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Soil arthropod diversity in three different land management intensities of Wanagama Forest, Yogyakarta, Indonesia

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Abstract. *Damayanti A, Triyogo A, Musyafa. 2023. Soil arthropod diversity in three different land management intensities of Wanagama Forest, Yogyakarta, Indonesia. Biodiversitas 24: 1799-1808.* Soil arthropods represent a wide range of ecological functions, and information on their abundance and diversity can be used as an indicator of the health and fertility of an ecosystem. Land use development, techniques, frequency, and management intensity can affect the arthropod soil population. The purpose of this study was to investigate how arthropods respond to soils managed in (NM) in various ways, such as intensive management land (IM), medium land management (MM), and land without management (NM). Field data was collected on the three areas for three months using an observation plot of 20x20 m^2, followed by soil and litter samples taken using the monolith method from five points measuring (50x50x5) cm^3 in each observation plot. Pitfall traps and the Berlese-Tullgrenn method were used to collect the soil arthropods from the sample monolith of each plot. As a result, seven dominant taxa of soil arthropods were identified: Collembola, Formicidae, Acari, Araneae, Coleoptera, Gryllidae, and Termitidae. This study found a significant difference in arthropod soil abundance based on land type, with NM, MM, and IM having the highest abundance, respectively. Individual abundance, however, was not followed by arthropod soil richness. With a diversity index of 3.61, MM has the highest species richness, followed by IM (3.03) and NM (0.39). Morphospecies diversity differences within each taxon follow land type differences. This study shows that different environmental conditions occur due to differences in land management, which can impact the population, abundance, and diversity of soil arthropods. Furthermore, the frequency and intensity of land management should be evaluated to ensure that people do not have a negative impact on the presence of beneficial soil arthropods.

Keywords: Arthropod diversity, land use management, soil arthropod, pioneer

INTRODUCTION

Forests provide an ecosystem that supports many animals (Brockerhoff et al. 2017), especially soil arthropods (Ghazali et al. 2016). Soil arthropod population was considered an important component in the ecosystem, which role in carbon and nutrient cycling by modulating the quality and quantity of resources (Yang and Gratton 2014). Furthermore, their contribution through the decomposition and humification of the organic matter impacts soil health (Bagyaraj et al. 2016; Meehan et al. 2019; Neher and Barbercheck 2019). Thus, their presence is an essential indicator of soil health (Gossner et al. 2014). Despite their positive effect on the ecosystem, soil arthropods are very sensitive component as their community structure is affected by the environment, vegetation cover, and climate (Ball et al. 2022), habitat disturbances (Perry et al. 2018), and soil management practices (Gonçalves et al. 2020). However, anthropogenic changes in forest land could impact soil arthropod diversity (Birkhofer et al. 2015). Several researchers have described how arthropod diversity develops under different environmental conditions (Scholwater 2016) and how anthropogenic changes, such as intensive land management, affect soil arthropod diversity (Košulič et al. 2021).

Indonesia has various land management practices for forest ecosystems, such as agroforestry and community forest. The agroforestry system aims to improve the land condition through intensive management (Achmad et al. 2022), preserve the environment, and improve community welfare (Hasannudin et al. 2022). Agroforestry is believed to be able to maintain agricultural products and supports livelihoods (Pandit et al. 2014) while at the same time being able to maintain biodiversity (Reith et al. 2022). One of the strategies to increase agroforestry products is to increase the diversity of the crops. Nonetheless, the need to gain high productivity from the various types of land is still debatable. As a practical land use management, farmers manage agroforestry by combining several components of crops and trees on a unit of land and do regular agricultural practices such as cultivation, burning, and weeding (Altieri et al. 2015). For instance, intensive practice land management had a dramatic negative effect on specialist species of ants (Asfiya et al. 2015).

Community forests are very important for the multiple ecosystem service values such as being a buffer for the ecosystem, carbon storage, ecological stability, water provision (Birch et al. 2014), and supporting the livelihood around the forest. As the next stage of agroforestry, community forest has a more complex ecosystem with less management intensity (Triyogo et al. 2017). It has diverse trees and understoreys planted randomly. The density is higher (Jactel et al. 2017), so they provide more organic matter, especially litter production (Donoso et al. 2013), a food source for soil arthropods. The trees and variety of understorey vegetation contribute to preserving soil arthropod diversity (Pardon et al. 2019) and conservation (Villanueva-Lopez 2019). In this study, the community forest is referred to as a mixed forest managed by the local farmer.

However, agroforestry and community forests have a land use management system different from pioneer land or undisturbed ecosystem. Land intensification is hypothesized as the leading diversity loss (Lichtenberg et al. 2017); meanwhile, the soil arthropod diversity is higher in the undisturbed ecosystem (Scholwater 2017). The Wanagama Education and Research Forest (ERF) I, as a model of the restoration project area in Yogyakarta, Indonesia, provides agroforestry and mixed forest and pioneer land. Compartment 6 in Wanagama ERF represents the pioneer (Triyogo et al. 2020), land undisturbed by any human activities and suitable for ecological studies. As an ecological process, the forest succession process could affect the structure and diversity of the soil arthropod community (Deng et al. 2022). Thus, the objectives of the present study were (1) to determine soil arthropod diversity in three different lands of forest ecosystems and (2) to understand the effect of different characteristics of forest ecosystems which may impact soil arthropod community.

MATERIALS AND METHODS

Study area

This study was conducted in Wanagama Education and Research Forest (ERF) I area, Gunungkidul District, Yogyakarta Special Region Province, Indonesia. The location was distinguished by vegetation component and different management land intensities such as intensive land management represented by agroforestry (IM), medium land management represented by mixed-forest (MM), and land with no management system represented by pioneer forest (NM) (Table 1). Sampling was carried out for three months (August-October 2021) to collect data on soil arthropod diversity and environmental measurement (Table 2). The environmental data were recorded by each plot, including temperature and humidity, obtained by thermohygrometer DEKKO 642N, the light intensity measured by light meter LX-101A, and pH level was tested by Kelway Instrument (Typ-36 TEW). All environmental data was taken during the daytime at around 12.00 to 02.00 PM (Triyogo et al. 2022).

Soil arthropod collection and identification procedure

Considering land conditions and topography, three replications of the square plot (20 x 20) m^2 were made by purposive sampling for each land use. Hence, there were nine plots of observation in total. Soil-surface arthropod was collected using hand sortation and pitfall trap (Triyogo et al. 2020; Knapp et al. 2022), whereas the soil-living arthropods were obtained by monolith method (Gonçalves et al. 2020). Nine pitfall traps were set for 2x24 hours in the center of the individual plot using a grid pattern (Triyogo et al. 2017). Thus, 81 pitfall traps for all land use were collected every month. The monolith method was done by digging (50 x 50 x 5) cm^3 of soil by the corner and center of each plot. Further, five points of monolith composited to obtain 1 kg of soil and 1 kg of litter continued to extract with the Berlese-Tullgrenn funnel (Vanhove et al. 2016). One kilogram of soil sample or litter sample was put inside the funnel. The duration of extraction was 96 hours or more, depending on soil conditions. Soil arthropods moved through the sieve and funneled slope because of the light bulb's heat and finally reached the bottle containing 70% ethanol (Fekkoun et al. 2021). Arthropods specimen were observed using a stereo zoom microscope (Carton DSZ44) and identified up to taxa group and family level using Triplehorn and Johnson (2005), Krantz (2009), inaturalist.org, and bugguide.net.

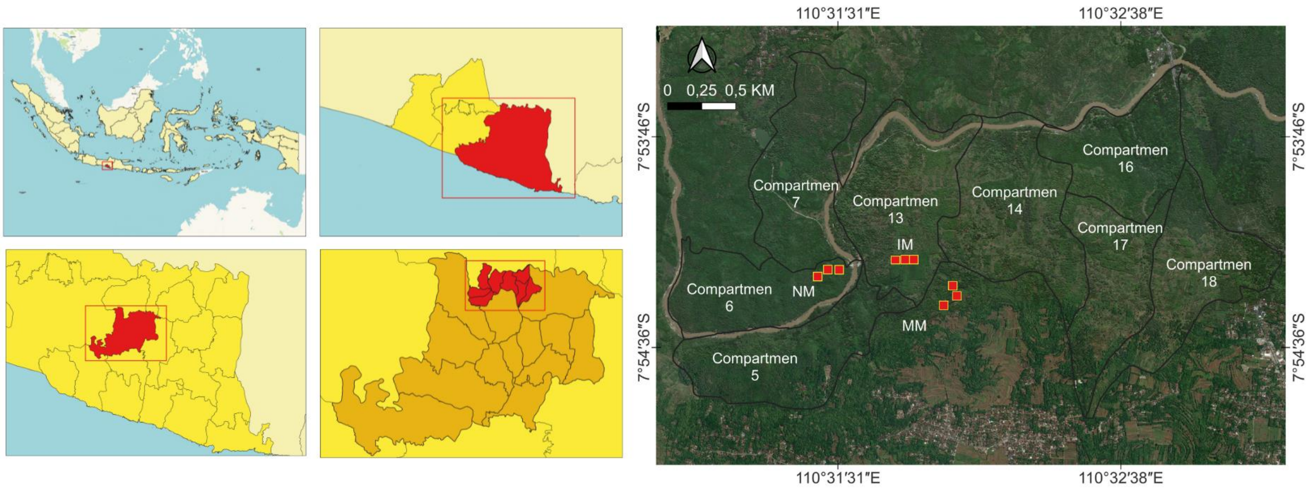

Figure 1. Research site in Wanagama Education and Research Forest (ERF) I of Gunungkidul District, Yogyakarta, Indonesia show each land use management, Intensive land management (IM) in compartment 13 area; medium land management (MM) in Banaran Village area; and no management (NM) in compartment 6 area

Table 1. Comparison of vegetation component and management intensity on three different land use

Parameters	Intensive management	Medium land management	No management
Vegetation characteristic	Crop (dominant), grass, wood	Wood (dominant) and shrub	Wood (dominant) and shrub
Vegetation component	Cassava (*Manihot utilissima*), pineapple (*Ananas comosus*), nut (*Arachis hypogaea*), teak (*Tectona grandis*)	Teak (*Tectona grandis*), mahogany (*Swietenia mahagoni*), fruit trees such as banana (*Musa* sp.)	Pioneer vegetation such as *Gliricidia sepium*, *Caesalpinia sappan*, *Melaleuca cajuputi*, *Santalum album*, *Anthocephalus cadamba*, *Calophyllum inophyllum*
Canopy cover	<50%	>50%	>50%
Land management	Planting, weeding, fertilizing, litter burning	Woodworking	None
Frequency of land management	Regular	Irregular	None

Table 2. Environmental factors among three different lands during observation (August, September, and October)

Environmental factor	Intensive management	Medium land management	No management
Soil temperature (°C)	35.17 ± 0.82	28.22 ± 0.45	30.43 ± 0.57
Soil humidity (%)	65.44 ± 1.68	79.00 ± 3.16	70.78 ± 4.87
Air temperature (°C)	36.32 ± 0.77	29.70 ± 0.33	32.39 ± 0.57
Light intensity (lux)	1685.89 ± 278.06	2389.89 ± 279.22	2229.22 ± 607.12
Litter thickness (cm)	0.14 ± 0.058	3.56 ± 0.05	2.23 ± 0.03
pH level	6.92 ± 0.02	6.84 ± 0.05	6.97 ± 0.02

Data analysis

The field data of soil arthropods were recorded based on land use and then classified as their taxa group. The differences in insect abundance in three land-use intensities management presented on a mean abundance of taxa per trap (combination of hand sortation, pitfall, and monolith) with error standards. The significance of differences in arthropod abundance in three land types was measured by one-way analysis of variance (ANOVA) using SPSS ver 25. Diversity was estimated by Shannon-Wiener Diversity Indices (H'), richness indices, and evenness indices. Therefore, to assess which environmental drivers are significantly correlated to the taxa abundance, Principle Component Analysis (PCA) was used with the function of the vegan R package in software R studio v. 1.4.1717.

RESULTS AND DISCUSSION

Soil arthropod diversity

The field study of three different land use intensity managements showed various soil arthropods population belonging to Collembola, Formicidae, Acari, Coleoptera, Araneae, Gryllidae, Termitidae, and others (Table 3). A total of 38,947 individuals of soil arthropods were recorded during the study. Out of these, 35,627 individuals were from pioneer land (NM), 2168 from the mixed forest (MM), and 1152 from agroforestry (IM). The result of the study revealed the presence of 403 morphospecies under seven taxa of soil arthropods in the area of Wanagama Education and Research Forest I. Among all the groups of arthropods, Collembola, Formicidae, and Acari were the predominant group in all research sites, with a total composition of more than 50% in each land type (Table 3). Furthermore, there is a significant effect on the relative abundance of Collembola, Acari, Coleoptera, and Gryllidae but no significant effect on Formicidae, Araneae, and Termitidae (Figure 2). Overall, the family diversity of the soil arthropods in three intensities management showed in Table 4.

Our result showed a high comparison among three different intensities of land management. The diversity indices explained by Shannon-Wiener, richness, and evenness indices showed that IM and MM had a high number. Nonetheless, NM had the lowest number in each criterion, explaining the lowest diversity and distribution despite its richness indices being in high number in 16.69 (Table 5).

Factor affecting soil arthropod diversity

The PCA result showed that the six environmental factors could explain 59.5% of the total variation on the x1 axis and 20.3% on the x2 axis of the total variation. The distribution of soil arthropods is influenced by environmental factors (Figure 3).

Table 3. Relative abundance of different groups of soil arthropods in three different forest ecosystems

Group of taxa	Intensive land management	Medium land management	No management
Collembola	31.51% (363)	23.66% (513)	94.21% (33,564)
Formicidae	49.39% (569)	46.13% (1000)	2.55% (907)
Acari	1.91% (22)	13.98% (303)	1.29% (459)
Coleoptera	3.82% (44)	3.74% (81)	1.23% (437)
Araneae	4.86% (56)	4.06% (88)	0.12% (41)
Gryllidae	2.08% (24)	2.12% (46)	0.17% (59)
Termitidae	1.74% (20)	1.94% (42)	0.12% (42)
Miscellanies	4.69% (54)	4.38% (95)	0.33% (118)
Total	1152	2168	35,627

Note: Miscellanies consist of 10 taxa with a total average of fewer than 0.5 individuals per trap

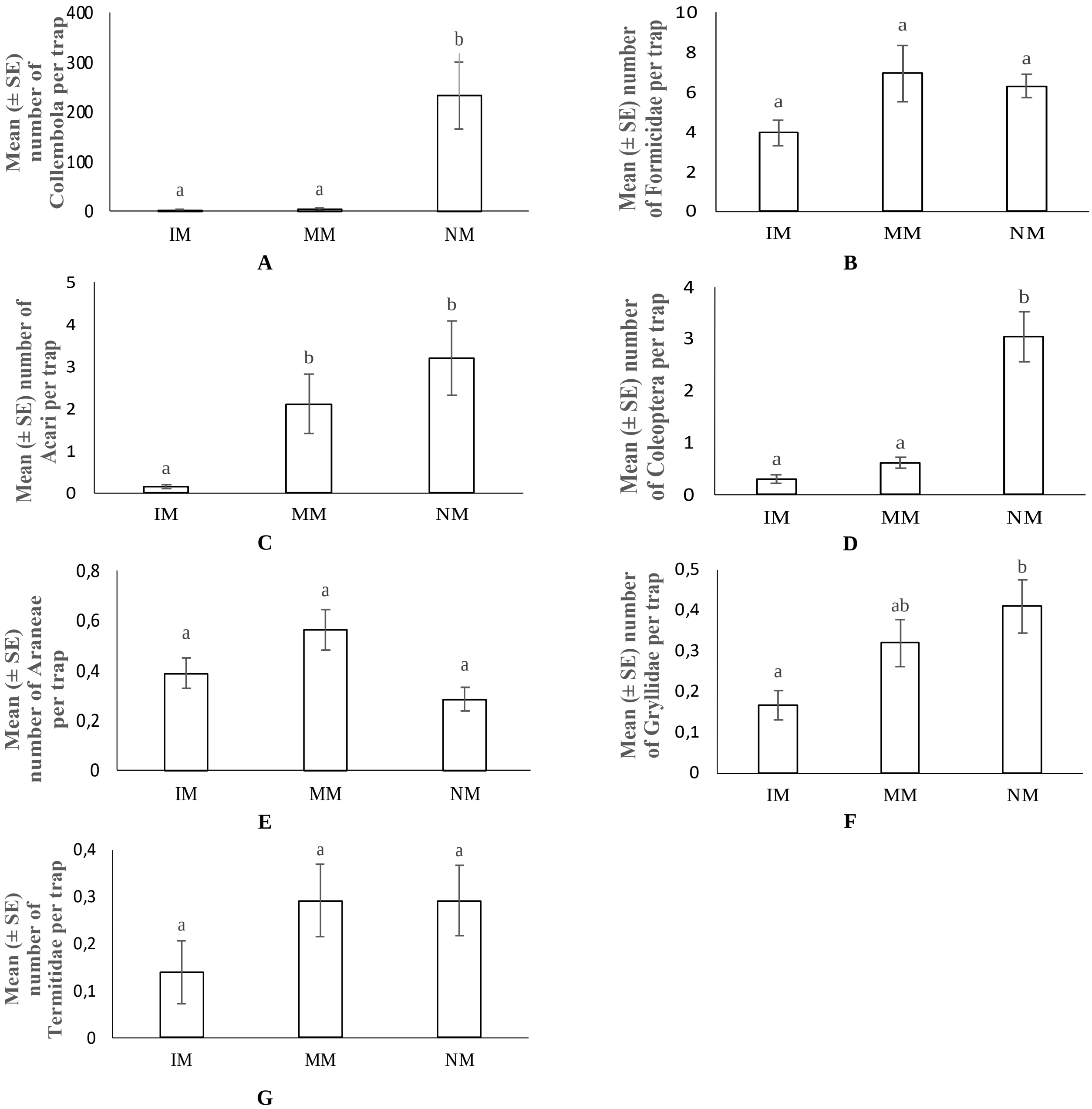

Figure 2. The mean number of soil arthropods per trap (A) Collembola; (B) Formicidae; (C) Acari; (D) Coleoptera; (E) Araneae; (F) Gryllidae; and (G) Termitidae in three different intensities land management. Different letters mark significant differences (p-value<0.001) (IM: Intensive Land Management; MM: Medium Land Management; NM: No Management)

Table 4. Soil arthropod structure on three different intensities of land use management

Class/ Subclass	Order	Sub Order	Family	Intensive land management		Medium land management		No management	
				NuM	NuI	NuM	NuI	NuM	NuI
Entognatha/ Collembola	Entomobryomorpha		Cyphoderidae	3	8	2	38	3	6
			Entomobryidae	-	-	6	26	2	16
			Isotomidae	1	1	1	7	-	-
			Paronellidae	4	9	3	4	1	6
			Tomoceridae	-	-	-	-	1	1
	Poduromorpha		Hypogastruridae	1	345	1	436	2	33535
			Neanuridae	-	-	1	1	-	-
			Onychiuridae	-	-	1	1	-	-
Insecta/ Pterygota	Hymenoptera		Formicidae	37	569	52	1000	30	907
	Coleoptera		Anthicidae	2	3	-	-	1	1
			Carabidae	-	-	3	3	1	1
			Chrysomelidae	1	1	-	-	-	-
			Cucujidae	1	1	-	-	-	-
			Curculionidae	-	-	-	-	1	2
			Dytiscidae	-	-	1	1	-	-
			Latridiidae	-	-	1	1	-	-
			Nitidulidae	1	21	2	6	1	5
			Scarabaeidae	1	9	4	30	3	15
			Scydmaeninae	1	1	2	3	2	3
			Staphylinidae	5	6	7	24	5	407
			Xyleborus	-	-	2	2	2	2
	Orthoptera		Gryllidae	13	24	14	46	12	59
	Blattodea		Kalotermitidae	1	1	1	1	-	-
			Rhinotermitidae	1	16	1	13	1	2
			Termitidae	1	3	5	28	6	40
Chelicerata/ Arachnida	Sarcoptiformes	Oribatida		5	12	16	281	17	437
	Trombidiformes	Prostigmata		5	9	4	7	6	10
	Parasitiformes	Mesostigmata		-	-	-	-	2	2
Chelicerata/ Arachnida	Araneae		Anyphaenidae	-	-	1	1	-	-
			Cheiracanthiidae	-	-	2	2	-	-
			Clubionidae	3	3	2	2	-	-
			Ctenidae	-	-	-	-	2	2
			Desidae	-	-	1	1	-	-
			Dictynidae	1	1	6	7	2	2
			Dysderidae	2	8	1	1	2	2
			Gnaphosidae	-	-	1	1	-	-
			Hahniidae	1	3	2	5	3	8
			Linyphiidae	3	5	10	19	3	10
			Lycosidae	6	20	7	23	2	2
			Mygalomorphae	1	2	1	2	1	1
			Oecobiidae	-	-	1	1	1	1
			Oxyopidae	1	1	-	-	-	-
			Phalangiidae	1	2	1	2	-	-
			Salticidae	1	2	1	1	6	6
			Sicariidae	3	5	2	15	2	2
			Sparassidae	-	-	1	1	-	-
			Tetragnathidae	1	1	2	2	1	4
			Theridiidae	2	3	2	2	1	1

Table 5. Diversity (H'), Richness, and Evenness (E) indices of soil arthropods in three different land managemen

	Intensive land management	Medium land management	No management
Shannon-Wiener Diversity Indices (H')	3.03	3.61	0.39
Richness Indices	20.85	29.81	16.69
Evenness Indices (E)	0.607	0.664	0.075

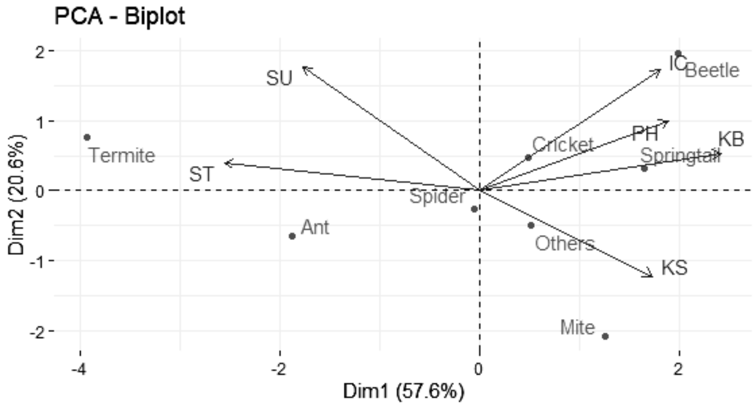

Figure 3. The PCA ordinance shows the composition of soil arthropods based on land type and environmental factors. Note: SU: air temperatur; ST: soil temperature; KS: litter thickness; KB: humidity; IC: light intensity; pH: soil pH

Discussion

Soil arthropod diversity

In this research, we investigated that soil arthropod diversity differs according to the intensity of land management and environmental characteristic in each forest type. The highest abundance of soil arthropods was found in a pioneer land with no management practice (Table 3). The pioneer land in compartment 6 Wanagama ERF I was an undisturbed forest covered by pioneer tree species and understories such as *G. sepium* and *C. sappan* (Triyogo et al. 2020). Most soil arthropods in each land management practice were Collembola, Formicidae, and Acari. This result also aligns with Eckert et al. (2022) and Roy et al. (2021), which stated that those three taxa dominated in undisturbed forest. The impressive abundance of Collembola found in pioneer land confirmed by Wale and Yesuf (2022) that Collembola is one of the dominant taxa found, especially in undisturbed forests.

The abundance of Collembola was higher in NM (233.08 ± 67.1 individual per trap) than in IM (2.52 ± 1.09 individual per trap) and MM (3.56 ± 1.64 individual per trap) (Figure 2A). There is a significant difference between the three land management intensities which Collembola abundance was significantly different in NM than its abundance in IM and MM (Collembola: df: 2; F value: 6.020; p-value <0.01). The abundance of Collembola had the same pattern as the abundance of Coleoptera, which has a high abundance in IM (0.30 ± 0.08 individual per trap); MM (0.61 ± 0.11 individual per trap); and NM (3.03 ± 0.48 individual per trap) (Figure 2D), where there was a significant difference in NM to another management practices (Coleoptera: df: 2; F value: 10.420; p-value <0.01). Those have a different result from other taxa, such as Acari and Gryllidae. The abundance of Acari differs, such as in IM (0.15 ± 0.05 individual per trap); MM (2.10 ± 0.70 individual per trap); and NM (3.18 ± 0.88 individual per trap) (Figure 2C). There was a significant difference in Acari abundance in MM and NM with IM (Acari: df: 2; F value: 13.269; p-value <0.001). In contrarily for the Gryllidae, a significant difference had shown only in IM and NM (Gryllidae: df: 2; F value: 4.461; p-value <0.01), with the abundance of Gryllidae in IM (0.16 ± 0.03 individual per trap); MM (0.32 ± 0.06 individual per trap); NM (0.41 ± 0.07 individual per trap) (Figure 2F). The abundance of Formicidae, Araneae, and Termitidae was not significant in three land management practices (Formicidae: df: 2; F value: 1.203; p-value >0.05); (Araneae: df: 2; F value: 2.779; p-value >0.05); (Termitidae: df: 2; F value: 2.703; p-value >0.05) (Figures 2B, E, G). Formicidae had known as ubiquitous arthropods, which can be found everywhere (Zina et al. 2022). Meanwhile, the Araneae had a high abundance in MN as it is easier to be found among diverse vegetation, especially in dense understories (Hunt et al. 2020). It has a consistent result with Pashkevich et al. (2022), which stated abundance of Araneae is not affected by management practice.

Despite the highest abundance in NM, this finding did not follow by the family richness. The family level identification showed MM had the highest richness of soil arthropods with 174 morphospecies. It is followed by NM (125 morphospecies) and IM (110 morphospecies) (Table 4). High family richness is found in a community forest with medium management practice, which had an irregular activity. As a consequence, it is likely that the canopy cover, understorey, and litter in community forest were more abundant and tended to be favored by the soil arthropods community (Perry et al. 2018; Pardon et al. 2019), especially for Collembola: Neanuridae, Onychiuridae; Coleoptera: Dysticidae, Latridiidae; and Araneae: Anyphaenidae, Cheiracanthiidae, Desidae, Gnaphosidae, Oecobiidae, Sparassidae which only can be found in community forest (Table 4). It had the greatest diversity because of rare disturbances, allowing the rich community to develop and persist (Kinnebrew et al. 2022). MM was characterized by diverse vegetation, which can increase the diversity of organisms (Triyogo et al. 2017). The presence of litter thickness in MM also contributes as soil organic matter to maintain the soil arthropod community (Potapov et al. 2017).

We found two families of Coleoptera (Chrysomellidae and Cucujidae) only occurred in IM. In the agricultural ecosystem, Coleoptera is often exposed by regular activities such as soil tillage and fertilizer application.

Chrysomellidae is known as a pest in the agricultural ecosystem. Their presence indicates ecological changes, especially in successional and vegetation structures (Sánchez-Reyes et al. 2019). Meanwhile, Cucujidae is a scavenger found in the agricultural ecosystem (Susilo et al. 2009; Na'im and Nasirudin 2021; Kubiak et al. 2022). Several families are only found in NM (Collembola: Tomoceridae; Acari: Mesostigmata; Araneae: Curculionidae and Ctenidae). During this study, NM has a lot of canopy gaps which may increase the abundance of Collembola: Tomoceridae (Perry et al. 2018). It is common to find Acari (Mesostigmata) less than other Acari's order because Mesostigmata has a different microhabitat, like a tree trunk (Seniczak et al. 2021). The highest family abundance in NM is Hypogastruridae. That is consistent with Perry et al. (2018) that Hypogastruridae is the highest family found in the undisturbed forest than other families of Collembola.

The result of the soil arthropod community's diversity, richness, and evenness indices calculation shows various values (Table 5). The richness and evenness indices have been combined mathematically in various ways to calculate diversity indices based on proportional abundance (Schowalter 2022). The Shannon-Wiener diversity indices (H') showed that IM and MM had 3.03 and 3.61, respectively, and NM had 0.39. Based on the value, the IM and MM had the same high diversity level, but NM was categorized as low diversity. The species richness indices showed IM, MM, and NM had a value of 20.85, 29.81, and 16.69, respectively. In addition, all of those land management practices had a high species richness diversity. For the evenness indices, IM and MM had 0.607 and 0.664; meanwhile, NM had 0.075. This result meant that the species distribution in NM was the lowest than other land practice management. On the evenness indices, a value close to 1 indicates that all species are in the same abundance. In the NM, the low evenness indices value indicates an uneven distribution of a species or family. In this study, some families in NM were not evenly distributed, such as Collembola: Hypogastruridae, which has an impressive abundance of up to 33.535 individuals. At the same time, some families like Formicidae, Staphylinidae, and suborder Oribatida also have a higher number than others (Table 4).

Factor affecting soil arthropod diversity

The previous study showed the importance of environmental factors under different land use management (Mhlanga et al. 2022). IM has a dynamic land development from time to time. The species selection to plant on this land, regarding vegetation, is limited depending on the benefit needed by farmers. Plants on IM were deliberately planted in regular maintenance, generally. Farmers in agroforestry compartment 13 Wanagama ERF I start cultivating the land at the end of August and plant the crops in early September or closer to the rainy season. The maintenance activities started with soil processing, including land clearing and soil tillage, giving fertilizer, planting, weeding, and litter burning every week. High management intensity in agroforestry is unavoidable and impacts the vegetation (Kinnebrew et al. 2022).

There is a relationship between the decrease in soil arthropod abundance and richness, with increased agricultural management intensity (Tsiafouli et al. 2015; Kinnebrew et al. 2022). That explained of almost all soil arthropod groups had a lower abundance in IM than in other lands (Figure 2). The diversity of functional arthropod communities decreases depending on pesticide applications (Sattler et al. 2020). Low species diversity will indicate habitat quality and an early warning disturbance to the land (Solar et al. 2016). The higher soil arthropod diversity means the soil is in good condition, and the lower diversity of soil arthropod diversity means the soil is in poor condition (Lestari and Susanti 2019).

However, agroforestry is mentioned as a win-win solution to increase community welfare and provide ecological benefits, proposed as a sustainable agricultural system that combines the old system of agriculture with the forestry ecosystem (Torralba et al. 2016; Murniati et al. 2022). Although IM has high diversity, richness, and evenness indices, their development needs to be evaluated because several families can be found in NM and MM but are absent in IM (Table 4); and IM also has the lowest abundance of each taxon (Figure 2). The absence of a functional group of arthropods in this land can threaten the ecosystem's quality. The family of arthropods that exist can be found in various habitats categorized as generalist species. On the contrary, those that can only be found in certain environmental factors are categorized as specialist species. These two groupings become a benchmark for a bioindicator (Taradipha et al. 2019). As some groups of arthropods have an imminent relationship with their habitat, it is important to observe the level of change by their presence or absence (Spiller et al. 2018).

Moreover, when compared to IM, MM has far less intensive land management. Generally, the mixed forest mentioned in this study is advanced agroforestry, where most plants are woody. There is no special maintenance, but the farmers usually prune the branches to make a growth space for the tree, harvest the grass to feed livestock, and cut the trees at irregular intervals. The lack of maintenance activities for the plants and the presence of litter left on the forest floor cause an abundance of food sources for soil arthropods. Thus, the abundance is higher, supported by the diversity indices and the number of morphospecies in this ecosystem. Meanwhile, the NM represented by pioneer land is an ecosystem not visited by humans and is mentioned as undisturbed land. Although without management, the soil arthropod family in this ecosystem is less than MM because of the thinner litter, depending on its vegetation structure.

The environmental factors in a habitat also support forming environmental characteristics, distinguishing one habitat from another. We observed six environmental factors, including air temperature (SU), soil temperature (ST), litter thickness (KS), humidity (KB), light intensity (IC), and soil pH (pH). In this study, the abiotic factor that is closely related to Collembola abundance is humidity (Figure 3). This is also reinforced by A'Bear (2013) that humidity is one of the determining factors for the existence of Collembola. The great abundance of Collembola was closer to Acarina presence, which tends to be affected by litter thickness. That explains their presence in MM and NM might be caused by thick litter in MM and NM (2-3 cm). Litter in MM and NN was a food source for the Acarina and a shelter from direct sunlight and maintained the humidity (Colloff 2009). The existence of food sources, such as fungi and rotting litter on the forest floor, drive a high abundance of mites (Zhang 2003). There was no litter in IM because of regular activities such as litter burning every week (Table 1). This sensitive characteristic considered Acari and Collembola suitable bioindicators for evaluating soil quality (Menta and Remelli 2020). Generally, the presence of Collembola will be followed by a higher abundance of Formicidae in the same area because of predation interaction, where Formicidae acts as predator and Collembola as their prey (Larabee and Suarez 2014).

Environmental factors such as air and soil temperatures greatly affect the density of soil organisms because they affect the soil organic matter decomposition level. In this study, soil temperature brought an impact on Termitidae. Some termites are generally more foraged in warmer temperatures, especially in the dry season (Janowiecki and Vargo 2021). On the other hand, some types of soil arthropods tend to decline on land with high light intensity due to low canopy cover (Wiranegara et al. 2018), as in this study, it affected the abundance of Coleoptera. Palmu et al. (2014) stated that different land use characteristics, such as plant composition, affect the Coleoptera community so that plant diversity can increase Coleoptera richness. This explained why the abundance of Coleoptera in IM was very low, driven by the plant selection and less canopy cover, which increased sunlight absorption and soil temperature. Meanwhile, the Gryllidae and Araneae were also terrestrial arthropods whose existence is affected by understory plant diversity.

In conclusion, we stated that different types of land management have various impacts on soil arthropods. Furthermore, the intensity of land management affected the soil arthropods mentioned in this research, including Collembola, Formicidae, Acari, Coleoptera, Araneae, Gryllidae, and Termitidae, which are commonly used to illustrate field conditions. Hence, research on the response of soil-living arthropods, especially for the several families only found in one land type, should be investigated to evaluate each land management.

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