CO-12

Species diversity of ants in different land use types in dry season at Wiang Sa District, Nan Province

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Abstract : Ants are highly eusocial insects (Hymenoptera: Formicidae). They have been wildly studied and used as natural enemies in biological control programs and bioindicators in ecosystems. However, there is a limited study of ant diversity in different land use types in Nan province. Therefore, the aims of this presentation were to investigate and compare ant species diversity in community forest (CF), teak plantation (TP) and integrated farming (IF) areas in a dry season, in Wiang Sa District, Nan Province. Four sampling methods; hand collecting with a constant time, sugar-protein bait trap, pitfall trap and soil sifting, were used to collect ant specimens in January, March, and May 2015. Biological and physical factors were recorded. The results showed that there were six subfamilies, 33 genera, 59 identified species of ants in all land use types. The highest species richness was found in the IF (48 species), followed by CF (34 species) and TP (29 species), respectively. The highest species similarity was found between the TP and the IF. *Solenopsis geminata,* an introduced species, was found in the TP and IF areas. Percentage of tree coverage in the TP was significantly different from CF and IF. Shrub coverage was found only in the CF. Among land use types, relative humidity and air temperature were not significantly different, while soil moisture content, soil surface temperature and soil temperature were significantly different. Different physical and biological factors among land use types might be the cause of differences in species richness.
Keywords : diversity, community composition, ant, Nan

Introduction

An increase of human populations causes industrial and agricultural expansion. As the results, forest areas have been highly reduced and disturbed by human activities and land conversion. The variety of land use management can differentially affect animal and plant diversities and environments. A lower disturbance may increase biodiversity and microhabitats (Kwon and Park, 2005; Lain *et al*., 2008), whereas a higher disturbance often results in negative effects (Matsumoto *et al*., 2009). Indicator organisms, especially insects, which are sensitive to environmental changes, are frequently used for monitoring ecological dynamics.

Ants (Hymenoptera: Formicidae) are one of invertebrate groups that have been widely used as reasonably bioindicators for monitoring the environmental changes. They are abundant and ubiquitous in both natural habitats and disturbed areas (Majer, 1983; Andersen, 1990; Hoffmann *et al*., 2000). The estimated species of ants is about 20,000 species (Hölldobler and Wilson, 1990) and approximately 12,500 species have been described in various habitats ranging from desolated forests to urban areas (Lach *et al*., 2010). In addition, they are sensitive to environmental change. Therefore, many studies have used the ants as a representative animal in ecological surveys (Agosti *et al*., 2000) and suggested the uses of ants as bioindicators in land use (Underwood and Fisher, 2006).

Nan province, northern Thailand has been dominated by plentiful forests. However, it is recently confronting of forest degradation and deforestation due to the expansion of annual crop and monoculture-based forestry plantation (e.g. teak and rubber). This situation may lead to the biodiversity loss in many forest areas in the province. Therefore, biodiversity and ecological study are required to understand the recent situation and data shall be used to set up an appropriate biodiversity management plan.

Most of the ant diversity studies in Nan province have been carried out in forest areas (Torchote, 2010), however, this research focused on the three land use types in order to understand the ant diversity in diverse disturbed habitats. The aims of this study were (1) to compare diversity and community composition of ants in three different land use types, including community forest (CF), teak plantation (TK) and integrated farming area, and (2) to determine the relationship between environmental factors and species richness.

Methodology

1. Study sites (3 land use types)

The study sites were located in the Wiang Sa district, Nan province. Three land use types were selected, as follows:

a. Community forest : This site represented a natural habitat type (little disturbance). It covered 12.8 ha and located in Lainan Subdistrict (18°35'24.8532"N, 100°46'46.3440"E)

b. Teak plantation : This site represented a monoculture-based forestry plantation. It covered 1.21 ha and located in Lainan Subdistrict (18°34'46.4160"N, 100°46'38.6040"E), and

c. Integrated farming area : This site represented a mixed cropping system. Perennial and annual crops have been cultivated, including rice, vegetables, orange and lime, which livestock was included. The integrated farming was managed as organic integrated farming with an application of manure. The site covered 1.56 ha and located in Khueng Subdistrict (18°32'33.8"N 100°47'17.0"E).

2. Ant sampling method

In each land use type, a permanent plot of 15 m × 50 m was selected as a sampling area.

Four sampling methods were used in January, March, and May 2015 for ant trapping in each sampling area.

a. Hand collecting with constant time : Each permanent plot (15 m × 50 m) was divided into three strip-quadrats (5 m × 50 m). The ants were extensively collected from bare ground, leaf litter, decaying logs, shrubs and trees (from ground level up to 2 m) for 30 minutes at each quadrat during 9:00 – 11:00 am and 13:00 – 16:00 pm.

b. Sugar-protein baiting trap : Each permanent plot was divided into 30 quadrats (5 m × 5 m). Canned tuna fish was mixed with honey at a 1:1 ratio was used as the bait. Three grams of bait was placed on the center of a piece of cotton cloth (9 cm × 9 cm). The baited cloth was placed on each quadrat and the ants were collected after 45 minutes.

c. Pitfall trap : Each permanent plot was divided into 30 quadrats (5 m × 5 m), as above, except that a hole was dug at the center of each quadrat. A plastic container (16 oz.) was placed in each hole with the lip of the trap being the same level with the soil surface. Petroleum gel was coated on the inner lip of the plastic container and some detergent solution was poured into the trap to at about 2-cm depth. Each trap was collected after 24 hours.

d. Soil sifting : In each quadrat, the soil sample was randomly collected in an area of 25 cm × 25 cm with 5-cm depth. The soil samples were sieved with 0.5 cm × 0.5 cm mesh and the ants were collected.

3. Ant preservation and identification

The ant specimens were preserved in microtubes, which contained 70 % ethyl alcohol. The specimens were identified to the genera and species levels (Bolton 1994, 1995; Wiwatwittaya and Jaitrong, 2001 and Jaitrong and Nabhitabhata, 2005). The specimens were also compared with reference collections at Museum of Zoology, Faculty of Science, Chulalongkorn University, Ant Museum, Faculty of Forestry, Kasetsart University and reexamined carefully by Dr. Sasitron Hasin (the ant expert from center for advanced studies in Tropical Natural Resources, Kasetsart University).

4. Environmental factors

Each permanent plot was divided into 15 quadrats (5 m × 10m), which were selected stratified 8 sampling plots. The sampling plots were used for recording physical data, except air temperature and relative humidity, which were measured at the same time of ant collections, as well as biological factors. The environmental factors were measured to investigate their relationship with ant diversity.

a. Physical factors : Air temperature and relative humidity were measured using thermo-hygrometer at the center of each permanent plot. Soil surface temperature and soil temperature were measured at surface and at 20-cm depth, respectively. Soil pH were measured by mixing soil samples with distilled water at 1:1 ratio by volume and measured by pH meter. Soil moisture content was measured weigh both before and after incubating 50 g of soil in an oven at 105 ± 5°C for 24 hour. Soil texture was evaluated by measuring the thickness of layers precipitated for 7 days from mixing 200 g of soil samples with distilled water in 1,000 ml graduate cylinder.

b. Biological factors : Percentage of tree, shrub, and herb coverage were measured.

5. Data analyses

a. Ant diversity index : Diversity indices and statistical analysis were performed as follows:

The Shannon-Weiner's diversity index (*H'*) (Krebs, 1999) was calculated to measure diversity in each land use type using the formula $H' = -\sum_{i=1}^{s} p_i \ln p_i$, where p_i is the proportional abundance of the i^{th} species = (n_i/N).

Pielou's evenness index (*J'*) (Krebs, 1999) was calculated to determine the equal abundance of ant in each land use type using the formula $J' = H'/lnS$, where S is the number of species.

The Sørensen's similarity coefficient (Krebs, 1999) was used to determine similarity of ant species among land use type using the formula SQ = $2c/a+b$, where a is the number of species in sample a; b is the number of species in sample b; and c is the number of species in both samples.

Normality and homogeneity of variances of data were analyzed by Shapiro – Wilk test and Levene's test. For parametric data, One-way ANOVA was used to assess the differences of the mean number of ant species among land use types with a significance level of $P < 0.05$. For non-parametric data, Mann-Whitney *U* test was used to test differences of the mean of the Shannon-Weiner's diversity index and Pielou's evenness index among land use types with a significance level of $P < 0.05$. Importance ant species were assorted from percentage of occurrences to find ant pests species. Mean abundance of the ant pests species were analyzed using Mann-Whitney *U* test to assess the differences in the mean number of the ant pests species between land use types.

b. Environmental factors : Mann-Whitney *U* test was used to assess the differences of the mean of environmental factors between land use types with a significance level of $P < 0.05$.

c. Correlation between species richness and environmental factors: Pearson correlation was used to determine the relationship between environmental factors and species richness.

All analyses were performed with the SPSS program (version 17)

Results and Discussion

1. Species diversity

1.1 Species richness and species diversity indices

In all study sites, a total of 33,091 individual ants were collected, which represented 59 species, 33 genera belonging to 6 subfamilies: Dolichoderinae, Dorylinae, Formicinae, Myrmicinae, Ponerinae and Pseudomyrmecinae

Species-rich genera were *Polyrhachis* (5 spp.), *Pheidole* (5 spp.), *Tetramorium* (5 spp.), and *Monomorium* (4 spp.).

Highest number of subfamilies were found in the IF (6 subfamilies) followed by CF and the TP (Table 1). Most of the ant genera were found in the integrated farming area (28 genera), followed by the community forest (23 genera) and the teak plantation (20 genera). The ant species showed similar trend, most of them was found in the integrated farming area (48 species), followed by the community forest (34 species) and the teak plantation (29 species).

However, Ant species richness did differ significantly in only IF (ANOVA, $F_{2,6}$ = 5.28, P = 0.48) (Figure 1A).

Shanon-Weiner's diversity index (*H′*) was higher in the CF than other land use types (Figure. 1B). *H′* were clearly lowest in the IF, but *H′* were not significantly different among land use types.

Pielou's evenness index (*J′*), which determine the equal abundance of ant in each land use type showed that ants' abundance in TP were more equal than other land use types (Figure. 1C). *J′* were clearly lowest in the IF, but, surprisingly, *J′* were not significantly different among land use types.

1.2 Species composition differences

The Sørensen's similarity coefficient revealed that in TP and IF had similar ant species composition, with a value of 0.68. CF and TP had similar ant species composition, with a value of 0.63. CF and IF had similar ant species composition, with a value of 0.53 (Table 2).

1.3 Abundance of Importance ant species

The result from percentage of occurrences (Table 3) revealed that 11 species such as *Camponotus rufoglaucus*, *Camponotus* sp. 7 of AMK, *Crematogaster* sp. 9 of AMK, *Trichomyrmex destructor*, *Oecophylla smaragdina*, *Pheidole taivanensis*, *Odontoponera denticulata*, *Tapinoma melanocephalum*, *Anoplolepis gracilipes*, *Crematogaster rogenhoferi*, *Monomorium pharaonis* were found more than 70 % of occurrences in all land use type.

From these 11 species, four of which are non-native species: *Trichomyrmex destructor*, *Tapinoma melanocephalum*, *Anoplolepis gracilipes* and *Monomorium pharaonis* and one of which is a beneficial species utilizes by local people: *Oecophylla smaragdina*.

The five species were assumed as dominant pest species from the percentage of occurrences. From these result, we compared abundance of 5 of dominant pest species among land use types to evaluate colonization. The mean of individuals of *A. gracilipes* and *M. pharaonis* were significantly different in only CF (Table 4).

1.4 Species diversity in comparison with other studies

The proportion of ant species in subfamily Myrmecinae was highest in all areas, followed by Formicinae, Ponerinae, Dolichoderinae, Pseudomyrmecinae and Dorylinae. This result was supported by Hölldobler and Wilson (1990) and Bolton (1994) due to the fact that Myrmecinae is the largest family containing diverse genera and species. Moreover, this subfamily is almost found in all zoographic regions (except arctic and antarctic regions). The subfamily Dorylinae was the lowest proportion in this study which found only 1 species. It might be because in Thailand only two genera in the subfamily were recorded (Wiwatwitaya and Jaitrong, 2001). Dorylinae was almost entirely subterranean in their mode of life, rarely coming to the surface except in dull, cloudy weather (Ward, 2013) and a few number of workers, so it was occasionally collected (Wiwatwitaya and Jaitrong, 2001).

Highest species richness was found in the integrated farming area, followed by the community forest and the teak plantation. In contrast, the diversity index of ants was the highest in the community forest, followed by the teak plantation and the integrated farming area. This might be because the present of dominant ant species, *Trichomyrmex destructor*. The highest species richness was found in the integrated farming area that might be caused by the slight high tree cover, herb cover and soil moisture content. Moreover, the integrated farming area has various microhabitats and food sources created by human activities. The lowest species richness in the teak plantation might be because this area was burned in March 2015. The fire might create negative impact on litter dwelling species (Arnan et al., 2006).

We also found *Solenopsis geminata*, a non-native species that prefers to nest in open sunny shade areas, in the teak plantation and the integrated farming area. This species was reported in agricultural areas and around human settlements, but not in forest (Jeanne, 1979). Moreover, *Centromyrmex* sp. was found in the community forest. Many species of *Centromyrmex* are termitolestic ants, which found in the cavities of termitaries and pray on them. (Wheeler, 1936, Dejean and Fénéron, 1996). They are apparently entirely subterranean, and thus rarely encountered (Weber, 1964).

From the percentages of occurrences, five species including, *T. destructor*, *P. taivanensis*, *T. melanocephalum*, *A. gracilipes M.pharaonis* and *O. smaragdina*, were assumed as dominant pest. High percentages of occurrences of these ant species suggested that they might have either high competitive capability or broad niche. One of these five species, *A. gracilipes* was found in all land use types but it was significantly different only in the community forest which meant this species has high colonization. It might be because this species prefer to live in moist habitat. Importantly, this species was reported among the 100 most pervasive and destructive invasive species in the world according to the IUCN/SSC Invasive Species Specialist Group (Lowe et al., 2000). Moreover, it was the most notably implicated in the 'ecological meltdown' of Christmas Island (O'Dowd, et al., 2001; 2003). Introduced populations of *A. gracilipes* can exhibit unicolonial behavior by forming multiple, populous high-density supercolonies. On Christmas Island, *A. gracilipes* was recorded to achieve the highest density of foraging ants ever recorded (Abbott, 2005). So, some concern for this species should be raise at the community forest.

2. Environmental factor

2.1 Biological factors

The mean of tree coverage of teak plantation was significantly different from community forest and integrated farming area. The mean of herb coverage was significantly different among the three land use types. Herb coverage was highest in the integrated farming area, followed by the community forest and the teak plantation (Table 5).

2.2 Physical factors

The mean of relative humidity and air temperature were not significantly different among the three different land use types whereas soil surface temperature was significantly different among the three land use types. Soil surface temperature was highest in the teak plantation, followed by the integrated farming area and the community forest. The mean of soil temperature of community forest was significantly different from teak plantation and integrated farming area. The mean of Soil moisture content of teak plantation was significantly different from community forest and integrated farming area (Table 6).

Soil pH in community forest, teak plantation and integrated farming area ranges 5.92 to 7.69, 5.82 to 6.54, and 5.96 to 6.83, respectively. Soil texture in the community forest was sandy clay loam. The soil texture in the teak plantation and the integrated farming area were loam.

3. Correlation between species richness and environmental factors

In all study sites, we did not find a correlation between species richness and environmental factors.

In the CF, we found a highly positive correlation between species richness and relative humidity (p-value = 0.037, r = 0.998). In the TP, we found a highly negative correlation between species richness and air temperature (p-value = 0.034, r = -0.999).

According to this result, the tree coverage and herb coverage might affect the soil moisture content and soil surface temperature, so the community forest and the integrated farming area had higher soil moisture content, but lower soil surface temperature. The positive correlation between species richness, relative humidity in the community forest and also highly negative correlation between species richness and air temperature were found in the teak plantation because ants are small size that makes them dry out more quickly. This result was confirmed by Bestelmeyer (1997) who reported that temperature and relative humidity play an important role in determining ant diversity.

4. Future research

Our results in this research were only in the dry season. We plan to collect ant specimen in the wet season using the same technique in the same sites. Thereafter, we will analyze data and compare the results between two seasons in order to improve understanding on ant diversity and dynamics in different land use types.

Conclusion

The species diversity of ant in three different land use types, community forest, teak plantation and integrated farming areas, located in Wiangsa distraict, Nan province was investigated. Six subfamily, 30 genera and 59 species of ants was recorded. The highest Shannon-Wiener (H’) species diversity index was found in community forest. This land use type also had high Pielou’s evenness index (J ́). Some ant genera were found only in the community forest and the integrated farming area. Rare species of subterranean ant was found in the community forest. Non-native species, *T. destructor*, *P. taivanensis*, *T. melanocephalum*, *A. gracilipes* and *M. pharaonis* , were found in all land use types. The awareness of an introduce species should be considered in those areas. Moreover, research in wet season will be carried out to improve understanding on ant diversity and dynamics in these study sites.

Acknowledgements

We are grateful to Miss Saifon Kumtem (Chief Administrative of the Lainan Subdustrict Administrative Organization), Mr. Luckchai Chaichana, Mr. Apisit Muenjina for helps for specimen collection and study sites. We thank to Mr. Naratip Chantarasawat from Department of Biology, Faculty of Science, Chulalongkorn University and Dr. Sasitorn Hasin: post doctoral researcher, from center for advanced studies in Tropical Natural Resources, Kasetsart University for suggestions on ant identification. We would like to acknowledge the Chulalongkorn University Forest and Research Station, Lainan Subdistrict, Wiang Sa district, Nan province for offering accommodation during the field study. Financial supports for this research are fully acknowledged: Chulalongkorn University’s Graduate Scholarship in the Auspicious Occasion of His Majesty the King’s 72nd Anniversary, the Plant Genetic conservation Project Under The Royal initiative of Her Royal Highness Princess Maha Chakri Sirindhorn, Sponsorship of Graduate Student Research under CU Academic Network in the region (CU-ANR) and The 90th Anniversary of Chulalongkorn University Fund (Ratchadaphiseksomphot Endowment Fund).

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Table 1. The number of subfamilies, genera, and species of the ants in three different land use types.

Study sites	Subfamilies	Genera	Species
CF	5	23	34
TP	5	20	29
IF	6	28	48

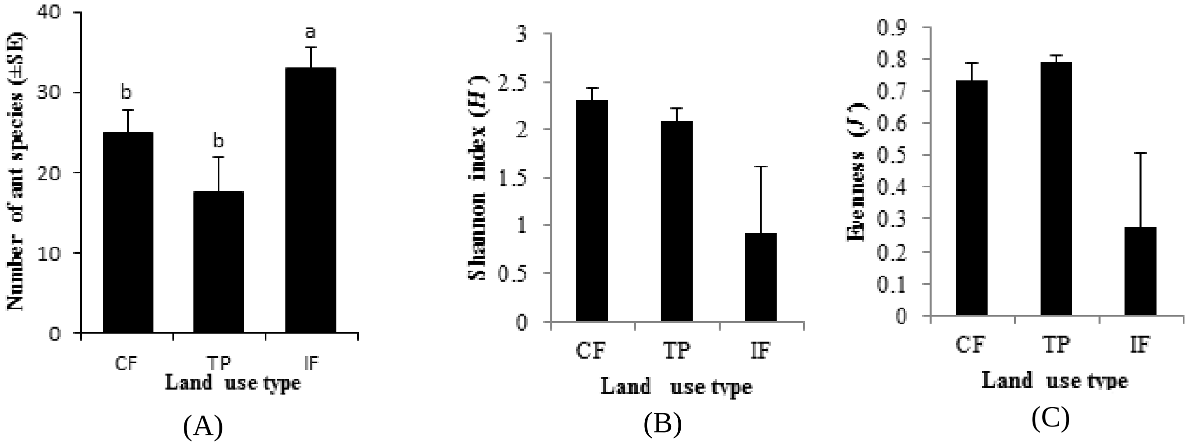

Figure. 1. (A) Mean number (±SE) of ant species collected by all methods during the dry season (*N* = 3). Different letters indicate significant differences between study sites (LSD, $p \leq 0.05$), (B) Mean (±SE) of Shannon's diversity index (*H*´) of ant species collected by pitfall traps during the dry season (*N* = 3), (C) Mean (±SE) of Pielou's evenness index (*J*´) of ant species collected by pitfall traps during the dry season (*N* = 3).

Table 2. The Sørensen's similarity coefficient of ants in three different land use types

Study sites	CF	TP	IF
CF	1	-	-
TP	0.63	1	-
IF	0.57	0.68	1

Table 3. List, percentage of occurrences and total individual of ants in three different land use types by all methods.

Species	(%) Occurrence			
	CF	TP	IF	Overall
Camponotus rufoglaucus (Jerdon, 1851)	100	100	100	100
Camponotus sp. 7 of AMK	100	100	100	100
Crematogaster sp. 9 of AMK	100	100	100	100
Trichomyrmex destructor (Jerdon, 1851)	100	100	100	100
Oecophylla smaragdina (Fabricius, 1775)	100	67	100	89
Pheidole taivanensis Forel, 1912	100	67	100	89
Odontoponera denticulata (Smith, 1858)	100	100	67	89
Tapinoma melanocephalum (Fabricius, 1793)	100	67	67	78
Anoplolepis gracilipes (Smith, 1857)	100	67	67	78

Table 3. List, percentage of occurrences and total individual of ants in three different land use types by all methods. (continue)

Species	(%) Occurrence			
	CF	TP	IF	Overall
Crematogaster rogenhoferi Mayr, 1879	100	67	67	78
Monomorium pharaonis (Linnaeus, 1758)	100	67	67	78
Paratrechina longicornis (Latreille, 1802)	0	100	100	67
Plagiolepis demangei Santschi, 1920	67	33	100	67
Monomorium floricola (Jerdon, 1851)	67	33	100	67
Pheidole planifrons Santschi, 1920	100	33	67	67
Diacamma vagans (Smith, 1860)	100	0	100	67
Iridomyrmex anceps (Roger, 1863)	0	100	67	56
Carebara diversa (Jerdon, 1851)	67	0	100	56
Meranoplus sp. 3 of AMK	100	0	67	56
Monomorium sp. 1 of AMK	67	67	33	56
Solenopsis geminata (Fabricius, 1804)	0	67	100	56
Tetraponera allaborans (Walker, 1859)	33	67	67	56
Tetraponera rufonigra (Jerdon, 1851)	100	67	0	56
Nylanderia sp. 2 of CUMZ	0	33	100	44
Nylanderia sp. 4 of CUMZ	100	33	0	44
Cardiocondyla emeryi Forel, 1881	0	33	100	44
Crematogaster aurita Karawajew, 1935	67	33	33	44
Meranoplus bicolor (Guérin-Méneville, 1844)	0	33	100	44
Tetramorium simillimum (Smith,1851)	0	33	100	44
Plagiolepis sp. 2 of AMK	67	0	33	33
Polyrhachis laevissima Smith, 1858	0	33	67	33
Cardiocondyla wroughtonii (Forel, 1890)	33	0	67	33
Monomorium chinense Santschi, 1925	67	33	0	33
Tetramorium smithi Mayr, 1879	0	0	100	33
Tetramorium sp. 6 of AMK	0	0	100	33
Tetramorium walshi (Forel, 1890)	0	0	100	33
Technomyrmex kraepelini Forel,1905	0	33	33	22
Polyrhachis bicolor Smith, 1858	0	0	67	22
Cataulacus granulatus (Latreille, 1802)	33	0	33	22
Pheidole parva Mayr, 1865	0	0	67	22
Recurvidris recurvispinosa (Forel, 1890)	67	0	0	22
Centromyrmex feae (Emery,1889)	67	0	0	22
Bothriomyrmex sp. 1 of AMK	33	0	0	11
Dolichoderus thoracicus (Smith, 1860)	0	0	33	11
Ochetellus sp. 1 of AMK	0	0	33	11
Cerapachys longitarsus (Mayr, 1879)	0	0	33	11
Nylanderia sp. 1 of CUMZ	0	0	33	11
Polyrhachis abdominalis Smith, 1858	0	0	33	11
Polyrhachis dives Smith, 1857	0	0	33	11
Polyrhachis proxima Roger, 1863	33	0	0	11
Cardiocondyla nuda (Mayr,1866)	0	0	33	11

Table 3. List, percentage of occurrences and total individual of ants in three different land use types by all methods. (continue)

Species	(%) Occurrence			
	CF	TP	IF	Overall
Pheidole sp. 5 of CUMZ	33	0	0	11
Pheidole sp. 6 of CUMZ	33	0	0	11
Tetramorium kheperra (Bolton, 1976)	0	0	33	11
Anochetus graeffei Mayr,1870	0	0	33	11
Hypoponera sp. 2 of CUMZ	33	0	0	11
Mesoponera sp. 1 of CUMZ	33	0	0	11
Pseudoneoponera rufipes (Jerdon, 1851)	0	0	33	11
Tetraponera difficilis (Emery, 1900)	0	0	33	11
Total richness	**34**	**29**	**48**	**59**
Total abundance (individuals)	**4,462**	**2,730**	**25,899**	**33,091**

Table 4. Mean of individuals (±SE) of dominance ant species (pest) collected by baiting traps during the dry season (N = 3). Different letters indicate significant differences between study sites (Mann-Whitney *U* test, $p \leq 0.05$)

Species	CF	TP	IF
A.gracilipes	222.17 ± 172.67^{a}	6.33 ± 3.33^{b}	1.33 ± 1.15^{b}
M. pharaonis	41.83 ± 28.65^{a}	$5.33 \pm 4..94^{b}$	0.00^{b}
O. smaragdina	58.17 ± 48.84^{a}	13.33 ± 8.78^{a}	17.67 ± 13.24^{a}
T.melanocephalum	7.17 ± 3.59^{a}	8.50 ± 7.53^{a}	42.67 ± 41.87^{a}
T.destructor	98.83 ± 76.22^{a}	284.50 ± 179.74^{a}	3429.83 ± 1556.53^{a}

Table 5. The mean of biological factors (±SE) comparison between three different land use types. Different letters indicate significant differences between study sites (Mann-Whitney *U* test, $p \leq 0.05$)

Biological factor (Mean±SE)	Study site		
	CF	TP	IF
Tree coverage (%; n = 96)	49.74 ± 2.15^{a}	36.67 ± 2.53^{b}	46.67 ± 1.75^{a}
Shrub coverage (%; n = 96)	24.58 ± 2.26^{a}	0	0
Herb coverage (%; n = 24)	15.21 ± 4.20^{b}	6.67 ± 3.02^{c}	51.25 ± 7.14^{a}

Table 6. The mean of physical factors comparison between three different land use types. Different letters indicate significant differences between study sites (Mann-Whitney *U* test, $p \leq 0.05$)

Physical factor (Mean±SE)	Study site		
	CF	TP	IF
Relative humidity (%; n = 24)	55.21 ± 2.16^{a}	58.71 ± 3.26^{a}	60.13 ± 2.72^{a}
Air temperature (°C; n = 24)	33.46 ± 1.04^{a}	33.65 ± 1.05^{a}	33.83 ± 1.11^{a}
Soil moisture content (%; n = 24)	4.02 ± 0.69^{a}	1.69 ± 0.28^{b}	4.59 ± 0.65^{a}
Soil surface temperature (°C; n = 192)	30.44 ± 0.40^{c}	35.14 ± 0.47^{a}	33.02 ± 0.50^{b}
Soil temperature (°C; n = 192)	26.88 ± 0.32^{b}	29.09 ± 0.37^{a}	28.52 ± 0.37^{a}