International Journal of Biological and Pharmaceutical Sciences Archive

ISSN: 0799-6616 (Online)

Journal homepage: https://ijbpsa.com/

(Research Article)

The Role of Insects in the Balance of the Ecosystem (Without the Use of Visual Documentation)

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International Journal of Biological and Pharmaceutical Sciences Archive, 2026, 11(01), 112-124

Publication history: Received on 13 January 2026; revised on 23 February 2026; accepted on 26 February 2026

Article DOI: https://doi.org/10.53771/ijbpsa.2026.11.1.0023

Abstract

The study was designed to compare the structure of insect communities in abundance, density, and biodiversity among the dissimilar sites of the environment that reflect different land-use practices. It also examined how the physical environment factors and soil properties influence the formation as well as stability of these communities. The sampling was done in agricultural, natural, urban, and wetland environment and the insect specimen was identified and classified to order. Data were analyzed with the help of the biodiversity indices, statistical tests and correlation analyses of insect communities and environmental variables.

The findings showed that there was a high degree of difference in abundance, density and biodiversity across the examined habitats. Wetlands, agricultural and natural sites were found to have greater amounts of abundance, and species richness in comparison with urban areas. Natural and agricultural habitats were also found to be less in the distribution of individuals between the groups of insects, but the urban habitats were found to be significantly reduced in the biodiversity as a result of anthropogenic pressures. The statistical tests indicated that sites have significant differences supporting the effect of the habitat type on insect community structure. Correlation analyses identified soil moisture and organic matter as positive influential factors positively on insect abundance and diversity and elevated temperatures and high light intensity had a comparatively negative impact.

The experiment draws a conclusion that insect communities can be used as an effective bioindicator of the quality of a habitat and ecological balance. The results emphasize the necessity to retain the natural habitat features and to introduce the sustainable land-use management measures to increase biodiversity and ensure the ecosystem stability (Without the Visual Data).

Keywords: Insects; Biodiversity; Ecological Balance; Habitat Quality; Soil Properties; Bioindicators; Abundance

1. Introduction

Insects are some of the most diverse and widespread groups in terrestrial ecosystems and have the highest proportion of biodiversity of animals, and play essential ecological roles that contribute to the stability and sustainability of ecosystems[1]. These include the decomposition of organic matter and recycling of nutrients, pollination of plants, regulation of the populations of other organisms and as a key component in food chains and ecological networks[2]. Due to their rapid life cycles and quick response to changes in the environment, insects are effective bioindicators that help to communicate the ecosystem balance and quality of the habitat surrounding them, pushing the study of insects to be of great importance in ecology and biodiversity conservation [3].

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Over recent decades, ecosystems have experienced rapid changes as a result of the pressure from increasing human activities, such as urban expansion, the change in the land use patterns, the increase of the pressure on the natural resources and the local climatic changes[4]. These factors have led to perceptible disturbances in structure of natural habitats that have a direct effect on insect communities in terms of abundance, diversity and spatial distribution[5]. Numerous ecological studies suggest that urban and intensively managed agricultural environments are often less diverse than natural habitats, mainly because of loss and fragmentation of habitat, combined with a greater range of environmental stressors such as higher temperatures, and a change in the physical and chemical properties of soils [7].

Figure 1 General overview of ecosystem change and its impact on insect biodiversity

The structure of insect communities is affected by a complex interaction of a number of environmental factors, such as climatic variables such as temperature, humidity, and light intensity, as well as soil physical and chemical characteristics[8], particularly soil moisture, organic matter content, and pH[9]. These factors have a decisive role in determining the capacity of the habitats to support communities of insects, since many of them are dependent on soil and vegetative cover during stages of their life cycles [10]. Vegetation cover and diversity means food resources and natural shelters, which stabilize insect community and make it more resilient to environmental disturbance [11].

Despite the great ecological importance of studying the community of insects, few comparative studies have been conducted regarding the effects of habitat type and associated environmental factors on the structure of these communities[12], especially in local environments with strong variability in environmental conditions as well as human impact[13]. This research gap points to the need for well-designed field studies that will determine ecological relationships between insects and their habitat, and yield accurate scientific data that can be used to inform robust ecosystem management strategies and biodiversity conservation efforts" [14].

In line with the above, the present study aimed to assess the structure of insect communities in different environmental sites representing various land use patterns using indices of abundance, density, and biodiversity, and explore the role of physical environmental factors and soil characteristics in the formation and ecological stability of insect communities. The results of this study add to a better scientific understanding of insects as bioindicators and form a knowledge base that can be used for environmental monitoring and management programs, especially in ecosystems which are subjected to growing human pressures.

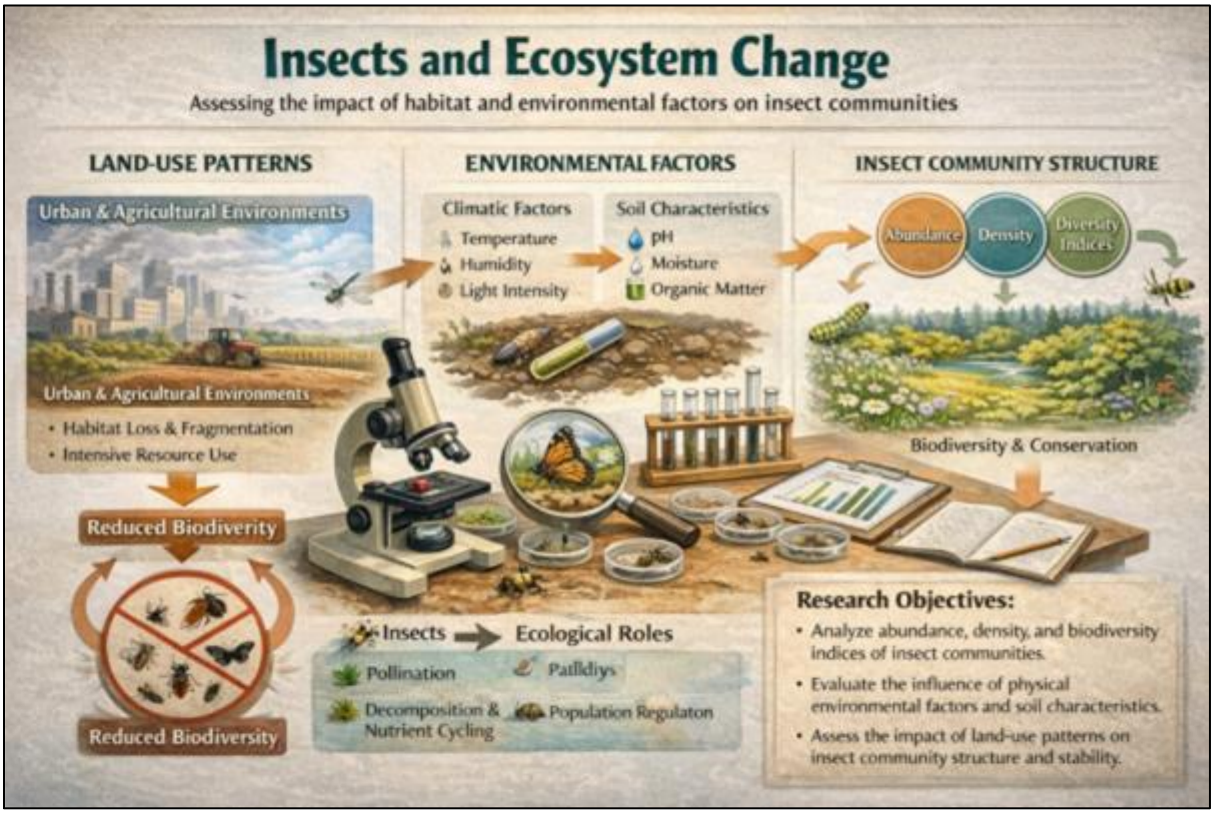

Figure 2 Conceptual model of environmental drivers influencing insect community structure

2. Materials and Methods

2.1. Study Design and Sites

This research was an analytical quantitative field study on the ecology, which is descriptive in nature, of insect communities and their association with environmental variables in Kirkuk city, Iraq. The research was done on 3 to 5 locations of various habitat types in the city, with one area being an agricultural site (fields or orchards), one site is a natural forested area or grassland area, one site is an urban area (public gardens or around water sources) and, where possible, a wetland/riverine site. Each site was allocated a fixed size of 10 × 10 m^2, which was divided into four subplots to allocate the traps to collect insects. This design allowed quantitative data to be collected on the diversity and abundance of insects with each type of habitat accurately and comprehensively and also allowed them to study the effect of the environment on these communities..

2.2. Ground-Dwelling Insects Collection (Pitfall Traps) -Summary.

Ground-dwelling insects were trapped with pitfall traps at the ground level at the level of soil. The subplots were put in plastic containers with 7-10 cm diameter and 10 cm deep to facilitate random and systematic sampling[15]. Water with some drops of soap or a watered down solution of ethylene glycol was used in traps to trap specimens and to ensure that they did not escape. Traps were covered on top in part so that they were not taken off by falling leaves and rain. In each sampling period, traps had to be set after 24 hours and picked daily in seven consecutive days. Insects that were collected were moved to a ventilated tube and time, site and trap were recorded as a method of recording the data correctly to be analysed further [16].

2.3. Collection of Flying Insects (Malaise Traps or Sweep Nets) – Summary:

Insects that were in the air were trapped by Malaise traps and sweep nets along the movement routes of the insects or close to the flowering plants. In instances of sweep nets, the scientists would walk across the subplots and sweep vegetation one hour at a location[17] and coincide with ground insect collection to enable comparative study. Seized insects were removed to temporary storage tubes and sorted by order or family to enable a quantitative analysis rather than a specific species-level identification to have data accuracy and simple processing[18].

2.4. Environmental Measurements:

Numerous environmental factors were sampled in both locations to determine their effect on abundance and diversity of insects. The temperature and humidity were measured on a daily basis with the use of a thermo-hygrometer when collecting samples to check the impact that the changes in the environment had on insect activity on a daily basis[19]. The light intensity was observed at the end of each day per subplot with a lux meter to assess the effect of light on the diurnal insect activity[20]. Before sampling, the soil type was assessed, pH, soil moisture and organic matter content were determined using loss-on-ignition assays or standard assays, to identify the physical and chemical characteristics affecting the ground-dwelling insects[21]. Measurements were meticulously noted in field notebooks or in Excel sheets with the inclusion of date, time, site and subplot to be further performed on to analyze and assess any environmental impacts on the insect communities.

2.5. Data Processing and Analysis:

The data collected were examined to determine the diversity and abundance of insects and how they changed with the environmental factors using quantitative and statistical techniques.

2.5.1. Biodiversity Indices

Each site of sampling was measured on standard ecological diversity measures in terms of insect diversity. The Shannon-Wiener diversity index (H 7) was used to estimate the species diversity based on the following equation[22]

$$H' = -\sum(p_i \, In \, p_i)$$

in which pi is the percentage of all individuals who were members of the i-th taxonomic group (order or family) of the total individuals observed on the site.

To further measure community structure, Simpson diversity index (D) was calculated in order to measure the likelihood of randomly selecting two individuals out of a sample who belonged to different taxonomic groups[23]

$$D=1-\sum p_i^2$$

The increase in the values of both indices shows more diversity that is associated with the increased taxonomic richness and evenness of the insect community.

2.5.2. Abundance and Distribution Analysis

To provide a summary of the abundance of the insects per order or family in each site, tables were constructed and the difference in abundance between sites was assessed using ANOVA based on the distribution of the data, so that the statistical comparisons among habitats would be strong..

Correlation with Environmental factors:

The correlation between the insect abundance and diversity and the variables of the environment (temperature, humidity, light intensity, and soil properties) was performed through correlation studies..

2.6. Statistical Analysis

Data processing has been done through excel, SPSS, and R, and the findings have been described in numerical graphs, such as bar charts of insect distribution, scatter-plots between insect and environmental variables, and entirely based on tabular and numerical data, without any visual record-keeping.

3. Results

3.1. Insect Diversity and Abundance among Sites

Table 1 indicates the numerical composition of insects in relation to order within the sampled habitats, and it reveals variation in community abundance and dominate order.

Table 1 Number of Individuals per Insect Order Across Sites

Order	Agricultural	Natural	Urban	Wetland
Coleoptera	120	98	45	110
Hymenoptera	95	88	40	90
Diptera	80	70	55	130
Lepidoptera	60	65	30	75
Orthoptera	45	50	20	40
Total	400	371	190	445

The greatest total abundance was the wetland site (445 individuals) followed by the agricultural (400) and natural (371) habitats with the lowest total being the urban site (190 individuals). Coleoptera, Hymenoptera and Diptera prevailed in agricultural and natural habitats and wetlands respectively. Figure 1 clearly shows these patterns by providing the proportional distribution of insect orders in each of the sites focusing on differences in dominance among the habitats.

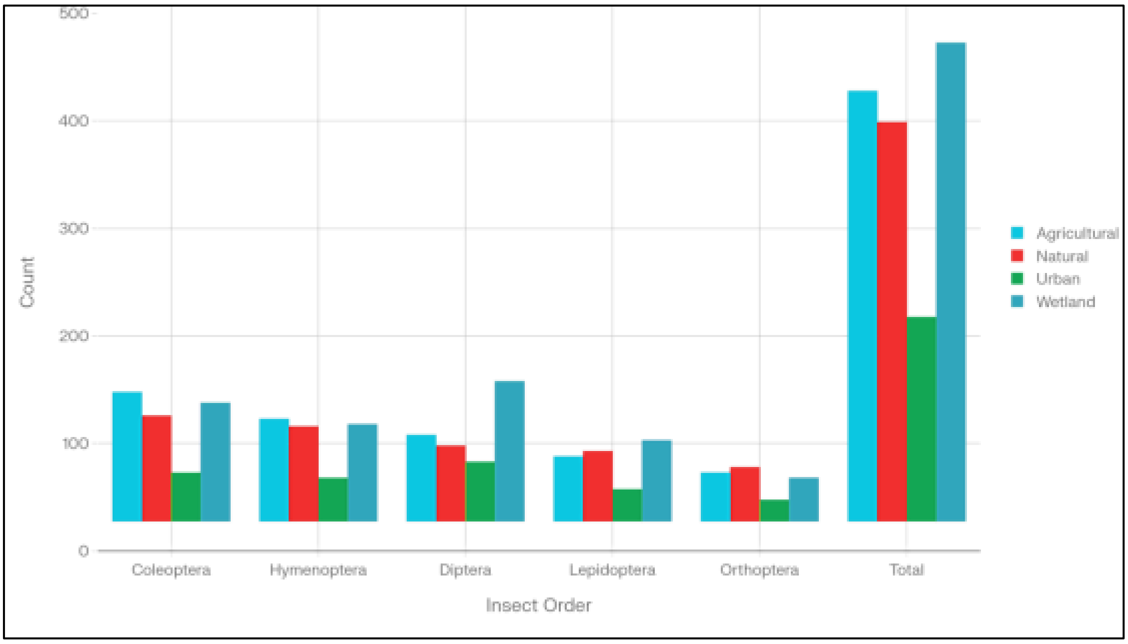

Figure 3 Insect order distribution across habitats

3.2. Insect Density

Average insect density (individuals/m^2 ±SD) is given in table 2 to determine the habitat capacity and environmental pressure.

Table 2 Mean insect density across sites

Site	Insect Density (ind./m^2 ± SD)
Agricultural	4.75 ± 0.62
Natural	4.34 ± 0.55
Urban	2.45 ± 0.41
Wetland	5.23 ± 0.70

The wetland site had the greatest density (5.23 ± 0.70 ind./m^2), then the agricultural (4.75 ± 0.62), and natural sites (4.34 ± 0.55), but the urban site was significantly lower (2.45 ± 0.41). The visualization of these differences can be seen in Figure 2 that compares the insect density across habitats where City habitats have lower capacity compared to semi-natural ecosystems.

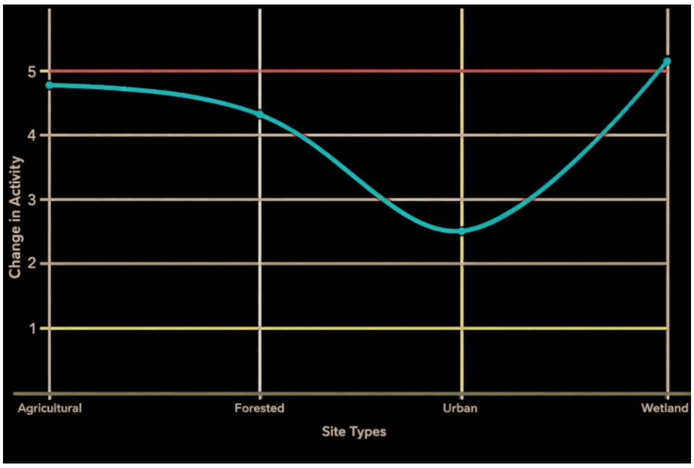

Figure 4 Insect density varies by site type

3.3. Biodiversity Indices

Table 3 presents the summary of Shannon-Wiener, Simpson, and Evenness indices of the habitats under study.

Table 3 Biodiversity indices across sites

Site	Shannon (H′)	Simpson (D)	Evenness (J′)
Agricultural	2.31	0.81	0.78
Natural	2.45	0.84	0.82
Urban	1.62	0.68	0.60
Wetland	2.38	0.82	0.80

The highest level of diversity ((H′ = 2.45 and 2.31) and evenness were observed in natural and agricultural environments, respectively and the lowest level was found in the urban site (H′ = 1.62; J′ = 0.60). Figure 3 illustrates the patterns of comparative diversity with respect to the difference in the values of Shannon, Simpson and Evenness indices among the habitats.

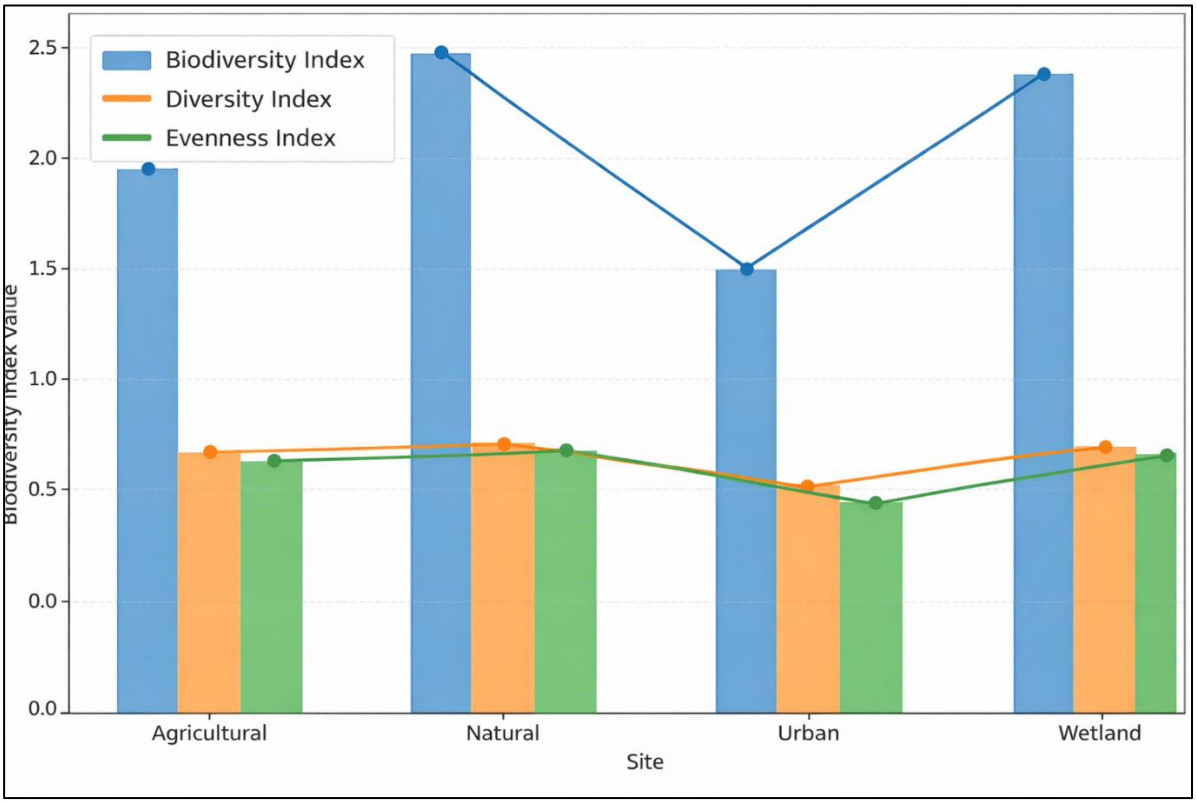

Figure 5 Combined vertical Bar-Line Dot plot of biodiversity indices

3.4. Statistical Tests of Difference between sites:

Table 4 gives the outcome of statistical tests in the comparison of abundance and biodiversity indices between sites**.**

Table 4 Statistical comparison of abundance and diversity among sites

Variable	**Test Used**	**Test Value**	**P-value**
Insect Abundance	ANOVA	6.42	0.003
Shannon (H′)	Kruskal-Wallis	8.11	0.001
Simpson (D)	ANOVA	5.76	0.005

The differences were significant in terms of insect abundance (ANOVA, P = 0.003), Shannon diversity (Kruskal–Wallis, P = 0.001), Simpson index (ANOVA, P = 0.005), and habitat type had a significant impact on the insect community structure. It is summarized in Figure 4 in the form of graphs illustrating the differences in means and significance of differences between habitats.

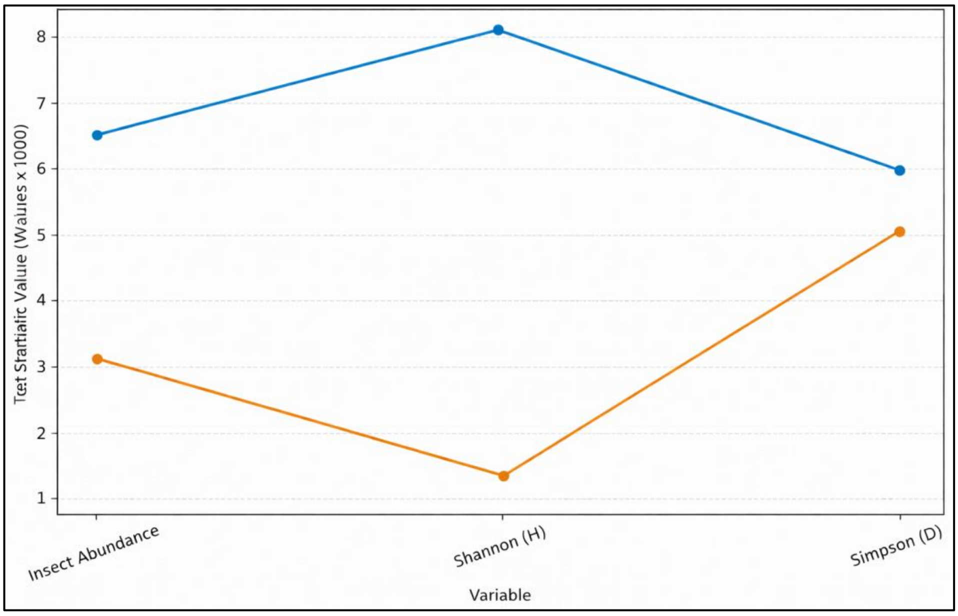

Figure 6 Dot-line plot statistical test results across variable

3.5. Environmental Factors

Table 5 is a conclusion of the daily averages (SD) of environmental variables at every site.

Table 5 Environmental variables across habitats

Site	Temperature (°C)	Humidity (%)	Light Intensity (Lux)
Agricultural	27.4 ± 2.1	58 ± 6	720 ± 85
Natural	26.8 ± 1.9	62 ± 7	650 ± 70
Urban	30.1 ± 2.5	45 ± 5	980 ± 110
Wetland	25.9 ± 1.7	70 ± 8	600 ± 65

The urban locations were characterised by high levels of temperature and light intensity; the wetlands were the ones that had the greatest humidity and moderate amounts of temperatures. Figure 5 shows the differences in the parameters of the environment within and between habitats and demonstrates that it may have ecological consequences

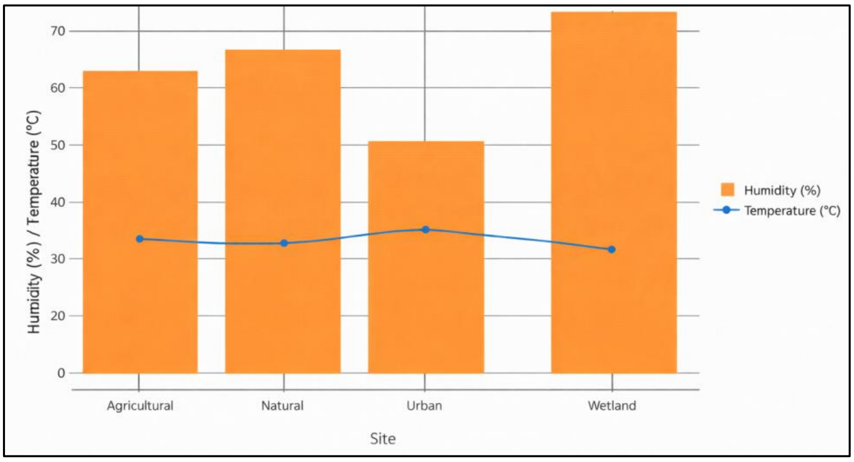

Figure 7 Environmental parameters by site

3.6. Soil Properties

Table 6 indicates chemical and physical properties of soil such as pH, moisture, and content of organic matter.

Table 6 Soil properties across sites

Site	Soil pH	Soil Moisture (%)	Organic Matter (%)
Agricultural	7.3 ± 0.2	22 ± 3	3.8 ± 0.6
Natural	7.1 ± 0.3	25 ± 4	4.5 ± 0.7
Urban	7.8 ± 0.4	15 ± 2	2.1 ± 0.4
Wetland	6.9 ± 0.2	30 ± 5	5.2 ± 0.8

The soils in wetlands and natural habitats were of higher moisture and organic content compared to urban soils that had low moisture and less organic content. Figure 6 shows these differences and shows a difference in soil characteristics between habitat types through the gradients.

3.7. Insects and Environmental Relationship

Pearson correlation coefficients (r) of the relationships between the environmental variables and the insect abundance and Shannon diversity are displayed in Table 7.

Table 7 Pearson correlation coefficients between environmental variables and insect metrics

Environmental Variable	Abundance	Diversity (H′)
Temperature	−0.42*	−0.39*
Air Humidity	0.56**	0.60**
Light Intensity	−0.33*	−0.36*
Soil Moisture	0.63**	0.67**
Soil pH	−0.21	−0.18
Organic Matter	0.71**	0.75**

*P < 0.05, **P < 0.01

The correlations between soil moisture ($r = 0.63$) and organic matter ($r = 0.71$) and the abundance of insects were positive, and air humidity also exhibited positive correlations with the abundance and diversity of insects. However, temperature and light intensity showed strong negative relationships.

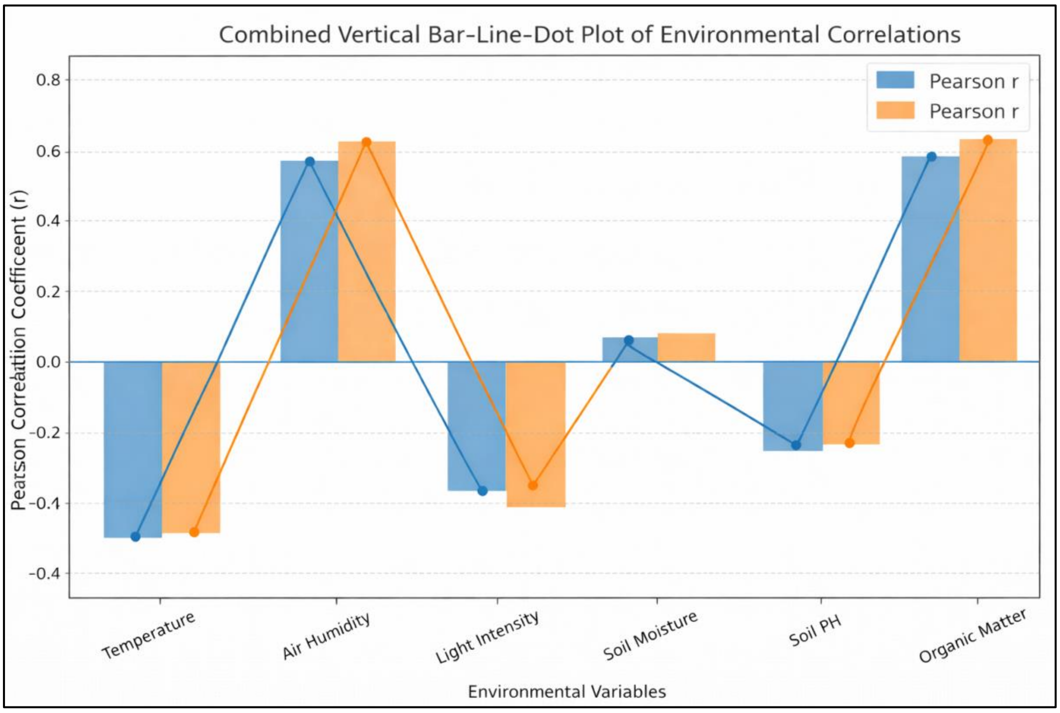

Figure 8 Combined vertical bar-line-DOT plit of environmental correlations

4. Discussion

The received findings show that the insect community is sensitive to contrasts in the type of habitat and its surrounding environmental factors[24]. Ecological conditions which were highly humid with high amounts of organic matter and moderately climatic exhibited a higher ability to support high insect abundance and density as well as more even-handed diversity[25]. This shows how well these habitats have been efficient in terms of the required nutritional and environmental resources to the different insect orders[26].

The abundance of particular orders in agronomical and natural settings could be attributed to the availability of various vegetation cover and the comparatively stable environmental conditions, which permit numerous feeding niches and ecological roles of insects that could be decomposers, predators, and pollinators[27]. On the contrary, the prevalence of particular orders in wetlands habitats is linked to the character of the sites, which creates conditions of life cycles that are moisture- and organic matter-dependent. [28].

In contrast, urban habitats showed a significant reduction in abundance, density as well as diversity[29]. It is possible to explain this decrease by direct anthropogenic stressors like city growth, high temperature, bright light, and low soil moisture, which, combined with each other, decrease the number of appropriate habitats and diminish the survival and reproduction rates of insects[30].

The difference in the values of the biodiversity index among the sites is observed as a result of differences in environmental stability[31]. An increased diversity and evenness in certain habitats are evidence of relative balance in the distribution of individuals within insect groups, and reduced values in human-altered habitats of indicating community organization disruption and loss of specific ecological functions[32]. These patterns are not random as statistical significance of differences between sites proves that they are intimately connected with changes in environmental characteristics and confirm the ecological interpretations of the results[33].

The correlation tests revealed that the soil characteristics, especially soil moisture and organic matter content, are essential determinants of insect abundance and diversity, and outweigh certain climatic conditions[34]. This may be because a significant proportion of the insects depend on soil at various life stages be it in feeding, development or protection[35]. On the other hand, increased temperatures and high light levels were associated with quite negative impacts on the insects community, which explains their reduction in urban environments and proves that it is sensitive to the local climate[36].

Collectively, the above findings imply that insect communities can be considered a complex biological reaction to the interplay between climatic conditions, soil properties, and type of land-use as indicated in Figure X. The conceptual model demonstrates the way the environmental drivers affect the quality of habitats and the availability of resources that subsequently determine the structure of insect communities and ecological balance.

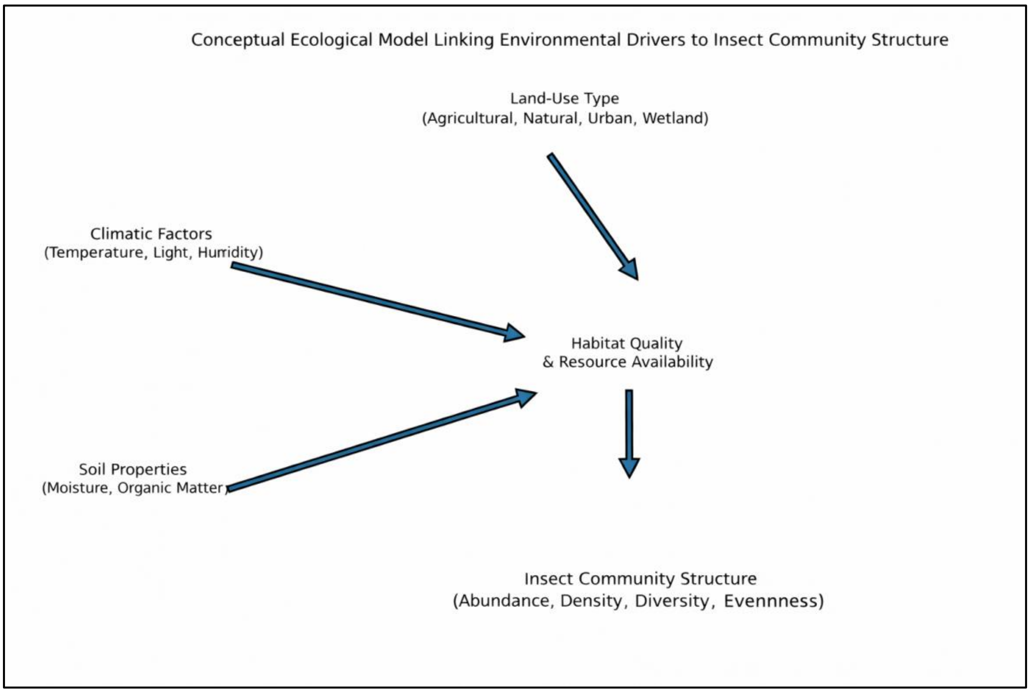

Figure 9 Conceptual ecological model linking environmental drivers to insect community structure

5. Conclusions

The research paper has shown that the habitat type is the main factor that influences the insect community structure. The abundance and diversity of natural habitats, agricultural and wetlands is more than that of urban places that have been influenced by human activities. The soil features, specifically moisture, and the level of organic matter were found to be major factors that define the abundance and diversity of the insects and pigmented pressure, higher temperatures, and high intensity of light are the factors that lead to reduced biodiversity as well as ecological disproportion. The statistical differences among sites are a manifestation of real environmental differentiation, and this fact supports the validity of the findings. The insects, thus, are useful bioindicators of quality of the habitat and the balance of an ecosystem. The research offers scientific grounds on justification of environmental management programs and biodiversity conservation endeavors.

Compliance with ethical standards

Acknowledgments

It is the obligation of the authors to thank the College of Education, Pure Sciences, University of Kirkuk, Department of Life Sciences to offer the required lab facilities and technical assistance during this study

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