CHAPTER IV

ANT SPECIES DIVERSITY IN MIXED DECIDUOUS FOREST, TEAK PLANTATION AND AGRICULTURAL AREA

4.1 Introduction

Ants play several important ecological roles. They play many roles in an ecosystem as preys, predators, detritivores, mutualists, and herbivores, and these functions are related to species and genera they belong to (Alonso, 2000; Schultz and McGlynn, 2000). Ants have numerous advantages that make them ideal for biodiversity and environmental monitoring studies. Ants are eusocial organisms, contributing to ants' numerical and biomass dominance, high diversity, and presence in almost every habitat throughout the world. Moreover, there are other advantages, such as fairly good taxonomic knowledge, ease of collection, and stationary nesting habits that allow them to be resample overtime, sensitive to environmental change (Alonso and Agosti, 2000).

Thong Pha Phum district, Kanchanaburi province, western of Thailand, located at the junction among three ecoregions, therefore, high diversity of habitats and organisms, particularly ants, are expected. Moreover, this area also has many land use types. There are mixed deciduous forest, national park, government plantation (teak and rubber tree), and agricultural areas, such as fruit orchard, rice and field crop cultivation. However, there was no study in ant diversity in these modification habitats. Variation in land use patterns has produced areas differing in vegetative cover, management, and some environmental factors.

With the increasing loss of habitats and biodiversity around the world, there is an urgent need for biodiversity assessments to be carried out during the conservation planning process (Alonso, 2000), as well as factors influencing biodiversity variation, such as habitats and/or land use types. This study determined and compared ant species diversity and ant species composition in different land use type; mixed deciduous forest, teak plantation, and agricultural area represented by fruit orchard. The basic knowledge of species diversity and species composition in different land use types from this study will assist for evaluation on the ant status for conservation management in the future.

4.2 Materials and Methods

4.2.1 Sampling Methods

In each of the three habitat types, a permanent plot of 15 × 50 m^2 was selected as a sampling area. The surveys at each site were conducted every month, from September 2007 to September 2008 inclusive. Five sampling methods were used to study the species diversity of ants in each habitat.

4.2.1.1 Handling capture with constant time

Each permanent plot (15 × 50 m^2) was divided into three strip-quadrats (5 × 50 m^2), and one person collected the ants for 30 minutes at each quadrat. The ants in each habitat were collected in three alternating time periods, in the morning, late morning and afternoon. The ants were extensively searched for on the bare ground, in the leaf litter, under stones, in decaying logs and under and on shrubs and from bases up to 1.5 m on trees. The ants were collected using forceps and gathered into a plastic vial filled with 95% ethyl alcohol. Each vial was labeled according to its plot, study site, collecting method, and collecting date. The specimens were taken back to the laboratory and classified. The handling capture samplings had been conducted once every month for 13 months.

4.2.1.2 Sugar-protein baiting trap (applied from Bestelmeyer et al., 2000)

Each permanent plot was divided into 30 smaller quadrats (5 × 5 m^2). Canned tuna fish was mixed with 80% (w/v) sugar solution at a 1: 1 (w/v) ratio and was used as the bait. Three grams of bait were placed directly on the center of a piece of cotton cloth (9 × 9 cm^2). The baited cloth was placed on each quadrat, and the ants on the cloth were harvested after 45 minutes. The ants found in the cloth piece were collected into a plastic vial filled with 95% ethyl alcohol. Each vial was labeled according to its plot, study site, collecting method, and collecting date. The specimens were taken back to the laboratory, classified, and counted individually. In total, there were 30 baits per each study site and the baited samplings had been conducted once every month for 13 months.

4.2.1.3 Pitfall trap (applied from Bestelmeyer et al., 2000)

Each permanent plot was divided into 30 quadrats, similar to the baiting method detailed above, except that a hole was dug at the center of each quadrat. A plastic container (8 cm diameter × 12 cm height) was placed in each hole with the lip of the trap level with the soil surface. Petroleum gel was applied around the inner lip of trap and a 2% (v/v) (alkylbenzene sulfonate Sunlight®, Unilever Thai Holding Comp.) detergent solution was poured into the trap to a depth of about two cm. Samples were collected after 24 hours and preserved in labeled plastic vials containing 95% ethyl alcohol. Each vial was labeled according to its plot, study site, collecting method, and collecting date. The specimens were taken back to the laboratory, classified, and counted individually. The pitfall tap samplings had been conducted once every month for 13 months. Each trap was not placed directly on any ant nest.

4.2.1.4 Leaf litter sifting

Each permanent plot was divided into 30 (5 × 5 m^2) quadrats, as above, from which ten were randomly selected. The leaf litter was collected from within a 1 × 1 m^2 quadrat positioned in the center of each selected 5 x 5 m^2 quadrat. In total, there were 10 leaf litter samples per each site. After collection, the leaf litter samples were sieved with a 0.8 × 0.8 cm^2 mesh and the ants were collected using forceps and gathered into a plastic vial filled with 95% ethyl alcohol. Each vial was labeled according to its plot, study site, collecting method, and collecting date. The specimens were taken back to the laboratory, classified, and counted individually. Leaf litter sifting samplings had been conducted once every month for 13 months.

4.2.1.5 Soil sifting

The soil was sampled in the same sampling quadrat as the leaf litter sample (above) in each site. In the center of the leaf litter sampling quadrat, the soil was collected in an area of 25 x 25 m^2 to five cm depth from the soil surface. The soil samples were sieved with 0.8 × 0.8 cm^2 mesh and the ants were collected using forceps and gathered into a plastic vial filled with 95% ethyl alcohol. Each vial was labeled according to its plots, study site, collecting method, and collecting date. The specimens were taken back to the laboratory, classified, and counted individually. Soil sifting samplings had been conducted once every month for 13 months.

4.2.2 Study of Physical Factors

4.2.2.1 Percentage of soil particle

The soil particles were determined three replicates of soil sampling and select randomly from each study site. The soil particles were determined by the Bouyoucos Hydrometer method (Department of Soil Science, Faculty of Agriculture, Kasetsart University, 2006). The percentages of soil particles were calculated.

4.2.3 Ant Identification

The specimens were card mounted in standard form for identifying to the genera and species level. The identification was based on the keys by Bolton (1994) and Wiwatwitthaya and Jaitrong (2001). The specimens were also compared with reference collections at Ant Museum, Faculty of Forestry, Kasetsart University and Museum of Zoology, Faculty of Science, Chulalongkorn University. Unidentified specimens were coded based on their reference collections, the sp. of AMK is the code of Ant Museum, Kasetsart University, the eg. following with a number is the code of Katsuyaki Eguchi, and the sp. of CUMZ is the code of Chulalongkorn University Museum of Zoology.

4.2.4 Data Analysis

The Shannon-Wiener's species diversity index (Krebs, 1999), was used to calculate the diversity of ants collected from four of the collection methods, i.e. the sugar-protein baiting trap, pitfall trap, leaf litter sifting and soil sifting. This is because hand collection with its inherent bias cannot be used to reliably support the relative abundance of each species. The formula of the Shannon-Wiener's species diversity index used is presented below:

$$H' = \sum_{i=1}^{s} (p_i)(\ln p_i)$$

Where, H' = Species diversity index

s = Number of species

p_i = Proportion of the total sample belonging to i^{th} species

The evenness index (Krebs, 1999) was calculated to determine the equal abundance of ants in each study site as follows:

$$\text{Evenness} = \frac{H'}{H'_{MAX}}$$

Where, H' = Observed index of species diversity

H'_{MAX} = Maximum possible index of diversity

The Sorensen's similarity coefficient (Krebs, 1999) was used to measure the beta-diversity or the similarity between two study sites as follows:

$$S = \frac{2a}{2a + b + c}$$

Where, S = Sorensen's similarity coefficient

a = Number of species in site A and site B

b = Number of species in site B but not in site A

c = Number of species in site A but not in site B

4.3 Results

4.3.1 Species Richness of Ants among Three Study Sites

Across the three sites 129 ant species and morphologically recognizable taxa (62 species and 67 morpho-species) from 49 genera were recorded which represents a reasonably good species richness. As showed in Table 4.1, these ants belonging to the nine subfamilies; Aenictinae, Cerapachyinae, Dolichoderinae, Dorylinae, Formicinae, Leptanillinae, Myrmicinae, Ponerinae, and Pseudomyrmecinae. The highest percentage of ant species number was in Myrmicinae (39%), followed by Ponerinae (25%) and Formicinae (19%), other subfamilies were lower than 5%. The genus *Pheidole* and *Polyrhachis* contained the highest species number (9), followed by the genus *Tetramorium*, *Leptogenys,* and *Pachycondyla* which has 8, 8, and 7 species, respectively. However, some genera were found only 1 or 2 species, such as *Philidris*, *Acropyga*, *Oecophylla*, *Rhopalomastix*, *Odontoponera*, *Platythyrea,* and *Probolomyrmex* (Table 4.1).

Table 4.1 The subfamily*, genera, and number of ants species in overall study site at Huai Khayeng sub-district, Thong Pha Phum district, Kanchanaburi province

Subfamily	Genera	Number of species
Aenictinae (5%)	*Aenictus*	6
Cerapachyinae (2%)	*Cerapachys*	3
Dolichoderinae (4%)	*Philidris*	1
	Tapinoma	2
	Technomyrmex	2
Dorylinae (1%)	*Dorylus*	1
Formicinae (19%)	*Acropyga*	1
	Anoplolepis	1
	Camponotus	3
	Oecophylla	1
	Paratrechina	6
	Plagiolepis	2
	Polyrhachis	9
	Pseudolasius	1
Leptanillinae (2%)	*Leptanilla*	2
Myrmicinae (39%)	*Calyptomyrmex*	1
	Cardiocondyla	3
	Carebara	1
	Cataulacus	1
	Crematogaster	5
	Lophomyrmex	1
	Meranoplus	1
	Monomorium	5
	Myrmecina	1
	Myrmicaria	2
	Oligomyrmex	3
	Pheidole	9
	Pheidologeton	3
	Recurvidris	1

Subfamily	Genera	Number of species
	Rhopalomastix	1
	Solenopsis	1
	Strumigenys	3
	Tetramorium	8
	Vollenhovia	2
Ponerinae (25%)	*Amblyopone*	3
	Anochetus	2
	Centromyrmex	1
	Diacamma	1
	Gnamptogenys	1
	Harpegnathos	1
	Hypoponera	3
	Leptogenys	8
	Odontomachus	1
	Odontoponera	1
	Pachycondyla	7
	Platythyrea	1
	Ponera	1
	Probolomyrmex	1
Pseudomyrmecinae (3%)	*Tetraponera*	4
Total	49	129

* The percentages in the subfamily column were percentages of the ant species number in each subfamily in overall study sites.

The highest number of subfamilies were found in the mixed deciduous forest (9 subfamilies) followed by the teak plantation (8 subfamilies), and the lowest was in the durian orchard (7 subfamilies). The ant genera were in similar trend, the highest was found in the mixed deciduous forest (42 genera), followed by the teak plantation (38 genera), and the lowest was in the durian orchard (26 genera). With respect to the comparative ant communities between the three sites, the highest number of species was recorded in the mixed deciduous forest (100 species), followed by the teak plantation (77 species), and the lowest in the durian orchard (46 species) (Table 4.2).

Table 4.2 The total number of subfamilies, genera, and species of the ants and the species diversity (H') and evenness indices in the mixed deciduous forest, teak plantation, and durian orchard at Huai Khayeng sub-district, Thong Pha Phum district, Kanchanaburi province

Study sites	Subfamilies	Genera	Species	H'	Evenness
Mixed deciduous forest	9	42	100	2.387	0.562
Teak plantation	8	38	77	1.463	0.365
Durian orchard	7	26	46	1.997	0.545

There were no Leptanillinae found in the teak plantation and no Cerapachyinae and Pseudomyrmecinae found in the orchard. Myrmicinae was the subfamily that found highest in species number in overall study area. Dorylinae was found only 1 species in the three habitats (Figure 4.1).

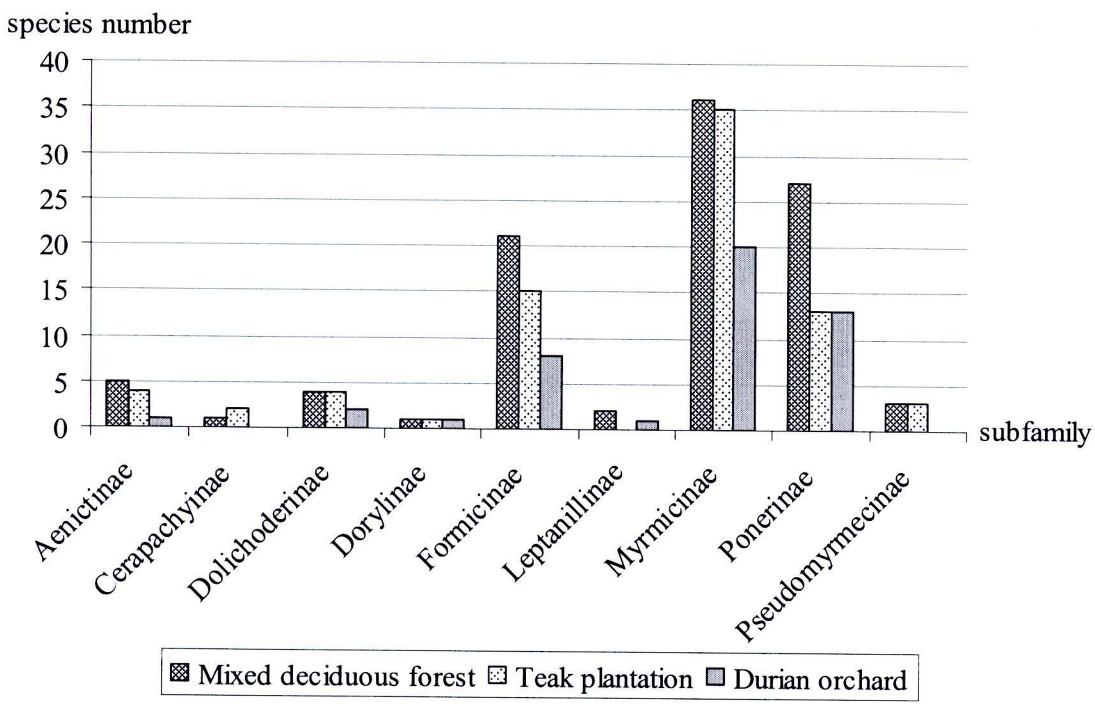

Figure 4.1 The ant species number in each subfamily among three study sites at Huai Khayeng sub-district, Thong Pha Phum district, Kanchanaburi province

Some species, such as *Pachycondyla luteipes*, *Pheidologeton affinis*, and *Odontoponera denticulata*, were found in all three land use types, while other species, such as *Acropyga acutiventris*, *Polyrhachis (Myrma) illaudata*, *Odontomachus rixosus*, and *Centromyrmex feae*, were found only in the mixed deciduous forest. Some ant species, such as *Camponotus (Myrmamblys)* sp.1 of AMK, *Myrmicaria brunnea*, and *Cerapachys* sp.5 of AMK, were found only in the teak plantation, and also some species were found only in the orchard, such as *Pheidole rabo*, *Solenopsis geminata*, and *Hypoponera* sp.3 of AMK. However, some species were found in both mixed deciduous forest and teak plantation, such as *Anoplolepis gracilipes*, *Oecophylla smaragdina*, and *Recurvidris* sp.3 of AMK (Table 1-A Appendix A).

4.3.2 Species Diversity Index among Three Study Sites

The Shannon-Wiener's species diversity index indicated that the year round diversity was the highest in the mixed deciduous forest (2.387), followed by the durian orchard (1.997) and lastly the teak plantation (1.463). Moreover, the highest value of the evenness index of ants was in the mixed deciduous forest (0.562), followed closely by the durian orchard (0.545), whereas the teak plantation was markedly lowers (0.365) (Table 4.2).

The mean of species diversity index of 13 months was the highest in the mixed deciduous forest (1.91±0.17), followed by the durian orchard (1.50±0.09) and the lowest was in the teak plantation (1.18±0.13). Moreover, the significantly difference was found only between the mixed deciduous forest and the teak plantation ($p \leq 0.05$) (Table 4.3).

Table 4.3 The mean* of species diversity index of ants from the three habitats at Huai Khayeng sub-district, Thong Pha Phum district, Kanchanaburi province

Study sites	Mixed deciduous forest	Teak plantation	Durian orchard
Species diversity index (mean±SE)	1.91 ± 0.17^{a}	1.18 ± 0.13^{b}	1.50 ± 0.09^{ab}

* The mean of diversity index in each column with the different letter were significantly different between the study sites by ANOVA ($p \leq 0.05$) with *Tukey's* multiple-rank test ($p \leq 0.05$).

4.3.3 Species Similarity between Sites

The species similarity between the mixed deciduous forest and the teak plantation, as evaluated by Sorensen's similarity coefficient, was the highest (0.655) while that between the teak plantation and the durian orchard and between the mixed deciduous forest and the durian orchard were intermediate (0.455) and the lowest (0.397), respectively (Table 4.4).

Table 4.4 The Sorensen's similarity coefficient of ants from the three habitats at Huai Khayeng sub-district, Thong Pha Phum district, Kanchanaburi province

Study sites	Mixed deciduous forest	Teak plantation	Durian orchard
Mixed deciduous forest	1	-	-
Teak plantation	0.655	1	-
Durian orchard	0.397	0.455	1

4.3.4 The soil particle

The three types of percentages of soil particle were similar trend in the mixed deciduous forest and the durian orchard whereas the teak plantation was distinctively in sand, silt, and clay percentages (Table 4.5).

Table 4.5 The mean percentages of each soil particle from the three habitats at Huai Khayeng sub-district, Thong Pha Phum district, Kanchanaburi province

Study sites	Percentage of soil particle (mean ± SE)		
	Sand	Silt	Clay
Mixed deciduous forest	72.91±1.76	8.09±1.29	18.99±1.55
Teak plantation	47.53±0.88	19.33±0.33	34.14±0.58
Durian orchard	76.98±1.26	6.45±0.73	16.57±0.79

4.4 Discussion

The proportion of ant species number in each subfamily in overall area found in this study supported the result from Phoonjumpa (2002), Suriyapong (2003), Bourmas (2005), and Hasin (2008) which reported that the subfamily Myrmecinae was the highest, followed by Ponerinae and Formicinae, respectively. This may be due to the fact that Myrmecinae is the largest subfamily in the world (about 4,400 species) based on both the number of genera and species, and this subfamily occurs throughout the world in all major habitats more than the others, so it can be often found more than the others (Hölldobler and Wilson, 1990; Bolton, 1994).

Dorylinae was found less than the others at only 1% in overall area. It may be because worldwide there is only one genus (*Dorylus*) belonging to this subfamily. Moreover, in Thailand, only three species of *Dorylus* have been referred by Ant Museum, Kasetsart University, the largest ant museum in Thailand. Leptanillinae was found 2 species in this study, due to the fact that this subfamily was small and rare, and their food source and habitats are also limited (Wiwatwitaya, and Jaitrong, 2001; Suriyapong, 2003). Cerapachyinae and Pseudomyrmecinae were found only 3 and 4 species, respectively, that may be because these subfamilies were found only 1-2 genera in Thailand (Wiwatwitaya, and Jaitrong, 2001) and had specific habitat. *Cerapachys* was found nest only in the leaf litter and action as generalist predators, temporal nest site, a few number of worker, so it was occasionally collected (Wiwatwitaya, and Jaitrong, 2001; Hasin, 2008). *Tetraponera* was nest in the twig and plant cavity and forage on the ground (Wiwatwitaya, and Jaitrong, 2001).

The highest in ant species numbers were found in genus *Pheidole* and *Polyrhachis* which similar to previous report. Bourmas (2005) reported that *Polyrhachis* and *Pheidole* was the first and second in species number in Huai Khayeng sub-district. The ant genus *Pheidole* has been one of the large genera in the family Formicidae (Eguchi, 2001). This genus distributes worldwide in the tropics and warm temperate regions (Brown, 2000). *Pheidole* is the one of the prevalent ground-dwelling genus (in both species richness and abundance) in world tropics (Ward, 2000). However, several ant genera were found only 1 or 2 species in Thailand (Wiwatwitaya, and Jaitrong, 2001). Those were *Anoplolepis, Recurvidris*, *Centromyrmex, Myriella*, *Cataulacus, Carebara*, *Pseudolasius*, *Proatta*, *Oecophylla*, *Solenopsis*, and *Odontoponera*. Therefore, the percentages of these genera were lower than the other genera.

The overall genera and species number of ants in this study was lower than the previous report of ant diversity in Huai Khayeng sub-district. Bourmas (2005) studied in the Golden Jubilee reserve forest, 9 subfamilies, 56 genera, and 202 species were found. It may be because the study was done in 4 forest types: dry evergreen forest, lower mixed deciduous forest, dry upper mixed deciduous, and disturbed mixed deciduous forests that may have more diversity than these 3 study sites (mixed deciduous forest, teak plantation, and durian orchard). Moreover, the ants were surveyed in the temporal plots that might have a chance to find more species than in this study that was the permanent plot.

Both the species richness and the diversity indices of ants were the highest in the mixed deciduous forest, whereas the ranked order (mixed deciduous forest > teak plantation > durian orchard for species richness and mixed deciduous forest > durian orchard > teak plantation for diversity index) showed a slight difference between the teak plantation and the durian orchard. The relatively high ant species diversity in the mixed deciduous forest may be caused by the correspondingly high diversity in the plant community and as such would potentially reflect the differences in the canopy cover and leaf shedding. In this scenario, the leaf litter, soil moisture content, and leaf litter biomass in each study site would likely be affected by differences in each plant community, as reported by Bourmas (2005) and Hasin (2008). The difference in leaf litter biomass in each habitat type was affected to the soil fauna that was the food source of ants (Bourmas, 2005). Moreover, there were various microhabitats in the forest sites, such as leaf litter, decaying logs and under stones or bark. In the mixed deciduous forest site, many predatory ants were found including litter specialist predators, such as *Leptogenys* and *Oligomyrmex*, and litter generalist predators, such as *Hypoponera* and *Anochetus*. The various in habitats, forest types, and food sources were affected to the species diversity of ants (Andersen, 2000).

The distinct of the percentage of soil particle in the teak plantation might be another reason. The highest in clay percentage that made this area very hard in the dry season and more saturated denseness in the wet season that were not suitable to be a nest site for many ant species. The species richness of ants in the natural mixed deciduous forest higher than in the teak plantation was similar to the reported trend for ant diversity at Sabah, Malaysia which was higher in the primary and secondary forests than in the oil palm plantation (Yahya, 2000).

The durian orchard had the lowest species richness compared among the study sites. It may be because the durian orchard has been continually adjusted and disturbed by farmer practices over many years. Moreover, the durian orchard had no shading tree in the area. The loss of shade trees might produce a shortage of nesting sites and resources leading to reduce ant diversity. Lack of nesting sites is suggested to be the cause the loss of ant diversity along the agricultural intensification gradient (Armbrecht and Perfecto, 2003). Although the durian orchard had the lowest species richness, it had a higher evenness index than in the teak plantation, and was at almost the same level as the natural forest (ranking for evenness is mixed deciduous forest ~ durian orchard > teak plantation) (Table 4.2), which reflected in the higher species diversity index than in the teak plantation. Another possible reason is that most of the ants found in the durian orchard were genera that usually form large colonies containing large numbers of workers and can found all year round, such as *Pheidologeton*, *Pheidole*, and *Solenopsis*. In the durian orchard, the leaf litters (from pruning process) were gathered around the tree, except after the harvesting period when the leaf litters were abandoned (June to August), so the moisture was maintained by the grass cover. Moreover, in the tree canopy the durian orchard, agrochemicals, such as pesticides and fertilizers, were applied all year round, so there were no arboreal ant species in this area except for *Polyrhachis (Campomyrma) halidayi*, which was found only as one individual (reproductive caste) with no evidence of persistence (nest site or workers), whereas this species was persistent in the natural forest.

The similarity indices indicated that the species composition of ants was higher between the natural forest and the teak plantation than that between the mixed deciduous forest and durian orchard. The similarity in species composition of ants between the mixed deciduous forest and the teak plantation was higher than 60%, whereas the index between the mixed deciduous forest and the durian orchard was lower than 50%. These may indicate that the mixed deciduous forest ant species have higher ability to recovery in the teak plantation than in the durian orchard where has been continuously modified by the farmers. Comparing with the primary land use as a natural forest, this result suggests that these two modified land uses reduced the ant diversity and that, despite the fire in the teak plantation during the sampling year, the durian orchard could support lower ant diversity than the teak plantation. This might be due to the fact that the tree canopy of the durian orchard was treated all year round by agrochemicals, including pyrethroid and organophosphate pesticides and mixed fertilizers for nitrogen, phosphorus and potassium. The herbicide glyphosate also affected some arthropods and other food sources, such as weed nectar and seeds, were also used. These agrochemicals differentially affected the ant species composition through either direct poisoning or indirectly through loss of prey species and so explain the different ant species composition in the durian orchard compared to that in the teak plantation and mixed deciduous forest. Therefore, the canopy ants, even ant species commonly found in disturbed areas, such as *Oecophylla smaragdina*, or other canopy ants, such as *Crematogaster*, *Tetraponera*, and some *Polyrhachis*, were absent in the durian orchard. Moreover, ants predatory that might control some insect pests in this area, such as *Odontoponera denticulata,* were regulated by the practice of the farmer. The limited of nesting resources in the orchard and change in microhabitat conditions because of the area management may become increasingly important to explain the low of diversity of litter ants when the forest were transformed into chemically intensive, durian orchard. Similar to the study in coffee plantation, Armbrecht, Perfecto, and Silverman (2006) found the loss of diversity of litter ants when the traditional, forest-like coffee farm was transformed to intensive and un-shaded coffee plantation.