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# Distribution of soil macroarthropods in differently using land parts of tropical rainforest Padang, Indonesia

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**Abstract:** Soil macroarthropods, as a component of the soil community, directly feel the impact of land use changes. Not only the density but understanding the soil macroarthropods distribution pattern will help in providing an insight into the quality of soil health. The sampling process was carried out using the pitfall trap methods on the forest, logged forest areas, mixed gardens, and monoculture gardens in the tropical rainforest of Bukit Pinang-Pinang Padang, Indonesia. The results showed that the forest as a natural habitat supported the density of soil macroarthropods among other land use types. The density in the forest, logged forest area, mixed garden, and monoculture garden sequentially is about 20.29, 13.18, 15.2 and 12.21 indv/m$^2$. The presence frequency high value of soil macroarthropods was found in the forest, and for some soil macroarthropods, such as Hymenoptera, Diptera, and Araneits, the importance value increases when their habitat is disturbed. The fertile soil in intensive monoculture gardens does not support the individuals' total number, types, and density of soil macroarthropods. On the other side, the dominant soil macroarthropods prefer disturbed soil conditions and will decrease their presence frequency if chemical compounds are introduced into the soil. Land use change in the Bukit Pinang-Pinang tropical rainforest area causes changes in the distribution pattern of soil macroarthropods. The changing tendency of distribution patterns in fragmented habitats is due to nutrient availability, limited resources and land treatment. Habitat fragmentation affects not only the abundance and density of individuals and types of soil macroarthropods but also the distribution pattern, which not only threatens their existence and the environment but also has the potential to regenerate.

**Keywords:** agroecosystem; landscape; diversity; fauna; microenvironment

Tropical rainforest areas often become the target of land use change for agroecosystems. The prevailing pattern of agricultural production and activity is illustrated by transforming natural ecosystems into artificial ecosystems of agricultural cultivation (FAO 2011). Changes in the composition and structure of the landscape result in a reduction in the number of species, speciation size, and diversity of soil macroarthropods. In addition, the input of chemical compounds as an effort to improv and quantity of agricultural production will increase the burden on the soil in maintaining soil biological communities. Soil macroarthropods as soil fauna that are sensitive to the environment will directly feel the impact, such as millipedes, centipedes, ants, Coleoptera (adults and larvae), Isopoda, spiders, Hemiptera, termites, Dermaptera, Lepidoptera, Diptera, and others (Villanueva-López et al. 2019). Whereas these soil macroarthropods, at the same time, they play an important role as an indicator of soil health by maintaining the balance function of the e ecosystem balance function and the soil's physical properties

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addition, the abundance reduction and changes in land use also cause changes in the distribution pattern of soil macroarthropods. Habitat fragmentation that causes the loss of natural forest plants into logged forest areas and replaced with monoculture and mixed gardens will cause changes in the microclimate, reduce the distance from one another, and affect the fitness of soil macroarthropods, reducing mobility in carrying out activities, especially foraging, and mating success (Fahrig 2003). The results of research by Galindo et al. (2022) showed that the average abundance of soil macroarthropods such as Hymenoptera (228.6), Coleoptera (99.6), Diplopoda (96.4) and Araneae (39.5) in the forest decreased in the abandoned land type, namely Hymenoptera (138.6), Coleoptera (89.6), Diplopoda (16.6), Araneae (11.5) and in the coffee plantation, the dominant soil macroarthropod groups increased in average numbers, namely Hymenoptera (274.2) and Coleoptera (172.8), while the non-dominant soil macroarthropod groups decreased, namely Diplopoda (17.3) and Araneae (12.8).

Soil macroarthropods have weak migratory abilities, where the soil community's composition and distribution can rapidly change due to land use changes. In forests and other habitat types, generally, the microenvironment under land cover and the presence of litter can affect the distribution pattern of soil macroarthropods (Mulder 2006). Zhang et al. (2016) also state that the abundant soil organic matter content is associated with species richness and biodiversity. Litter, as the main source of soil organic matter, creates a microclimate that affects the distribution of soil macroarthropods.

Research on the density and distribution of soil macroarthropods in several land use types in tropical rainforest areas in the Padang was carried out in the Bukit Pinang-Pinang area, part of the Bukit Barisan series in Padang. This area has been divided into several land use types, namely: forest areas, mixed gardens, and monoculture gardens. Changes in the natural habitat conditions of the soil community into several land use types will affect the dynamics of the soil macroarthropods distribution which have an impact on their contribution to the environment. This study aims to see and understand the distribution pattern of soil macroarthropods on these land use types. We suspect that the disruption of the natural habitat of soil macroarthropods not only reduces the density of soil macroarthropods but also changes the distribution pattern of soil macroarthropods, which affects the existence and sustainability of soil macroarthropods.

## RESEARCH METHODOLOGY

**Study area.** The research was conducted in the Ulu Gadut Region, Bukit Pinang-Pinang, Padang. This area is a series of Bukit Barisan Padang with a large tropical rainforest area. Geographically, the research location is at 100°29'40'' and 100°30'20'' east longitude and bet, between 0054'55'' and 0054'45'' south latitude, an altitude of 460– 650 m a.s.l. (Figure 1). Bukit Pinang-Pinang is a wet tropical rainforest that

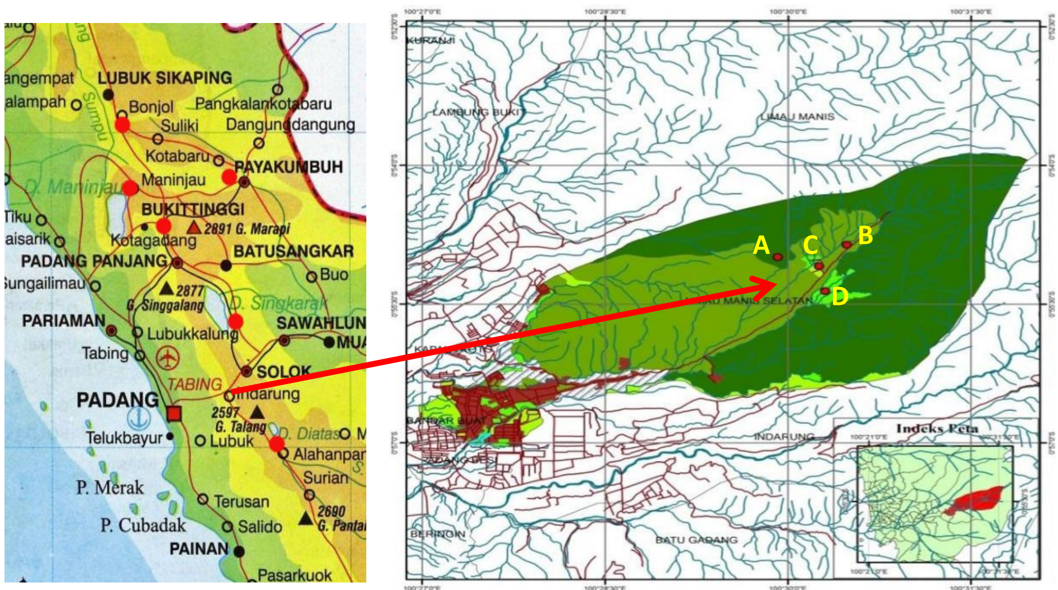


Figure 1. Map of Ulu Gadut area, Bukit Pinang-Pinang Padang city

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has a very high diversity of trees. In 1 ha of the plot area, there are 472 plant species (Hermansah 2003), so this area is interesting for most of the world's scientists, especially researchers from Andalas University, to study the area (Marsandi et al. 2017). Although overall this area still looks natural and preserved, some areas have changed into four types of land use, including forest, logged forest areas, mixed gardens, and monoculture gardens – cocoa plantations which have been having on for more than ten years, except logged forest area carried out in this year (Figure 2).

Based on surveys and interviews conducted with local farmers, this land conversion has occurred since decades ago, except for the logged forest area, which was carried out this year. The logged forest area has characteristics of former logging, fallen branches/twigs and some have begun to decay accompanied by grass that has begun to grow. The mixed garden land type is located adjacent to open land. In this land type, many diverse fruit plants grow, including mangosteen (*Garcinia mangostana* L.), cocoa (*Theobroma cacao* L.), sawo (*Manilkara zapota* L.), durian (*Durio zibethinus* L.), banana (*Musa acuminate* L.), cinnamon (*Cinnamomum burmani* (Nees) Bl), water guava (*Syzygium aqueum* (Burm.f.) Alston), duku (*Lansium domesticum* Corr.) and coffee (*Coffea canephora* L.) that are managed non-intensively (limited use of chemical compounds). At the same time, the monoculture garden land type is cultivated by cacao (*Theobroma cacao* L.) under the mixed garden, where plant cultivation is carried out intensively.

**Research methodology.** Soil sampling was carried out in a composite manner, while soil macroarthropods were carried out for four consecutive months.

## Measurement of soil abiotic factors

Determination of the sampling point is done by purposive sampling, which is based on the representation of an area by dividing one area of land use type into 3 plots based on the slope of the land, namely the top, middle, and bottom with a size of 40 × 40 m. In each of these plots, 4 subplots of composite sampling points were determined. So in one land use type, there are 12 soil samples obtained, and the total is 48 samples in all land use types observed. Disturbed soil samples were taken using a soil drill at a depth of 10 cm, while intact soil samples were taken using a sample ring at a depth of 10 cm. Measurement of

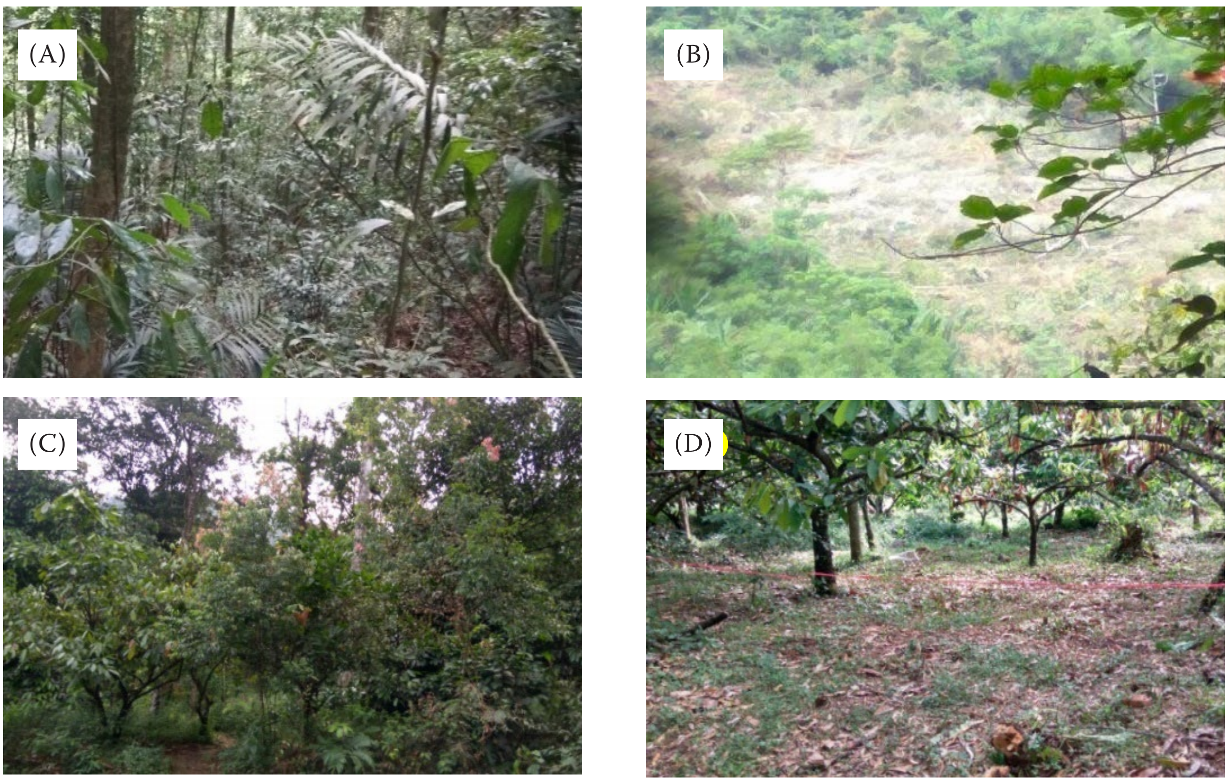


Figure 2. Research locations for several types of land use (A – forest; B – logged forest area; C – mixed gardens; D – monoculture gardens) in Bukit Pinang-Pinang

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soil abiotic factors consisted of soil pH (electrometric pH meter), soil volume weight (ring sample method), soil moisture content (gravimetric method), and soil texture (hydrometer method).

### Soil macroathropod distribution analysis

Determination of sampling points was carried out by purposive sampling on predetermined plots with a size of 40 × 40 m at the top, middle, and bottom in each land use type, then divided into 4 sub-plots of 40 × 10 m with pitfall trap methods and the plastic glass has a height of 11.5 cm, a top diameter of 9 cm, and a bottom diameter of 5.5 cm, with the addition of approximately 150 mL of propylene glycol, which was installed for a period of 24 h.

The macroarthropods samples obtained were collected in the laboratory and then were identified and observed under a microscope using the Soil Insect identification manual. In this case, we determined the taxon at the order level.

**Data analysis.** Data analysis was carried out using the Statistical Program for Social Science (SPSS), where abiotic soil factors consisting of soil physical and chemical properties were carried out one-way ANOVA test at the 95% significance level to compare the conditions of soil abiotic factors on four different land types. Soil macroathropods were analysed by calculating the total number of individuals and types of soil macroarthropods, the relative density of soil macroathropods (RD), the relative presence frequency of soil macroathropods (RF), index of soil macroathropods importance and distribution (Id) of soil macroathropods in each land type of Bukit Pinang-Pinang, Padang, West Sumatra, Indonesia. The formula is as follows:

$$\text{D (A)} = \frac{\text{number of individuals type A}}{\text{number of sampling units}} \rightarrow$$

$$\rightarrow \text{RD} = \frac{\text{density (D) type A}}{\text{density (D) type A}} \times 100\%$$

$$\text{F (A)} = \frac{\text{number of plots type A found}}{\text{total number of plots}} \rightarrow$$

$$\rightarrow \text{RF} = \frac{\text{frequency (F) type A}}{\text{total frequency of all types}} \times 100\%$$

Importance value index = RD + RF

$$Id = n\frac{\sum x^2 - \sum x}{(\sum X)^2 - \sum x}$$

Where: Id – distribution index (Morisita); RD – relative density; $n$ – number of measuring plots; F – frequency; $\Sigma x$ – total number of individuals of a species in a community; RF – relative frequency; $\Sigma x^2$ – sum of the squares of the total individuals.

## RESULT AND DISCUSSION

**Soil biodiversity physicochemical factors.** Characteristics of physical and chemical properties (physicochemical) describe the abiotic environment of soil macroarthropods. In this case, the forest is a control variant because the area was originally a forest that was then utilised by local communities into several land types, namely abandoned logging areas, mixed gardens, and monoculture gardens. Table 1 shows that land use changes affect the soil physicochemical value: increased soil pH value, decreased soil water content, and other fluctuating physical and chemical factors. Changes in soil pH due to land use from logged forest areas to mixed gardens and monoculture gardens (Table 1) indicate an effort to improve soil fertility. Forests with an acidic pH of 4.85 change to 5.00 after losing the vegetation. Although not significant, changes in soil pH in logged forest areas prove that the loss of immature soil organic matter will reduce organic acids (Crespo-Mendes et al. 2019). Furthermore, changes in pH continued to increase with the change in the type of logged forest area to mixed gardens and monoculture gardens, namely 5.68 and 5.78. Plantation cultivation activities with the input of organic matter and chemical compounds into the soil affect changes in soil pH.

The soil's bulk density (BD) value in logged forest areas is 0.79 g/cm$^3$ higher than in the forest at 0.73 g/cm$^3$. This is caused by several factors such as the loss of vegetation, which causes direct sunlight to hit the ground and tree felling activities that cause soil compaction. Crop cultivation practices and aboveground organic matter are important in soil density formation. In addition, the shape of the soil texture also contributes to the condition of the soil density. According to reduced soil litter in an area will cause low organic matter content, increasing soil density. In addition, the clay loam soil texture type in the crop cultivation practices depicts lower soil density conditions. Furthermore, Keller and Håkansson (2010) added that soil bulk density decreases due to increased soil nutrient content for plants, including soil organic matter which causes the soil to fraction

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Table 1. Soil physicochemical values in several types of land use in the Bukit Pinang-Pinang tropical rainforest area, Padang City

| Soil properties | Forest | Logged forest area | Mixed gardens | Monoculture gardens |
|---|---|---|---|---|
| pH | 4.85 ± 0.3942[a] | 5.00 ± 0.2328[a] | 5.68 ± 0.3309[b] | 5.78 ± 0.3232[b] |
| Bulk density (g/cm$^3$) | 0.73 ± 0.0805[a] | 0.79 ± 0.0580[b] | 0.70 ± 0.0592[a] | 0.66 ± 0.0463[a] |
| Moisture content (%) | 0.37 ± 0.1275[b] | 0.24 ± 0.0821[a] | 0.26 ± 0.1325[a] | 0.24 ± 0.0846[a] |
| Sand (%) | 16.30 ± 0.0107[ab] | 12.02 ± 0.0575[a] | 29.39 ± 0.0639[b] | 20.97 ± 0.0439[ab] |
| Silt (%) | 31.34 ± 0.0598[a] | 36.72 ± 0.1018[a] | 37.07 ± 0.1435[a] | 42.94 ± 0.0289[a] |
| Clay (%) | 52.36 ± 0.0614[a] | 51.35 ± 0.0658[a] | 33.54 ± 0.1249[a] | 36.09 ± 0.0354[a] |
| Soil texture class | clay | clay | clay loam | clay loam |

The numbers followed by different lowercase letters showed a significant difference at the level of 5% ($P < 0.05$) according to Tukey's significant difference test on the ANOVA test

to become lighter. Light soil texture fractions will cause the soil bulk density to be lower. This is in line with the data obtained that the BD decreased in mixed gardens, namely 0.70 g/cm$^3$ and 0.66 g/cm$^3$ in monoculture gardens. This result indicates the soil becomes looser. Lathat and cultivation practices with the addition of soil nutrients, especially soil organic matter, will facilitate the decomposition process which results in a lighter soil texture and reduces the soil bulk density value. Soil water content values decreased in all types of soil observed (Table 1). The decreasing concentration of water content cannot be separated from human activity disturbances and changes in land vegetation. According to Rasouli et al. (2019) plant vegetation interacts closely with water hydrological processes especially in reducing the proportion of rainwater that falls on the soil surface and increasing the infiltration of water into the soil. Reduced vegetation cover will worsen the abundance of water in the soil. High levels of vegetation cover ensure an abundance of organic matter, which in turn increases water-holding capacity by altering soil structure and making more water available in the soil for use by plants.

Soil texture is important in building soil communities' habitat framework, including soil macroarthropods. Forests and logged-over forests have a clay soil texture which indicates that the area has a high ability to retain water regardless of the influence of plant vegetation. Clay-textured soils are smooth, sticky, and slippery and have a larger surface area, so their ability to retain water and provide nutrients is also high. The clay fraction with a particle size < 2 μm contains an electrical charge that becomes the site of soil anion and cation exchange (soil chemical reactions). The soil types of mixed and monoculture farms have a clayey loam texture class. This indicates that these soils are preferred by cultivated plants (Eyong and Ofem 2020) stated; that clayey loam is considered the best for agricultural production because it contains more water and nutrients than sandy soil and has better drainage, aeration, and tillage properties than clay.

Other abiotic factors affect completing the components of the framework for making up the habitat of soil macroarthropods, namely temperature, humidity, and rainfall (Table 2), which are fairly stable conditions in each sampling month with insignificant changes.

Table 2. Data on average temperature, humidity, and rainfall (environmental)

| Date | November 2017 | | | December 2017 | | | January 2018 | | | February 2018 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | T | Rh | C | T | Rh | C | T | Rh | C | T | Rh |
| 4–6 | 8 | 28 | 77.6 | | | | | | | | | |
| 10–12 | | | | 3 | 27.5 | 74.7 | | | | | | |
| 13–15 | | | | | | | 4 | 27.3 | 73 | | | |
| 17–19 | | | | | | | | | | 16.5 | 27.8 | 78.3 |

Data on the average temperature, humidity, and rainfall were taken during the sampling process in the field. C – rainfall; T – temperature; Rh – relative humidity

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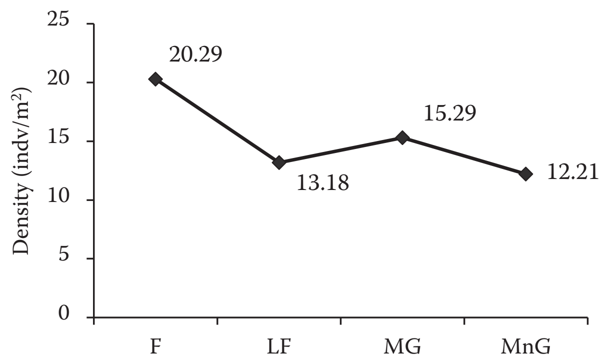


Figure 3. Soil macroarthropod density in several land types of the Bukit Pinang-Pinang tropical rainforest area of Padang, West Sumatra. F – forest; LF – logged forest; MG – mixed garden; MnG – monoculture garden

**Soil macroarthropods density.** The total dynamic diversity of individual macroarthropods in each land use type forms the density of soil macroarthropods communities, which indicates the thriving ecosystem in supporting soil health and maintaining its ecological function. Based on Figure 3, soil macroarthropods density was relatively similar, where the forest became a natural habitat with the highest density and diversity of soil macroarthropods species compared to other land types. According to Gonçalves et al. (2021), soil macroarthropods are important assets for the soil ecosystem's function and can adapt morphologically to the soil as a good quality habitat from the soil abiotic factors aspects, availability of nutrients, and the absence of disturbances.

The density of soil macroarthropods in each land type of the tropical rainforest area of Bukit Pinang-pinang shows that the forest is an appropriate natural habitat for their home (Figure 3). The highest soil macroarthropod density of 20.29 indv/m$^2$ was found in the forest land type (F), while the logged-over land type (LF) had a density value of 13.18 indv/m$^2$. In mixed gardens (MG), the density value was 15.29 indv/m$^2$; in monoculture gardens, the density of soil macroarthropods was 12.21 indv/m$^2$. Rossi and Blanchart (2005) mentioned that the high density of soil macroarthropods in forest land types compared to logged and cultivated land in tropical rainforest areas is due to forest land having a high diversity and availability of substrates. Diversity and availability of food substrates for fauna, which is triggered by the cycle of soil macroarthropods, the high and diverse abundance of leaves and twigs in the form of forest litter. This will support the activity and proliferation of soil macroarthropods. In addition, the soil macroarthropods component is an invertebrate soil fauna that is sensitive or responds first to environmental disturbances caused by land use change. Interestingly, the logged forest area has almost the same density and diversity as the forest and mixed garden dominated by Hymenoptera and Coleoptera (Figure 4). Although it does not look much different, it is interesting to study this further. We assumed that leaf litter, dead wood, and grass that started to grow were one of the factors causing the formation of an effective habitat for soil macroarthropods that almost resembled an open grassland habitat with litter and decayed wood debris. This statement is supported by David (2014) logged forests that have begun to overgrow grass accompanied by litter and weathered logs as habitat fragments are semi-natural habitats for soil macroarthropods. Likewise, in monoculture gardens, although the density value of soil macroarthropods is low, the dominance of Hymenoptera and Coleoptera shows a relatively similar number of values. Barros et al. (2002) intensification of land

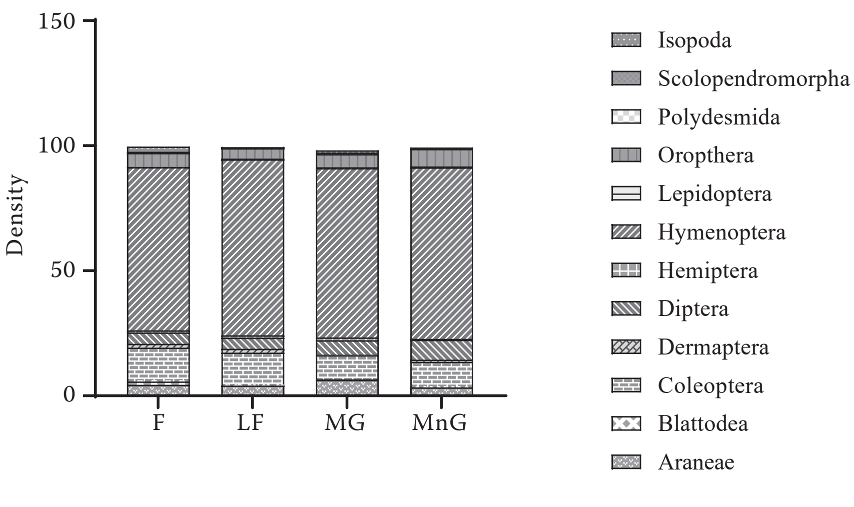


Figure 4. Soil macroarthropods density in each observation land use types. F – forest; LF – logged forest; MG – mixed garden; MnG – monoculture garden

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use reduces the density of soil macroarthropods, where litter and grass functions that turn into weeds become homes for soil macroarthropods to survive. The adaptability of Hymenoptera and Coleoptera is the main reason these two groups are able to survive and dominate garden monocultures with densities that almost resemble other land types in the Bukit Pinang-Pinang tropical rainforest area.

**Frequency of presence and importance value index of soil macroarthropods.** The frequency of presence (Fq) and the importance value index (IVI) in several land use types can be seen in Table 3. The data shows that Hymenoptera has the highest percentage of Fq in logged forest areas, namely 33.10%, where ants dominate it. Rasplus et al. (2010) stated that most habitats colonised by the Hymenoptera correspond to habitats humans have modified. This is also supported by the data we obtained that apart from logged forest areas, the highest frequency of Hymenoptera presence was also found in monoculture gardens, namely 31.65%. Although the cultivation activity of maintaining and caring for plantation crops reduces the total number of individuals, types, and density of soil macroarthropods, Hymenoptera can adapt to this environment. It is supported by Lange et al. (2008); Hymenoptera is a generalist predator on plantation land, which is the most aggressive in using available resources and can adapt to the environment.

Hymenoptera in logged forests and monoculture gardens had the highest important value indexes of 103.42% and 100.23%, respectively. The abundance of Hymenoptera that dominates each type of land provides an opportunity for this group to be a bio-indicator of soil health. Sugiarto and Mardji (2016) stated that the dominant species in a community will have a high index of importance. The importance of Hymenoptera is seen in the type of logged forest and monoculture gardens. These two areas are anthropogenic land in the Bukit Pinang-Pinang area. The presence of ants in logged forest areas and monoculture gardens plays a vital role in soil ecosystem interest. According to Diame et al. (2018), an agroecological management approach with abundance is an approach that combines various functional elements of an agroecosystem.

Soil macroarthropods with low IVI usually tend to be soil macroarthropods with low abundance values, such as Blattodea and Isopoda, in logged forest areas with an important value index of 0.00. It is not that this group not having a role in the environment; it is just that we see it with a small composition so that the roles and functions are not seen directly. The logged forest area has lost its vegetation as land cover, affecting the abundance of most soil macroarthropods. The very small number of Blattodea and Isopoda in the pitfall trap raises the assumption that this group is unsuitable for living on this type of land. Negasa et al. (2017) stated that with a lower even loss of vegetation diversity, the ability to provide energy and food sources for soil macroarthropods would be lower. This has an impact on the growth and activity of soil macroarthropods which are decreasing

Table 3. Presence frequency and important value index of soil macroarthropods

| Taxa | Presence frequency (%) | | | | Importance value index (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | F | LF | MG | MnG | F | LF | MG | MnG |
| Araneae | 10.81 | 11.94 | 14.74 | 8.21 | 15.25 | 16.06 | 21.18 | 11.57 |
| Blattodea | 3.36 | 0.00 | 0.66 | 0.00 | 4.64 | 0.00 | 0.80 | 0.00 |
| Coleoptera | 21.78 | 21.15 | 17.81 | 21.16 | 35.28 | 34.33 | 27.45 | 31.41 |
| Dermaptera | 6.00 | 2.71 | 0.64 | 2.11 | 7.51 | 4.16 | 0.85 | 2.96 |
| Diptera | 12.62 | 9.62 | 13.04 | 15.02 | 17.25 | 14.16 | 18.82 | 22.99 |
| Hemiptera | 3.63 | 3.43 | 4.91 | 1.43 | 4.43 | 4.34 | 6.06 | 1.73 |
| Hymenoptera | 21.54 | 33.10 | 13.25 | 31.65 | 86.82 | 103.42 | 96.33 | 100.23 |
| Lepidoptera | 0.36 | 1.35 | 1.27 | 2.13 | 0.45 | 1.69 | 1.64 | 2.53 |
| Orthoptera | 11.86 | 12.80 | 11.26 | 13.54 | 17.42 | 16.99 | 16.50 | 20.50 |
| Polydesmida | 0.00 | 0.74 | 0.64 | 1.38 | 0.13 | 0.94 | 1.12 | 1.74 |
| Scolopendromorpha | 1.69 | 0.68 | 0.63 | 0.70 | 2.07 | 0.84 | 0.79 | 0.80 |
| Isopoda | 5.37 | 0.00 | 2.18 | 0.68 | 7.42 | 0.00 | 3.01 | 0.87 |

F – forest; LF – logged forest; MG – mixed gardens; MnG – monoculture gardens

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so that some will migrate. In addition, Bufebo et al. (2021) also stated that the large number of soil macroarthropods migrating from one land type was also caused by the land vegetation loss, which made the habitat hot due to direct sunlight.

**Distribution of soil macroarthropod.** The distribution of soil macroarthropods in several land use types in the tropical rainforest of Bukit Pinang-Pinang is shown in Figure 5 — a variation of the simple distribution probability value of soil macroarthropods that were analysed by the Kruskal-Wallis non-parametric method. The boxplot shows the diversity of distribution patterns of each land use type. The distribution pattern shows the average distribution trend of soil macroarthropods. Our results confirm that land use changes affect the soil macroarthropods distribution pattern. The disturbing natural habitat changes the diversity of soil macroarthropods distribution patterns.

The forest indicated the dominance of the uniform pattern on soil macroarthropods. The average distribution pattern of forest soil macroarthropods has a value of < 1 (Figure 5). A uniform pattern but with more varied types of soil macroarthropods in the forest convinced us that the forest is suitable as a home for soil macroarthropods. Regular distribution in natural habitats indicates that individuals are scattered in certain places. According to Krebs et al. (1989), uniform distribution patterns in nature are often caused by competition between very strong individuals, such as antagonistic organisms that divide space equally. Although resources are available in nature, the boundaries of the organism's territory have governed the distribution of soil macroarthropods in their natural habitats.

Changes in land use have become logged forest areas, mixed gardens, and monoculture gardens have changed the distribution pattern of soil macroarthropods to become more diverse. The uniform distribution pattern in the forest changes to irregular dispersal due to changes in land use. The distribution pattern on the logged forest, mixed gardens, and monoculture gardens also tend to clump together (distribution value > 1). Soil macroarthropods are pressured by changes in natural habitats due to logging and agricultural activities. This causes food sources to be non-uniform, and individual soil macroarthropods tend to be present in groups at certain food sources. Although clumped distribution patterns often occur in soil macroarthropods individuals, we assume that in this case, the clumped distribution pattern that appears is a change as an adaptation to getting resources and surviving. Briones (2018) added that group dispersal is an individual's effort to endure in a habitat.

Changes in the distribution pattern will affect the activity as well as the quality and quantity of soil macroarthropods life. Here, we try to explain in detail and systematically the changes in the distribution pattern of soil macroarthropods periodically for four months. We emphasise that presenting complete data on the distribution of soil macroarthropods every month is an attempt to detect the certainty and dynamics of the soil macroarthropods distribution and explain that changes in the soil macroarthropods distribution pattern depend on environmental factors. This statement is supported by Wu and Wang (2019), environmental conditions affect the distribution pattern of soil macroarthropods. Next, Hugo-Coetzee and Roux (2019) add that the distribution can be influenced by time, month, or year. Changes in distribution patterns also occur among groups of migratory soil macroarthropods, which may be present in the summer months and disappear in the winter. Nevertheless, soil macroarthropods are abundant and able to survive in separate areas. Certain

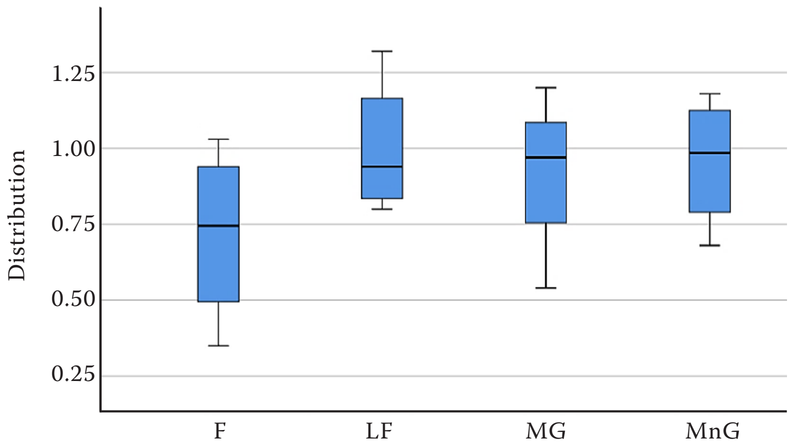


Figure 5. Boxplot diagram of soil macroarthropods distribution data on each land use type. F – forest; LF – logged forest; MG – mixed garden; MnG – monoculture garden

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environmental conditions may favour the social form of these soil macroarthropods. The distribution of soil macroarthropods in the tropical rainforest can be more affected by the dry season or the onset of the monsoon.

The soil macroarthropods distribution value based on the sampling time of 4 months on each land use type can be seen in Table 4. The distribution value is dynamic and not fixed at any time, but overall it can represent the distribution pattern of soil macroarthropods groups in each land use type. Araneae have a uniform distribution pattern in forest and logged forest areas. Araneae is globally distributed mostly in warm to tropical climates and are predators, especially entomophagous that regulate insect populations in the wild and agroecosystems (Singh 2021). The uniform distribution type of Araneae indicates that spiders have their respective territories in hunting. The presence of other spiders at a closer distance will threaten the availability of food sources, so resident spiders will behave aggressively toward other spiders that enter their territory (Lubin and Bilde 2007).

Coleoptera, Diptera, and Orthoptera have dynamic distribution patterns every month and tend to clumped distribution patterns. On the other hand, the dominance of Hymenoptera provides an opportunity for this order to have an absolute clumped distribution pattern. According to Adams and Tschinkel (1995), based on the competitive interaction of young ant colonies by manipulating and measuring their spatial distribution, it is known that the colony distribution pattern naturally occurring in adult populations is significantly clumped. Hymenoptera survives better in clumped distributions gaining easier access to resources. Furthermore, other individuals clumped occur because they cannot disperse from their parents (Forbes et al. 2018). Porter (1992) and Zhang et al. (2022) added that the Hymenoptera distribution with high abundance caused no differences in social form caused by habitat characteristics (closeness to trees, vegetation type, soil type, climatic conditions, topography, ground cover, and sun orientation). So, Hymenoptera spreads in groups.

However, Table 4 shows that the absolute distribution change occurred in Orthoptera. The change into monoculture gardens has changed the distribution pattern of Orthtoptera to clump as a whole for each month. We assume that this change is caused by the influence of agricultural land cultivation activities that can potentially cause the loss of non-target species, which will disrupt the balance of the ecosystem. In addition, Karinasari et al. (2021) also added that this condition would affect the ecosystem balance in the food chain cycle. Chemical compounds that accumulate from year to year can be brought into

Table 4. Distribution of soil macroarthropods by time for 4 months

| Taxa | Forest | | | | Logged forest | | | | Mixed gardens | | | | Monoculture gardens | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (%) | | | | | | | | | | | | | | | |
| | 1st | 2nd | 3rd | 4th | 1st | 2nd | 3rd | 4th | 1st | 2nd | 3rd | 4th | 1st | 2nd | 3rd | 4th |
| Araneae | 0.99 | 0.00 | 0.77 | 0.33 | 0.87 | 0.00 | 0.00 | 0.53 | 1.36* | 1.14* | 0.00 | 0.91 | – | 0.00 | 0.00 | 1.20* |
| Blattodea | 0.00 | – | 2.40* | 0.00 | – | – | – | – | – | – | – | – | – | – | – | – |
| Coleoptera | 0.92 | 1.00** | 0.93 | 1.06* | 2.57* | 1.37* | 0.83 | 1.40* | 1.20* | 1.85* | 0.90 | 0.95 | 1.07* | 0.90 | 0.92 | 0.36 |
| Dermaptera | 0.00 | 0.00 | 0.00 | 0.43 | – | – | – | 1.67* | – | – | – | – | – | – | – | 0.00 |
| Diptera | 0.67 | 0.00 | 1.88* | 1.14* | 1.20 | 3.23* | 0.00 | 0.00 | 2.06* | 0.57 | 1.00** | 1.75* | 1.60* | 0.86 | 1.40* | 0.00 |
| Hemiptera | 0.00 | 0.00 | – | 0.00 | 0.00 | – | 0.00 | – | 0.00 | 0.00 | – | 0.00 | – | – | – | – |
| Hymenoptera | 1.42* | 0.98 | 1.08* | 3.04* | 0.98 | 1.20* | 1.97* | 1.16* | 2.25* | 1.11* | 1.35* | 1.22* | 1.28* | 1.17* | 1.10* | 1.31* |
| Lepidoptera | – | – | – | – | – | – | – | – | – | – | – | – | 0.00 | – | – | – |
| Orthoptera | 1.19* | 0.79 | 1.14* | 0.80 | 0.43 | 0.80 | 2.00* | 0.43 | 1.54* | 1.14* | 0.00 | 1.00** | 1.94* | 1.33* | 1.07* | 1.20* |
| Polydesmida | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Scolopendromorpha | 0.00 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Isopoda | 1.23* | 0.00 | 0.00 | – | – | – | – | – | 0.00 | – | 0.00 | – | – | – | – | – |

*Clump; **Random; no star – uniform; 0.00 – no visible pattern of distribution; – Can not be calculated; 1st – first month; 2nd – second month; 3rd – third month; 4th – fourth month the tissues of organisms through the food transfer process and their concentration will continue to increase in organisms at the highest trophic level. The reduction in this group will add to the more aggressive invasion power of plant pests. This will continue to be a repeating cycle and cause more damage if not addressed immediately.

Soil macroarthropods groups with a random distribution pattern are not very common. There were only a few random distribution patterns found, namely in Coleoptera in the forest in the second month, Diptera in the mixed garden in the third month, and Orthoptera in the mixed garden in the fourth month. We assume that this pattern could be due to the individual's relatively lower abundance. The irregular distribution pattern of soil macroarthropods can also be simplified to life forms that depend on relatively limited habitats. In addition, Schlägel et al. (2020) also state that the forces that regulate the vectorial distribution of organisms are wind, water, or some other environmental movement, or stochastic (random), as in the case of seasonal changes, which gives no indication, where dispersing organisms may eventually settle.

In conclusion, changes in land use in tropical rainforests into logged forests, mixed gardens, and monoculture gardens are a form of threat to soil macroarthropods. This damage the natural habitat structure of soil macroarthropods which causes changes in its distribution pattern. Components of physical and chemical properties of soil are important factors as the soil abiotic components that make up the soil macroarthropods habitat. Increasing soil fertility in mixed gardens and monocultures gardens based on the physical and chemical aspects of the soil cannot be separated from human intervention in trying to produce productive plants. The density of soil macroarthropods became unstable due to habitat fragmentation in the Bukit Pinang-Pinang. The ecosystem simplification has caused soil macrofauna to be pressed, and their numbers are decreasing drastically due to the addition of chemical compounds inputs for the maintenance and productivity of production plants. The distribution pattern of soil macroarthropods becomes irregular and tends to change due to fluctuations in abundance and changes in habitat conditions. We assume that changes in distribution patterns will not only have an impact on the density of soil macroarthropods but also affect subsequent regeneration, which will have an impact on local extinction and potentially damage the environment and ecosystem balance. We expect mixed gardens for sustainable management of agriculture. This opens an opportunity to see the ability of organic fertilisers to save the environment and balance the agricultural ecosystem.

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