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Monitoring of Natural Enemies (Hymenoptera) on Different Lands Use: Study from Agroforestry, Community Forest, and Pioneer Land

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Abstract

Land use and management must be carried out to ensure the sustainability of land ecological function. The presence of natural enemies that suppress pest populations is an essential component of the ecological function. Monitoring the presence of natural enemies and avoiding silvicultural activities that threaten the presence of natural enemies are important aspects of land management. This study investigates the presence of natural enemies on three different land uses: agroforestry, community forests, and pioneer lands. Insect monitoring was carried out at an established plot (20 m × 20 m) for three months using passive sampling (pitfalls and sticky traps) placed using a grid and a diagonal method. The study surveyed phytophagous insects, such as leafhoppers, flies, thrips, and aphids. However, most specimens captured were represented by the natural enemies; Hymenoptera consists of predators (Formicidae) and parasitic wasps (Trichogrammatidae and Scelionidae). The results show that community forests and pioneer lands support the existence of Formicidae. This study indicates that in agroforestry, there are variations in the population of Formicidae based on the period of ongoing land management. Agroforestry provides a more suitable place for the existence of Trichogrammatidae and Scelionidae.

Keywords: *insect diversity, hymenopteran, land use, monitoring, natural enemies*

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Introduction

The increasing need for land in humans is followed by the emergence of various models of land management and use to reach optimum results (Vanwalleghem et al., 2017; Huang et al., 2019). Yield orientation is no longer limited to the economic value but also considers ecological aspects (Wang et al., 2017; 2018; Rosa-Schleich et al., 2019). To obtain optimal economic and ecological value, forest conversion activities, cropping practices, or agroforestry systems must be followed by silvicultural techniques and appropriate management strategies. In the context of ecology, the level of biodiversity and ecological services on land is very important. One of indicator that can be used as an approach to ecological services is through the presence of natural enemies (Thompson et al., 2014; Kazemi et al., 2018). Natural enemies have a very important role in the ecosystem through a top-down mechanism in determining the abundance of herbivores (Kos et al., 2011; Staab & Schuldt, 2020). In terms of integrated forest management, natural enemies that suppress pest populations are a key component. Thus, land use and management must be carried out in a way that supports the presence of natural enemies and avoids activities that threaten the existence of natural enemies (El-Wakeil & Volkmar, 2013).

Cultivation and land-use practices affect the composition and structure of the overlying vegetation, and this may affect the insect communities associated with that vegetation (Allan et al., 2013; Castagneyrol et al., 2017; Jactel et al., 2017). The practice of mixed cropping as a land management practice has a positive impact on the abundance of potential natural enemies and results in land conditions that are more resistant to damage by pest insects (Thomson & Hoffman, 2009; Jactel et al., 2017; Clemente-Orta et al., 2020). It was further stated that in certain land type an increase in biodiversity would be associated with an increase in the population of natural enemy insects (Parsons & Frank, 2019). On the other hand, inappropriate land management practices, pesticide use, and habitat fragmentation can result in decreased population and performance efficiency of natural enemies (Rehman & Powell, 2010; Grubisic et al., 2018; Leather & Pope, 2018).

The orders Coleoptera, Diptera, Hemiptera, and Hymenoptera are known to play vital ecological functions as natural enemies (Dassou & Tixier, 2016; McCravy, 2018). Because of various advantages, insects from the order Hymenoptera have been used extensively in previous research on natural enemies (Koul & Dhaliwal, 2003; Honek et al., 2018; Tougeron et al., 2018; Triyogo et al., 2020). In both natural and agricultural cropping systems, hymenopteran insects play key roles as predators and parasitoids that feed on phytophagous insects (Wielgoss et al., 2014; Stüber et al., 2021). Hymenopteran predators and parasitoids are effective natural enemies that can attack prey and parasitized hosts at various stages, reducing the number of phytophagous in an ecosystem (Koul & Dhaliwal, 2003; Halim et al., 2018). The effectiveness of Hymenoptera parasitoid wasps (Braconidae and Trichogrammatidae) in reducing the population of various insect pests has been reported, including the bagworm, *Metisa plana* (Lepidoptera: Psychidae), on oil palm plantations (Halim et al., 2018); *Aphis* sp. (Hemiptera: Aphididae) on cereal plantations (Honek et al., 2018; Tougeron et al., 2018); stem borers *Diatraea* spp. (Lepidoptera: Crambidae) on sugarcane (Vargas et al., 2015); gall-making wasp, *Dryocosmus kuriphilus* (Hymenoptera: Cynipidae) on chesnut tree (Quacchia et al., 2013).

Similar to parasitoids, Hymenoptera predators, mostly from the ant group (Formicidae), have previously been reported to perform effectively supressing insect pest. Ants (Formicidae) are significant biological pest controls in a wide range of agricultural cropping systems (Offenberg, 2015; Suenaga, 2017; Triyogo et al., 2020). The effectiveness of predatory ant has been reported, including *Azteca* spp. suppressing the coffee berry borer (*Hypothenemus hampei*) (Aristizábal & Metzger, 2018); *Crematogaster antaris* reduces termites in date palm farms (Latifian et al., 2018); *Myopopone castanea* controls the horn beetle population *Oryctes rhinoceros* (Coleoptera: Scarabaeidae), a pest in oil palm plantations (Widihastuty et al., 2018).

Wanagama I Education and Research Forest (ERF) is an example of successful forest and land rehabilitation in many aspects (biophysical, hydrological, and socio-economic). The Wanagama I ERF area is approximately 670 ha and is located in Gunung Kidul Regency, Yogyakarta Special Region Province. This forest area is divided into many sections, each with its land use and management strategy for specific objectives (rehabilitation, agroforestry, and tourism). Land use differences in the Wanagama I ERF area are thought to involve differences in biodiversity, particularly insect biodiversity, on each land. The presence of natural enemies (predators and parasitoids) from the Hymenoptera order and their variety and abundance on various land uses in the Wanagama I ERF area is the focus of this study. Agroforestry, community forest, and pioneer land were some of the lands use used to represent different land management activities. We compared insect communities using three approaches: first, differences in insect abundance in general based on their roles as phytophagous and natural enemies; second, phytophagous and natural enemy dominance based on taxa on the three land uses; and third, insect diversity (phytophagous and natural enemies) by using an ecological index. In particular, we would like to determine: 1) if there are differences in the abundance of insects (phytophagous and natural enemies) among the three land uses, and 2) do the dominant insects as natural enemies differ between the three types of land?

Methods

Study area This study was performed in Wanagama I ERF and the surroundings including villages adjacent to the forest, Gunung Kidul District, Yogyakarta Province, approximately 35 km south-east of Yogyakarta City, Indonesia. The research focus was on three different lands representing different land managements, including: i) agroforestry, observed in compartment 13; ii) community forest area, conducted in Banaran Village; and iii) pioneer land compartment 6. In addition, the distance recorded between three habitats were about 3 km (Figure 1).

The difference between these three lands was marked by the vegetation component and the intencities of human

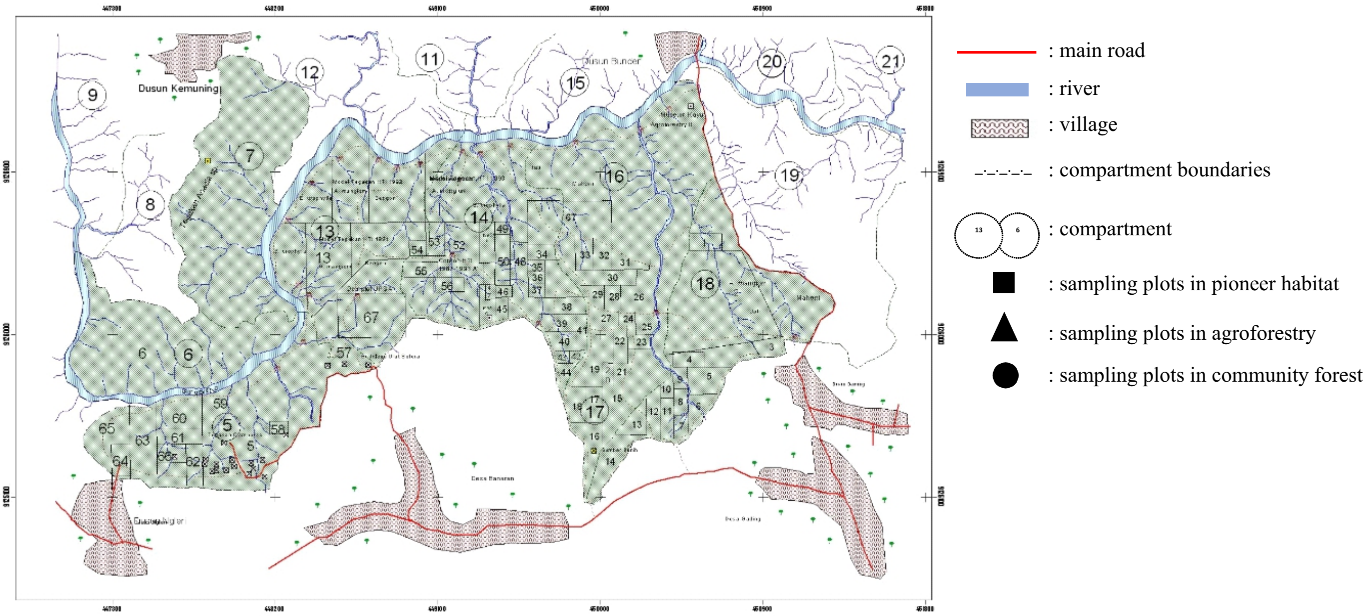

Figure 1 The spatial arrangement of the plots used on each habitat, pioneer (compartment 6), agroforestry (compartment 13), and community forest (Banaran Village) was indicated by square, triangle, and circle form, respectively. (Forest map is a collection of Wanagama Forest Office).

interventions (Table 1). Therefore, field observation and insect collection were conducted during August, September, and October including the data analyses on insect and environment. Table 2 shows the measurement of various parameters, which were recorded alongside, including air temperature of each plot, obtained with a temperature probe (Baldr Digital Thermometer), light intensity, determined using a digital lux meter (DX-100 Takemura Electric Works Ltd.), and also percentage humidity. The abiotic environment data were taken during daytime, at 12.00 to 02.00 pm.

Insect collection and identification procedure The square observation plots, measuring plots 20 m × 20 m, were made for each land use. The number of observation plots was three plots for each type of land; therefore, there were nine plots total. Further, the observation plots were purposively placed considering land conditions, topography, and the minimum distance between plots (10 m). Insect collection was conducted on each plot using two different traps: a pitfall and *a sticky trap*. Also, nine pitfall traps and five sticky traps were placed in the center of the individual plot using a grid and diagonal method for pitfall and sticky, respectively (Triyogo et al., 2020), hence a total of 81 *pitfalls* and 45 *sticky traps*. The insect collection process was performed two times a month (once per two weeks), summing up to 6 observations during a three-month observation.

The insect specimens were initially sorted and identified to order level and the identification of insect based on their trophic level (Phytopagous, predator and parasitic wasps) was continued until morphospecies of family level using available reference (Borror et al., 1989; Goulet & Huber, 1993; Bolton, 1994; Heterick, 2009; Terayama, 2009) and through online ant data bases (bugguide.net; Antweb.org; and Antbase.net). In addition, specimen observation was conducted using the stereomicroscope (SCW PG Carton Optical Industries). The observation of natural enemies is focused on the Hymenoptera order, which include predatory insects (Crabonidae, Formicidae, Pompilidae, Sphecidae and Vespidae) and parasitic wasps (Bethylidae, Braconidae, Chalcididae, Diapriidae, Eulophidae, Eupelmidae, Evaniidae, Ichneumonidae, Mymaridae, Scelionidae, and Trichogrammatidae).

Data analysis The total abundance of individual insect and the mean abundance, was pooled based on land use. Insect's data were counted in total and then classified according to their trophic function (phytophagous and natural enemies) and shown as percentage graphs. Subsequently, the difference between land uses on insect abundance, trophic function (phytophagous and natural enemies), and insect's

Table 1 Comparison of vegetation components and human activities on three different land use

	Agroforestry	Community forest	Pioneer land
Vegetation components	Trees (*Tectona grandis*); *Moringa oleifera*); Old perennial tropical grass (*Pennisetum purpureum*); Cassava (*Manihot utilisima*); Pineaple (*Ananas comusus*); Billygoat weed (*Ageratum conyzoides*); Corn (*Zea mays*)	Trees (*Tectona grandis*; *Swietenia* sp.; *Artocarpus* spp.); Banana (*Musa* sp..).	Pioneer tree species (*Gliricidia sepium*); Shrubs (*Caesalpinia sappan* and *Eupatorium odoratum*)
Tree canopy layer	1	3	2
Description of human activities	In this present study, activities of farmer were present including crop cultivation. As a consequences, there were plant and soil maintenance conducted by farmer including weed control manually by hand, burning the weeds, fertilization, and the soil around the plant crops is cultivated by hand.	There was no activities but firewood collection	No human activities. This area provides an initial haracterization of the WG's condition prior to land rehabilitation. There was not much vegetation growing, and it's dominated by pioneer trees and shrubs.

Table 2 Abiotic measurement between three different land uses during three-month observation (August, September, and October)

	Agroforestry	Community forest	Pioneer land
Litter thickness (cm)	0	2.83 ± 0.20	1.86 ± 10.12
Soil temperature (°C)	38.13 ± 0.14	36.16 ± 0.26	32.33 ± 0.26
Soil humidity (%)	43.90 ± 0.35	49.46 ± 0.58	64 ± 0.48
Air temperature (°C)	37.57 ± 0.18	36.43 ± 0.21	31.76 ± 0.19
Air humidity (%)	46.86 ± 0.41	50.36 ± 0.53	64.23 ± 0.35
Light intensity (Lux)	85,222.33 ± 3.00	42,955 ± 43.50	26,694.66 ± 60.60

taxa were calculated and presented on a mean abundance of insects per trap (combination of pitfall and sticky trap) with error standards. The significance of differences in insect abundance, trophic function, and insect's taxa in each land use was investigated by multiple mean comparisons using one-way analysis of variance (ANOVA) using SPSS ver 22. In addition, the Shannon-Weiner diversity index (H`) and species richness (Krebs, 2009) were measured to compare the insect communities of the three land uses**.**

Results and Discussion

Insect abundance No significant differences in relative abundance of insect between community forest (101.66 ± 27.6 individuals trap^{-1}) and pioneer land (95.12 ± 61.9 individuals trap^{-1}), however there is a significant different found in agroforestry (30.37 ± 18.29 individuals trap^{-1}) (df = 2; F value = 3.78; p-value < 0.05) (Figure 2a). The composition and structure of insects in three land uses had different ecological roles. The identification of insects based on the role of each observation land was divided into three major groups, namely phytophagous, natural enemies, and others (Figure 2b). The small number (<5 individuals trap^{-1}, all months combined) of scavengers and detritivores were recorded but not presented. The results of the data analysis showed that insects, which had the most significant percentage based on functional status, were insect groups with functional status as phytophagous (Figure 2b).

The findings of this study indicate that variations in land conditions with different management intensities, including agroforestry (high-intensity management), community forests (low human intervention), and pioneer land (no intervention), affect insect abundance. This finding is consistent with previous studies, which found that variations in ecosystems and land management can impact insect abundance (Chen et al., 2011; Forister et al., 2019). In particular, changes in insect diversity in a field will affect the abundance of natural enemies (Bianchi et al., 2006; Thomson & Hoffman, 2009). In contrast to agroforestry, pioneer land and community forests have had the highest number of insects. According to previous studies, the abundance of insects in an area is related to the presence of resources (Shin et al., 2021). The abundance of resources in the form of vegetation is most widely available on community forest land and pioneer land, as has been shown in this study area.

Furthermore, the lack of tree habitus vegetation, high air temperature, and low air humidity on agroforestry land (Table 2), might contribute to a decline in the amount and dispersion of insects (Karuppaiah & Sujayanad, 2012; Fornoff et al., 2021). Low tree canopy cover influences the microclimate and causes insects to disperse in search of a suitable microclimate for nesting locations (Leidinger et al., 2019; Adams et al., 2020). Another possibility is that the current vegetation composition influences low prey resource availability, resulting in a decline in the natural enemy population (Fornoff et al., 2021). The dominance of one tree species, *Gliricidia sepium*, characterizes the pioneer land in this study. Pioneer land has a low plant diversity; however, the habitus of *G. sepium* in the form of old trees in large numbers can provide an ideal environment for insects. It is thought that the abundance of undergrowth, including *Caesalpinia sappan* and *Eupatorium odoratum*, impacts the abundance of insects in pioneer land. Previous research has shown that the dominance of plant species as resources (monoculture) and the habitus of large trees can affect the abundance of insects (Connor et al., 2000; Shin et al., 2021).

Meanwhile, community forests contain many plants with varying habits, including trees (wood and fruits), shrubs, and herbs. Insect abundance is high in community forests, where it supports the theory that ecosystems with high plant diversity support the existence of more diverse and complex insect communities (Ebeling et al., 2018). Meanwhile, the amount and type of vegetation cultivated in early agroforestry ecosystems were limited, and human intervention in land management would influence insect abundance. Elephant grass was harvested for animal feed during the sampling period, and weeds on cassava and pineapple planted plants were cleared.

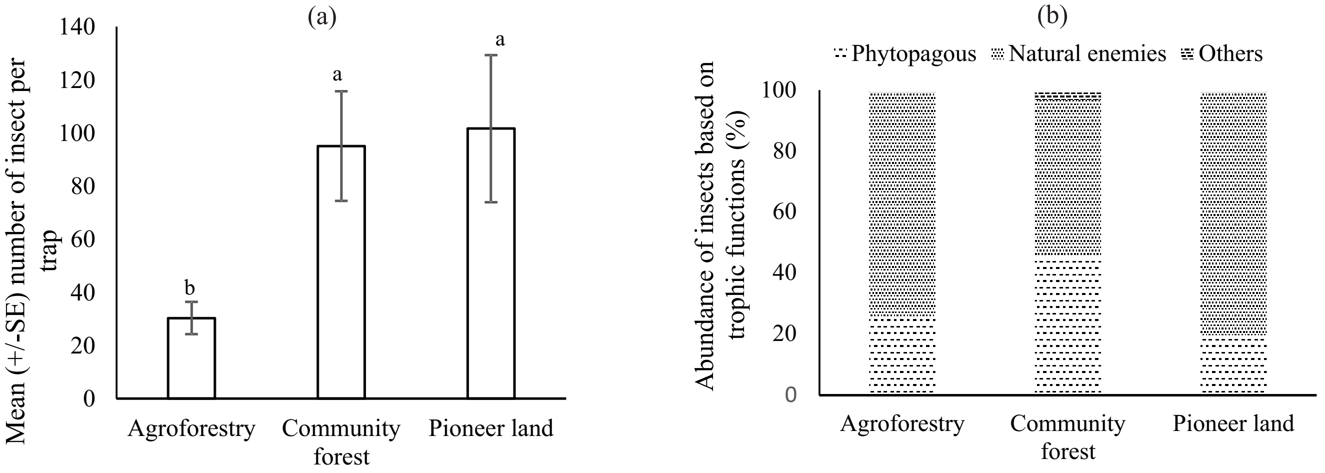

Figure 2 (a) The mean number of insects in general per trap and (b) Composition of the ecological role of insects in three different land use (agroforestry, community forest, and pioneer land). Different letters denote significant differences (p-value < 0.001).

The abundance of insects in three land uses showed the same trend, with natural enemies and phytophagous being the dominant insect. However, there are differences in the abundance proportions for natural enemies and phytophagous in agroforestry (73.5% and 25.8%, respectively), community forest (51.2% and 45.5%), and pioneer land (79.8% and 19.4%). The highest number of total phytophagous insects was found in community forests, while the lowest number was found in agroforestry. Previous research suggested that the abundance of phytophagous was influenced by the number of plant species and the percentage of land cover (Shin et al., 2021), as shown by community forests in this study. The low phytophagous in agroforestry land is determined by several factors, such as agroforestry phase, farmer management intensity, and the presence of natural enemies. The influence of trees in creating shaded areas was still minimal in early agroforestry because the utilization of horizontal space resources for seasonal crops was more than 50% (Suryanto et al., 2005). Plant diversity was very low in early agroforestry, and there was only one tree canopy stratification, *Tectona grandis*, and young *Moringa oleifera*. Aphids, thrips, and fruit flies are common insect pests on pineapple plants (Mia et al., 2019), but they were limited to agroforestry land in this study.

Phytophagous The abundance of phytophagous differed significantly between three land uses. Greater number of phytophagous were found on community forest (31.06 ± 6.7 individuals trap^{-1}), followed by pioneer land (16.87 ± 4.5 individuals trap^{-1}), and agroforestry (8.05 ± 1.91 individuals trap^{-1}) (df = 2; *F* value = 28.31; p-value < 0.001) (Figure 3a). While, the highest abundance of natural enemy insects was found on pioneer land (22.9 ± 6.7 individuals trap^{-1}); however, it was not significantly different on community forest (34.9 ± 15.3 individuals trap^{-1}) and agroforestry (69.1 ± 30.0 individuals trap^{-1}) (df = 2; *F* value = 1.46; p-value = 0.252) (Figure 3b).

Leafhoppers were found to be the most abundant of the phytophagous insects, followed by flies, thrips, and aphids. While the other phytophagous groups, including bugs, beetles, grasshoppers, lepidopterans, psyllids, and weevils, were obtained in small numbers, and data was not shown. Significantly greater number of leafhopper were found in community forest (23.88 ± 9.39 individuals trap^{-1}) and declining in pioneer land (7.93 ± 2.77 individuals trap^{-1}) and agroforestry (3.12 ± 0.83 individuals trap^{-1}) (df = 2; *F* value = 33.01; p-value < 0.001) (Figure 4a). Fly abundance show the same pattern as leafhopper, with the most abundant in the community forest (6.08 ± 1.05 individuals/trap), then pioneer land (2.3 ± 0.64 individuals trap^{-1}) and agroforestry (2.2 ± 0.51 individuals trap^{-1}) (df = 2; *F* value = 8.18; p-value <0.001) (Figure 4b). Thrips were common in pioneer land, show the higher abundance than that in community forest dan agroforestry (Figure 4c) (df = 2; *F* value = 3.52; p-value < 0.05). Aphids show not significantly different in abundance among three different land uses (df = 2; *F* value = 1.67; p-value = 0.212) (Figure 4d).

In three types of land, four dominant phytophagous taxa were observed: leafhoppers, flies, thrips, and aphids, all found in varying abundance. Agroforestry land showed more suitable for the presence of aphids. Leafhoppers and flies found suitable habitats in community forest ecosystems, while thrips are most abundant in pioneer land. Leafhopper insects (Cicadellidae) have a broad host range, according to previous studies (Freytag & Sharkey, 2002; Dominguez et al., 2021), and their occurrence is linked to tree canopy or canopy structure (Kishimoto-Yamada et al., 2015). Community and pioneer forests have more dense tree crowns than agroforestry among the three types of land examined. The highest abundance of Cicadellidae insects was observed in insect communities in forests, with the flowering season influencing the abundance of Cicadellidae (Schuh & Slater, 1995; Kishimoto-Yamada et al., 2015), which occurred in October in this observation.

The observation was carried out as the rainy season began in October when the trees in the community forest and pioneers began to grow new shoots. The presence of tree habitus and fruit plant species in community forests can be

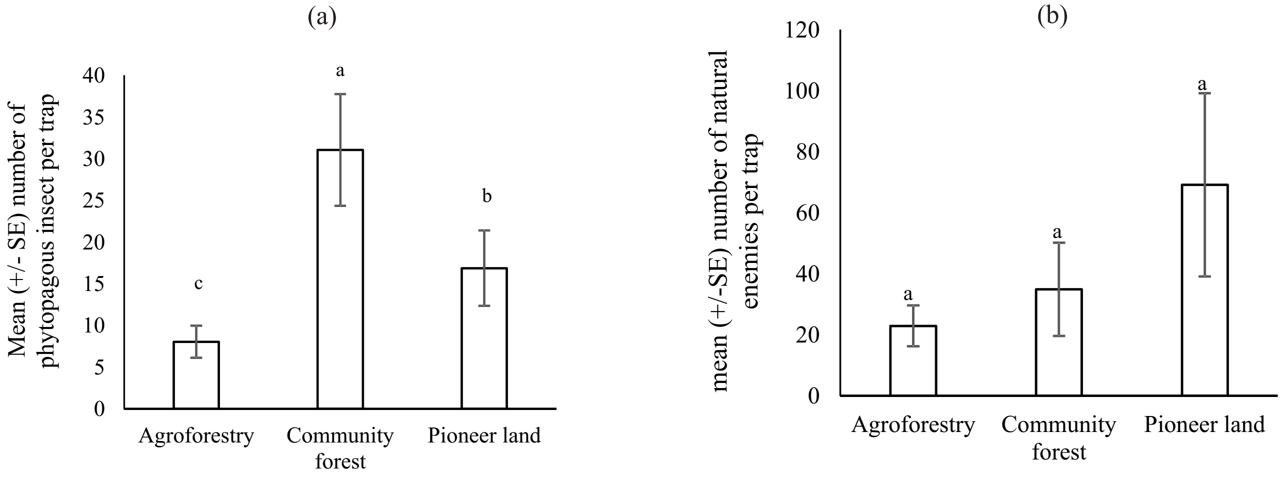

Figure 3 The mean number of insects per trap (a) as phytophagous and (b) natural enemies in three different land use (agroforestry, community forest, and pioneer land). Different letters denote significant differences (p-value < 0.001).

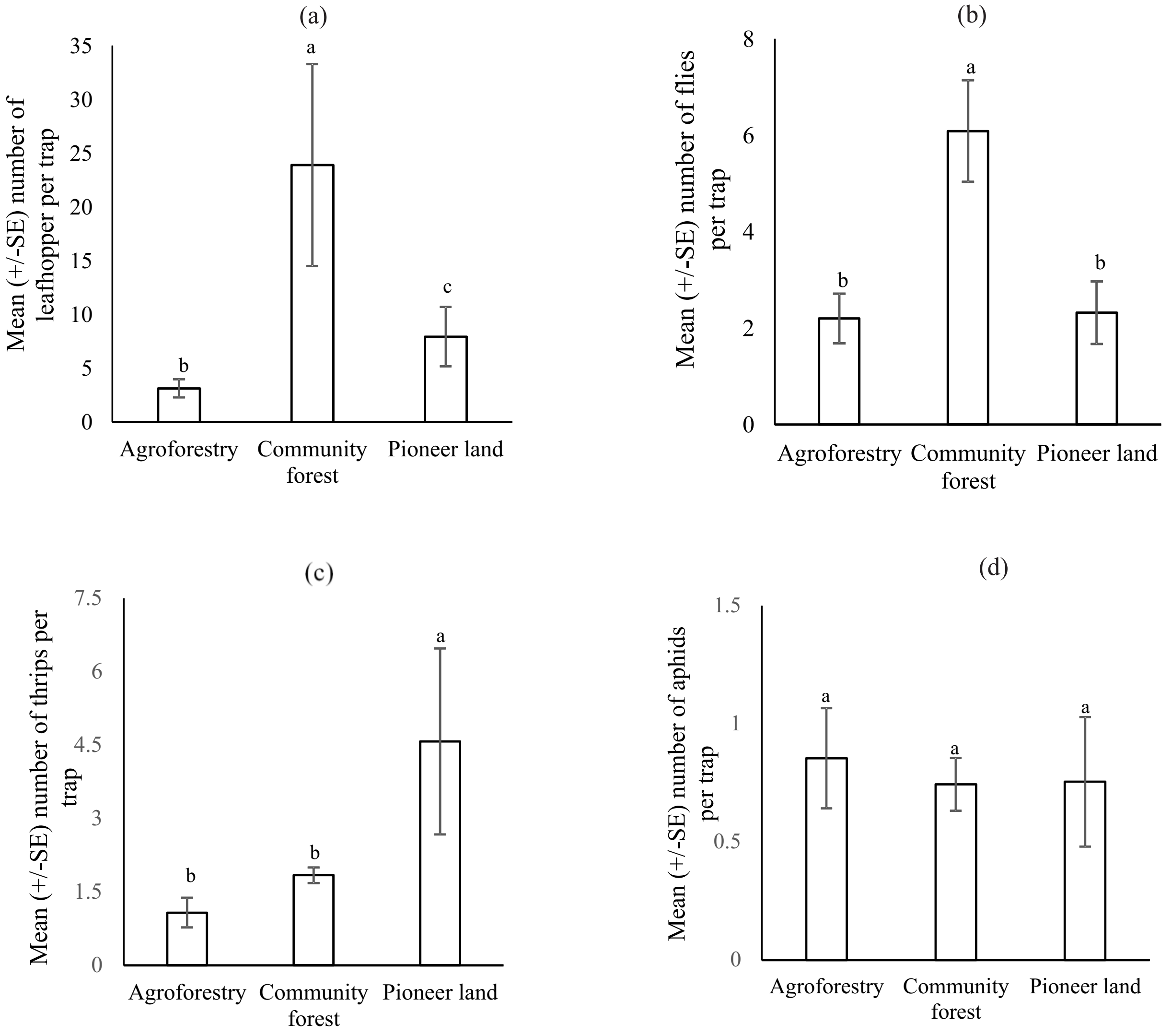

Figure 4 Phytophagous insects that showed greatest abundance on different land use (agroforestry, community forest, and pioneer land). (a) leafhopper, (b) flies, (c) thrips, and (d) aphids. Different letters denote significant differences (p-value < 0.001).

utilized as food resources and a place to shelter for groups of flies such as leafminer (Agromyzicae) and fruit flies (Tephritidae). Thrips were abundant on pioneer land, harming young shoots. Thrips are omnivorous insects, and one of the species (*Adelphithrips* sp.) consumes Asteraceae shrubs as host plants (Martin & Mound, 2004), which are abundant on pioneer land. In addition, in pioneer land, *G. sepium*, although generally free of insect pests, *G. sepium* is also known to host aphids (*Aphididae* sp.) (Boa & Lenne, 1996; COMACO, 2014). On pioneer lands, the presence of Gamal in large numbers and sizes and the existence of understory supports phytophagous populations, particularly aphids and thrips.

Natural enemies Coleoptera, Diptera, Hemiptera, Hymenoptera, Mantodea, Neuroptera, and Odonata were seven orders which have the potential to be natural enemies. The overall number of predatory insects from all land uses was not significantly different (df = 3; F value = 1.48; p-value = 0.246). However, the abundance of insects varies based on the insect orders. Hymenoptera dominated throughout all land uses and months of observation (>90%), with the other orders accounting for a small percentage (<10%). Formicidae were the most dominant Hymenoptera predators (>90 %), while Pompilidae, Sphecidae, Vespidae, and Crabonidae were all in relatively small numbers (<10%). There was no significant difference in Formicidae abundance between pioneer land and community forest (115.17 ± 22.2 vs. 88.85 ± 23.2 individuals trap^{-1}). However, there was a significant difference between Formicidae population on agroforestry land (24.80 ± 11.2 individuals trap^{-1}) (Figure 5a).

Eleven families of Hymenoptera (parasitic wasp), including Bethylidae, Braconidae, Chalcididae, Diapriidae, Eulophidae, Eupelmidae, Evaniidae, Ichneumonidae, Mymaridae, Scelionidae, and Trichogrammatidae, were obtained. Trichogrammatidae (>60%) and Scelionidae (>30%) are the most abundant families in all land uses, whereas other families are in small numbers. Although not significant, there is a trend for the highest abundance of Trichogrammatidae and Scelionidae on agroforestry land compared to community forest and pioneer land (Richogrammatidae: df = 2; *F* value = 0.44; *p*-value = 0.649 and Scelionidae: df = 2; *F* value = 7.02; *p*-value <0.05) (Figure 5b and Figure 5c).

This study shows that different land uses can have many natural enemies. The observations of natural enemies (Hymenoptera) were dominated by predator ants (Formicidae) and parasitic wasps (Trichogrammatidae and Sceliotidae). In comparison to agroforestry, community forest and pioneer ecosystems tend to become the most suitable habitat for the presence of ants. The community forest produced a high abundance of ants, as expected. Plants in an ecosystem are a good predictor of ant diversity (Li et al., 2017; Staab & Schuldt, 2020). The existence of a large tree canopy encourages the presence of ants (Davidson et al., 2003; Hernández-Flores et al., 2021), for example, *Camponotus Crassus* and *Pheidole* spp. ant colonies, nesting on the ground but actively foraging on plants (Anjos et al., 2017). The presence of natural enemies, particularly ants, appears to be supported by litter thickness and soil temperature in community forests and pioneers (Table 2).

Our results corroborate previous findings that the presence of litter on the forest floor positively affects the presence of ants (Yanoviak & Kaspari, 2000). Litter has an essential role in the presence of ants, particularly the types *Odontomachus* spp., *Ectatomma* spp., and *Trachymyermex* spp. (Yanoviak & Kaspari, 2000). Ant abundance will alter in response to the changes in ecosystem conditions (Hernández-Flores et al., 2021). Furthermore, ant abundance may decrease as a result of changes in land conditions caused by human activities (clear-cutting, land clearing) or natural forces (forest fire, windfalls) (Zettler et al., 2004), which is consistent with findings that ants were lowest in agroforestry.

The abundance of Trichogrammatidae and Scelionidae parasitoids shows a different pattern, which tended to be higher in agroforestry areas than in community forests and pioneer lands. Predators and parasitoids were affected differently by vegetation conditions and existing management activities on agroforestry land. The presence of perennial tropical grass (*P. purpureum*) encourages several

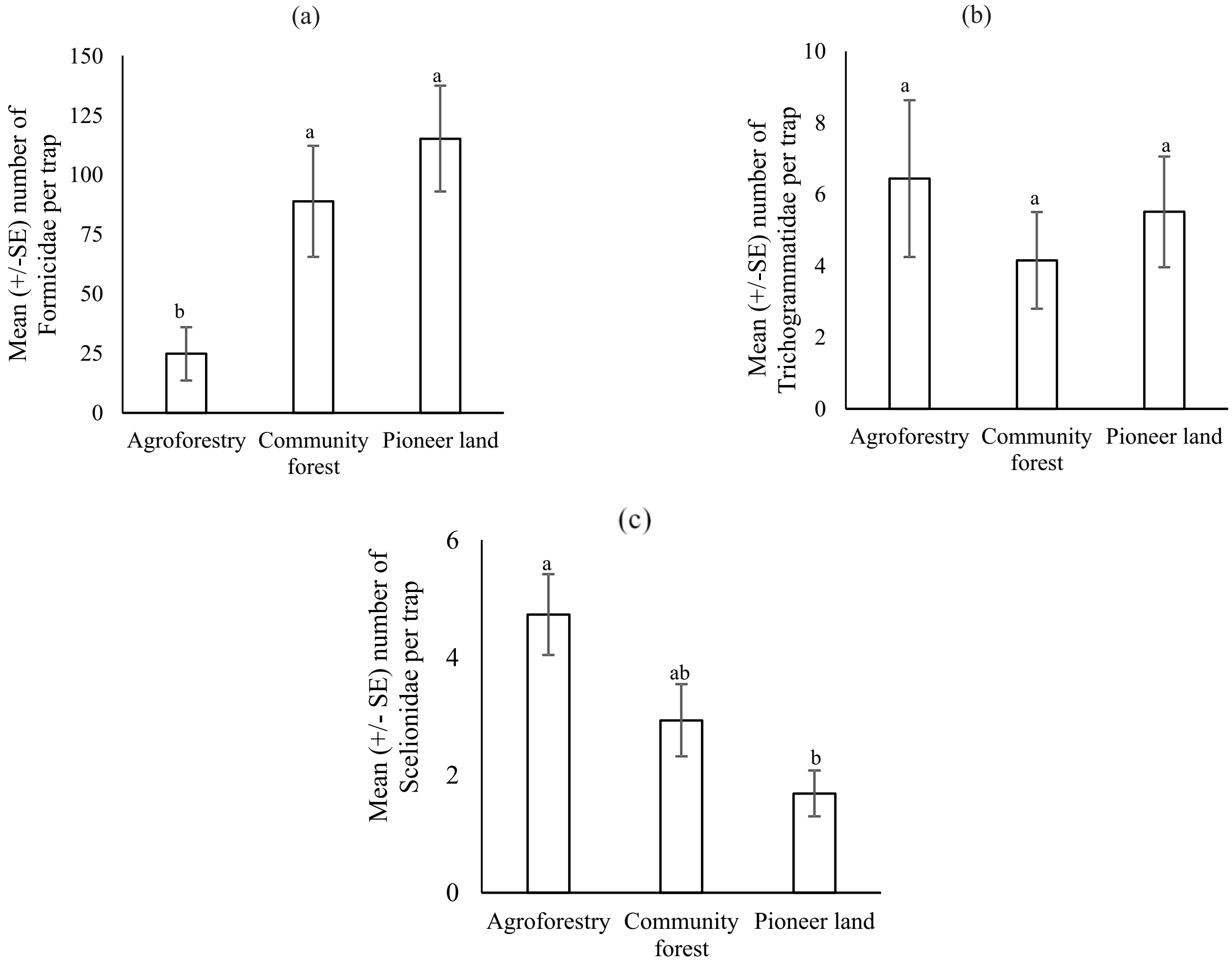

Figure 5 The abundance of Hymenopteran natural enemies (a) Formicidae, (b) Trichogrammatidae, and (c) Scelionidae at three different land use (agroforestry, community forest, and pioneer land). Different letters denote significant differences (*p*-value < 0.001).

Hymenoptera parasitoid insects, particularly Scelionidae, for protection and a good supply of Hemipteran hosts (Triplehorn & Johnson, 2005; Masfiyah et al., 2014). Farmers' soil cultivation activities seem to have not influenced the abundance of Scelionidae because these parasitoid insects' activity is not always on the soil surface (Anggara et al., 2015).

The high population of Trichogramatidae is assumed to be responsible for a reduced population of leafhoppers, flies, and thrips on agroforestry land. Leafhoppers have natural enemies; the most of these are egg parasitoids, with the rest including nymph and adult parasitoids (Mahesh et al., 2019). In Asia, the parasitoid Trichogrammatidae is an important natural enemy of agricultural pests, including Hemipteran insect pests (Triapitsyn et al., 2018). Other conditions that can allow parasitic wasps to develop on agroforestry land are the presence of refugia plants such as *billygoat weed* (*A. conyzoides*) and corn (*Zea mays*) (Setyadin et al., 2017).

The diversity of insects focused on their trophic functions (phytophagous and hymenopteran natural enemies) were obtained by using diversity index analysis (H') and species richness (SR). Index diversity (H') of phytophagous in agroforestry (H' = 2.70) was higher than pioneer land (H' = 2.55) and community forest (H'= 2.47) (Table 3). Hymenopteran natural enemies (predators and parasitoids) show different patterns, with the value of H' and species richness showing the highest value in community forest (Predator H' = 1.92; SR = 47 and Parasitoid H' = 2.16; SR = 27) followed with pioneer land (Predator H' = 1.09; SR = 37 and Parasitoid H' = 1.47; SR = 20) and agroforestry (Predator H' = 1.44; SR = 28 and Parasitoid H' = 1.45; SR = 11) (Table 3).

The value of the diversity index of phytophagous in three locations showed the diversity included in the medium category (Krebs, 1989). Agroforestry has the highest diversity index, suggesting that while the total number of individuals obtained is lower, each constituent species is present in significant numbers. While insects' total number and species richness in community forests are higher, most species are present in lower numbers than in agroforestry. Light intensity, temperature, humidity, vegetation, and land management activities are all factors that can influence insect diversity (Jactel et al., 2017; Hamblin et al., 2018; Triyogo et al., 2020). The community forest environment had the highest value for natural enemies' diversity and species richness index. This indicates that several species of natural enemies found in community forests are in high abundance. Meanwhile, the number of individuals for each natural enemy species is low in agroforestry and pioneer.

Modifications in ecosystems and land use will alter the composition of the community structure and the number of insects that live there. As a result, changes in micro-environmental parameters such as air temperature, soil conditions, litter, humidity, and light intensity can directly impact insect abundance, diversity, and distribution. Pioneer land has a low plant diversity; however, the habitus of old trees in large numbers can provide an ideal environment for insects, as shown by the community forest. Meanwhile, agroforestry lands with diverse vegetation but few trees produce lower insect numbers. This study showed that phytophagous dominance in each land type differed, with leafhoppers and flies (community forest), thrips (pioneer land), and aphids dominating in the three land uses. Consequently, there are differences in the abundance of hymenopteran natural enemies in the three fields, especially predators and parasitoids.

Conclusion

This study shows that the difference in land uses, including agroforestry, community forests, and pioneer land affects insect abundance. The abundance of insects in each land use is related to the presence of resources. The presence of prey insects as a food source for natural enemies and vegetation (trees and other habitus) as resources for phytophagous. Different insect communities are based on their roles (phytophagous and natural enemies) on land with different intensities of management and composition of vegetation. Land management activities have a different effect on the abundance of natural enemies, particularly predatory ants and parasitic wasps. Our research provides information about the effect of management activities carried out on several different land uses by using an ecological approach, particularly the presence of natural enemies. Anthropogenic changes in the form of human intervention in land management will potentially confront ecological issues in the future, particularly in sustaining the existence of natural enemies in the ecosystem.

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Table 3 Index diversity (H') and species richness (SR) of insect based on it is trophic functions (phytophagous, predator, and parasitoid) at three different land uses (agroforestry, community forest, and pioneer land)

Land use	Phytopagous		Predatory insects		Parasitoid	
	H'	Species richness	H'	Species richness	H'	Species richness
Agroforestry	2.70	38	1.44	28	1.45	11
Community forest	2.47	58	1.92	47	2.16	27
Pioneer land	2.55	44	1.09	37	1.47	20

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