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Managing sustainable agroecosystem: Study on diversity of parasitic Hymenoptera on riparian sites of oil palm and rubber plantation

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Abstract. Parasitic Hymenoptera is important natural enemies to control pest population but threatened by habitat transformation. It is important to know the sustainable management agroecosystem that may conserve beneficial insects. There is still minimum research about the effect of riparian buffers effect on Hymenoptera diversity. The objectives of this research were to study parasitic Hymenoptera species richness and abundance in oil palm and rubber plantation, investigate the effect of riparian sites on diversity and species composition across the different habitat. The research was conducted in Jambi Province, Sumatra, Indonesia which consists of two different agroecosystems, oil palm, and rubber plantation. Parasitic Hymenoptera was collected by direct sampling using insect nets and traps using a yellow pan and malaise traps. Parasitic Hymenoptera species richness was different among oil palm and rubber plantation. Oil palm had higher species richness than rubber plantation. Riparian buffers sites, either oil palm or rubber plantation, had higher numbers of parasitic Hymenoptera species richness and abundance than upland dry sites. These results are related to the high number of wild flowering plants species richness in riparian buffers sites. Community structure between riparian and dry agroecosystem was not different. The same agroecosystem provided the same feeding source and host for parasitoid. Therefore, managing sustainable agroecosystem should consider the presence of wild flowering plants that may preserve parasitic Hymenoptera diversity in providing natural enemy services in an agroecosystem.

Keywords: conservation, flowering plant, natural enemy, parasitoid

1. Introduction

The increasing human population resulted in transforming natural habitat into simplified agroecosystem in order to fulfill basic human needs. Humans are already an appropriate their net primary productivity for their use as food, feed, and fuel. The consequences of large-scale natural habitat transformation into simplified production system has resulted in the loss of species diversity and changes in community composition [1,2,3]. Natural habitat transformation also led to changes in ecological processes and interactions between the tropical levels, including natural enemies, herbivore and host plants. Increasing chemical and mechanical input to support high yield has led to negative impacts on the environment, especially biodiversity [4]. Exploiting natural habitat for high yield agriculture is pushing the boundaries of sustainability [5].



Oil palm and rubber are important commodities in Indonesia, yet they played as main contributors of natural habitat transformation [6,7,8]. Oil palm covered over 14.5 million hectares and produce over 45 million tons with Indonesia and Malaysia as the largest producers [9,10]. Indonesia also had 3 million hectares of rubber plantation, produced about 2.7 million tons and played as the greatest worldwide exporter of natural rubber [11]. Oil palm expansion in Indonesia was not only contributed to the loss of primary forest but also secondary, plantation forest and pre-existing cropland [12].

The Rapid expansion of monoculture, especially oil palm cultivation, changed hydrological function and water quality [13]. Water management was aimed at minimizing the impact of drought and floods; irrigation through river stream was one of water management that was applied in Indonesian oil palm plantation [14]. This made some oil palm plantations were located adjacent to rivers, riparian sites. Previous researches stated that the presence of riparian may affect invertebrate diversity. Flowering plants alongside the riparian margin in oil palm plantation can support the lives of bumblebee and butterflies by providing shelter and nesting locations [15]. The diversity, abundance and species richness of dung beetle were declined following the further distance from the riparian boundary. Not only that, the community composition was also different between oil palm cultivation which located near and far from the riparian [16].

Hymenoptera is one of the four great orders of insects, the other three being Coleoptera, Lepidoptera, and Diptera [17]. Hymenoptera is composed of 2 suborders, 27 superfamilies, 132 families, and 8423 extant genera have been described [18]. Hymenoptera has a beneficial role in the ecosystem especially as parasitoid to control herbivore insects population. A parasitoid is a natural enemy that could specifically control pests, have an abundant population in the ecosystem and able to reduce pest population significantly [19]. Parasitoid plays valuable roles in causing mortality of herbivores than predators or pathogens and maintaining the diversity of natural communities [20][21]. The valuable roles provided in controlling the herbivore population by parasitoid can be used as tools in a sustainable agroecosystem.

Considering the importance of parasitoid in the agroecosystem, we need to define and introduce an ecosystem that balances economic potential and its diversity concern. The information about the effect of the riparian site on the diversity of parasitic Hymenoptera was also still lacking. With this background, we focused to explore diversity and community structure of parasitic Hymenoptera between dry and wet on oil palm and rubber plantation. This research was aimed to (1) investigate the impact of riparian sites to the diversity of parasitic Hymenoptera, and (2) compare the species composition and community structure of parasitic Hymenoptera across different habitat site of the agroecosystem.

2. Materials and methods

2.1. Study sites

The research was conducted in oil palm and rubber plantation in Harapan Landscape, Jambi Province, Indonesia. Dry and wet sites were chosen for each commodity. The wet sites were the plantation located adjacent to the river. Each of the two habitat condition (dry and wet), four sites sized 20 m x 20 m in each plantation were established, for a total of 16 plots. Each plot had four transect area for insect sampling.

2.2. Sample collection and identification

We collected the insect by direct sampling and traps. Insect sweep net was used during direct sampling. Direct sampling was done by using transect walks which adapted from FAO protocol [22](Figure 1). Yellow pan and malaise traps were used as traps. Four yellow pan traps and a malaise trap were set up in each plot (dry oil palm, wet oil palm, dry rubber, wet rubber). Each trap was set up for 2 x 24 hours in the plot. Field sampling was conducted from 30 July to 6 November 2018.

All specimens were stored in 70% ethanol and were identified to morphospecies level using a stereo microscope and an identification book guide [23].

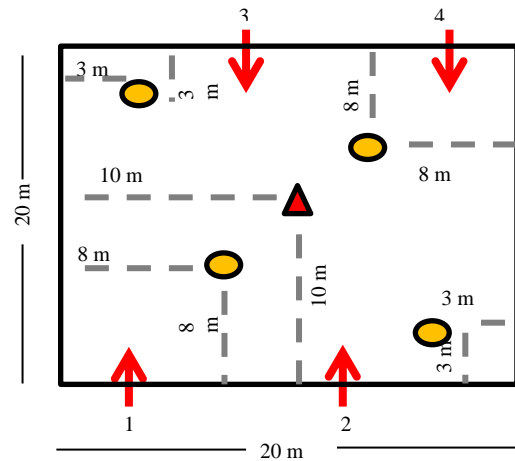


Figure 1. Schematic of sampling plot Transect of sweep net direction; place of yellow pan traps; place of malaise trap.

2.3. Data analysis

Shannon-Wiener and Simpson indexes [24] were calculated to know the diversity and dominance of parasitic Hymenoptera in each agroecosystem. Analysis of variance (ANOVA) was calculated to understand the difference of parasitoid richness and abundance between oil palm, rubber plantation and their habitat sites. Parasitoid community structure was compared between agroecosystem and habitat condition based on Bray-Curtis index then digitalized into nonmetric multidimensional scaling (NMDS) to show its relation. Analysis of similarity (ANOSIM) was tested to understand the significant differences of parasitoid community structure between agroecosystem and habitat condition [25]. All analyses were performed using R statistic software [26].

3. Results

3.1. Species richness and abundance

We collected 786 individual of parasitic Hymenoptera which consist of 24 families and 153 morphospecies. Total morphospecies and abundance of parasitoid in oil palm plantation were higher than rubber plantation (Table 1). Both riparian sites of oil palm and rubber plantation had higher numbers of species richness and abundance than the dry site. Parasitic Hymenoptera species richness was significantly different between different agroecosystem (P=0.02) but not in different habitat site (P=0.06). Parasitoid abundance was not had significantly different between different agroecosystem (P=0.06) and habitat site (P=0.16).

Table 1. Parasitic Hymenoptera species richness in different habitat sites of agroecosystems.

Habitat sites	Family	Morphospecies	Abundance	Shanon-Wiener Index	Simpson Index
Dry					
Oil palm	20	75	170	4.07	0.98
Rubber	18	67	110	4.01	0.98
Sub total	22	106	280		
Riparian					
Oil palm	22	104	379	4.11	0.98
Rubber	16	64	127	3.96	0.98
Sub total	23	130	506		
Total	24	153	786		

Scelionidae had the highest number of species richness and abundance in agroecosystem, both in riparian and dry sites, followed by Eulophidae, Encyrtidae, and Braconidae (Figure 1). Basically, parasitic Hymenoptera families had highest numbers of species richness and abundance in the riparian oil palm plantation, except Bethylidae, Eucharitidae, and Ichneumonidae. Bethylidae had the highest number of species richness and abundance in dry rubber but Eucharitidae and Ichneumonidae had the highest in dry oil palm plantation. There were some families that only found in one site, including Evaniidae and Mymarommatidae that only found in riparian oil palm.

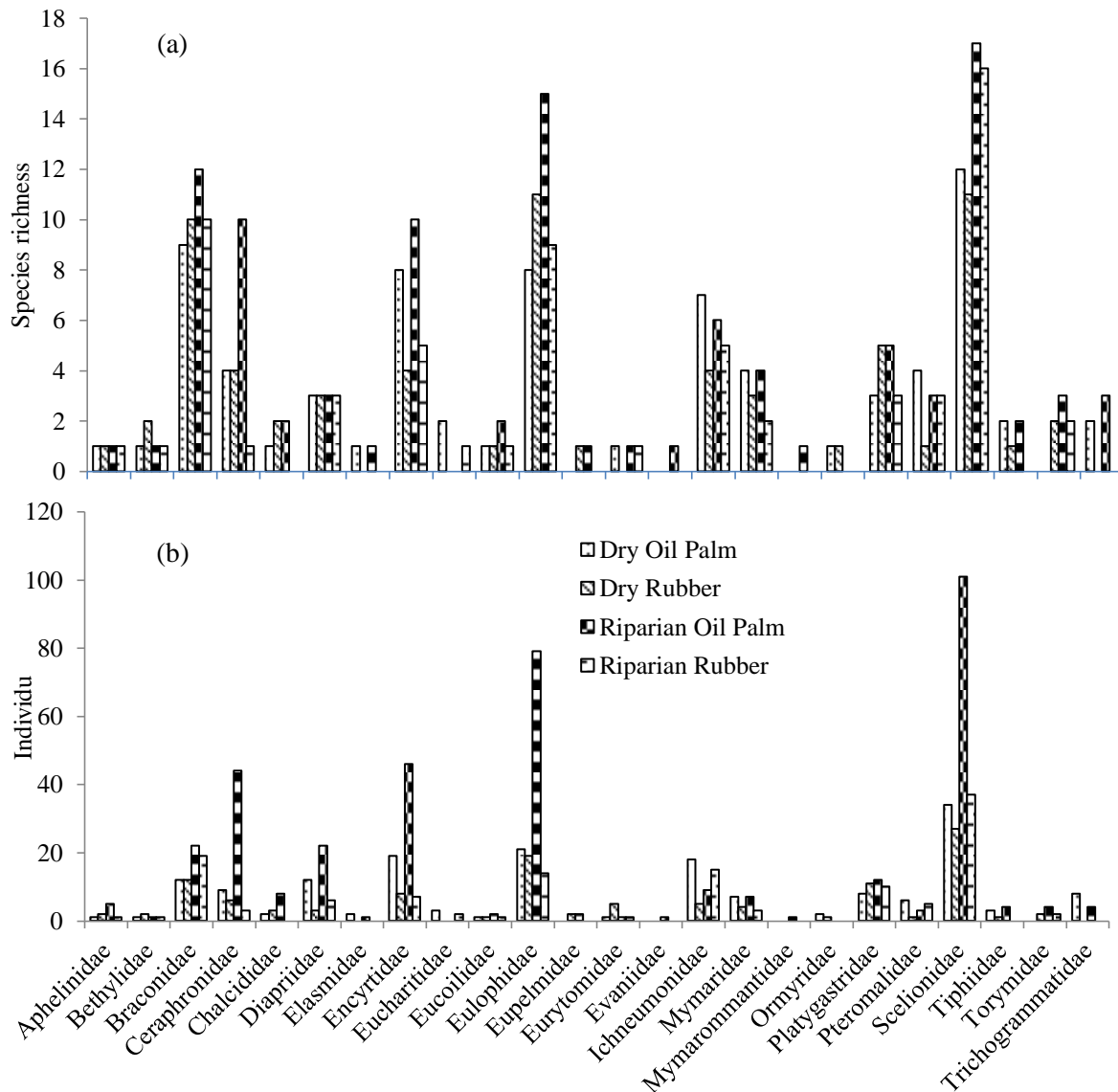


Figure 2. Species richness (a) and abundance (b) of parasitic Hymenoptera family.

Parasitic Hymenoptera diversity was influenced by the presence of understory flowering plants. The research resulted that parasitic Hymenoptera species richness and abundance were increased following the increasing of understory flowering plants richness (Figure 3).

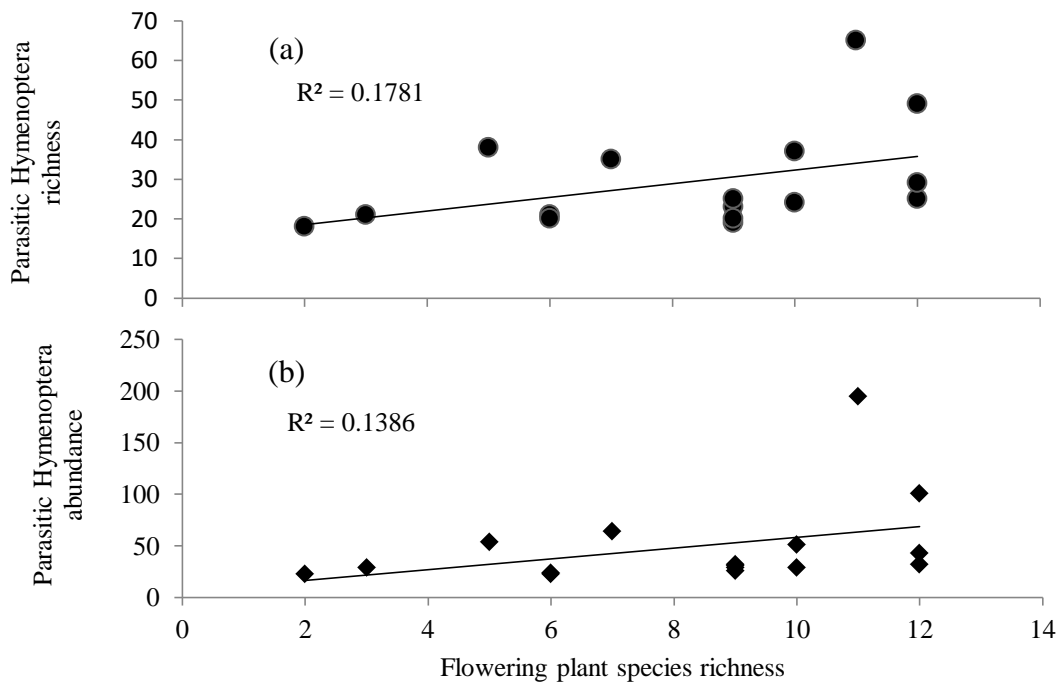


Figure 3. Correlation between understory flowering plant species richness and parasitic Hymenoptera species richness (a) and abundance (b).

3.2. Species composition and community structure in different land-use type and condition

The Bray-Curtis index showed that the same agroecosystem had a higher similarity of parasitoid species composition than the different agroecosystem (Table 2). The lowest species similarity was found between dry oil palm and wet rubber plantation.

Table 2. Similarities of parasitic Hymenoptera species (Bray-Curtis index) between different agroecosystem.

Agroecosystem	Dry rubber	Dry oil palm	Riparian rubber	Riparian oil palm
Dry rubber	1			
Dry oil palm	0.43	1		
Riparian rubber	0.39	0.39	1	
Riparian oil palm	0.30	0.42	0.29	1

Analysis of Similarity (ANOSIM) resulted that parasitoid species composition was different between oil palm and rubber plantation (R= 0.22, P=0.04) but not different between dry and riparian on each agroecosystem (ANOSIM, oil palm R= 0.11, P= 0.37; rubber R=0.08, P=0.34). NMDS ordinations showed that parasitoid community structure between dry and riparian was similar, either on oil palm or rubber plantation (Figure 4).

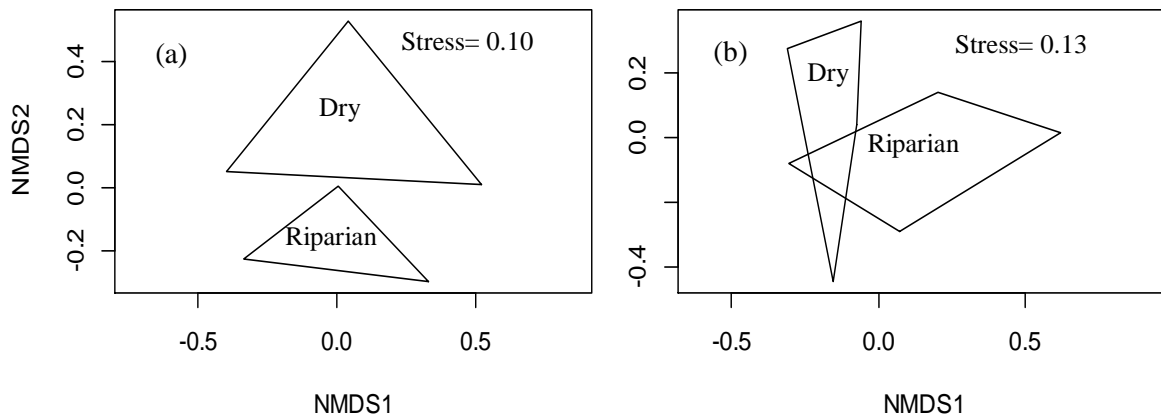


Figure 4. Variation in parasitoid community structure in (a) oil palm and (b) rubber plantation in non-metric multidimensional scaling (NMDS) ordination.

4. Discussion

This study showed that the riparian sites of agroecosystem had higher species richness and abundance of parasitic Hymenoptera than upland dry sites. Riparian were located adjacent river or water flow which had riparian vegetation zone. Riparian vegetation buffer zone functioned to filter sediment, nutrient, and pesticide which came from upland agriculture [27][28] Riparian vegetation zone can increase the species richness of understory flowering plant in that site. Parasitic Hymenoptera species richness and abundance was higher on the riparian site because parasitoid used flowering plants as primary non-host food [29]. Habitats which sources of sugar are abundant are particularly good for parasitoid [30].

Oil palm and rubber plantation had different parasitic Hymenoptera diversity. Oil palm plantation had higher numbers of parasitic Hymenoptera diversity than rubber plantation. Oil palm plantation had an open canopy so that parasitic Hymenoptera was suitable to live in there. Diversity of parasitic Hymenoptera was also affected by host availability. Rubber plantation was known as less pest attack, different than in oil palm plantation. In the study site, oil palm plantation had higher numbers of understory vegetation than rubber plantation which made oil palm had more complex on vegetation composition. Parasitic Hymenoptera diversity and function were higher on the ecosystem which had complex than simple vegetation composition [31].

Parasitic Hymenoptera species composition was not different between riparian and dry site neither in oil palm nor rubber plantation, however oil palm and rubber had different species composition. The same agroecosystem provided the same feeding source and host for parasitoid. It is indicated that species composition of parasitic Hymenoptera was closely associated with plant community structure and availability of its host [32].

There were some parasitoid families that only found on an agroecosystem. Evaniidae and Mymarommatidae were parasitoid families that only found in riparian oil palm plantation. Evaniidae was an abundant family of Evanoids in tropics area and parasite cockroach [33], Mymarommatidae was often found from leaf litter or soil extractions but its host still needs to be discovered [34]. The presence of Evaniidae on oil palm plantation was speculated by the location of oil palm plantation that located near the village because cockroach, its host, was abundant in urban area and warehouse.

Scelionidae was the most abundant family found in this research. Scelionidae are generalist egg parasitoid and mostly occurs in more open and sunny habitats [35]. The high abundance in oil palm and rubber plantation was caused by the habitat condition which open and sunny. The capability of Scelionidae, Eulophidae, Encyrtidae, and Braconidae to adapt to any environment condition and have wide host preference made them cosmopolitan and dominant in different habitats and agroecosystem.

Bethylidae was the only Chrysidoids superfamily found in this study. This is related that Bethyidae was the largest family of Chrysidoids superfamily and abundant in tropical areas [36].

The same species on same land-use type, both dry and wet site, were higher than the same species on a different land-use type. This happened because the same land-use type provided the same feeding source and host for parasitoid. It is indicated that the community composition of parasitic Hymenoptera was closely associated with plant community structure and availability of its host [30, 32].

5. Conclusion

Even there was no difference of species composition between riparian and dry site, parasitic Hymenoptera diversity was higher on riparian sites. The presence of flowering plants increased parasitic Hymenoptera diversity. Therefore in managing sustainable agroecosystems we need to maintain the diversity of understory flowering plants in order to preserve parasitic Hymenoptera diversity to provide natural enemy services.

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