulu et al., 2008).

The presence of pH and soil moisture in Tembokrejo strongly correlated with the order Diplopod, Diptera, Acari, and Isopods. Diplopods represented by the family Polidesmidae are known to act as saprophages with a diet covering fragments of leaves, fruits, flowers, and wood remains, similar to the order of Isopods represented by the family Philloscidae (David, 2009). The Acari order, which includes the group of mites, is distinguished into two functions, as a parasite that infects eggs of the insect's groups or

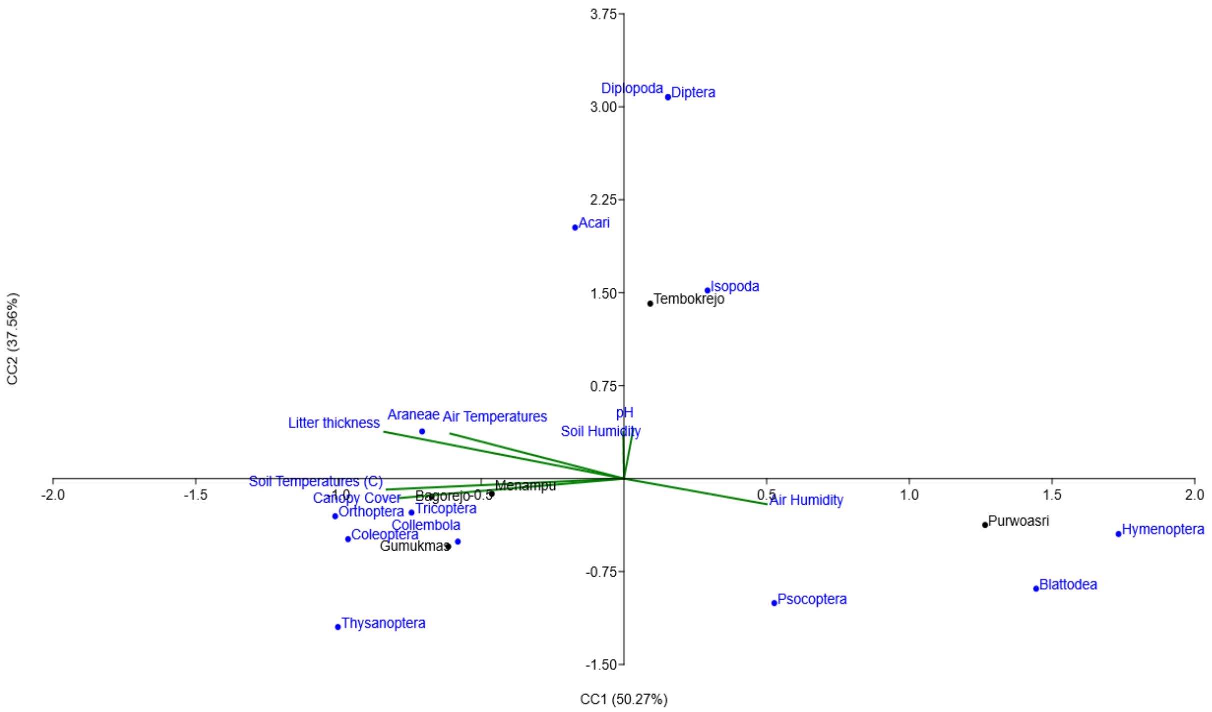

Figure 5. The results of *Canonical Component Analysis* (CCA) show the correlation of the order of soil microarthropods to environmental factors.

an associator by carrying out protection of insect eggs or skin (Khaustov et al, 2018), in this case it may include the Diptera group. The order Diptera of the family Chaliporiidae found in the larval phase may indicate the presence of feces or carcasses in the sampling area, as their sources to get food (Heath, 1982; Stoffolano, 2022). The humidity of the air in Purwoasri is strongly correlated with the orders Psocoptera, Blattoidea, and Hymenoptera. Psocoptera includes booklice (family Stenopsocidae) feeding on microepiphytes present on the surface of the soil as well as plants (Anonby, 2019). The Blattodea represented by Termitidae contributes to the breakdown and digesting of detritus such as cellulose-rich wood residues. In addition, the similarity of this family of Termitidae with the order Hymenoptera (family Formicidae) is to create a web of soil labyrinths useful for soil air circulation (de Oliveira et al., 2022; Meilina et al., 2017). This condition can be an assumption if the air humidity in Purwoasri may have supported the ecological response in the Formicidae and Termitidae families.

CONCLUSION

The diversity and structure of the microarthropod community of the moorland of the five villages in Gumukmas District represent varied soil conditions, with the largest abundance of families and orders found in Tembokejo. However, based on alpha-diversity ecological parameters that show low to moderate levels, it indicates the need for moor rehabilitation efforts to restore the diversity of soil microarthropods in the future. In addition, the correlations shown by the CCA show a specific contribution to each abiotic component of the land in supporting the composition of the soil microarthropod order at the study site.

ACKNOWLEDGMENT

We would like to express our gratitude to Mr. Pitoyo as a field companion during the research and data collection process. We are also grateful to the reviewers who have helped throughout the process in publication. Thanks to the Faculty of Mathematics and Natural Sciences, Universitas Brawijaya as a facilitator with DPP / SPP funds

(Community Service Contract No. 2459 / UN10. F09/PN/2022).

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