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# Ground-dwelling ants species diversity (Hymenoptera: Formicidae) at conservation forest and oil-palm plantation in Sumatra, Indonesia

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## ABSTRACT

**This study aimed to investigate the diversity of ground-dwelling ant species within the conservation forest patch and the plantation area of an oil-palm plantation in Sumatra. Modified quadra protocol was applied to collect ants at five sites in the conservation forest and one location in the oil-palm plantation. A total of 76 ground-dwelling ant species belonging to 36 genera and six subfamilies were collected. The subfamily Myrmicinae was the highest in total species number (31) collected followed by Formicinae (29) and Ponerinae (9). The diversity index for the overall species collected was 3.00. Ant species diversity in both sites showed that the area still retains high diversity value for ants, and presumably for other taxa as well.**

**Key words :** Biodiversity, conservation forest, ground ants, oil-palm plantation, Sumatra.

## INTRODUCTION

Albeit being more abundant in the tropical region, ants inhabit most continents and play an important role in functioning the ecosystems. Ants composed a significant part of total animal biomass and were described as ecosystem engineers (Folgarait, 1998). Previous studies reported that ant's diversity was affected by the conversion of primary rainforest to the agriculture area (Brühl and Eltz, 2010; Fayle *et al*., 2010). The difference in habitat conditions may impose on the composition of ant species (Dac and Phuong, 2016; Schreven, 2018). The plantation, which converted from previously natural forested habitat, was also predicted as affecting factor for ant diversity (Onishi *et al*., 2016). Ants possess great potential as a biological control agent in the agroecosystem, and they have the viability to be combined within the Integrated Pest Management. Hence, it is crucial to identify any formicid fauna that presents in a given agroecosystem (Diame *et al*., 2018).

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There was a handful of ant studies in Sumatra, yet the least conducted in anthropogenic areas. Including the study on ant composition in banana plantation indicated with BBTV symptom in West Sumatra (Herwina *et al*., 2013). Other studies were located in Sumatran natural forest, such as the finding of *Odontomachus minangkabau*, new ant species from the Forest of Research and Educational Biology of Universitas Andalas (Satria *et al*., 2015); ant composition at four types of land use in the surrounding of Harapan Forest and Bukit Dua belas National Park, Jambi Province (Rubiana *et al*., 2015); as well as ant diversity in *Macaranga* trees in Tidar Kerinci Agung Inc., West Sumatra (Putri *et al*., 2015).

The Tidar Kerinci Agung Inc. (after this TKA Inc.) is an oil-palm plantation company that possesses land concession of about 28.064 ha, comprised of a region shared in between West Sumatra and Jambi Province. To comply with the green oil-palm requirement, the company maintains an area of 2,400 ha named Conservation Forest of Prof. Sumitro Djojohadikusumo (hereinafter conservation forest) (Tidar Kerinci Agung Inc., 2011). Previously, there were 28 arboreal ant species from five subfamilies, 11 tribes, 17 genera, and 5,277 individuals collected from five *Macaranga*

species in this conservation forest (Putri *et al*., 2015). Despite the possible higher ground-dwelling ant in this area, this aspect somewhat neglected in the previous study. Given the assumption that ants' domination should also apply in each habitat type and unique environment within the boundary of the TKA Inc., hence we aimed to investigate the diversity of ground-dwelling ant species within the conservation forest and at the oil-palm plantation.

## MATERIALS AND METHODS

Ants were collected at TKA Inc.'s conservation forest and oil-palm plantation covering the area that administratively located between two regencies, Solok Selatan and Dharmasraya, in West Sumatra Province. The sites ranged from 275 - 650 m elevation, where temperature measured between 19 - 30°C, humidity from 63 - 77%, and rainfall between 3,000 - 4,000 mm/year (Table 2). Ant samplings were undertaken at five sites in conservation forest, and one site within oil-palm plantation using modified Quadra Protocol (Hashimoto *et al*., 2001). The collection works at conservation area were detailed as follow; at Miniature forest (MF) and IPK4 sites on October 22, 2014; at Sungai Basah (S Basah) on March 26, 2015; at Bintang Maria (B Maria) and Bukit 9 sites on March 31 and April 1, 2016, respectively. Ants were collected by using two transects at conservation forest (one set at the forest edge, another within it); meanwhile sampling at the oil-palm plantation was conducted at a site adjacent to the IPK4 site by using a single transect.

Samplings at conservation forest used two 180 m transects divided into three sub-transects (60 m each). Each sub transect was inspected with four different methods: hand collecting, leaf litter sifting, soil core sampling, and honey bait trap (Fig. 1). The leaf litter sifting was not applied for the work at oil-palm plantation, due to no leaf litter observed therein. The hand collection method sampled ants at lower vegetation, under the logs, rocks, and ground surface; any sighted ant was then picked using forceps. In leaf litter sifting method, leaf litters were collected, sifted onto a white tray to detect ants individual before sampled. Both methods were applied for 30 min in each sub transect. For the soil core method, five soil core masses (dimension

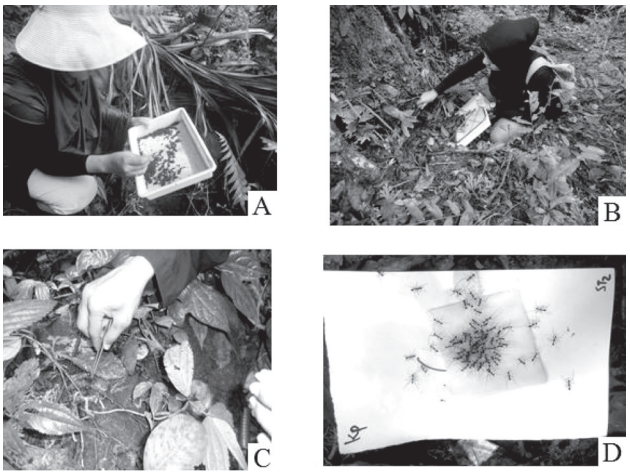


**Fig. 1.** Quadra protocol methods in each transect at conservation forest of TKA Inc. in West Sumatra, Indonesia (A) Soil Core Sampling, (B) Leaf Litter Sifting, (C) Hand Collecting and (D) Honey Bait Trap.

20 × 20 × 15 cm) were drilled from the ground at equal intervals along each sub transect. The soil core masses were sorted with hand-sieve onto the white tray where ants detected and collected. In the last method, 15 traps were prepared using baits of honey drop placed on a piece of paper and set on the forest floor at four meters interval along the sampling transect. Attracted ants then collected with forceps and put into the vial filled with 96% ethanol.

Ant specimens were identified using guidances books (Bolton, 2016; Jaitrong, 2011; Hashimoto, 2003) until the genus and morpho-species level. In case a specimen could not be identified using identification guides, nor with reference materials, it is then written as morpho-species with additional code "HH" (after the collection manager Henny Herwina) and SKY (after Seiki Yamane). All specimens collected in this study are deposited in the Laboratory of Animal Taxonomy in the Biology Department of Universitas Andalas, Padang, West Sumatra, Indonesia. Ant diversity was calculated using the Shannon-Wiener index (Maguran, 2004). Estimate S Ver. 9.0 was in use to calculate the rarefaction curves of the observed and estimated number of ant species among study sites (Colwell, 2013), while PRIMER v 7 is for calculating similarities among transects and sites (Clarke and Gorley, 2015).

## RESULTS AND DISCUSSION

A total of 76 species of ground-dwelling ants belonging to 36 genera and six subfamilies were collected from the conservation forest and oil-palm plantation. The subfamily Myrmicinae became the highest in the total number of species collected (31), followed by Formicinae (29) and Ponerinae (9). *Pheidole* sp. 1 of HH, *Pheidole* sp. 3 of HH, and *Carebara affinis* were species with the highest number of individuals collected, as well as recorded in all study sites (Table 1). Total subfamilies observed among sites in conservation forest ranged from five to six, while in oil-palm plantation only with four subfamilies. The dominancy trend for subfamily Myrmicinae, Formicinae, and Ponerinae was similar to previous studies given these subfamilies known to well adept with various types of environment, especially on Myrmicinae (Herwina and Nakamura, 2007; Herwina *et al*., 2013; Putri *et al*., 2015).

Several genera with high species numbers were observed in the subfamily Formicinae (*Camponotus* with 13 species, *Polyrhachis* with six species and *Nylanderia* with four species), then in Myrmicinae (*Pheidole* with eight species, *Crematogaster* and *Tetramorium* with four species each and *Monomorium* with three species). All dominant genera in this study were also recorded from several sampling works conducted at other forested and agricultural areas in West Sumatra (Herwina, *pers. obs.*). *Pheideole* was a genus with the highest species number at the Educational and Biological Research Forest of Universitas Andalas (Herwina *et al.*, 2018). *Tetramorium,* together with *Technomyrmex* were dominant genera recorded at the banana plantation indicated with BBTV symptoms (Herwina *et al.,* 2013). *Crematogaster* was previously recorded as the highest in species numbers at a rubber plantation in Cambodia (Hoshoishi *et al.*, 2013).

Total genera for sites in conservation forests ranged from 18-26 while in the oil-palm plantation was 16 (Table 2). Total species number for sites in conservation forest ranged from 35 in B Maria site up to 51 in IPK4 site and 26 species recorded in the oil-palm plantation. The total species number at this oil-palm plantation was considerably high in the regard that the sampling conducted using only one transect, while other sites with two each. Total species number at the oil-palm plantation was higher than MF site (forest edge), Bukit 9 site (forest edge), and B Maria site (forest edge) (Table 3).

Total ants collected by single transect at the oil-palm plantation were higher than those collected at similar oil-palm plantation habitat in Sabah, Malaysian Borneo (26 compared to 23 species) (Brühl and Eltz, 2010). The total species number collected in this study, however, was lower than what observed in previous studies; 84 species at cacao plantation and forest areas in Southeast Sulawesi (Asfiya *et al.*, 2015); or 101 species at four types land-use around Harapan Forest and Bukit Dua Belas National Park, Jambi Province (Rubiana *et al*., 2015). The differences of habitats and methodologies used in each study could result in different results, albeit the Shanon Wiener diversity index for all ant species in this study came out as the highest, 3.00 (Table 3). This index indicated the high ant biodiversity inhabit in this area.

In Table 4, B Maria and Bukit 9 sites shared the highest similarity (59.65) while Bukit 9 sites and oil-palm plantation as the lowest (12.27). The similarity indices among the rest of the sites paired were not significantly different except for MF-Bukit 9 sites, MF-B Maria sites, and Bukit 9-B Maria sites. Accumulation curve showed that species number increased by the number of transects sampled. Species number was observed quite lower than what estimated for transect 1 and 2, before later increasing at transect 4 and 5. There was no significant increment between observed and estimated species numbers for transect seven until transect 11. Most of the ant species in the oil-palm plantation were assumingly collected during this study, indicated by the asymptote curve type produced from species collected here (Fig. 2).

The conservation forest in TKA Inc. was fragmented by oil-palm plantation blocks. Land fragmentation affects ant community composition by changing abiotic conditions, the availability of food sources and nest sites, and the abundance of mutualist or competitors. Increased edge habitat in fragmented landscapes may facilitate invasions by non-native ant species, which eventually alter the composition of native ant communities (Crist, 2009). In the present study, several invasive ant species

**Table 1.** List of ant families, species and total individuals collected at conservation forest and oil-palm plantation in TKA inc.

| S. No. | Subfamily species | Total number of individuals | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | OP | T |
| Dorylinae | | | | | | | | |
| 1 | *Aenictus laeviceps* (Smith, 1857) | | 1 | | 59 | | | 60 |
| 2 | *Cerapachys jacobsoni* Forel, 1912 | | 11 | | 24 | 5 | | 40 |
| Dolichoderinae | | | | | | | | |
| 3 | *Dolichoderus thoracicus* (Smith, 1860) | 13 | 13 | 27 | 27 | 41 | | 121 |
| 4 | *Iridomyrmex anceps* (Roger, 1863) | 29 | | 17 | 3 | | 13 | 62 |
| 5 | *Tapinoma melanocephalum* (Fabricius, 1793) | | 1 | 7 | 42 | | 5 | 55 |
| 6 | *Technomyrmex kraepilini* Forel, 1905 | 10 | | | | | | 10 |
| Formicinae | | | | | | | | |
| 7 | *Colobopsis cf. saundersi* (Emery, 1889) | 1 | 3 | | 5 | 15 | | 24 |
| 8 | *Colobopsis* sp. 2 of HH | | 2 | | | | | 2 |
| 9 | *Colobopsis* sp. 69 of SKY | | 4 | | 14 | 5 | | 23 |
| 10 | *Dinomyrmex gigas* (Latreille, 1802) | 27 | 55 | | 11 | 17 | 2 | 112 |
| 11 | *Camponotus (Myrmamblys) bedoti* (Emery, 1893) | | 2 | | 6 | | | 8 |
| 12 | *Camponotus (Myrmosaulus) camelinus* (Smith, 1857) | | 1 | | 15 | 1 | | 17 |
| 13 | *Camponotus (Tanaemyrmex) arrogans* (Smith, 1858) | | 27 | | 2 | 1 | 9 | 39 |
| 14 | *Camponotus (Tanaemyrmex) festinus* (F. Smith, 1857) | | 1 | 1 | | | | 2 |
| 15 | *Camponotus (Tanaemyrmex) odiosus* (Forel, 1886) | | 6 | | 1 | 21 | | 28 |
| 16 | *Camponotus (Tanaemyrmex*) sp. 12 of SKY | | | | 1 | | | 1 |
| 17 | *Camponotus (Tanaemyrmex)* sp. of HH | | 1 | | | | | 1 |
| 18 | *Camponotus* sp. of HH | | | | | 1 | | 1 |
| 19 | *Echinopla melanarctos* Smith, 1857 | 1 | 6 | 2 | 2 | 1 | | 12 |
| 20 | *Polyrhachis (Myrma) hosei Donisthorpe*, 1942 | 6 | 12 | 4 | 4 | 4 | 2 | 32 |
| 21 | *Polyrhachis (Myrma) proxima* Roger, 1863 | | 21 | 3 | 1 | 3 | 11 | 39 |
| 22 | *Polyrhachis (Myrma) villipes* Smith, 1857 | 2 | 7 | | | | | 9 |
| 23 | *Polyrhachis (Myrmhopla) armata* (Le Guillou, 1842) | | | | | | 1 | 1 |
| 24 | *Polyrhachis (Myrmhopla) hector* Smith, 1857 | | 2 | | 2 | | 3 | 7 |
| 25 | *Polyrhachis (Polyrhachis) olybria* Forel, 1912 | 9 | 3 | 5 | 11 | 7 | | 35 |
| 26 | *Acropyga* sp. of HH | | 15 | | | | | 15 |
| 27 | *Anoplolepis gracilipes* (Smith, 1857) | | 229 | 5 | | | 125 | 359 |
| 28 | *Euprenolepis procera* (Emery, 1900) | 31 | 18 | | | | 5 | 54 |
| 29 | *Nylanderia* sp. 1 of HH | 2 | 9 | | 6 | 8 | 1 | 26 |
| 30 | *Nylanderia* sp. 2 of HH | | | | | | 8 | 8 |
| 31 | *Nylanderia* sp. 3 of HH | | 4 | | | 13 | | 17 |
| 32 | *Nylanderia* sp. 6 of HH | | 1 | | | 1 | | 2 |
| 33 | *Paraparatrechina* sp. 1 of HH | 3 | 2 | | 1 | | | 6 |
| 34 | *Paraparatrechina* sp. 2 of HH | 69 | 101 | 46 | 5 | 19 | 7 | 247 |
| 35 | *Pseudolasius* sp. 1 of HH | | | 1 | 3 | | | 4 |
| Myrmicinae | | | | | | | | |
| 36 | *Pheidole longipes* (Latreille, 1802) | 19 | 1 | 517 | 5 | 5 | | 547 |
| 37 | *Pheidole* sp. 1 of HH | 971 | 203 | 101 | 412 | 218 | 2 | 1907 |
| 38 | *Pheidole* sp. 2 of HH | 222 | 25 | 59 | 81 | 16 | | 403 |
| 39 | *Pheidole* sp. 3 of HH | 201 | 100 | 92 | 50 | 39 | 8 | 490 |
| 40 | *Pheidole* sp. 8 of HH | | | | | | 2 | 2 |

*Contd...*

*Table 1 contd...*

| S. No. | Subfamily species | Total number of individuals | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | OP | T |
| 41 | *Pheidole* sp. 9 of HH | | | 56 | | | | 56 |
| 42 | *Pheidole* sp. 14 of HH | | 8 | | | | | 8 |
| 43 | *Pheidole* sp. 16 of HH | | 1 | | | | | 1 |
| 44 | *Carebara* cf. *affinis* (Forel, 1915) | 87 | 130 | 104 | 21 | 35 | 53 | 430 |
| 45 | *Carebara* cf. *pygmaeus* Emery, 1887 | | 1 | 6 | | | | 7 |
| 46 | *Strumigenys* sp. of HH | 3 | | | | | | 3 |
| 47 | *Strumigenys koningsbergeri* Forel, 1905 | | | 16 | | | | 16 |
| 48 | *Acanthomyrmex ferox* Emery, 1893 | | | 6 | | | | 6 |
| 49 | *Cataulacus horridus* Smith, 1865 | | 9 | | 2 | | | 11 |
| 50 | *Cataulacus* sp. of HH | | | | | 4 | | 4 |
| 51 | Crematogaster (Decacrema) borneensis Andre, 1896 | 32 | 159 | 8 | 159 | 39 | 12 | 409 |
| 52 | Crematogaster (Orthocrema) longipilosa Forel, 1907 | 1 | | | 1 | | 2 | 4 |
| 53 | Crematogaster (Paracrema) modiglianii Emery, 1990 | | 35 | 2 | 27 | | | 64 |
| 54 | *Crematogaster (Physocrema) sewardi* (Forel, 1901) | | 6 | | | | | 6 |
| 55 | *Lophomyrmex bedoti* Emery, 1893 | 39 | 32 | 89 | 97 | 73 | 1 | 331 |
| 56 | *Meranoplus castaneus* Smith, 1857 | | 5 | | | | | 5 |
| 57 | *Meranoplus mucronatus* Smith, 1857 | 3 | 37 | | | 36 | | 76 |
| 58 | *Tetramorium (Rhoptromyrmex)* sp. of HH | | | 2 | | | | 2 |
| 59 | *Tetramorium kheperra* (Bolton, 1976) | 39 | 27 | 9 | 18 | 28 | 10 | 131 |
| 60 | *Tetramorium* cf. *bicarinatum* (Nylander, 1846) | | | | 3 | | | 3 |
| 61 | *Tetramorium pacificum* Mayr, 1870 | | | | 1 | | | 1 |
| 62 | *Paratopula* sp. of HH | 5 | | | | | 1 | 6 |
| 63 | *Myrmicaria brunnea* Saundersi, 1842 | 6 | | 2 | | 2 | | 10 |
| 64 | *Monomorium floricola* (Jerdon, 1851) | | | 2 | 13 | | 175 | 190 |
| 65 | *Monomorium* sp. of HH | 9 | 17 | 2 | 2 | | 46 | 76 |
| 66 | *Aphaenogaster (Deromyrma*) cf. *feae* Emery, 1889 | | | | 11 | 6 | | 17 |
| Ponerinae | | | | | | | | |
| 67 | *Anochetus* sp. 2 of HH | 1 | 1 | | | | | 2 |
| 68 | *Brachyponera* sp. 28 of sky | 2 | 2 | 28 | | | | 32 |
| 69 | *Diacamma holocericum* (Roger, 1860) | 31 | 7 | 55 | 19 | 29 | | 141 |
| 70 | *Diacamma scalpratum* (Smith, 1858) | 3 | | 1 | | | | 4 |
| 71 | *Hypoponera sp*. 1 of HH | | | | | 9 | | 9 |
| 72 | *Leptogenys diminuta* (Smith, 1857) | 5 | 9 | | 1 | 2 | | 17 |
| 73 | *Odontomachus rixosus* F. Smith, 1857 | 38 | | 39 | 3 | 53 | | 133 |
| 74 | *Odontoponera denticulata* (F. Smith, 1858) | 3 | | 5 | | | 14 | 22 |
| 75 | *Odontoponera transversa* (F. Smith, 1857) | 17 | 29 | 71 | 4 | 71 | 1 | 193 |
| Pseudomyrmecinae | | | | | | | | |
| 76 | *Tetraponera attenuata* F. Smith, 1877 | 2 | 5 | 1 | 6 | | | 14 |

1-5 = conservation forest sampling sites (1 = MF, 2 = IPK4, 3 = S Basah, 4 = Bukit 9, 5 = B Maria), OP = oil-palm plantation site, T = Total number of individuals.

collected in either conservation forest and oil-palm plantation such as *Tapinoma melanocephalum*, *Anoplolepis gracillipes* and *Monomorium floricola.* They are widely recognized as household infested ants in West Sumatra.

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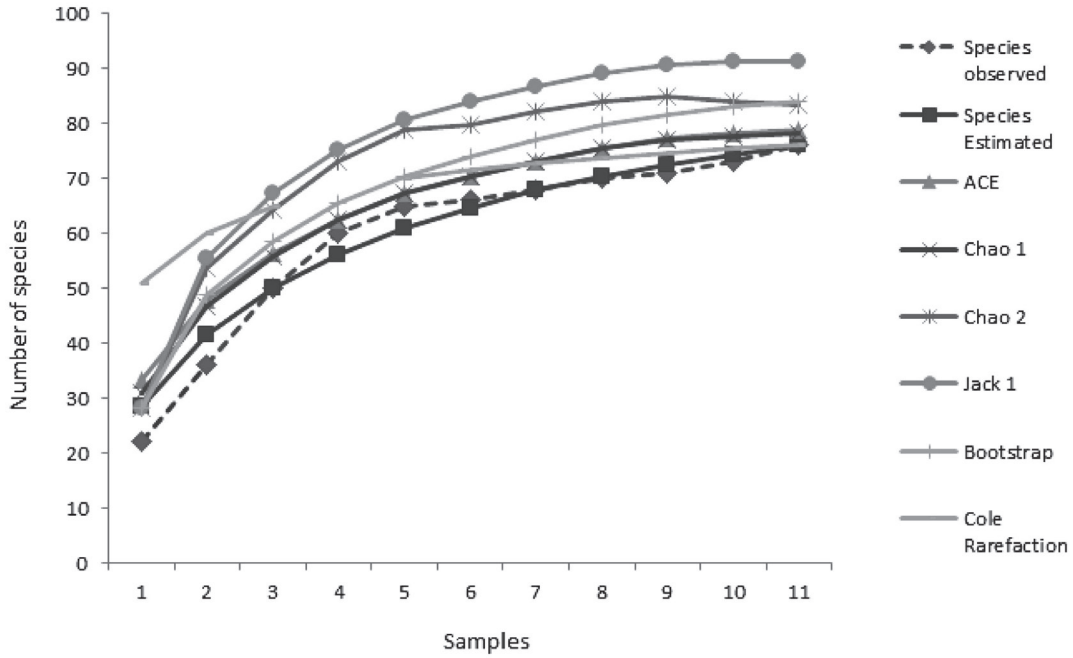


**Fig. 2.** Accumulation curve ant species calculated by Estimate S 9.0 program (AC, Chao 1, Chao 2, JackKnife 1, Bootstrap and Cole Rarefaction) at five sampling sites (transect 1-2: MF site, transect 3-4: IPK4 Site, transect 5-6; S Basah site, transect 7-8; Bukit 9 site, transect 9-10: B Maria site) of Conservation Forest and one site in Oil-palm Plantation (transect 11) of TKA Inc.

**Table 2.** Elevation, temperature, humidity, rainfall, and diversity indices at five sampling sites of conservation forest and one site of the oil-palm plantation of TKA Inc.

| Sampling sites | 1 | 2 | 3 | 4 | 5 | OP | Total |
|---|---|---|---|---|---|---|---|
| Elevation (asl) | 350 | 450 | 650 | 275 | 500 | 450 | 445.83* |
| Temperature range (°C) | 23-29 | 23-29 | 19-26 | 25-30 | 21-28 | 23-29 | 19-30** |
| Humidity (%) | 85 | 86 | 92 | 80 | 90 | 86 | 86.5* |
| Rainfall (mm/year) | 3800 | 3800 | 4000 | 3000 | 3600 | 3800 | 3666.67* |
| Total number of species | 36 | 51 | 35 | 43 | 35 | 26 | 76 |
| Total number of genera | 26 | 25 | 23 | 24 | 18 | 16 | 36 |
| Total number of Subfamily | 5 | 6 | 5 | 6 | 5 | 4 | 6 |
| Diversity indices | 2.00 | 2.57 | 2.43 | 2.52 | 2.77 | 1.6 | 3 |

1-5 = conservation forest sampling sites (1 = MF, 2 = IPK4, 3 = S Basah, 4 = Bukit 9, 5 = B Maria), OP = oil-palm plantation site, * = average, ** = range in total.

**Table 3.** The total number of species, genera, subfamily, and diversity index at each transect of conservation forest and one transect of the oil-palm plantation of TKA Inc.

| Transects | 1EF | 1IF | 2EF | 2IF | 3EF | 3IF | 4EF | 4IF | 5EF | 5IF | OP | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | 22 | 31 | 40 | 32 | 28 | 26 | 24 | 30 | 24 | 29 | 26 | 76 |
| Genera | 16 | 24 | 24 | 19 | 20 | 18 | 14 | 16 | 17 | 20 | 16 | 36 |
| Subfamilies | 4 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 4 | 6 |
| N | 945 | 997 | 718 | 689 | 589 | 802 | 667 | 454 | 378 | 450 | 519 | 7208 |
| DI | 1.61 | 2.13 | 2.57 | 2.37 | 2.34 | 2.22 | 1.83 | 2.53 | 2.73 | 2.43 | 1.6 | 3.00 |

(1 = MF, 2 = IPK4, 3 = S Basah, 4 = Bukit 9, 5 = B Maria, EF = Edge of Forest, IF = Inside Forest), OP = oil-palm plantation.

**Table 4.** Similarity indices (Bray Curtis indices) of ants at five sampling sites of conservation forest (1 = MF, 2 = IPK4, 3 = S Basah, 4 = Bukit 9, 5 = B Maria) and OP = oil-palm plantation of TKA Inc.

| Sites | 1 | 2 | 3 | 4 | 5 | OP |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | 43,809 | | | | | |
| 3 | 37,819 | 35,420 | | | | |
| 4 | 59,298 | 46,996 | 32,332 | | | |
| 5 | 53,865 | 48,712 | 43,128 | 59.65 | | |
| OP | 15,831 | 39,982 | 15,595 | 12,265 | 13,573 | |

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## REFERENCES

Asfiya, W., Lach, L., Majer, J.D., Heterick, B. and Didham, R.K. 2015. Intensive agroforestry practices negatively affect ant (Hymenoptera: Formicidae) diversity and composition in Southeast Sulawesi, Indonesia. *Asian Myrmecology*, **7**: 87-104.

Bolton, B. 2016. AntCat.org: *An online catalog of the ants of the world.* Available at: http://antwiki.org, accessed January 2016.

Brühl, C. and Eltz, T. 2010. Fueling the biodiversity crisis: species loss of ground-dwelling forest ants in oil palm plantations in Sabah, Malaysia (Borneo). *Biodiversity and Conserv.,* **19**: 519-29.

Clarke, K.R. and Gorley, R.N. 2015. *PRIMER v7: User Manual/Tutorial*. PRIMER-E, Plymouth.

Colwell, R.K. 2013. Estimate-S: *Statistical estimation of species richness and shared species from samples,* Version 9, Users Guide and application. Available at: http://purl.oclc.org/estimates. Accessed November 2016.

Crist, O.T. 2009. Biodiversity, species interactions, and functional roles of ants (Hymenoptera: Formicidae) in fragmented landscapes: a review, *Myrmecological News*, **12**: 3-13.

Dac, N.D. and Phuong, N.L.T. 2016. Diversity and abundance of ants (Hymenoptera: Formicidae) in Phu Luong, Thai Nguyen province, Vietnam. *J. Vietnamese Environ.*, **8**: 45-49.

Diame, L., Yves Rey, J., Francois Vayssières, J., Grechi, I., Chailleux, A. and Diarra, K. 2018. Ants: major Functional Elements in Fruit Agro-Ecosystems and Biological Control Agents, *Sustainability*, **10**: 1-8.

Fayle, T.M., Turner, E.C., Snaddon, J.L., Chey, V.K., Chung, A.Y.C., Eggleton, P. and Foster, W.A. 2010. Oil palm expansion into rain forests greatly reduces ant biodiversity in canopy, epiphytes and leaf-litter. *Basic and Appl. Ecol.,* **1**: 337-45.

Folgarait, P.J. 1998. Ant biodiversity and its relationship to ecosystem functioning: A review. *Biodiversity and Conserv.*, **7**: 1221-44.

Hashimoto, Y., Yamane, S. and Mohammed, M. 2001. How to Design an Inventory Method for Ground-Level Ants in Tropical Forest, *Nature*, *and Human Activities*, **6**: 25-30.

Hashimoto, Y. 2003. *Identification guide to the ant genera of Borneo*, ***In***: Inventory and Collection, Y. Hashimoto and H. Rahman (Eds.), UMS-BBEC Press.

Herwina, H. and Nakamura, K. 2007. Ant species diversity studied using pitfall traps in a small yard in Bogor Botanical Garden, West Java, Indonesia. *Treubia*, **35**: 99-116.

Herwina, H., Nasir, N., Jumjunidang and Yaherwandi. 2013. The composition of ant species on banana plants with Banana Bunchy-top virus (BBTV) symptoms in West Sumatra, Indonesia. *Asian Myrmecology*, **5**: 151-61.

Herwina, H., Satria, R., Yaherwandi and Sakamaki, Y. 2018. Subterranean ant species diversity (Hymenoptera: Formicidae) in Educational and Biological Research Forest of Universitas Andalas, Indonesia. *J. Ent. and Zool. Stud.*, **6**: 1720-24.

Hoshoishi, S., Ngoc, A.L., Yamane, S. and Ogata, K. 2013. Ant diversity in rubber plantations (*Hevea brasiliensis*) of Cambodia. *Asian Myrmecology*, **5**: 69-77.

Jaitrong, W. 2011. *Identification Guide to the Ant Genera of Thailand*. Pathum Thani: Thailand National Science Museum Press.

Magurran, A.E. 2004. *Measuring Biological Diversity*. Blackwell Publishing. Oxford.

Onishi, Y., Jaitrong, W., Suttiprapan, P., Buranapanichpan, S., Chanbang Y. and Ito, F. 2016. Ant Species Diversity in Coffee Plantation in Chiang Mai Province, Northern Thailand. *The Thailand Natural History Museum J.*, **10**: 33-48.

Putri, D., Herwina, H., Arbain, A. and Handru, A. 2015. Ant species composition in *Macaranga* spp. Trees at a conservation forest of palm oil plantation in West Sumatra, Indonesia. *J. Ent. and Zool. Stud.*, **4**: 342-48.

Rubiana, R., Rizali, A., Denmead, L.H., Alamsari, W., Hidayat, P., Pudjianto, Hindayana, D., Clough, Y., Tscharntke, T. and Buchori, D. 2015. Agricultural land use alters species composition but not species richness of ant communities. *Asian Myrmecology*, **7**: 73-85.

Satria, R., Kurushima, H., Herwina, H., Yamane S. and Eguchi, K. 2015. The trap-jaw ant genus *Odontomachus* Latreille (Hymenoptera: Formicidae) from Sumatra, with a new species description. *Zootaxa.*, **4048**: 001-036.

Schreven, S.J.J., Perlett, E.D., Jarret, B.J.M., Marchan, N.C., Harsanto, F.A., Purwanto, A., Sýkora, K.V. and Harrison, M.E. 2018. Forest gaps, edge, and interior support different ant communities in a tropical peat-swamp forest in Borneo. *Asian Myrmecology,* **8**: 1-13.

Tidar Kerinci Agung Inc. (Tidar Kerinci Agung Company) 2011. *Plantation and Oil Palm Mill* (In Indonesian with English summary). Company Profile.

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