Species diversity, distribution, and functional groups of ants in Mt. Agad-agad, Iligan City, Philippines

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Abstract. Ants play a vital role in numerous ecological processes in the ecosystem. They are involved in nutrient cycling, soil aeration, seed dispersal, and represent an indicator of habitat condition. The study was conducted to determine the species diversity, distribution, and functional group composition of ants near the residential area and agro-ecosystem of Mt. Agad-agad, Brgy. Puga-an, Iligan City, Philippines. Ants were collected using baits and by hand. A total of 4047 individuals belonging to four subfamilies, 17 genera, and 23 species were documented in the two sampling sites. The highest species diversity was recorded in the agro-ecosystem with H'=2.74, and the highest species richness was 3.96 in the same location. 5 invasive species were documented, including *Paratrechina longicornis*, recorded in both sampling sites. The most abundant functional group was Generalized Myrmicinae (36%) near the residential area, while Subordinate Camponotini (29%) was abundant in the agro-ecosystem. The results suggest that existing land-use influences taxonomic diversity, distribution and functional group composition of ants, and the presence of invasive species indicates the magnitude of anthropogenic disturbances in the area.
Key Words: agro-ecosystem, anthropogenic, invasive, Puga-an, species richness.

Introduction. Ants are ecologically important due to their inherent ecological qualities that include their potential use as biological control agents (Lim et al 2008; Offenberg & Witwatwitaya 2010). They facilitate seed dispersal (Handel & Beattie 1990), induce soil modification (Dostal et al 2005), and nutrient cycling (Verchot 2003). Ants are highly responsive to anthropogenic impacts on the environment (Folgarait 1998), and plant abundance influences ant species diversity and distributions (Human et al 1998; Fergnani et al 2008; Cardoso & Schoereder 2014). Moreover, changes in land use influence the functional group composition of ants. The species belonging to generalist and opportunistic groups were more frequent in an active pasture than in a primary forest (García-Martínez et al 2015). For instance, *Paratrechina longicornis* is more abundant in disturbed areas, while some species of *Trachymyrmex* are absent because of their sensitivity to disturbances (Fernández 2003; Longino 2007). Hence, ants are recognized as one of the potential bioindicators in ecological change associated with human land-use (Andersen 1997).

Currently, there are 577 species of ants in the Philippines, with 213 endemic and 7 introduced species (https://www.antweb.org/). At least 265 species are known to be present on the island of Luzon, while 99 species are recorded in Mindanao. The current number of known ants in Mindanao indicates that the island needs more inventory studies.

Mount Agad-agad is located near the center of the highly urbanized City of Iligan. It is bordered on the south by the Puga-an Mountain Range, on the southwest by the Ugdongan Mountain Range, on the northwest by Luyong Hills, and on the north by

Cigaluga Hills. It has an estimated elevation of 490 m above sea level (masl). Mount Agad-agad has been proposed to be established as a Protected Area. Currently, no faunal inventory studies have been conducted in Mt. Agad-agad, particularly on ants. The present work aimed to determine the species diversity, functional group composition, and aggregation of ants at Mt. Agad-agad in Brgy. Puga-an, Iligan City.

Material and Method

Study site. Fieldwork was conducted at Mt. Agad-agad in Brgy. Puga-an, Iligan City, Philippines. Two sampling sites were selected based on the existing land-use types in the area (Figure 1). Sampling site 1 is located near the residential area and lies at the coordinates 8°12'25.4"N latitude and 124°16'05.5"E longitude. On the other hand, sampling site 2 is an agro-ecosystem and lies at the coordinates 8°12'36.3"N latitude and 124°16'15.7"E longitude.

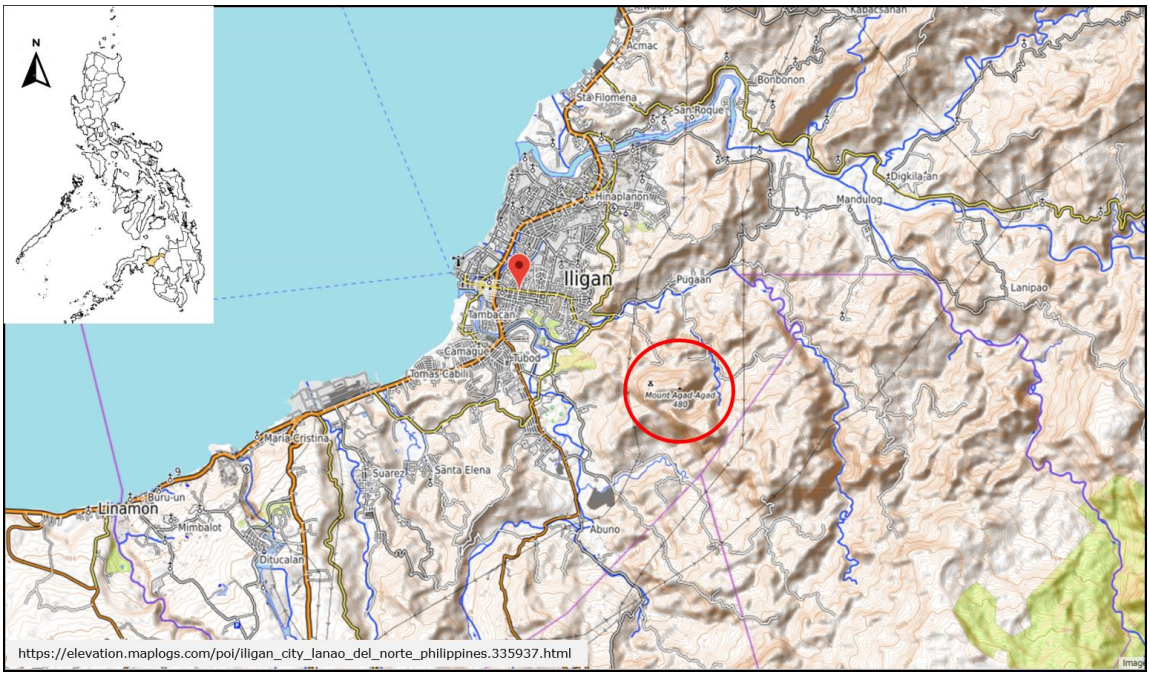

Figure 1. The location of Mount Agad-agad in Brgy. Puga-an, Iligan City.

Collection and identification of samples. Field sampling was conducted on November 9, 16, and 23, 2019 for a total of 72 h. Ants were collected using active sampling method (direct sampling) and passive sampling method (baiting with hotdog). The collected samples were sorted in the Terrestrial Biodiversity Laboratory of Mindanao State University, Iligan Institute of Technology, and preserved in 95% ethyl alcohol. All specimens were identified using published taxonomic references, and AntWeb v.8.55.2 - an online reference database of ants.

Statistical analysis. The diversity indices were determined using the software PRIMER ver.7 (Clarke & Gorley 2015). The SIMPER (Similarity Percentage) analysis was used to examine the contribution of each species and was calculated from the Bray-Curtis dissimilarity matrix to the observed differences in species composition between sampling sites. Before the statistical analysis, the abundance data were log10(n+1) transformed to reduce the heterogeneity of variance (Zar 1984). Also, Biodiversity PRO software was used to determine the aggregation of ant species in the sampling sites of Mt. Agad-agad, Iligan City.

Results and Discussion

Species composition. The study documented a total of 4047 ant workers belonging to 23 species, 17 genera, four subfamilies in Mt. Agad-agad, Iligan City, Philippines (Table 1). The endemic species *Polyrhachis follicula* and *Polyrhachis armata* were recorded only in the agro-ecosystem; *Paratrechina longicornis*, an introduced ant species, was found in both sampling sites. Invasive species include *Tapinoma melanocephalum, Anoplolepis gracilipes, Solenopsis geminata, P. longicornis,* and *Odontomachus simillimus*.

Table 1

Species composition of ants in Mount Agad-agad, Iligan City

Species	*Distribution (Antweb)*	*FunctionaL group (Brown 2000)*	*Threat level (Sarnat 2008)*
Subfamily Dolichoderinae			
Dolichoderus thoracicus Smith, 1860	Widespread	TCS	
Tapinoma melanocephalum Fabricius, 1793	Widespread	O	Medium
Iridomyrmex anceps Roger, 1863		DD	
Subfamily Formicidae			
Anoplolepis gracilipes Smith,1857	Widespread	HCS	Medium
Camponotus sp AGD01		SC	
Oecophylla smaragdina Fabricius,1775	Widespread	TCS	
Paratrechina longicornis Latreille, 1802	Introduced	O	High
Polyrhachis armata Le Guillou, 1842		SC	
Polyrhachis follicula Menozzi, 1926	Endemic	SC	
Polyrhachis chapmani Kohout, 2006	Endemic	SC	
Polyrhachis sp AGD01		SC	
Subfamily Myrmicinae			
Carebara diversa Jerdon, 1851		C	
Crematogaster sp AGD01		GM	
Crematogaster sp AGD02		GM	
Crematogaster sp AGD03		GM	
Dilobocondyla cf. chapmani Wheeler, 1924		TCS	
Pheidole sp AGD01		GM	
Pheidole sp AGD02		GM	
Solenopsis geminata Fabricius, 1804	Widespread	TCS	Medium
Subfamily Ponerinae			
Diacamma rugosum Le Guillou, 1842	Widespread	O	
Odontomachus simillimus Smith, 1858	Widespread	O	Low
Odontoponera transversa Smith, 1857		SP	
Tetraponera extenuata Ward, 2001		TCS	

Note: C - cryptic species; TCS - tropical climate specialist; DD - dominant Dolichoderinae; GM - general Myrmicinae; HCS - hot-climate specialists; O - opportunists; SC - subordinate Camponotini; SP - specialist predators.

Based on species occurrences, defined as the number of times that a given species was collected at a particular sampling site (Groc et al 2014), the most abundant species near the residential area was *Solenopsis geminata* (34.99%), which was often found nesting on soil, and mounds were common along the trail near crops. The disturbances and anthropogenic activities have been attributed to the spread of *S. geminata* that facilitates colonization and reestablishment (Hill et al 2008). Moreover, *Carebara diversa* was the

most abundant species in the agro-ecosystem (19.89%). This species was commonly found foraging on dead plant material, shrubs, under rocks, and in grasses. *C. diversa* was also documented feeding on grasshoppers, crickets, and earthworms, and has shown aggressive behavior, just like *S. geminata*, in colonizing available food resources. The substantial aggression of *S. geminata* toward non-nestmates may influence species nest colonization and the community composition of ants, possibly due to their competitive ability (Lai et al 2015; Philpott et al 2018).

Furthermore, there were three invasive species documented near the residential area. The species *Tapinoma melanocephalum, Anoplolepis gracilipes, and Solenopsis geminata* are classified as 'Medium' threats, while *Paratrechina longicornis* is classified as a 'High' threat level. In contrast, the agro-ecosystem documented two invasive species, *P. longicornis* and *Odontomachus simillimus.* Unlike most invasive species found, *O. simillimus* is the only one with a low threat level*. P. longicornis* was the most common invasive species found in vegetables and fruits sold in the market of Iligan City. Also, *Solenopsis geminata* was found nesting inside the package of a laptop delivered from a warehouse (personal observation). The dispersal of these invasive species was associated with transported household goods, agricultural products, human activities, and commerce in both domestic and international (Global Invasive Species Database 2021). Thus, the impact of invasive species in the agriculture sector is inevitable because of its effect on seedling recruitment and weed spread; in the environment sector, it affects the leaf litter breakdown in forests, which could completely change the forest structure (FAO 2018). Moreover, endemic species often have limited environmental tolerance. The study documented two endemic species in the agroecosystem of Mt. Agad-agad. The result may indicate the need to promote efforts on conservation and sustainable use of land resources, to mitigate the potential impact of agricultural activities on the diversity of ants and especially on endemic species that play a vital role in the ecosystem.

The results of the SIMPER analyses between sampling sites revealed a species similarity of 41.17%. *Carebara diversa, Dolichoderus thoracicus, Crematogaster* sp. AGD01, and *Crematogaster* sp. AGD02 were identified as the major contributors to the observed similarities in ant species composition (Table 2). In this study, the species *C. diversa* was found actively foraging on dead plant material, shrubs, under rocks, and in grasses. On the other hand, Andersen (1997) found *C. diversa* mostly on soil and litter. In contrast, *D. thoracicus* is an arboreal species and a generalized forager (Brown 2000). The species is also present in habitats where dominant Dolichoderine are not abundant (Andersen 1997). In addition, both *Crematogaster* sp. AGD01 and *Crematogaster* sp. AGD02 are arboreal species and generalized foragers (Brown 2000). The genus *Crematogaster* is present in general habitats and its members are efficient foragers (Andersen 1997). The observed similarity between sampling sites can be attributed to the existing land-use types and vegetation types that may have influenced the species composition of ants in the area. The plants provide microhabitats, favorable microclimate, and food resources for ants. Furthermore, the presence of *D. thoracicus* in the agro-ecosystem has been reported to influence the reduction of plant-insect pests (Khoo & Ho 1992). Thus, *D. thoracicus* in the sampling site might also be beneficial to the crops in the area.

Table 2

Results of SIMPER analysis between the sampling sites of Mt. Agad-agad

Species	*Ave. similarity*	*Species contribution (%)*	*Cumulative contribution (%)*
Carebara diversa	9.96	24.19	24.19
Dolichoderus thoracicus	9.84	23.91	48.09
Crematogaster sp. AGD01	8.59	20.85	68.95
Crematogaster sp. AGD02	7.9	19.18	88.13

Furthermore, the species distribution of ants in Mt. Agad-agad demonstrates a regular and random aggregation, with 21.74% and 78.26%, respectively (Table 3). The species *D. thoracicus, P. longicornis, Carebara diversa, Crematogaster* sp. AGD01, and

Crematogaster sp. AGD02 exhibit a regular aggregation, and can be found in both sampling sites. However, most species exhibit a random aggregation, where a species can be found either in the residential area or in the agro-ecosystem only. Aggregation differs among ant species (Martínez-Ferrer & Campos-Rivela 2017). This can be due to loss of habitat complexity or having a homogeneous environment.

Table 3

Results of species aggregation between the two sampling sites in Mt. Agad-agad

Species	*Variance*	*Mean*	*Chi-sq*	*d.f.*	*Probability*	*Aggregation*
Dolichoderus thoracicus	0	0.5217	0	1	0.992	Regular
Tapinoma melanocephalum	0.1787	0.299	0.5979	1	0.554	Random
Iridomyrmex anceps	0.0354	0.133	0.266	1	0.612	Random
Anoplolepis gracilipes	0.1404	0.2649	0.5299	1	0.526	Random
*Camponta*s sp. AGD01	0.0354	0.133	0.266	1	0.612	Random
Oecophylla smaragdina	0.0721	0.1899	0.3798	1	0.545	Random
Paratrechina longicornis	0.0002	0.3424	0.0007	1	0.977	Regular
Polyrhachis armata	0.0839	0.2048	0.4096	1	0.53	Random
Polyrhachis follicula	0.0589	0.1716	0.3432	1	0.565	Random
Polyrhachis chapmani	0.0453	0.1505	0.301	1	0.59	Random
Polyrhachis sp. AGD01	0.0209	0.1023	0.2047	1	0.656	Random
Carebara diversa	0	0.5237	0	1	0.994	Regular
Crematogaster sp. AGD01	0.0003	0.4906	0.0006	1	0.979	Regular
Crematogaster sp. AGD02	0	0.4555	0	1	0.994	Regular
Crematogaster sp. AGD03	0.0209	0.1023	0.2047	1	0.656	Random
Dilobocondyla cf. chapmani	0.0209	0.1023	0.2047	1	0.656	Random
Pheidole sp. AGD01	0.1164	0.2413	0.4825	1	0.505	Random
Pheidole sp. AGD02	0.0209	0.1023	0.2047	1	0.656	Random
Solenopsis geminata	0.1821	0.3017	0.6035	1	0.557	Random
Diacamma rugosum	0.1031	0.227	0.4541	1	0.508	Random
Odontomachus simillimus	0.1195	0.2445	0.4889	1	0.508	Random
Odontoponera transversa	0.1255	0.2505	0.5011	1	0.514	Random
Tetraponera extenuata	0.0786	0.1982	0.3964	1	0.536	Random

Species richness and diversity. Results showed that the diversity index and species richness were higher in the agro-ecosystem than in the residential area (Table 4). The reduction in species richness in the residential area was possibly due to the presence of dominant species, including *T. melanocephalum* and *S. geminata*. The abundance of dominant ants is high (Parr & Gibb 2010).

Table 4

Diversity indices of ants in two sampling sites of Mt. Agad-agad

Diversity indices	*S*	*N*	*d*	*J'*	*H'*
Residential	11	2941	2.55	0.97	2.33
Agro-ecosystem	17	1106	3.96	0.97	2.74

Note: S - no. of species; N - total individuals; d - species richness; J' - Pielou's evenness; H' - diversity index.

Also, the observed changes in the existing land use due to human settlement and agricultural expansion may have contributed to decreased ant diversity in Mt. Agad-agad, thus increasing the risk of invasion by invasive species due to altered habitats.

Functional group across land-use types. In this study, we found eight functional groups in two sampling sites (Figure 2). The agro-ecosystem has recorded the highest number of functional groups and is characterized by dominant understorey shrubs, such as *Lantana camara* and 'hagonoy' *Chromolaena odorata*. Among the most common crops are corn (*Zea mays*), coconut (*Cocos nucifera*), Cardava banana (*Musa acuminata* x *balbisiana*) (Philippine Statistics Authority 2012). According to Andersen (2000), the agro-ecosystem can provide a more structurally complex habitat that can support various functional groups of ants.

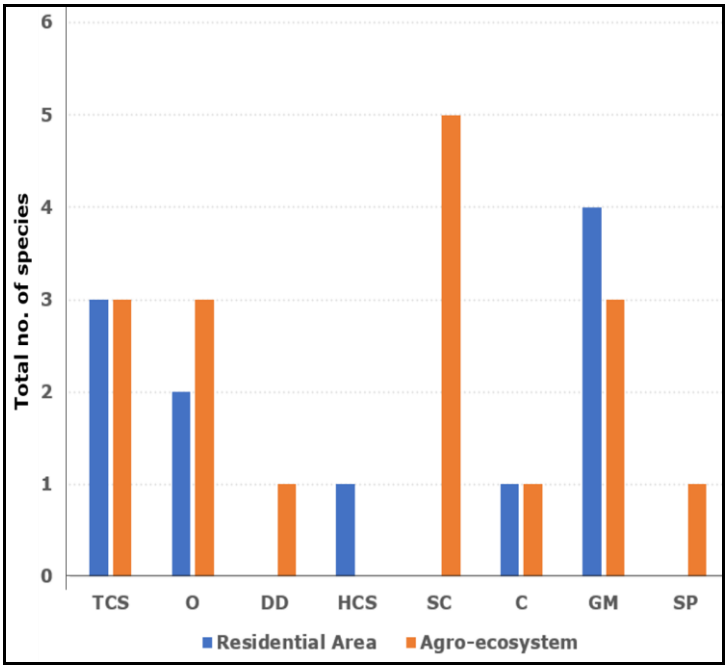

Figure 2. Functional group composition in different land-use types of Mt. Agad-agad, Iligan City; C - cryptic species; TCS - tropical climate specialist; DD - dominant Dolichoderinae; GM - general Myrmicinae; HCS - hot-climate specialists; O - opportunists; SC - subordinate Camponotini; SP - specialist predators.

Furthermore, the functional groups SC and SP were found exclusively in the agro-ecosystem. Subordinate Camponotini are composed of arboreal species foraging on different herbaceous plants, including *Camponotus* sp. AGD01*, Polyrhachis armata, P. follicula, P. chapmani,* and *Polyrhachis* sp. AGD01*.* This group has individuals with a large size and often found in shaded habitats (Andersen 1995; Parui et al 2015). On the other hand, specialist predators were composed of *Odontomachus simillimus* and *Odontoponera denticulata*, which prefer open areas and specialized nesting sites and prefer specific prey. Moreover, the most abundant were generalized Myrmicinae (GM) near the residential area, while subordinate Camponotini were most abundant in agro-ecosystem with 36% and 29% relative abundance, respectively. Both generalized myrmicines and subordinate camponotines were behaviorally dominant taxa and exhibit high abundance in lowland open habitats in the tropics, where insolation of soil surface is low. Also, the high abundance of GM was associated to their higher tolerance to environmental disturbances and absence of the dominant Dolichoderine functional group (Andersen 2000).

Conclusions. The agro-ecosystem of Mt. Agad-agad has the highest ant species diversity and functional group composition from the study sites. This is attributed to the existing land-use types in the area. The presence of *Paratrechina longicornis* indicates the magnitude of anthropogenic disturbances in the area. *P. longicornis* is primarily spread by human activities. Thus, inventory studies on ants in Mindanao will facilitate mapping the occurrence of invasive species, and increasing community awareness will help curb the spread.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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