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EFFECT OF ANTHROPOGENIC LAND-USE ON ARTHROPODS DIVERSITY IN SUB-TROPICAL PUNJAB, PAKISTAN

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ABSTRACT

Present study was conducted to assess the effect of different land-use types i.e., agriculture, planted forest, grassy plots and desert on the diversity of soil crawling arthropods at the university campus of The Islamia University of Bahawalpur, (Punjab) Pakistan. Weekly data was recorded using pit fall traps during spring and fall seasons, 2018. The total sampling efforts of 192 hours in each land-use type resulted in 2842 individuals of 115 taxa. Hymenoptera -largely comprising of three ant species, *Monomorium indicum, Monomorium pharaonis* and *Camponotus angusticollis* - was the most abundant taxon in all the four land-use types followed by Coleoptera, Arachnida and Hemiptera. The maximum number of distinct species (only found in a specific landscape) was found in grassy plots and the minimum in agricultural landscapes i.e., 24 and 9, respectively. Only five species were found common in all the four landscapes i.e., *M. indicum, M. pharaonis*, *C. angusticollis* (ants), *Lycosa poonaensis* (spider) and *Patanga succincta* (grasshopper). Agricultural land showed the higher values of evenness and Simpson diversity indices than that of grassy plots, suggesting more even distribution of species. The lowest value of Chao-1 indexes -suggesting the minimum number of rare species in agricultural landscape- further confirmed this finding. Results of present study suggest that agriculture is not a threat to soil arthropods biodiversity except some rare species. Moreover, since grassy plots and forests exhibited greater values of Shannon-Wiener, Simpson and Chao-1 indices than desert, plantation of forests in the desert and establishment of grassy plots within or near the buildings may encourage diversity of soil arthropods and associated taxa in higher tropic levels.

Keywords: Biodiversity, Arthropods, Landscapes, Desert, Agriculture.

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INTRODUCTION

Ever-increasing human population is leading to intensification in agriculture and urbanization at the cost of elimination of biodiversity and natural habitats (Venter *et al*., 2006). The ecosystem services associated with the biodiversity are also declining (Attwood *et al*., 2008). Biodiversity encompasses the variety of life on earth in an environmental system ranging from genes to entire ecosystem and its loss has become a foremost environmental concern during last few decades (Miguel *et al*., 2012). In worst-affected habitats with high degree of modifications and anthropogenic land use, species richness has been reduced by 76% and abundance by 39% (Newbold *et al*., 2015).

Since biodiversity is a complex concept and its assessment is also a complicated phenomenon therefore, it requires simplifications into quantifiable facets. For this purpose, several environmental indicators have been used especially when establishing some relationships with certain environmental factors e.g., degradation of habitat and ecosystem services on account of intensification in agriculture and land use change etc. (Olff and Ritchie, 2002; Gabriel *et al*., 2010).

Several groups of arthropods have been regarded as bio-indicator of habitat quality and conservation status of ecosystem for heavy metals pollution, fertilizer pollution, high input farming, improper waste disposal, pesticide pollution, environmental stress and quality of soil. These arthropods include carabid beetles, staphylinid beetles, spiders, mirid bugs, syrphid flies, oribatid mites, crustaceans and ants (Lobry-de-Bruyn, 1999; Paoletti and Hassall, 1999; Sommaggio, 1999; Langraf *et al*., 2016). Loss of arthropod biodiversity is parallel to the decline in ecosystem processes provided by them. For example, Richards (2001) reported low fruit and seed set in many crops due to decline in pollinators.

Arthropods are highly susceptible to habitat loss and land use (Krauss *et al*., 2003). Agricultural practices such as ploughing, rotavating, fertilizer and pesticide application, burning of residues have a negative impact on arthropod diversity (Olff and Ritchie, 2002; Gabriel *et al*., 2010). Aquatic insects are also affected by the anthropogenic disruption like boating, leakage of oil from ships and tourist movements etc. (Sharma and Rawat, 2009). On the other hand, anthropogenic land use also creates opportunities to some arthropods involved in delivering certain ecosystem services. Therefore, owing to their short life cycle and rapid response to environmental changes, arthropods are regarded as the good bioindicator of habitat quality (Paoletti and Hassall, 1999).

Urban arthropod assemblages are usually homogenized; dominated by generalists (polyphagous and multivoltine species) and loss of specialists (monophagous and univoltine species) (Sharma and Amritphale, 2007; Niemelä and Kotze, 2009). In the present study, we selected soil crawling arthropods as the indicator of habitat degradation since they are found in a wide range of habitats including agriculture, deserts, forests and semi-natural landscapes and play a vital role in ecosystem services of nutrient cycling, decomposition, regulating microclimate, pollination, and biological control (Altieri, 1999).

The objective of present study was to understand how anthropogenic land use affects soil crawling arthropod assemblages at the university campus of The Islamia University of Bahawalpur, Pakistan. The university campus is spread over 518 hectares and has variety of anthropogenic land use i.e., desert, planted forest, agriculture and grassy plots etc. which makes it an ideal place for such study.

MATERIALS AND METHODS

Study Site and Focal plots: The study was conducted at Baghdad-ul-Jadeed campus, The Islamia University of Bahawalpur, Punjab, Pakistan (29°22'16.3"N 71°45'52.9"E; 181 meters above sea level), scattered on an area of 518 hectares. The campus is characterized by a variety of landscapes and land-use types including naturally occurring desert, planted forest, agricultural land, ornamental grassy plots, roads and buildings. The district Bahawalpur is situated in southern part of Punjab province; characterized by cold winters and hot summers. It has subtropical climate with average annual rainfall of 83-218 mm while average daily minimum and maximum temperatures are 18.8˚C and 33.5˚C, respectively (Ahmad *et al*., 2019). We selected four landscapes for our study i.e., naturally occurring desert, planted forest, agricultural land and grassy plots.

Data Collection: Weekly data was recorded during three consecutive months of spring (March, April and May) and autumn (September, October and November). We choose spring and autumn seasons because some previous studies have suggested the maximum insect richness and abundance during these two seasons in the region (Sajjad and Saeed, 2010; Sajjad *et al*., 2012; Fayyaz 2016; Ramzan *et al*., 2021). Ten pitfall traps of one foot depth and half foot diameter were placed randomly (at least 20 feet apart from each other) in each focal landscape during each census. The pitfall traps were half filled with soapy water and kept open without any cover. For each census, a different location (at least 1000 feet away from previous locations) was chosen in each landscape. After 24 hours of pitfall installment, arthropods were collected using a nylon mesh. The collected arthropods were first morphotyped and then counted. Specimens of Arachnida, Chilopoda and Malacostraca were morphotyped only at class level. The most abundant and the common species among the four landscapes (i.e., three ant species, one spider species and one grasshopper species) were identified up to species level. The ants were identified using online keys of Indian ants available at https://www.discoverlife.org. Spiders were identified by the expert (acknowledgement). Grasshoppers and beetles were identified by comparing with the species description given on Indian Biodiversity Portal at https://indiabiodiversity.org. Soft bodied specimens were preserved in 70% ethyl alcohol while hard bodied arthropods were pinned or mounted.

Data Analysis: To measure sampling efforts, individual based rarefaction curves were used for the estimation of number of species (S) expected in a random samples of 'n' individuals, taken from a larger collection made up of 'N' individuals and 'S' species (Gotelli and Entsminger, 2005). Diversity of arthropods was assessed by using Shannon-Wiener index, Simpson Index (1-D), Evenness index and Chao 1 index. We also used rank abundance curve plots (using log series) as a way to find out the community structure (Magurran, 2004). Non-parametric hierarchal cluster analysis was used to see the similarity among four landscapes on the basis of abundance of arthropods using Bray and Curtis distance as input formula, as many cells in the data were zero. Non-parametric SIMPER test was applied to find the species more responsible for within group similarity in hierarchal cluster analysis. All the analyses were performed using PAST software (Hammer *et al*., 2001).

RESULTS

The community of arthropods was composed of 2842 individuals of 115 taxa (morphospecies) in four classes i.e., Insecta, Arachnida, Chilopoda and Malacostraca. The individual based rarefaction curves of the four landscapes are presented in Fig. 1. None of the four curves could attain asymptote. This indicates that with the increase in sampling efforts, probability of encountering new species is still there in all the four landscapes.

The abundance of different taxa in four land-use types is presented in Table 1. Hymenoptera was the most abundant taxon and Hemiptera was the least abundant taxon. Hymenoptera was the maximum in abundance in desert, Coleoptera in forest, Arachnida in agriculture, Orthoptera in grassy plots, Lepidoptera in forest, Diptera in agriculture and forests, Dictyoptera in grassy plots and Hemiptera in agricultural land. The species richness in four different land-use types is presented in Table 2. The maximum number of species of Hymenoptera (61.11%) was recorded in desert, Coleoptera in forest (65%) and Arachnida and Orthoptera in grassy plots i.e., 53.85% and 69.23%, respectively.

The maximum species richness was recorded in grassy plots followed by forest, desert and agricultural landscapes, respectively. Likewise, the maximum abundance was recorded in grassy plots followed by deserts, agricultural land and forests, respectively. The Simpson Index showed maximum diversity in agricultural land followed by forest, grassy plots and desert whereas, Shannon-Wiener Index showed the maximum diversity in forest followed by agricultural land, grassy plots and desert. Evenness followed Simpson Index. The value of Chao-1 was maximum in forest and minimum in agricultural land (Table 3).

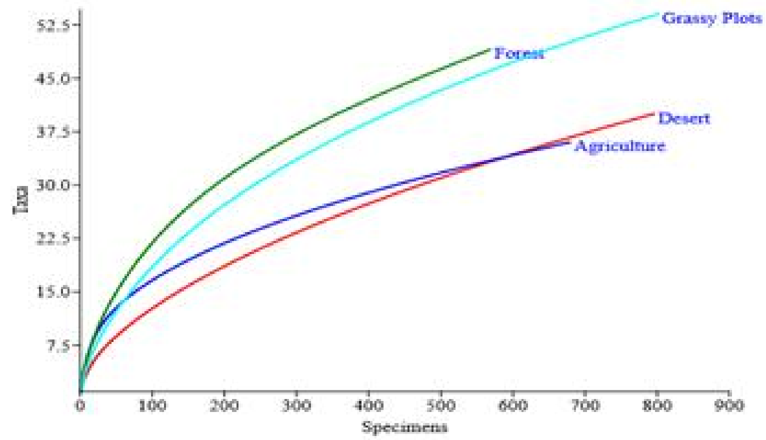

Figure 1. Individual based rarefaction curves of four landscapes

Similarity based hierarchical cluster analysis – using Bray and Curtis distance as input formula-combined agricultural land with forest whereas grassy plots and deserts were the diverse (Fig. 2). The multivariate SIMPER test showed that ants (*Monomorium pharaonis*) contributed highest to the within group similarity (i.e., 17%) of agriculture and forest landscapes. The maximum number of distinct species was found in grassy plots followed by forests, desert and agricultural landscapes i.e., 24, 18, 10 and 9, respectively. Only five species were found common in all the four landscapes. These included three ant species (*Monomorium indicum, M. pharaonic*, *Camponotus angusticollis*), a spider species (*Lycosa poonaensis*) and a grasshopper species (*Patanga succincta*).

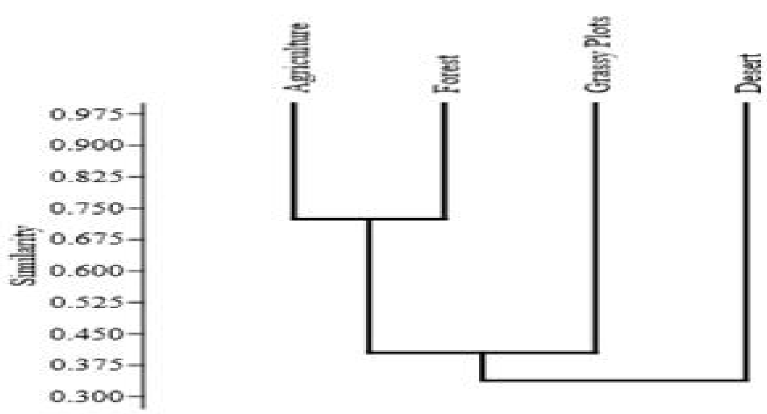

Figure 2. Similarity based hierarchy cluster analysis for four landscapes

The rank-abundance curves showed that there were few species with greater abundance while many species with lesser abundance in all the four landscapes. The three ant species (i.e., *M. indicum, M. pharaonis* and *C. angusticollis*) comprised the top most abundant species in desert, forest and grassy plots. A ground beetle (*Calosoma olivieri*) ranked third after two ant species in agriculture (Fig. 3).

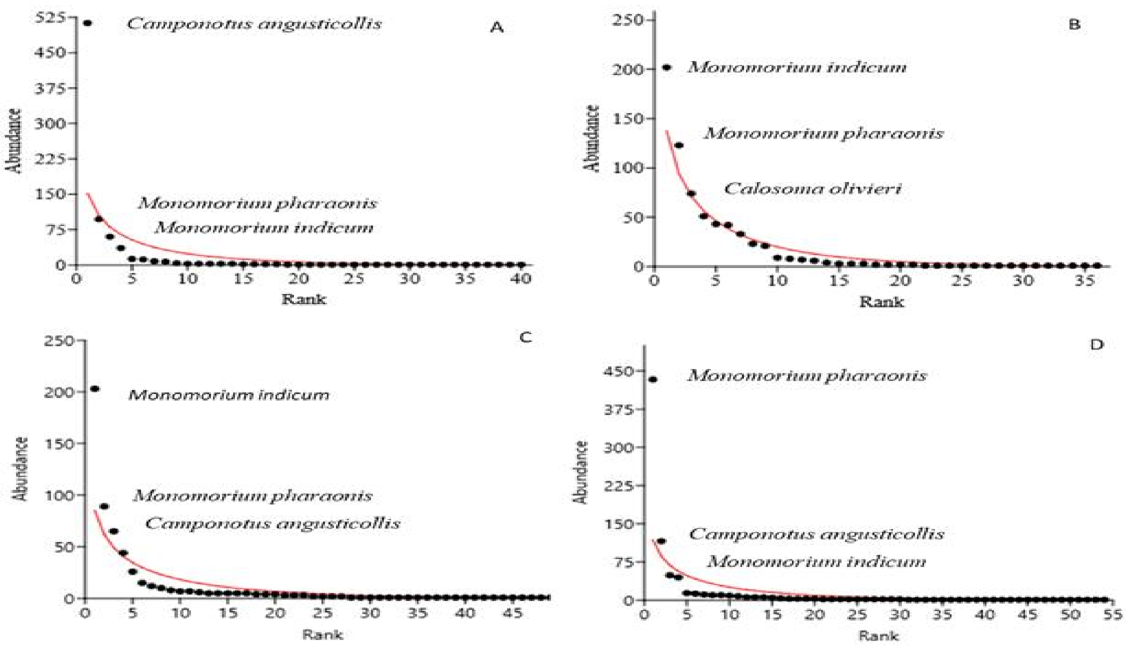

Figure 3. Rank abundance curves of arthropods in (A) desert landscape, (B) agricultural landscape, (C) forest landscape and (D) grassy plots. The top three most abundant taxa are mentioned in each landscape.

Table 1. Abundance of taxa in four different landscapes (percent abundance).

Taxa	Desert	Agriculture	Forest	Grassy Plots
Hymenoptera	696 (87.55)	360 (53.10)	375 (66.73)	605 (75.53)
Coleoptera	52 (6.54)	84 (12.39)	63 (11.21)	31 (3.87)
Arachnida	15 (1.89)	82 (12.09)	21 (3.74)	71 (8.86)
Orthoptera	11 (1.38)	62 (9.14)	17 (3.02)	64 (7.99)
Lepidoptera	1 (0.13)	7 (1.03)	18 (3.20)	2 (0.25)
Diptera	3 (0.38)	10 (1.47)	10 (1.78)	6 (0.75)
Dictyoptera	2 (0.25)	0 (0.00)	8 (1.42)	9 (1.12)
Hemiptera	2 (0.25)	2 (0.29)	2 (0.36)	1 (0.12)
Others	13 (1.64)	71 (10.47)	48 (8.54)	12 (1.50)

Table 2. Species Richness of arthropods in four different landscapes (percent number of species).

Taxa	Desert	Agriculture	Forest	Grassy Plots
Hymenoptera	11 (61.11)	5 (27.78)	9 (50.00)	8 (44.44)
Coleoptera	7 (35.00)	5 (25.00)	13 (65.00)	7 (35.00)
Arachnida	9 (34.62)	8 (33.33)	6 (25.00)	14 (53.85)
Orthoptera	6 (23.08)	6 (23.08)	8 (30.77)	18 (69.23)
Lepidoptera	1 (12.50)	5 (62.50)	4 (50.00)	1 (12.50)
Diptera	1 (33.33)	2 (66.67)	1 (33.33)	1 (33.33)
Dictyoptera	1 (33.33)	-	2 (66.67)	1 (33.33)
Hemiptera	2 (66.67)	1 (33.33)	2 (66.67)	1 (33.33)
Others	2 (28.57)	4 (57.14)	4 (57.14)	2 (28.57)

Table 3. Species richness, abundance, diversity and evenness of taxa in four different landscapes.

	Desert (Mean±S.E)	Agriculture (Mean±S.E)	Forest (Mean±S.E)	Grassy Plots (Mean±S.E)
Species richness	7.20±1.83	8.60±1.29	9.80±1.46	12.20±2.85
Abundance	54.00±10.57	55.00±8.85	48.80±6.36	106.60±42.76
Simpsons index	0.45±0.06	0.65±0.03	0.63±0.09	0.62±0.12
Shannon-Wiener index	0.97±0.12	1.44±0.09	1.50±0.23	1.48±0.33
Evenness index	0.44±0.08	0.53±0.06	0.50±0.08	0.42±0.06
Chao-1index	18.20±8.62	11.00±2.18	20.40±6.37	26.70±5.83

DISCUSSION

In the present study, Hymenoptera was the most abundant taxon in all the four landscapes. The members of insect order Hymenoptera perform important ecosystem functions of pollination and biological control (Greenleaf and Kremen, 2006). In the present study, 97% of hymenopterans were the ants. Ants are the most abundant arthropods distributed across the world, from the highest to the lowest altitudes (Collingwood, 1982; Rickert *et al*., 2014).

The cockroaches, on the other hand, were not recorded from agricultural landscape whereas they were abundant in forest and grassy plots. Cockroaches prefer to live in a wide range of conditions such as under dead or decaying leaves, under detached tree bark, under stones, in grass, in caves or burrows and in nest of ants etc. (Cochran and WHO, 1999). Such conditions are usually characteristic feature of forests and grassy plots and rarely exist in agricultural landscapes.

The results of this study showed the maximum abundance of Arachnids (43%) followed by Coleoptera (37%) and Diptera (35%) in agricultural landscape. For the survival of natural enemies in any habitat, they require availability of pollen, nectar and prey. Agricultural landscapes provide these resources in ample quantity even within a smaller piece of land (Landis *et al*., 2005). Spiders feed almost exclusively on insects (Riechert and Lockley, 1984) e.g., fruit flies, sciarid midges, aphids, cicadas and thrips in agricultural fields (Toft, 1995; Lang *et al*., 1999). In agricultural landscapes of Pakistan, spiders have shown resistance against several insecticides through the production of higher level of detoxification enzymes i.e., glutathione S-transferases, esterases and cytochrome P-450 mono-oxygenases (Rezac *et al*., 2010; Tahir *et al*., 2016). Spiders are predators and exist on third or fourth trophic levels of food web and for sure have less reproductive potential than many phytophagous insects. The other possible reason of their higher abundance is their aggressive searching behavior as most of the spiders were jumpers or runners in our study.

Most of the beetles in our study belonged to family Scarabaeidae. Laboratory studies have shown that carabid beetles can eat almost anything offered e.g., weeds and arthropods (Larochelle, 1990; Tooley and Brust, 2002). Lovei and Sunderland (1996) reported that number of eggs and their size is directly linked with diversity of food consumed by the female beetles. Moreover, tillage operations including deep plowing reported to have no or positive impact on population of ground beetles (Shearin *et al*., 2007).

In intensively managed agricultural landscapes, the diversity of ground beetles can be moderately high because they can survive in anthropogenically influenced landscapes (Lemic *et al*., 2017). In Canadian agricultural lands, ground beetles are reported to be the most abundant arthropods owing to their generalized feeding behavior i.e., predators, scavengers and few are seed feeders. However, type of crop and cropping season greatly influence ground beetle populations (Goulet, 2003). In the present study, Culicidae was the third most abundant taxon in agriculture. The irrigation water in rice fields is the most suitable habitat for mosquito breeding (Washino, 1980). Snow (1983) reported that mosquito species i.e., *Anopheles gambiae*, *A. rufipes* and *Culex neavei* were most abundant in irrigated rice cultivation. Similarly, in the present study ants were the most abundant species in all the four land-use types. Similarly, Graham *et al*. (2009) reported that ants were most abundant (85%) in forty different sites at forest, disturbed by military training. This abundance of ants in distributed landscapes may be due to their omnivorous feeding habits (Feldhaar *et al*., 2007).

The Shannon and Simpson indices were the highest for agricultural land and forest even they were less species rich than grassy plots. This could be due to high evenness values in both agricultural land and forest. The relationship between diversity indices and evenness is highly variable phenomenon depending upon sites under consideration and variation in resource utilization by species (Ma, 2005).

The values of Simpson's index followed the values of Shannon-Wiener index in all the four land-use types. Since our data set was very simple, the resultant values of different diversity indices (i.e., Shannon-Weiner Index, Simpson index and Evenness) exhibited similar trends in all the land-use types. However, in case of complex interactions, interpretation of results can be significantly changed due to the choice of index (Morris *et al*., 2014).

Although there was a big difference in abundance and species richness among the four landscapes but their diversity indices were very close to each other. The relationship between species richness and evenness among communities remains an unsolved problem in ecology from both empirical and theoretical perspectives, which reflects that these are independent components of biodiversity. This relationship is mostly driven by environmental and organismal properties (Soininen *et al*., 2012). For example, differences in abundance of soil arthropods are caused by the environmental conditions, vegetation diversity and abundance of litter in different landscapes (Zayadi *et al*., 2013). Therefore, the usage of multiple indices provides greater insight into the interactions (Morris *et al*., 2014).

Conclusion: It was concluded agriculture is not a threat to soil arthropods biodiversity except some rare species. Moreover, since grassy plots and forests exhibited greater value of Shannon-Wiener, Simpson and Chao-1 indices than desert, plantation of forests in the desert and establishment of grassy plots within or near the buildings should be encouraged for supporting the maximum biodiversity of arthropods and associated taxa in higher tropic levels.

Conflict of Interest: The authors declare that they have no conflict of interest.

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