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# The Influence of Land Management on Soil Mite (Acari: Oribatida, Prostigmata, and Mesostigmata) Communities as Bioindicators for Environmental Conditions

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***Abstract***

*As a soil-living organism, soil mite presence is important for ensuring sustainable land. Intensive management practices on forest land drive a change in its community structure. A field study was conducted in Wanagama Education and Research Forest I, Gunungkidul District, Yogyakarta Special Region Province, Indonesia, to assess the role and impact of the different forest management practices on the soil mite community. Soil samples from 15 representative soil sites were taken from the agroforestry, mixed-forest, and pioneer community forests. Collected individuals from August to October 2021 were taken by Berlese-Tullgenn Funnel and identified to morphospecies level. A total of 758 individuals of soil mites were recorded during the study period. Out of these, 21 individuals are from agroforestry, 288 individuals are from mixed-forest, and 449 individuals are from pioneer community forests. The results of the study revealed the occurrence of 3 taxa from 36 morphospecies of oribatid mites occurred in the area. The Shannon diversity indices of oribatid mites were 1.831, 1.424, and 0.867 in mixed-forest, agroforestry, and pioneer communities, respectively. The similarity indices showed there was a similar diversity in agroforestry and mixed-forest, either in pioneer communities. Through one-way ANOVA analysis, we stated that differences between of three management practices significantly affected soil mites, especially oribatida, rather than prostigmata and mesostigmata.*

*Keywords*: *bioindicators, forest management, land management, soil mite*

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## Introduction

Variations in land management systems can have an impact on the biodiversity of soil organisms, particularly arthropods (Roy et al., 2018; Menta & Remelli, 2020). Soil arthropods, as ecosystem components, play an important ecological role in bioindicators, nutrient cycling, organic matter decomposition, and soil structure maintenance (Castro-Huerta et al., 2015; Schuster et al., 2019; Wale & Yesuf, 2022). In intensive agricultural land management, a series of human activities in land management such as fertilization, harvesting techniques, and the use of herbicides can affect the presence of soil arthropods (Hansen et al., 2018; Rousseau et al., 2019; Fiera et al., 2020; Menta et al., 2020). Previous studies have shown that soil arthropods from the Collembola and Acari groups tend to be more abundant than other microarthropods in almost all terrestrial habitats (Coleman et al., 2017). The other arthropod groups, which also have an ecological role as detritivors such as Protura, Diplura, and Pauropods, are usually less abundant or rarely detected (Yadav et al., 2018). Their activities, however, contribute to the function of microarthropod communities in the decomposition process and can vary depending on the intensity of the disturbance and other environmental factors (Castro-Huerta et al., 2015; Wale & Yesuf, 2022).

Previous studies on soil arthropods from the taxa of soil mites mostly raised three dominant suborders, such as Mesostigmata (Hasegawa et al., 2013; Bolger et al., 2014; Napierala et al., 2018), Oribatida (Vacht et al., 2019; Chapman et al., 2023), and Prostigmata (Andrés & Mateos, 2006; Hasegawa et al., 2013). Mesostigmata can generally be found in several types of land and different niches; furthermore, its existence is closely related to soil or litter conditions (Manu et al., 2021). Previous research revealed that Mesostigmata, along with other soil arthropods, play an important role in the decomposition process and, as a result, indirectly affect land productivity (Bolger et al., 2014; Kamczyc et al., 2018; Seniczak et al., 2019). Oribatid mites are among the most diverse and plentiful animal decomposers. Furthermore, it was stated that low oribatid diversity was found on land with low productivity, so its presence was associated with soil fertility (Yadav et al., 2013). Since oribatid mite species prefer different microhabitat patches in temperate forests, their communities are widely dispersed among mineral soil, litter, mosses, lichens, dead wood, and tree bark (Wehner et al., 2018).

Previous research has discovered that oribatida is sensitive to tillage practices, whereas prostigmata can be abundant in agricultural and livestock production soils

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because their populations benefit from human activity (Socarrás & Izquierdo, 2014). The mite's presence of prostigmata was an intriguing indicator: for example, prostigmatid mites are abundant in temperate meadows and lawns, as well as being favored by anaerobiosis and being indicative of human soil disturbance (Kethley, 1990; Philips, 1990; Koehler, 1998; Crotty et al., 2016). Variations in ecosystems caused by different management practices that affect stand composition can have an impact on soil mite diversity and function, for example (Farská et al., 2014; Korboulewsky et al., 2015).

Wanagama Education and Research Forest I (ERF I) provides a model for the implementation of critical land restoration projects in Indonesia. The management area of Wanagama is divided into several compartments and includes an area of approximately 670 ha. Each compartment is managed with a different purpose (Triyogo et al., 2020) such as, for ecological studies, in compartments 5, 6, and 7, where one of them represents the Wanagama Forest's prior state before rehabilitation. Furthermore, compartment 16 includes plots designed for tourism and education purposes. The majority of the interactions with local people who lived near forest areas occurred in compartment 17, in which crops have been cultivated under tree stands using an agroforestry system.

A number of prior studies have elucidated the significant impact of above-ground communities, including vegetation, on ecosystem services and soil organisms (Hooper & Vitousek, 1997; Vitousek et al., 1997; Carney & Matson, 2006). Land-use change stands as the most profound human-induced modification to earth's ecosystems, leading to substantial alterations in plant communities. Hence, our hypothesis posits that variations in land management, accompanied by shifts in vegetation composition, result in subsequent changes. Moreover, variations in microenvironmental conditions arising from differences in vegetation composition will have consequences for arthropod communities, specifically soil mites (Acari group). We compared soil mite communities on three different land management practices in the Wanagama ERF I area, i.e., agroforestry, mixed-forest, and pioneer community forest. There are differences in land management practices among the of land, including management activities, the intensity of human intervention, and the vegetation that grows on it. Land management systems are key factors in the conservation of soil arthropods, especially soil mites. However, the information on the response of soil mites to different forest land practices is still rare.

Therefore, our aim is to describe the diversity of soil mites in different types of ecosystems at Wanagama ERF I, which represent differences in land management practices. Furthermore, this study will provide an overview of the condition of the land management system by answering the following questions such as: 1) how is the diversity of soil mites in each land management practice? and 2) does the difference in land management affect the diversity of soil arthropods, in particular the diversity of soil mites?

## Methods

**Study area** The field data collection was conducted in and around the Wanagama Education and Research Forest I area, Yogyakarta Special Region Province, Indonesia. The areas within the Wanagama forest area that are utilized have distinct purposes and management approaches which consist of compartments 13 (agroforestry/AF) and 6 (pioneer/PN). On the other hand, the areas outside the Wanagama forest area are community forests (mixed forest/MF) managed by the residents of Banaran Village, surrounding the Wanagama (Figure 1). The Oyo River serves as a natural boundary between compartments 13 and 6, while both the community forest and these compartments are separated by the Oyo River as well as a main road (Figure 1).

This study utilizes the differences in characteristics, particularly plant communities, possessed by each land-

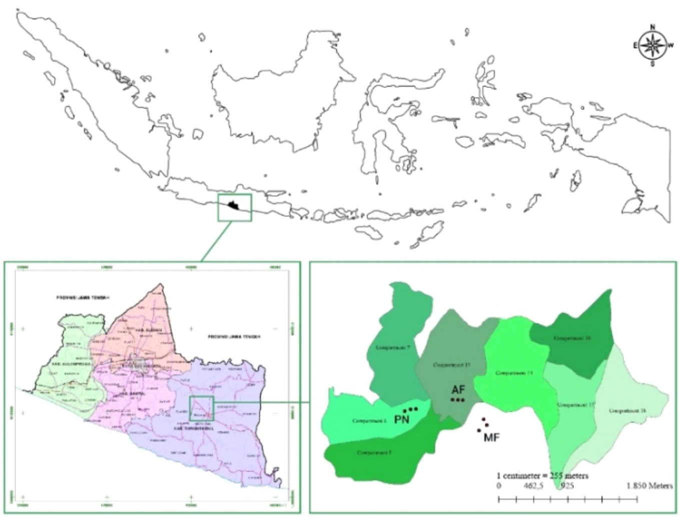



Figure 1 Research site in Wanagama Education and Research Forest I, Yogyakarta Special Region Province, Indonesia. Note: AF = compartment of agricultural area; MF = compartment of mixed-forest; and PN = compartment of pioneer. (Source: Wanagama's collection).

management practice. Based on the vegetation conditions, the lands were classified into three categories (Table 1). Table 2 presents measurements of different parameters recorded in each plot for three months of observation (AugustOctober 2021), including air temperature (measured with a Baldr Digital Thermometer), light intensity (determined with a DX-100 Takemura Electric Works Ltd. digital lux meter), and percentage humidity. The measurements were taken during the day between 12:00 p.m. and 2:00 p.m.. Further, visualization vegetation composition for each plot was obtained using the Sexi-FS software program (Table 2).

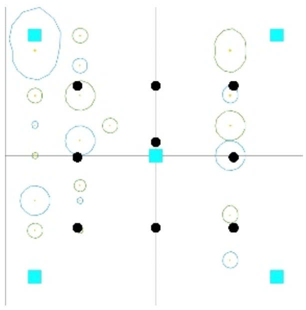
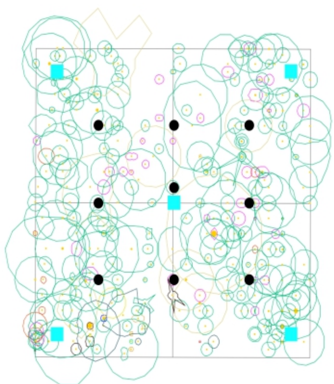
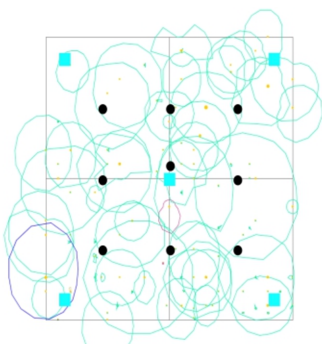
**Sample collection** For each land management, square (20 × 20) $m^2$ observation plots were made, which were placed purposefully with consideration of stand conditions and topography. The number of measuring plots is three replications for each land management, so there are a total of 9 observation plots. Soil arthropods were collected by first collecting soil and litter samples using the monolith method (Haneda & Marfuah, 2013; Vanhove et al., 2016), which comprised digging soil at each corner and the center of the measuring plot with a particular size (50×50) $cm^2$ and a depth of 5 cm. In total, 5 monolith points were obtained from each observation plot, which were then composited to obtain 1 kg of both soil and litter. Soil and litter samples were then taken

Table 1 Different characteristic of land management used as observation area (this study in parallel with Damayanti et al., 2023

| Land | Description |
|---|---|
| Agroforestry (AF) | AF represents a land with high human intervention. Human intervention is still immense because this compartment is in its early stages of agroforestry, where crops such as corn (*Zea mays*), cassava (*Manihot utilissima*), pineapple (*Ananas comosus*), and common grass (*Pennisetum purpureum*) are still predominated over woody plants such as teak (*Tectona grandis*). It is indicated by regular farming activities such as cultivating soil, intercrops planting, fertilizing, harvesting crops, and litter burning. |
| Mixed forest (MF) | MF has a lower human intervention than AF due to its absence of regular activity. But still, this land is maintained by the forest farmer, so there is a woodworking activity such as harvesting when needed. The land is dominated by woody plants such as teak (*Tectona grandis*), mahagony (*Swietenia mahagony*), *lamtoro* (*Leucaena leucocephala*), banana (*Musa* sp.), and *empon-empon* (traditional medicinal plants). |
| Pioneer (PN) | PN represents a land without any human interventions and it is dominated by pioneer plants, prior to rehabilitation, and was characterized by scattered soil patches among the rocks. The pioneer species *Glyricidae sepium* dominated with various ages with dense crown density and shrubs such as *Caesalpinia sappan* and *Eupatorium odoratum*. |

Criteria of diversity indices (H') referred to Prabowo et al. (2021) and Magurran (2004), meanwhile richness indices (R') referred to the Srivastava et al. (2022) and Margalef (1958).

Table 2 Environment measurement between three different land management during three-month observation (August, September, and October) (this study in parallel with Damayanti et al., 2023)

| Parameters | Agroforestry | Mixed-forest | Pioneer |
|---|---|---|---|
| Visualization of crown vegetation |  |  |  |
| Litter thickness (cm) | 0.14 ± 0.058 | 3.56 ± 0.05 | 2.23 ± 0.03 |
| Soil temperature (ºC) | 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 (%) | 36.32 ± 0.77 | 29.70 ± 0.33 | 32.39 ± 0.57 |
| Light intensity (Lux) | 1,685.89 ± 278.06 | 2,389.89 ± 279.22 | 2,229.22 ± 607.12 |

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to the laboratory for alternate extraction using the Berlese-Tullgrenn method (Anwar & Ginting, 2013; Fekkoun et al., 2021; Damayanti et al., 2023). As a result of the Burlese-Tullgren method, soil arthropods trapped in collection bottles were then identified up to the taxa level (Triplehorn & Johnson, 2005). Furthermore, the soil mites separated from soil arthopods were counted on digitally photographed soft ceramic plates, and the collected data was brought to the laboratory for identification up to the morphospecies level, then grouped into the sub order level, consists of oribatida, prostigmata, and mesostigmata. In addition, specimen observation was conducted using the stereo microscope (SCWPG Carton Optical Industries), while taxonomic keys were used for species identification (Zhang, 2003; Krantz & Walter, 2009; Hasegawa et al., 2014; Ihsan et al., 2021), and through online databases (inaturalist.org).

**Data analysis** Soil arthropod collections were grouped based on taxa level, then the number of individuals, average, and relative abundance in each land management were calculated. A one-way ANOVA test (IBM SPSS ver. 25) was conducted to determine the effect of different land management on the individual abundance of each soil arthropod taxa. Because assumptions of normality were not met, we used a data transformation to analyze all the data from the field observations and experiments. To solve the problem that arises from the discreteness of the number of individuals, we use a common logarithm $\log(x + 1)$, where $x$ is the number of individuals, so that we are able to easily back-transform the variable (modification of Yamamura (1999) and Swarnali et al. (2019)). Furthermore, data analysis was continued with a posthoc test (Tukey) to pairwise comparisons among the treatments. Soil mite collections are grouped according to the three dominant taxa found in this study. The number of individuals and the average abundance of each taxa were calculated based on each land management and month of observation. The soil mite community structure is indicated by species richness, diversity (H`) (Krebs, 2014), evenness index's (J`) (Pielou, 1969), and Jaccard's similarity indices. Principle component analysis (PCA) was used to assess and present a graph about which environmental factors (air temperature, soil temperature, light intensity, soil pH, humidity, litter thickness) are significantly correlated to soil mite abundance. Therefore, the function of the vegan R package in R Studio software v. 1.4.1717 was used.

## Results and Discussion

Soil arthropods are an important component of biodiversity. They influence soil nutrients by affecting the litter decomposition process and build soil structure directly and indirectly (Austin et al., 2014). The larger arthropods produce healthy soil and thus, a healthy ecosystem (Kumar & Singh, 2016). The present study was conducted to investigate the effects of land management of forest ecosystem on diversity and abundance of soil arthropods. Our result showed that Collembola, Acarina, and Formicidae were dominant in each land (Table 3). Those three taxa are the predominant group of soil arthropods (Eckert, 2018; Roy et al., 2021) especially Collembola and Acarina which are highly representative of ground-dwelling mesofauna arthropods (Frizzi et al., 2020). In contrast, another study reported more abundance of springtail than soil mite (Gutiérrez-López et al., 2014; Mohsin et al., 2022).

Even though the agroforestry system aims to support the livelihoods (Pandit et al., 2014) and maintain biodiversity (Reith et al., 2022) at the same time, we recorded the lowest abundance of soil arthropods. Kinnebrew et al. (2022) explained that there is a decrease in the diversity of soil arthropod because of land management. In this study, AF has regular activities such as soil tillage, planting, fertilizing, weeding, and litter burning. According to Siquera et al. (2014), management practices such as weed control and pesticide application affected the differences in community composition.

**Soil mite** The total number of soil mites was 758 individuals, divided into four suborders: oribatida, prostigmata, mesostigmata, and astigmatina (Table 4). Because of the extremely low astigmatina presence (<1%), the discussion is focused on the three dominant suborders obtained. Observations on the relative abundance of soil mites revealed varying results depending on land management. The oribatida, prostigmata, and mesostigmata showed the highest relative abundance in all three land managements. However, the results indicated that in the AF area, the relative abundance of prostigmata was higher than that in MF and PN land (Figure 2). The study indicated that there were seasonal fluctuations in soil oribatid and prostigmatid mite populations in all three land managements rather than mesostigmata (Figure 3). The individual number of oribatida decreased in October in AF and MF. Contrary to that, the individual number of prostigmata increased in October in both of those lands. This pattern did not apply to

Table 3 Relative abundance of different groups of soil arthropods on taxa level in three land uses in Gunungkidul, Yogyakarta (Indonesia) during three months observation (August – October 2021)

| Group of soil arthropods | Agroforestry | Mixed-forest | Pioneer |
|---|---|---|---|
| Collembola | 5.17% (3) | 48.86% (389) | 46.91% (471) |
| Acarina | 37.93% (21) | 36.18% (288) | 44.72% (449) |
| Formicidae | 41.37% (24) | 12.94% (103) | 6.67% (67) |
| Araneae | 6.89% (4) | 0% (0) | 0.29% (16) |
| Coleoptera | 8.62% (5) | 2.01% (16) | 1.39% (14) |
| Total | 57 | 796 | 1,004 |

*Data in parenthesis is represent the cumulative numbers across three months observation

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mesostigmata. However, oribatida, prostigmata, and mesostigmata increased in October only in PN.

The abundance of oribatid mites was higher in MF (1.42 ± 0.09 individuals per trap) and PN (1.29 ± 0.22 individuals per trap) than in AF (0.26 ± 0.10 individuals per trap) (Figure 4a). Prostigmata has a higher abundance in AF (0.27 ± 0.06), meanwhile it has a similar abundance in PN and MF (0.20 ± 0.11) (Figure 4b). Mesostigmata only appeared in PN (0.07 ± 0.04) (Figure 4c). The abundance from three suborders of soil mites found significant differences only in oribatida in compartment AF, with no significant difference between MF and PN (Table 5). In the three land managements, there was no significant difference in the total number of prostigmata

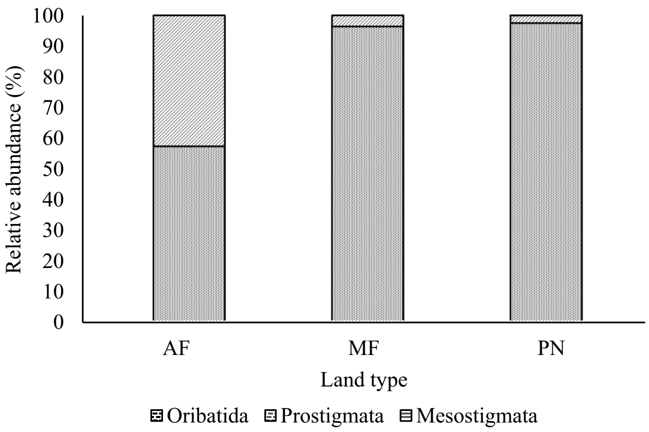


Figure 2 Relative abundance of oribatida, prostigmata, and mesostigmata in different land management. Note: AF = compartment of agricultural area, MF = compartment of mixed-forest, and PN = compartment of pioneer.

and mesostigmata. According to the present study, different land managements have different effects on the abundance of oribatida because they commonly correlated with forest-floor litter thicknes (Hasegawa et al., 2013). Meanwhile in this study, MF and PN have thicker litter than AF. The unsignificant number may be caused by similar environmental factors such as temperature, humidity, and soil quality in each land type which also support the soil mite's existence in those habitats (Doblas-Miranda et al., 2021). Some recent works also stated that the diversity of soil mites depends on the age and history of the land before it was established (Zayadi et al., 2013) and stage of ecosystem succession (Urbanowski et al., 2021).

The calculation of diversity indices for soil mites showed different numbers. In the agroforestry, mixed-forest, and pioneer forest the diversity indices were 2.1, 1.9, and 1.0, respectively (Table 6). The higher diversity of the oribatid mites is in agroforestry than in other management land practices such as mixed-forest and pioneer. Even though the richness indices of agroforestry are the lowest, the evenness indices were higher with the number of 0.9, showing that this practical management has a more balanced mite diversity than others (Table 6). Furthermore, similarity indices of oribatid mites were calculated using Jaccard's similarity index. Oribatid mites in agroforestry were highly dissimilar with mixed-forest but has a closer similarity to pioneer forest (Table 7).

The combination of indices and evenness indices is commonly used to describe the diversity indices (Schowalter, 2022). In this study, the species richness indices were included in the medium category for mixed-forest and pioneer, but they were included in the low richness category in agroforestry. Furthermore, the Pielou's evenness indices showed the result that agroforestry had more evenness diversity of morphospecies on oribatid mites because the indices closer to 1. Meanwhile, the evenness in the pioneer

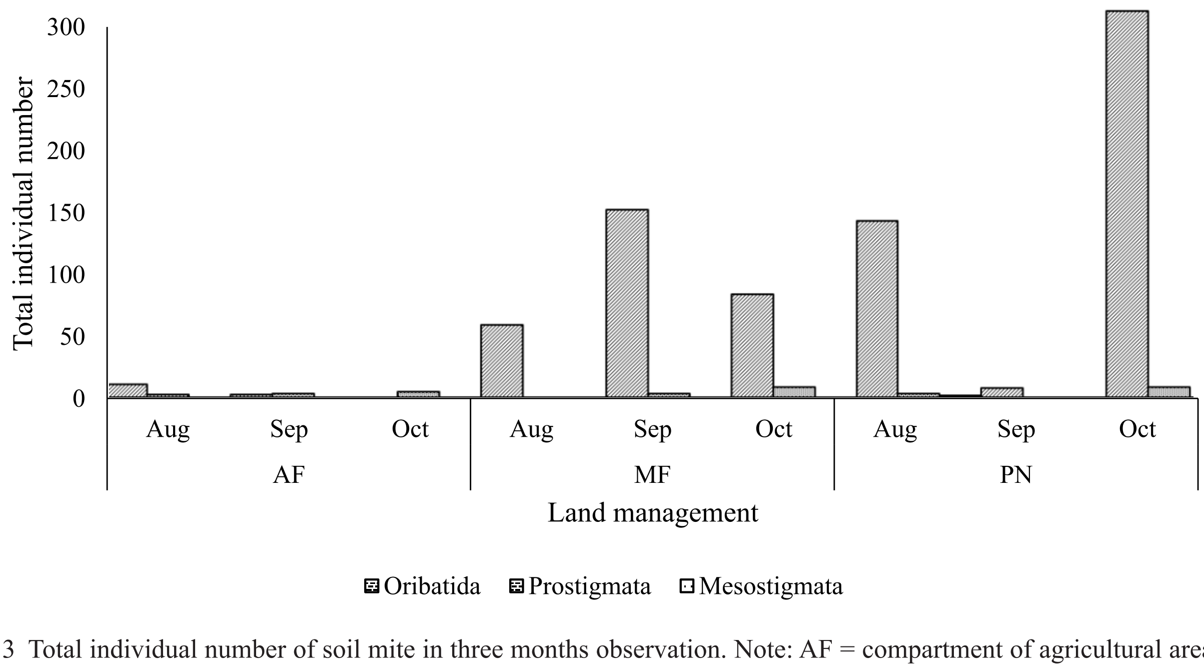


Figure 3 Total individual number of soil mite in three months observation. Note: AF = compartment of agricultural area, MF = compartment of mixed-forest, and PN = compartment of pioneer.

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Table 4 Morphospecies of soil mite diversity in three different land management

| Subclass | Order | Sub order | Family | Morphospecies | AF | MF | PN |
|---|---|---|---|---|---|---|---|
| Arachnida | Sarcoptiformes | Oribatida | Oribatida 1 | Mite 1 | 3 | 1 | 0 |
| | | | Oribatida 2 | Mite 2 | 5 | 0 | 0 |
| | | | Oribatida 3 | Mite 3 | 1 | 127 | 356 |
| | | | Oribatida 4 | Mite 4 | 2 | 14 | 5 |
| | | | Oribatida 5 | Mite 5 | 1 | 0 | 3 |
| | | | Oribatida 6 | Mite 6 | 0 | 0 | 1 |
| | | | Oribatida 7 | Mite 7 | 0 | 0 | 4 |
| | | | Oribatida 8 | Mite 8 | 0 | 0 | 1 |
| | | | Oribatida 9 | Mite 9 | 0 | 45 | 33 |
| | | | Oribatida 10 | Mite 10 | 0 | 15 | 0 |
| | | | Oribatida 11 | Mite 11 | 0 | 0 | 1 |
| | | | Oribatida 12 | Mite 12 | 0 | 27 | 5 |
| | | | Oribatida 13 | Mite 13 | 0 | 23 | 13 |
| | | | Oribatida 14 | Mite 14 | 0 | 5 | 2 |
| | | | Oribatida 15 | Mite 15 | 0 | 1 | 0 |
| | | | Oribatida 16 | Mite 16 | 0 | 11 | 2 |
| | | | Oribatida 17 | Mite 17 | 0 | 1 | 0 |
| | | | Oribatida 18 | Mite 18 | 0 | 1 | 0 |
| | | | Oribatida 19 | Mite 19 | 0 | 3 | 3 |
| | | | Oribatida 20 | Mite 20 | 0 | 2 | 3 |
| | | | Oribatida 21 | Mite 21 | 0 | 1 | 0 |
| | | | Oribatida 22 | Mite 22 | 0 | 0 | 3 |
| | | | Oribatida 23 | Mite 23 | 0 | 0 | 1 |
| | | | Oribatida 24 | Mite 24 | 0 | 0 | 1 |
| | Prostigmata | Prostigmata | Prostigmata 1 | Mite 25 | 0 | 2 | 1 |
| | | | Prostigmata 2 | Mite 26 | 0 | 2 | 2 |
| | | | Prostigmata 3 | Mite 27 | 0 | 4 | 0 |
| | | | Prostigmata 4 | Mite 28 | 2 | 1 | 1 |
| | | | Prostigmata 5 | Mite 29 | 4 | 2 | 4 |
| | | | Prostigmata 6 | Mite 30 | 1 | 0 | 0 |
| | | | Prostigmata 7 | Mite 31 | 1 | 0 | 0 |
| | | | Prostigmata 8 | Mite 32 | 1 | 0 | 0 |
| | | | Prostigmata 9 | Mite 33 | 0 | 0 | 1 |
| | | | Prostigmata 10 | Mite 34 | 0 | 0 | 1 |
| | | | Prostigmata 11 | Mite 35 | 0 | 0 | 1 |
| | Mesostigmata | Mesostigmata | Mesostigmata | Mite 36 | 0 | 0 | 1 |

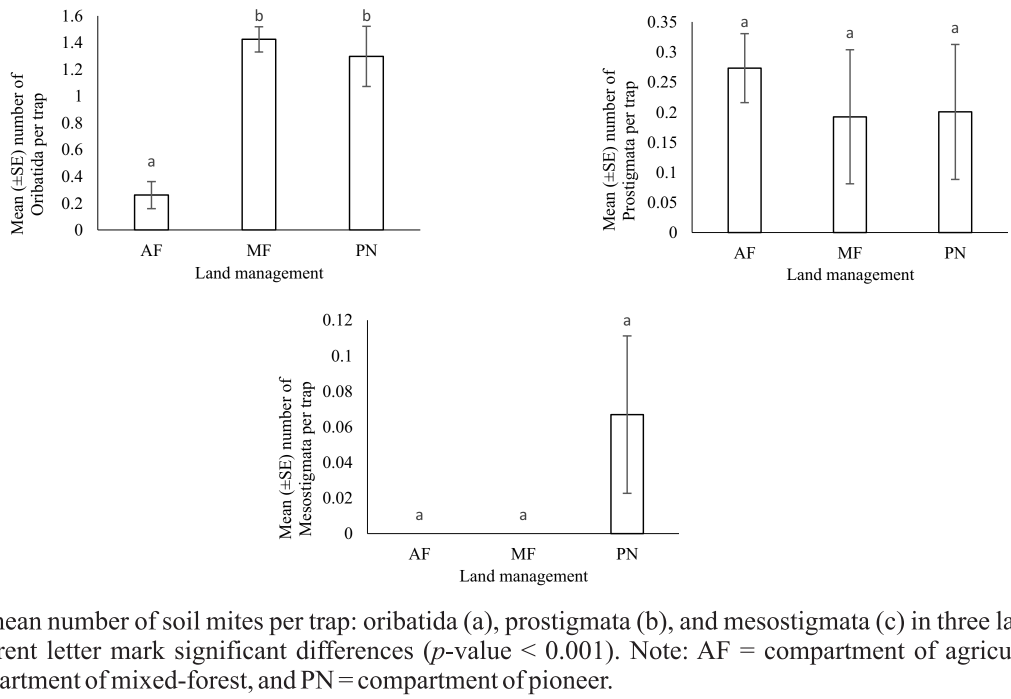


Figure 4 The mean number of soil mites per trap: oribatida (a), prostigmata (b), and mesostigmata (c) in three land managements. Different letter mark significant differences ($p$-value < 0.001). Note: AF = compartment of agricultural area, MF = compartment of mixed-forest, and PN = compartment of pioneer.

Table 5 Result of F ANOVA values for the effect of observation land type on soil mite abundance at the sub order level (data of soil mites abundance was transformed by using log x+1)

| Source of variation | *F*-value | | |
|---|---|---|---|
| | Oribatida | Prostigmata | Mesostigmata |
| Land management | 17.585*** | $0.210^{ns}$ | $2.286^{ns}$ |

Note: ***show significance at *p*-value <0.001 and ns show non significance value

Table 6 Diversity indices of oribatid mites in three study sites

| Mites collection sites | Shannon diversity indices (H') | Richness diversity indices | Pielou's evenness indices (E) |
|---|---|---|---|
| Agroforestry | 2.108 | 2.956 | 0.916 |
| Mixed-forest | 1.934 | 3.355 | 0.646 |
| Pioneer | 1.019 | 3.930 | 0.316 |

Table 7 Similarity indices of oribatid mites in three study sites

| | AF | MF | PN |
|---|---|---|---|
| AF | | | |
| MF | 0.4 | | |
| PN | 0.833 | 0.625 | |

Note: AF = compartment of agricultural area, MF = compartment of mixed-forest, and PN = compartment of pioneer.

community was lower than the other lands, caused by the presence of morphospecies which dominated this area. This case was also recorded by (Rohyani, 2020) which the low evenness indices desrcribe uneven distribution and depict the presence of a morphospecies that dominats the community structure. The similarity indices showed that AF and PN have a high similarity of species, with an index value of 0.83 (Table 7). As an old forest which was established more than 50 years ago, pioneer has the highest similarity indices. This result is reinforced by (Zaitsev et al., 2013) that the old and undisturbed forest condition supports a larger community, especially for the oribatid mite.

Mite as a soil arthropod component significantly contributes to mixing the organic material with mineral soil and also renewing soil (Manu et al., 2018) in the forest. As ground-dwelling arthropods inhabit top layer of soil, their presence is considered a good indicator of the ecosystem (Dhooria et al., 2016). We predicted that the soil mite community would be distinc over the different land managements. In line with this research, a previous study showed that larger number of mite species were found in natural undisturbed sites, most of which are absent from disturbed sites (Seniczak et al., 2019). An anthropogenic impact depresses the life activity of the oribatid mite species, which are more sensitive to disturbances, and therefore the less sensitive oribatid mites get an advantage in the competition (Kamczyz et al., 2018). Furthermore, other studies suggest that differences in anthropogenic activities can be followed by differences in mite diversity (Manu et al., 2021; Yadav et al., 2013).

We found thirty-six morphospecies of soil mites, which were divided into three suborders, such as oribatida, prostigmata, and mesostigmata. In this study, 24 morphospecies of 36 morphospecies of soil mites collected belonged to oribatid mite (Table 4). This result is consistent with Seniczak et al. (2019) who also found those three suborders. In this research, the abundance of oribatid mites was influenced by land management (Table 5). This is in line with Bolger et al. (2014) where oribatida was also affected by land characteristics.

Oribatid mites can be considered as early warning of stressful soil conditions (Hansen et al., 2018) a bioindicator of the ecosystem (Wehner et al., 2018; Kohyt et al., 2020). Meanwhile, the mesostigmatic mites (Acari: Parasitiformes: Mesostigmata) are among the main soil predators in boreal forests (Socarrás & Izquierdo, 2014). This report was driven by pioneer characteristics, as (Andrés & Mateos, 2006) stated that the forest habitat had more biomass and soil moisture than the cultivated area. This result is contradictory with (Manu et al., 2021) whereas the habitat, stand, and litter type only affected mesostigmatid abundance significantly, but not affected other taxa of soil mite. The abundance and richness of soil mites were not different from five management systems (Roy et al., 2018; Ihsan et al. 2021).

In the current study, different months (August to October) also showed different individual numbers of soil mites (Figure 3). The different compositions of soil mite taxa could be affected by different activities on agroforestry land in August, September, and October. Some kind of activity in that area was weeding and burning the soil litter. Agricultural practices in the agroforesty system could affect the invertebrate community (Andrés & Mateos, 2006). Meanwhile, in the forest ecosystem with no management (PN), it has a higher soil mite abundance, richness, and diversity than other land managements (Figure 4). Moreover, the mesostigmatid mite was only found in pioneers (Figure 4c) as it appeared in condition without any physical disturbances. The physical disturbance of the forest floor, in the form of compaction or mixing of organic and mineral soils during harvesting, decreased mesostigmatid (Kethley, 1990).

PCA was conducted to summarize the variation of environmental factors (air temperatur/AT), soil temperature/ST, light intensity/LI, soil pH/PH, humidity/HD, and litter thickness/LT) into fewer variables. The PCA scores examine the variables affected to the soil mite diversity in three different land management. First axis explained 68.6% while the second axis explained 31.4% (Figure 5). Each sub orders affected by a different group of

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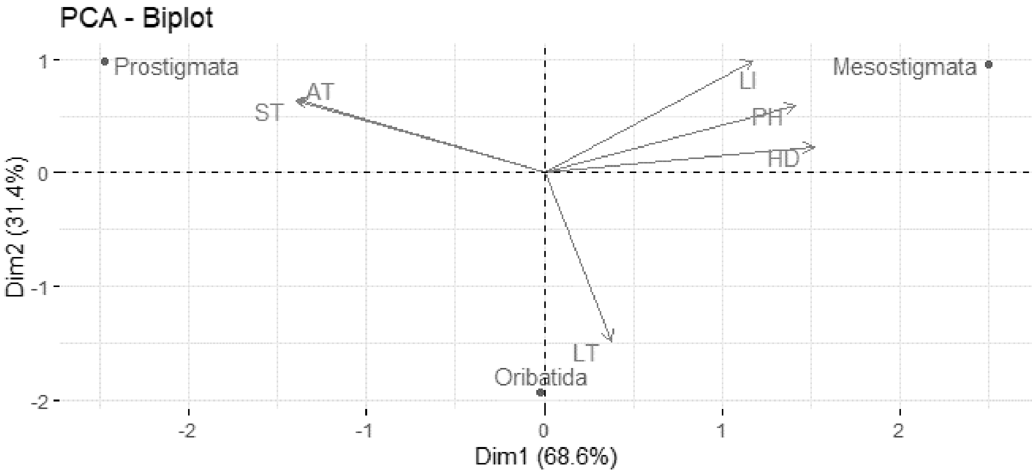


Figure 5 The PCA ordinance shows the composition of soil mite based on land management and environmental factors. Note: AT = air temperature, ST = soil temperature, LT = litter thickness, HD = humidity, LI = light intensity, PH = soil pH.

environmental factors. The abundance of sub order prostigmata was affected by the group of temperature (ST, SU), while sub order mesostigmata was affected by light intensity (IC), soil acidity (PH), and humidity (KB). This result was in line with Fujii and Takeda (2017) where mesostigmata were strongly determined by water content related to litter position. In other research, prostigmata and mesostigmata had a positive response to the different environmental factor in different elevation, while oribatida affected mainly affected by plant species richness (Liu et al., 2014). Meanwhile the abundance of sub order oribatida affected by litter thickness (KS). This explained as the result of Hasegawa et al. (2013) which described that the densities of oribatida positively correlated with the species richness of trees and so that may increase the diversity of the forest-floor litter. This result also shows that sub order oribatida was involved in decomposition process in forest floor.

## Conclusion

This study revealed the occurrence of 3 suborders from 36 morphospecies of soil mites in different land managements (agroforestry, mixed-forest, and pioneer land). However, the differet character of three land managements significantly affected to oribatid mite presence than prostigmata and mesostigmata. Although the diversity indices show low criteria and the richness indices show medium criteria, land with no management or human interventions (pioneer land) has the highest indices of similarity, differ with agroforestry and mixed-forest.

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## Disclosure Statement

I, Arina Damayanti, declare that all authors have no conflict of interest. The funding sponsors had no role in the design of the study, in the collection, analysis, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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