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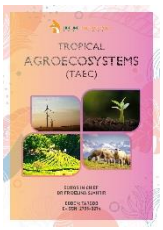

RESEARCH ARTICLE

DIVERSITY AND FUNCTIONS OF ANTS (HYMENOPTERA: FORMICIDAE) IN BANGABANDHU SHEIKH MUJIBUR RAHMAN AGRICULTURAL UNIVERSITY CAMPUS OF BANGLADESH

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ABSTRACT

Ants play a crucial role as ecosystem engineers and natural enemies of insect pests in different forests and agroecosystems. Bangladesh's varied agroecosystem harbors a diverse ant community, it can be utilized to track recent changes to the agricultural environment. However, it's utilization is deemed due to insufficient taxonomic checklist of ant fauna and their diversity pattern in various ecosystems in Bangladesh. This research aimed to measure the taxonomic and functional diversity of ants in an agroecosystem. Sampling was done by time-unit sampling (TUS) during March- April 2021 in different cropland habitats in Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) campus. A total of 172 individuals of 20 genera under 5 subfamilies were identified, of which Myrmicinae was the richest subfamily with 9 genera, while *Camponotus* is the most dominant genus in the ecosystem. Four habitats from BSMRAU campus significantly contributed on ant species richness and diversity matrix as revealed through Principal component analysis (PCA). The functional diversity of identified ant genera was explained using the results retrieved from Shannon Diversity Index, Species Evenness index and Effective number of species (ENS). The Shannon-Wiener diversity index of Field pathway (2.5202) is highest, followed by Entomology field (2.38086), agroforestry field (1.37315) and lowest in rice field (0.16794). Field pathway had the highest value due to comprising several types of vegetation alongside and non-ploughed soil. Rice field has only rice crops that were grown in a wetland; hence, water causes the lowest value. The evenness index (>0.75) implies the probability of stable communities in all the tested habitats except in rice field (0.242), which indicates a depressed community structure and is strengthened by the ENS value as 12.4, 10.8, 3.9, and 1.18 in the field pathway, in entomology field, agroforestry field, and rice field, respectively. The findings generated a comprehensive ant checklist and diversity indices with indicator species to measure the land type transformation and restoration in the agroecosystem of Bangladesh for future research.

KEYWORDS

Taxonomic Diversity, Ecosystem Engineering, Functional Diversity

1. INTRODUCTION

Natural ecosystems are profoundly altered by agricultural practices in a number of ways. The impacts of agricultural transformation on biodiversity conservation and ecosystem services are significant (Bilenca et al., 2012; Zhou et al., 2022). Ants (Hymenoptera: Formicidae) are conspicuous eusocial organisms in most terrestrial ecosystems, including crop lands of agroecosystem (Rabeling 2008; et al., Ward et al., 2010). Their diversification, richness, and behavioral specialization in an environment make them suitable as model organisms for a range of biological disciplines (Ness and Morin, 2008; Rabeling et al., 2008). They play major roles in the maintenance and functioning of many ecosystems; soil movement since they constitute significant proportions of the soil biomass and also crucial in agriculture since they have been found to influence yield, including seed dispersal (Del Toro et al., 2012; Basset et al., 2015; Denmead, 2016; Subedi, 2016). These creatures are extremely sensitive, human effect reduce their diversity, although it is not clear how such disturbance damages the maintenance of ant services to the ecosystem (Folgarait, 1998). The abundance and diversity of ants are frequently impacted by land management (Triyogo et al., 2020). Land-use change is well documented to cause species loss, decreased biodiversity, altered community structure, and reduction in ecosystem services. Reduced ecosystem services could also be caused by changes in species composition and disrupted trophic relationships between pests and their natural enemies (Rubiana et al., 2015; Rabello et al., 2021).

In several agroecosystems, ants perform a critical role as gardeners, mutualists, competitors, predators, scavengers, and biological agents of insect pests (Pal, 2006). Ants, which live above ground, are extremely vulnerable to any changes that have direct effects (Andersen, 2019). Ant density and climatic change have a direct connection, thus, even a small fluctuation in microclimate can be detected using ants due to their sensitivity to environmental changes (Jenkins et al., 2011; Anderson et al., 2003; Andersen, 2019). Species richness and diversity are crucial for measuring the impact of changes in species extinction because they can

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regulate the effects on network and ecosystem functioning (Morris, 2010). Taxonomic as well as functional diversity are two ways to assess an organism's biodiversity patterns (Sanders, 2003; Reymond et al., 2013). 'Taxonomic diversity' denotes the number and the relative abundance of species in a community and the 'functional diversity' refers to the various processes that are crucial to the community's structure and dynamic stability (Moore, 2013). The study of biodiversity has been addressed by using these two distinct methods *i.e.,* taxonomic diversity and functional diversity. Ant biodiversity is quite high, more than 13,800 species have been classified out of a total of 22,000 species; they are widely distributed geographically, ubiquitous, and important for ecosystem functioning (Ratchford et al., 2005; Muluvhahothe, 2018). Due to high taxonomic diversity in both morphological and molecular matrixes, ants are considered an ideal material for monitoring different agroecosystem by comparing species diversity in different habitat.

Over time, Bangladesh's agricultural sector has undergone structural changes (Deb, 2016). Although, Bangladesh with varied agroecosystem act as wide home to diversified ant community however, no comprehensive study on their taxonomy and diversity were performed for measuring the recent transformation of land use pattern. The campus of Bangabandhu Sheikh Mujibur Rahman Agricultural University, (BSMRAU) with diversified inland cropping associated with semi disturbed area can shed light the occurrences of diversified ant species towards preparing a comprehensive checklist for ant species for the first time in Bangladesh. The study of ant community is an effective technique to assess how Bangladesh's agroecosystems have changed recently and to learn more about how to maintain and preserve agricultural environment. Therefore, the objective of the present study was to reveal taxonomic diversity and richness of ants in different habitats of agroecosystem and to measure the functional diversity of ants in response to their habitat types in BSMRAU campus.

2. Materials and Methods

The detailed methodology for conducting this research is described below under the following subheadings.

2.1 Study Site

The sampling was conducted in the agricultural field of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) (24.0362ºN, 90.3959ºE) for monitoring agroecosystem (Figure 1). Identification, preservation and analysis of sample was done in the Laboratory of the Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur 1706.

2.2 Habitat Characterization

Bangabandhu Shiekh Mujibur Rahman Agricultural University (BSMRAU) campus covers an area of 187 acres. The university is located at South Salna of Gazipur city corporation, 35 km north from the capital of Bangladesh, Dhaka. It is located east of the Dhaka-Mymensingh Highway, 15 kilometers (9.3 miles) from the Gazipur district headquarters and 9.5 kilometers (5.9 miles) from Gazipur Chowrasta. The well-developed experimental farm area is about 50 acres (20 hectares) that situated in a rural area between Joydebpur Chowrasta and Rajendrapur National Park, bordered by the Madhupur Tract Shalforest.

Figure 1: Habitat types of agroecosystems in BSMRAU campus: A. Agroforestry field with multilayered vegetation; B. Entomology field with multiple crops; C. Rice field; D. Field pathway.

2.3 Sample Collection

Ants sampling was done during March-April 2021 by using the method Time-Unit Sampling for conducting this experiment. In this method, two time-units for 20 minutes was operated by hand picking at a stretch (Ogata, 2001). Each of the time unit samples was independent and was collected ants from the ground soil, leaf litters and vegetation biomass, tree. Then the samples were preserved in vials with 70% ethanol.

2.4 Sample Preparation and Identification

Collected specimens were transferred from vial to petri dish, and all dirty materials were cleaned with a brush dipped in water. Samples were then once again washed in alcohol. Washed samples were sorted into similar groups and put into separate vials by labeling each. For further identification, collected specimens were preserved on a dry basis by using card points and card mounts. Using scissors, white cardboard was cut into tiny triangular pieces. Each point was mounted on a macro-pin inserted near the base of the triangle using a wooden insect pinning block. Stainless steel insect pins were used to hold the points. Using water-soluble glue, the samples were glued to the tip of the point. The water-soluble glue was also used to attach ants to the points for later removal when needed. Prepared samples were then inspected under a fluorescence microscope, Micros cam500, Austria). Each taxonomic key was inspected to identify the ant samples. Subfamilies of ants (family: Formicidae) were mainly identified following the taxonomic keys provided (Dias, 2014). Also followed the Lucid key, PIA ant key, Antweb, and Antwiki websites. Ant genera of those subfamilies were identified by following several taxonomic keys of ants provided and also followed the Lucid key, PIA ant key, Antweb and Antwiki websites (Eguchi et al., 2011; General and Alpert, 2012; Dias, 2014; Eguchi et al., 2014; Borowiec, 2016). The major subfamily as well as the genus were identified using the following keys (Plowes and Patrock, 2000). After identifying all the specimens of ants collected from different characterized habitats, were labelled, sorted, and finally preserved as voucher specimens in the Insect Museum of the Department of Entomology (BSMRAU), Gazipur 1706.

2.5 Ant Diversity Analysis

2.5.1 Shannon-Wiener Diversity Index

The Shannon-Wiener Diversity Index (H′) was used to assess diversity of ant in two ecosystems (Krebs, 1999). A community's richness and evenness both rise with an increase in the index value.

With the following formula:

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

Where,

p_i = fraction of total samples *i.e.,* divide no. of individuals of a species i by total number of samples.

s = Number of species

2.5.2 The Evenness Index

The Evenness Index (J′) was used to determine the relative abundance of ant species in each habitat. This index usually has values between 0 and 1. A depressed community is indicated by a value of less than 0.5. The value indicates an unstable community if it is greater than 0.5 but less than 0.75. The community is stable when the value exceeds 0.75 (Ulfah et al., 2019).

With the following formula

Evenness =$J' = \frac{H'}{Hmax}$

Here, H'= the observed index of species diversity, and

$Hmax'$ =ln(S) = the highest possible index of species diversity.

2.5.3 Effective Number of Species

The Effective Number of Species (ENS) was used to calculate the actual diversity of the two ecosystems (Jost, 2006). The actual or true diversity that can be utilized to compare the two ecosystems which is estimated by using Shannon-Wiener diversity index.

$ENS = eH'$

Where,

H'= The observed index of species diversity

2.6 Statistical Package

Principal component analysis, PCA biplot, and cluster dendrogram were used to analyze the contribution of different characterized habitats in an agroecosystem. Generation of graphs on species diversity in four areas for measuring biodiversity and habitat composition and for detecting the correlation and the variance of the individuals were performed using Statistical Software language package "R".

3. Results and Discussions

3.1 Taxonomic Diversity of Ants

Different ant genera are found in agroecosystems. The number of individuals in each genus varies. A total of 172 ant individuals from 5 subfamilies, 20 genera were identified. Among the five subfamilies, Myrmicinae was the richest subfamily with 9 genera, followed by Formicinae with 5 genera, Ponerinae with 3 genera, Dolichoderinae with 2 genera, and Amblyoponinae with 1 genus (Table 1).

A total of 40 species belonging to 25 genera and 6 subfamilies were identified in the Kalaburagi district of northern Karnataka, India (Begum et al., 2021). Myrmicinae was the subfamily with the highest species richness among the other six subfamilies, followed by Formicinae, Ponerinae, Dorylinae, Pseudomyrmicinae, and Dolichoderinae. The finding is supporting the data of this present findings in the case of diversified ant communities.

Table 1: Diversity of Ant Genera in Agroecosystem (BSMRAU Campus).

Subfamily	Number of Genera	Total Individuals
Amblyoponinae	1	1
Dolicoderinae	2	28
Formicinae	5	59
Myrmicinae	9	67
Ponerinae	3	17
Total	20	172

(a) Genus Stigmatomma

(b) Genus Dolichoderus

(c) Genus Tapinoma

(d) Genus Anoplolepis

(e) Genus Camponotus(sp1)

(f) Genus Camponotus(sp2)

(g) Genus Camponotus(sp3)

(h) Genus Identified genus Nylanderia

(i) Genus Oecophylla

(j) Genus Paratrechina

(k) Genus Carebara

(l) Genus Cataulacus

(m) Genus Dilobocondyla

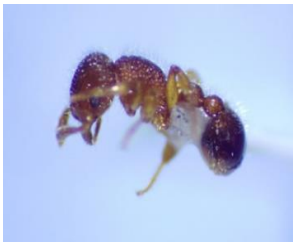
(n) Genus Meranoplus

(o) Genus Monomorium

(p) Genus Myrmicaria

(q) Genus Pheidole

(r) Genus Solenopsis



(s) Genus Tetramorium(sp1)

(t) Genus Tetramorium(sp2)

(u) Genus Diacamma

(v) Genus Harpegnathos

(w) Genus Leptogenys

Figure 2: Identified ant genera under Subfamily Amblyoponinae (a) under Subfamily Dolichoderinae (b-c), under Subfamily Formicinae (d-j), genera under Subfamily Myrmicinae (i-t), genera under Subfamily, Ponerinae(u-w) from different habitats of BSMRAU agroecosystem.

3.2 Estimation of Functional Diversity of Ants

Ant samples were collected from different habitats in BSMRAU. Those habitats show some correlations among them, so those correlations among different habitats in agroecosystem were analyzed using the correlation matrixes is presented in figure 3. Where the blue to white colors indicated positive correlation and the white to red color indicated negative correlation. Deeper the blue color indicated a strong positive correlation and deeper the red color indicated a strong negative correlation. In this figure, Field pathway had a strong positive correlation with entomology field which was 53%, agroforestry field had a positive correlation with entomology field and field pathway but weak. Rice field had a negative correlation with all habitats in agroecosystem.

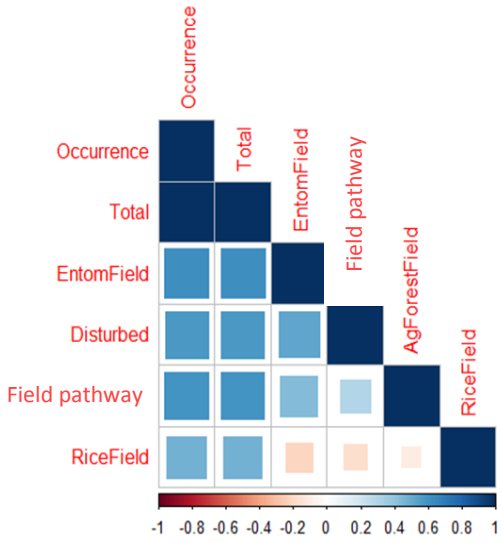


Figure 3: Correlation matrix among the different variables in agroecosystem

Ants from different habitats have been clustered, so the clustering pattern of ant genera was shown in the following cluster dendrogram (Figure 4). A Cluster Dendrogram represents the relationship of similarities among different ant genera and their corresponding localities. The height of the branch points indicates how close or how far habitats are from each other; the greater the height, the greater the distance of their corresponding habitats. In this cluster Dendrogram, 4 different clades have been observed. The genera belonging to 4 different clades are associated with their corresponding habitats. *Tapinoma* genus is simplicifolious and its long height indicates its habitat is substantially different from the habitats of the remaining genera. *Leptogenys* and *Meranoplus* are bifolious genera, found in habitat with close association, *Anoplolepis* and *Camponotus* are similar to previous two. The remaining genera are the same in clade, although there are variations in their height. *Monomorium, Carebara, Pheidole, Myrmicaria* are in same habitas; whereas, *Solenopsis, Paratrechina, Oecophylla, Nylanderia, Cataulacus, Stigmatomma, Dilobocondyla, Harpegnathos, Tetramorium, Dolichoderus, Diacamma* are in close association.

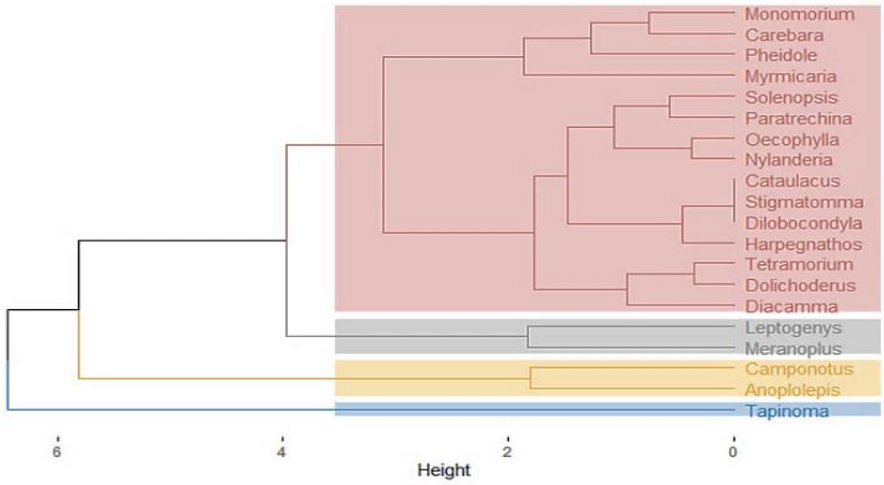


Figure 4: Clustering pattern among various genera of different habitats

The habitats with their corresponding ants showed some significant variances. A scree plot was performed to detect the number of components that need to be used in principal component analysis (PCA). And it is found that the first two components could explain more than 80% of the variation presented in Figure 5. Hence, in the PCA biplot analysis, two dimensions were considered.

The contribution of different habitats of BSMRAU Campus in ant diversity estimation is presented through PCA analysis (Figure 6). The color red to blue indicates the highest to lowest contribution. The findings suggested that rice field was found to have strong positive correlation with both dimension 1 and dimension 2. Whereas the agroforestry field, disturbed area (field pathway), and entomology field all contributed positively to dimension 1, but negatively to dimension 2.

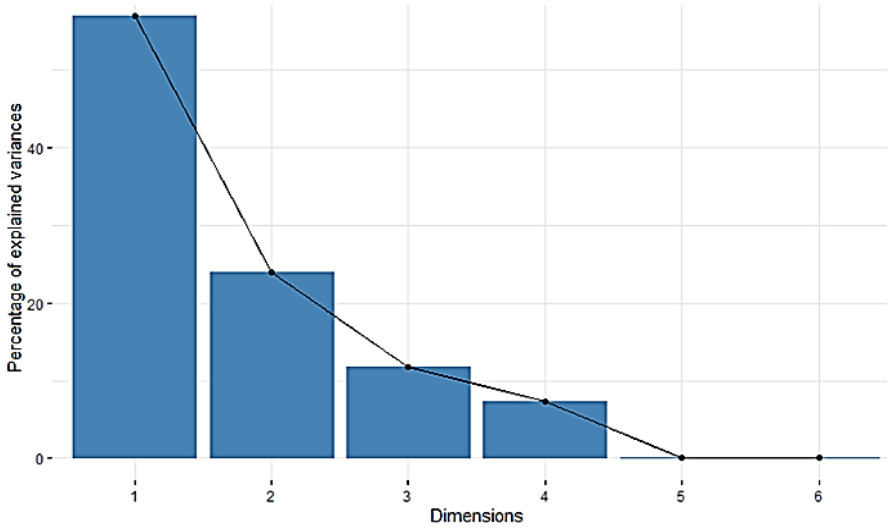


Figure 5: Contribution of different components in the variation (in percentage)

The second section of this chapter described the functional diversity of identified ant genera in different habitats of agroecosystem. In agroecosystem, most dominant genus is *Camponotus* (15.07%), followed by *Tapinoma* (14.53%), *Anoplolepis* (12.21%), *Meranoplus* (9.70%), *Pheidole* (8.72%), (Table 2).

Table 2: Relative Abundance of Identified Ant Genera in Four Habitats from BSMRAU Campus (Agroecosystem)

Subfamily	Genus	Agroforestry Field	Entomology Field	Rice Field	Field Pathway	Total	Occurrence (%)
Amblyoponinae	*Stigmatomma*	0	0	0	1	1	0.58%
Dolichoderinae	*Dolichoderus*	0	3	0	0	3	1.74%
	Tapinoma	0	0	24	1	25	14.53%
Formicinae	*Anoplolepis*	0	10	0	11	21	12.21%
	Camponotus	12	8	0	7	27	15.70%
	Nylanderia	0	0	0	3	3	1.74%
	Oecophylla	0	0	0	4	4	2.33%
	Paratrechina	0	2	0	2	4	2.33%
Myrmicinae	*Carebara*	0	4	0	4	8	4.65%
	Cataulacus	0	0	0	1	1	0.58%
	Dilobocondyla	0	0	0	1	1	0.58%
	Meranoplus	3	9	0	4	16	9.30%
	Monomorium	0	3	0	6	9	5.23%
	Myrmicaria	1	0	0	7	8	4.65%
	Pheidole	6	4	0	5	15	8.72%
	Solenopsis	0	3	0	3	6	3.49%
	Tetramorium	0	2	1	0	3	1.74%
Ponerinae	*Diacamma*	5	3	0	0	8	4.65%
	Harpegnathos	0	1	0	0	1	0.58%
	Leptogenys	0	7	0	1	8	4.65%
	Total	27	59	25	61	172	

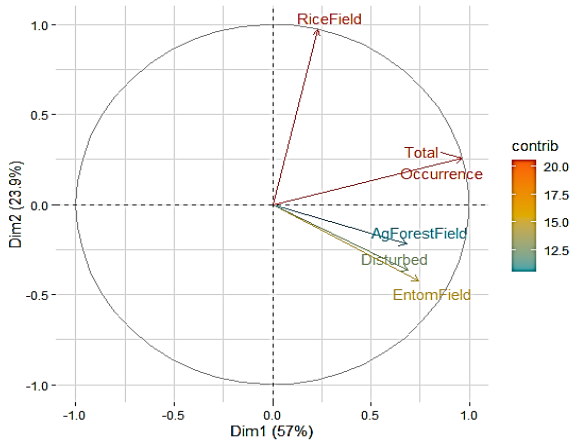


Figure 6: Contribution of different habitats in terms of two dimensions

The contribution of identified ant genera with reference to their corresponding habitat from BSMRAU campus is presented in PCA-Biplot diagram (Figure 7). The genus *Tapinoma* had a strong positive correlation with both dimensions. Genus *Camponotus, Anoplolepis, Meranoplu, Pheidole, Crematogaster* showed positive correlation with dimension 1, but negative correlation with dimension 2. *Solenopsis* had a negative correlation with both dimensions. Maximum reference data were found to cluster near the axis.

The Shannon-Wiener diversity index of Field pathway (2.5202) is the highest, followed by Entomology field (2.38086), agroforestry field (1.37315) presented in Table 3. The Shannon-Wiener diversity index is lowest in rice field (0.16794). Field pathway seems have to a high value reflecting the high richness of ant genera due to this habitat surrounding different agricultural fields, soil is not ploughed and there are several evergreen trees along roadside. Entomology field shows high due to multiple crops, *i.e.*, horticultural crops (tomato, brinjal, chili, cabbage, cauliflower, bean) and cotton were grown in different plots; hence the soil of different plots is managed by diversified agricultural practices. In agroforestry field, there are three layers of crops but there is somewhat

lower diversity. The reason is unknown, but their vegetation type (almond tree, dragon fruit tree and cabbage) may be the fact. Entomology field having higher diversity than that of agroforestry field suggested that the overall diversity and composition of ants are influenced by vegetation as well as soil characteristics (Jahan et al., 2022). Rice field has only rice crops i.e., monocropping grown in wetland, water may cause the lowest value. Because water disrupts the habitation and rearing of terrestrial ants in underground nests.

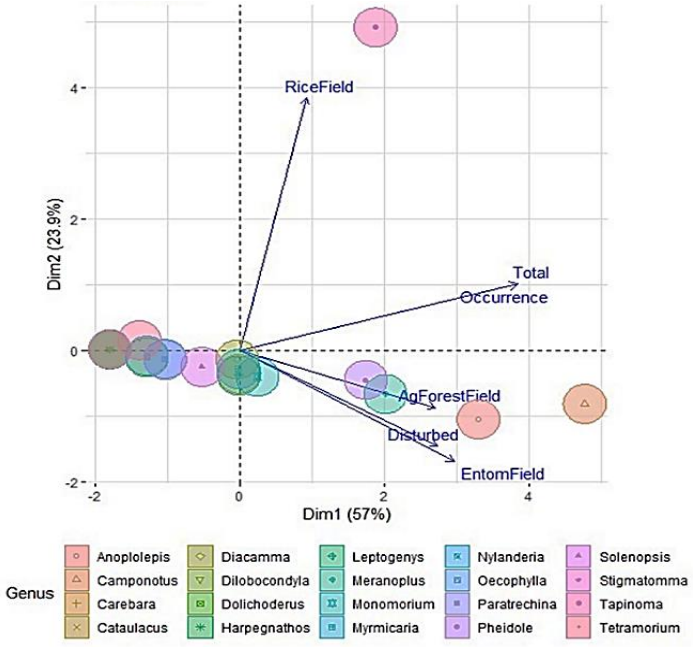


Figure 7: Biplot generated through principal component analysis corresponding with ant genera in BSMRAU campus

Table 3: The Shannon-Wiener Diversity Index (H´), Evenness Index (J´) and Effective Number of Species (ENS) of four different habitats of Agroecosystem

Area	Number of Genus	Number of Individuals	J´	H´	ENS
Agroforestry Field	5	27	0.85319	1.37315	3.94778
Entomology Field	13	59	0.92823	2.38086	10.8142
Rice Field	2	25	0.24229	0.16794	1.18287
Field Pathway	16	61	0.90897	2.5202	12.4311

This is strengthened by the ENS value (12.4, 10.8, 3.9, 1.18 in field pathway, in entomology field, agroforestry field and rice field respectively); By ENS values one can understand the true or actual differences among them (table 3). Table 3. showed that the evenness index more than 0.75 that means stable communities exist in all habitats (0.928, 0.908, 0.853 in entomology field, field pathway and agroforestry field respectively) except rice field (0.242). But in rice field, evenness index is less than 0.25 means depressed communities.

A group researchers conducted similar study to trace the disturbed and undisturbed habit that for detecting their influence on ant distribution and resulted that non ploughed organic farms showed higher species richness. Ploughing was observed to be the soil management practice with the greatest negative effect on ant species richness and ant biodiversity. Their study provides novel evidence of the non-ploughing organic farming role with respect to maintaining higher levels of ant functional diversity. Their findings are similar to the results of field pathway of the present study. Therefore, the present study suggests that ants take shelter in non-cultivated soils around agricultural fields during different soil management regimes.

4. Conclusion

A total of 20 genera of ants belonging to 5 subfamilies have been identified in the present study. The identified genera were *Stigmatomma*, *Dolichoderus, Tapinoma, Anoplolepis, Camponotus, Nylanderia, Oecophylla, Paratrechina, Carebara, Cataulacus, Dilobocondyla, Meranoplus, Monomorium, Myrmicaria, Pheidole, Solenopsis, Tetramorium*, *Diacamma, Harpegnathos, Leptogenys*). The checklist of ants in crop land ecosystems in the BSMRAU campus will be helpful for future diagnosis and restoration of changing habitat. The present study suggests that the submerged condition causes a dramatic reduction in ant richness in rice field, whereas the non-ploughed soil with diversified vegetation causes the highest diversity of ants. The diversity and function of ants are thus significantly influenced by agricultural techniques, land use patterns, and vegetation type that can be considered for ecosystem restoration.

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