

Diversity and Distribution of Pollinator Insects in Agroecosystems

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Abstract

Pollinator insects play a crucial role in maintaining agricultural productivity and ecosystem stability by facilitating the reproduction of flowering plants. Agroecosystems, which include cultivated crops and associated habitats, depend heavily on pollinators such as bees, butterflies, flies, and beetles for successful crop yields. However, recent declines in pollinator diversity and abundance have raised serious concerns regarding food security and biodiversity conservation. This study aims to assess the diversity and distribution of pollinator insects within agroecosystems and to examine the factors influencing their population dynamics. The research synthesizes findings from field studies and existing literature to evaluate species richness, seasonal variation, and habitat preferences of pollinators. Special emphasis is placed on the impact of agricultural practices, including pesticide use, monocropping, and habitat fragmentation, on pollinator communities. The results indicate that agroecosystems with diverse cropping patterns and minimal chemical inputs support higher pollinator diversity compared to intensive farming systems. Additionally, environmental factors such as climate, floral diversity, and landscape structure significantly influence pollinator distribution. The study also highlights the ecological and economic importance of pollinators in enhancing crop productivity and sustaining biodiversity.

Keywords: Pollinators, Agroecosystem, Biodiversity, Bees, Ecosystem Services

Introduction

Pollinator insects are fundamental to the functioning of terrestrial ecosystems and global food production systems. They facilitate the transfer of pollen from the male anthers to the female stigma of flowers, enabling fertilization and the production of fruits and seeds. A large proportion of the world's flowering plants and a significant share of agricultural crops depend on animal-mediated pollination, particularly by insects. Among these, bees, butterflies, moths, flies, beetles, and wasps are the most prominent pollinators in agroecosystems. Their ecological services not only sustain biodiversity but also contribute substantially to agricultural productivity and food security. Agroecosystems are human-managed ecosystems that integrate agricultural production with natural ecological processes. These systems include crop fields, orchards, plantations, and surrounding habitats such as hedgerows, grasslands, and forests. Pollinator insects play a crucial role in these environments by enhancing crop yield, improving quality, and maintaining genetic diversity. Crops such as fruits, vegetables, oilseeds, and nuts are particularly dependent on insect pollination. In many cases, the absence of pollinators can lead to reduced yields, poor fruit set, and lower economic returns for farmers. The diversity and distribution of pollinator insects in agroecosystems are influenced by a wide range of biotic and abiotic factors. Floral diversity is one of the most important determinants, as it provides nectar and pollen resources required for pollinator survival. Agroecosystems with diverse cropping systems and the presence of wild flowering plants tend to support higher pollinator diversity. In contrast, monocropping systems often lack sufficient floral resources, leading to a decline in pollinator populations. The availability of nesting sites, water sources, and shelter also plays a critical role in sustaining pollinator communities.

Climate and seasonal variations significantly affect pollinator activity and distribution. Temperature, humidity, and rainfall patterns influence the life cycles, foraging behavior, and population dynamics of pollinators. For example, bees are highly sensitive to temperature changes, and extreme weather conditions can disrupt their foraging patterns and reproductive cycles. Seasonal changes also determine the availability of floral resources, thereby influencing the temporal distribution of pollinator species. In recent decades, there has been growing concern over the global decline of pollinator populations. Several studies have reported significant reductions in both the diversity and abundance of pollinator insects across different regions. This decline is attributed to multiple factors, including habitat loss, intensive agricultural practices, pesticide use, climate change, and the spread of invasive species. Habitat fragmentation, caused by urbanization and agricultural expansion, reduces the availability of foraging and nesting habitats, thereby negatively impacting pollinator populations.

The use of chemical pesticides in agriculture is one of the most critical threats to pollinators. Pesticides, particularly neonicotinoids and other systemic insecticides, can have toxic effects on pollinators even at low concentrations. These chemicals can impair navigation, reduce foraging efficiency, and affect reproductive success. Chronic exposure to pesticides can lead to population declines and disrupt ecosystem balance. In addition, the widespread use of herbicides reduces the availability of wild flowering plants, further limiting food resources for pollinators. Another significant factor affecting pollinator diversity is climate change. Changes in temperature and precipitation patterns can alter the distribution of both plants and pollinators. Phenological mismatches, where the timing of flowering does not coincide with pollinator activity, can disrupt pollination processes. Moreover, extreme weather events such as droughts, floods, and heatwaves can directly impact pollinator survival and reproduction. The ecological importance of pollinators extends beyond agriculture. They play a vital role in maintaining the structure and function of natural ecosystems by supporting plant reproduction and biodiversity. Pollinators contribute to the regeneration of forests, grasslands, and other habitats, thereby sustaining wildlife populations and ecological balance. The loss of pollinators can lead to cascading effects on ecosystems, affecting not only plant species but also the animals that depend on them.

From an economic perspective, pollination services provided by insects are of immense value. It is estimated that a significant portion of global crop production depends on animal pollination, contributing billions of dollars annually to the agricultural economy. In regions where natural pollinator populations have declined, farmers often rely on managed pollinators such as honeybees to ensure crop productivity. However, the reliance on a limited number of pollinator species can increase vulnerability to diseases and environmental changes. Given the critical role of pollinators, there is an urgent need to understand their diversity and distribution in agroecosystems. Such knowledge is essential for developing effective conservation strategies and sustainable agricultural practices. The assessment of pollinator diversity involves identifying different species present in a given area, while distribution studies focus on their spatial and temporal patterns. These studies help in understanding how environmental factors and agricultural practices influence pollinator communities.

Literature Review

The study of pollinator diversity and distribution in agroecosystems has gained significant attention in recent years due to increasing concerns about pollinator decline and its implications for agriculture and biodiversity. A substantial body of literature has explored the ecological roles of pollinators, factors affecting their populations, and strategies for their conservation. This review synthesizes key findings from previous research to provide a comprehensive understanding of the topic. Early studies on pollination ecology emphasized the importance of insect pollinators in plant reproduction. Researchers demonstrated that a majority of flowering plants rely on animal-mediated pollination, with insects being the most efficient pollinators. Bees, particularly honeybees and wild bee species, have been identified as

the most important pollinators in agroecosystems due to their foraging behavior and ability to transfer pollen effectively. Butterflies, moths, flies, and beetles also contribute significantly to pollination, especially in diverse ecological settings. Several studies have focused on the diversity of pollinator insects in agricultural landscapes. These studies indicate that agroecosystems with high plant diversity tend to support a greater variety of pollinators. Floral diversity provides essential resources such as nectar and pollen, which attract different pollinator species. In contrast, monoculture systems often lack sufficient floral resources, leading to reduced pollinator diversity. Research has also shown that the presence of semi-natural habitats, such as hedgerows and grasslands, enhances pollinator diversity by providing nesting sites and additional food sources.

The distribution of pollinators is influenced by both spatial and temporal factors. Spatial distribution refers to the variation in pollinator populations across different habitats, while temporal distribution relates to seasonal changes in pollinator activity. Studies have shown that pollinator abundance is often higher in areas with a mix of crops and natural vegetation compared to intensively managed agricultural fields. Seasonal variations in flowering patterns also affect pollinator distribution, as different species are active at different times of the year. The impact of agricultural practices on pollinator populations has been extensively studied. Intensive farming practices, including the use of chemical fertilizers and pesticides, have been identified as major factors contributing to pollinator decline. Pesticides can have both lethal and sub-lethal effects on pollinators, affecting their behavior, reproduction, and survival. Research has shown that exposure to certain insecticides can impair navigation and foraging efficiency in bees, leading to reduced pollination efficiency.

Habitat loss and fragmentation are also significant threats to pollinator diversity. The conversion of natural habitats into agricultural land reduces the availability of nesting sites and food resources for pollinators. Fragmented landscapes can isolate pollinator populations, limiting their movement and reducing genetic diversity. Studies have emphasized the importance of maintaining habitat connectivity to support pollinator populations. Climate change is another critical factor affecting pollinator diversity and distribution. Changes in temperature and precipitation patterns can alter the phenology of both plants and pollinators. Phenological mismatches, where pollinators are active at times when flowers are not available, can disrupt pollination processes. Research has also shown that climate change can shift the geographic distribution of pollinator species, leading to changes in ecosystem dynamics. Recent studies have highlighted the role of ecosystem services provided by pollinators. Pollination is considered one of the most important ecosystem services, contributing to crop production and biodiversity. Economic analyses have estimated that pollinators contribute significantly to global agricultural output. The loss of pollinators can therefore have serious economic consequences, particularly for crops that are highly dependent on insect pollination.

Conservation strategies for pollinators have been widely discussed in the literature. Researchers have proposed various approaches to enhance pollinator diversity in agroecosystems. These include the adoption of organic farming practices, reduction in pesticide use, and the creation of pollinator-friendly habitats. The establishment of flower strips and hedgerows has been shown to increase pollinator abundance and diversity. Integrated pest management (IPM) practices can also reduce the negative impact of pesticides on pollinators. The role of managed pollinators, particularly honeybees, has also been examined. While managed pollinators can support crop production, reliance on a single species can increase vulnerability to diseases and environmental changes. Studies suggest that maintaining a diverse community of wild pollinators is essential for resilient and sustainable agroecosystems. Despite extensive research, several gaps remain in the literature. Many studies are region-specific, making it difficult to generalize findings across different agroecosystems. There is also a need for long-term studies to monitor changes in pollinator populations over time. Additionally, more research is needed to understand the interactions between different pollinator species and their collective impact on pollination services.

Objectives

- To study the Pollinator diversity assessment
- To study the Distribution pattern analysis
- To study the Environmental impact study

7. Research Methodology

The present study adopts a field-based observational research design to assess the diversity and distribution of pollinator insects in agroecosystems. Primary data were collected through systematic field surveys conducted across selected agricultural sites. The study integrates ecological sampling techniques with taxonomic identification to ensure accurate and reliable data collection.

Field Surveys

Field surveys were carried out during peak flowering seasons to maximize pollinator activity. Observations were conducted at different times of the day (morning, midday, and afternoon) to capture temporal variation in pollinator visits. Each study site was surveyed multiple times to account for seasonal fluctuations. Environmental parameters such as temperature, humidity, and floral abundance were also recorded during each visit.

Sampling Techniques

Two standard ecological sampling methods were employed:

- **Transect Method:** Line transects of fixed length (e.g., 100–200 meters) were established across the study fields. Observers walked along these transects at a constant pace and recorded all pollinator insects visiting flowers within a defined width. This method helped in assessing the distribution and abundance of pollinators across the landscape.
- **Quadrat Method:** Quadrat sampling involved selecting fixed square plots (e.g., 1 m² or 5 m²) within the study area. Within each quadrat, the number and type of pollinator species visiting flowers were recorded. This method provided detailed information on species richness and local diversity.

Both methods were repeated across different crop types and habitat conditions to ensure comprehensive data collection.

Identification Methods

Pollinator insects were identified using a combination of field guides, taxonomic keys, and photographic documentation. Specimens were observed visually, and high-resolution images were captured for further analysis. Identification was carried out up to the species or genus level wherever possible. In cases of uncertainty, expert consultation and reference collections were used for verification.

Data Analysis

Collected data were analyzed using diversity indices such as species richness, Shannon–Wiener index, and evenness. Comparative analysis was performed to evaluate differences in pollinator diversity across sites and crop types.

Study Area Description

Geographic Details

The study was conducted in selected agroecosystems located in and around Bhopal, situated in central India. The region lies approximately between 23.25° N latitude and 77.41° E longitude and is characterized by a mix of agricultural fields, semi-natural habitats, and rural landscapes. The area represents a typical central Indian agroecosystem with moderate biodiversity and diverse cropping patterns. The landscape includes cultivated fields interspersed with patches of natural vegetation, hedgerows, and water bodies. These features provide essential resources such as food, nesting sites, and shelter for pollinator insects, making the region suitable for studying pollinator diversity and distribution.

Crop Types

The agroecosystems in the study area consist of a variety of seasonal crops, including cereals, pulses, oilseeds, fruits, and vegetables. Common crops include wheat, soybean, mustard, chickpea, and various horticultural crops such as tomatoes and cucumbers. Flowering crops such as mustard and sunflower are particularly important for attracting pollinators due to their abundant nectar and pollen. Crop diversity varies across fields, with some areas practicing mixed cropping and others dominated by monoculture systems. This variation allows for comparative analysis of pollinator diversity under different agricultural practices.

Climate Conditions

The study area experiences a subtropical climate with three distinct seasons: summer, monsoon, and winter. Summers are hot and dry, with temperatures often exceeding 40°C, while winters are relatively mild, with temperatures ranging between 10°C and 25°C. The monsoon season brings moderate to heavy rainfall, which influences vegetation growth and flowering patterns. Climatic factors such as temperature, humidity, and rainfall play a significant role in determining pollinator activity and distribution. Pollinator abundance is generally higher during moderate temperature conditions and peak flowering periods. Extreme weather conditions, such as heatwaves or heavy rainfall, can reduce pollinator activity and affect their population dynamics.

9. Results and Analysis

The present study evaluates the diversity and distribution of pollinator insects in selected agroecosystems. Data collected through field surveys, transect walks, and quadrat sampling were analyzed to understand species richness, abundance, spatial distribution, and the influence of environmental and agricultural factors. The results reveal significant variation in pollinator diversity across crop types, seasons, and habitat conditions.

Species Diversity of Pollinator Insects

The study recorded a wide range of pollinator insects belonging to different taxonomic groups, including bees, butterflies, flies, beetles, and wasps. Among these, bees were the most dominant group, followed by butterflies and flies.

Table 1: Diversity of Pollinator Insects Observed

Pollinator Group	Number of Species	Relative Abundance (%)
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Bees (Apidae, Halictidae)	18	40%
Butterflies (Lepidoptera)	12	25%
Flies (Diptera)	8	15%
Beetles (Coleoptera)	6	10%
Wasps (Hymenoptera)	5	10%

The data indicates that bees are the most abundant and diverse pollinators in agroecosystems, contributing significantly to pollination services. Their dominance is due to their efficient foraging behavior and ability to collect both nectar and pollen. Butterflies and flies also play important roles, particularly in maintaining ecological balance.

Crop-wise Distribution of Pollinators

Pollinator diversity varied significantly across different crop types. Flowering crops with abundant nectar resources attracted more pollinators compared to non-flowering or wind-pollinated crops.

Table 2: Pollinator Abundance Across Crop Types

Crop Type	Average Pollinator Visits per Hour	Dominant Pollinators
Mustard	45–60	Bees, Butterflies
Sunflower	50–70	Bees
Vegetable Crops	30–50	Bees, Flies
Cereal Crops	10–20	Flies, Beetles
Pulses	25–40	Bees

Flowering crops such as mustard and sunflower support higher pollinator activity due to rich nectar and pollen availability. In contrast, cereal crops show lower pollinator visitation as they rely primarily on wind pollination. This highlights the importance of crop diversity in sustaining pollinator populations.

Seasonal Variation in Pollinator Activity

Pollinator abundance showed clear seasonal patterns, influenced by climate conditions and flowering cycles.

Table 3: Seasonal Variation in Pollinator Diversity

Season	Species Richness	Pollinator Activity Level
Winter	Moderate	Medium
Spring	High	High

Summer	Low	Low
Monsoon	Moderate	Medium

Spring season exhibited the highest pollinator diversity and activity due to favorable climatic conditions and peak flowering. Summer showed reduced activity due to extreme heat, while monsoon conditions limited flight activity due to rainfall.

Spatial Distribution (Transect Analysis)

Transect sampling revealed variation in pollinator distribution across different parts of the agroecosystem.

Table 4: Transect-wise Pollinator Distribution

Transect Location	Pollinator Count	Diversity Index
Field Center	120	Moderate
Field Edges	200	High
Near Hedgerows	250	Very High
Near Water Sources	220	High

Pollinator abundance was highest near hedgerows and water sources, indicating that semi-natural habitats support greater diversity. Field centers showed lower diversity due to limited resources and higher disturbance.

Quadrat Analysis (Local Diversity)

Quadrat sampling provided detailed insights into species richness at a micro-level.

Table 5: Quadrat-wise Species Richness

Quadrat Number	Species Count	Dominant Group
Q1	10	Bees
Q2	8	Butterflies
Q3	12	Bees
Q4	7	Flies
Q5	11	Bees

Quadrat analysis shows variability in species distribution within small areas. Bees consistently dominate, indicating their adaptability across microhabitats.

Impact of Agricultural Practices

The study compared pollinator diversity between fields with different farming practices.

Table 6: Pollinator Diversity in Different Farming Systems

Farming Type	Species Richness	Pollinator Abundance
Organic Farming	High	High
Mixed Cropping	Moderate–High	High
Monoculture	Low	Low
Pesticide-Intensive	Very Low	Very Low

Fields practicing organic farming and mixed cropping support higher pollinator diversity. In contrast, pesticide-intensive and monoculture systems negatively impact pollinator populations, reducing both abundance and diversity.

Influence of Environmental Factors

Environmental variables such as temperature and humidity significantly influenced pollinator activity.

Table 7: Environmental Factors and Pollinator Activity

Factor	Optimal Range	Effect on Pollinators
Temperature	20–30°C	High activity
Humidity	50–70%	Moderate–High activity
Rainfall	Low–Moderate	Moderate activity
Extreme Heat (>40°C)	Low	Reduced activity

Pollinator activity is highest under moderate climatic conditions. Extreme temperatures and heavy rainfall reduce activity and may affect survival.

Discussion

The findings of the present study provide a comprehensive understanding of biodiversity trends and the influence of agricultural practices on pollinator insects in agroecosystems. The results clearly indicate that pollinator diversity is closely associated with habitat heterogeneity, floral availability, and environmental conditions. Agroecosystems that maintain a mixture of crops along with semi-natural habitats such as hedgerows, grasslands, and flowering weeds support significantly higher pollinator diversity compared to intensively managed monoculture systems. This reflects a broader ecological principle that biodiversity thrives in environments where resource diversity and habitat complexity are maintained. A consistent trend observed in the study is the dominance of bees among pollinator groups, followed by butterflies, flies, beetles, and wasps. This dominance is primarily due to the efficiency of bees in foraging and their specialization in pollen collection. The relatively high species richness and evenness values observed in the study indicate that the agroecosystems still retain a balanced pollinator community. However, the uneven spatial distribution suggests that pollinators are concentrated in areas with better resource availability, such as field edges, hedgerows, and water sources. These areas provide

essential ecological services, including food, nesting sites, and shelter, which are often lacking in the central parts of intensively cultivated fields.

Seasonal variation further influences biodiversity patterns, with peak pollinator activity recorded during the spring season. This period coincides with optimal climatic conditions and abundant flowering, which together create favorable conditions for pollinator foraging and reproduction. In contrast, extreme summer temperatures and heavy monsoon rainfall reduce pollinator activity and may negatively impact their survival. These findings highlight the sensitivity of pollinators to climatic variability and underscore the potential risks posed by climate change, which may alter flowering patterns and disrupt pollinator-plant interactions. Agricultural practices play a decisive role in shaping pollinator diversity and distribution. The study demonstrates that organic farming and mixed cropping systems support higher pollinator abundance and diversity compared to monoculture and pesticide-intensive systems. Organic farming reduces exposure to harmful chemicals and promotes the growth of diverse plant species, thereby providing additional food resources for pollinators. In contrast, the use of chemical pesticides has been identified as a major factor contributing to pollinator decline. Pesticides not only cause direct mortality but also lead to sub-lethal effects such as impaired navigation, reduced foraging efficiency, and decreased reproductive success. These effects collectively result in reduced pollinator populations and diminished pollination services. Monocropping further exacerbates the problem by limiting floral diversity, which is essential for sustaining a wide range of pollinator species. The lack of continuous and diverse floral resources forces pollinators to migrate or face nutritional stress, leading to population decline. The study findings suggest that integrating sustainable agricultural practices, such as crop diversification and habitat conservation, can significantly enhance pollinator diversity. Such practices not only support ecological sustainability but also improve agricultural productivity by ensuring efficient pollination.

11. Ecological and Economic Importance

Pollinator insects are indispensable components of agroecosystems, contributing significantly to both ecological stability and economic productivity. Their primary role in facilitating pollination directly influences the reproductive success of a wide range of flowering plants, including many economically important crops. The findings of the present study reinforce the understanding that pollinators are essential for improving crop yield, enhancing quality, and maintaining genetic diversity. A substantial proportion of agricultural crops depends on insect pollination for successful fruit and seed production. Crops such as fruits, vegetables, oilseeds, and pulses benefit greatly from pollinator activity. Increased pollinator visitation leads to better fertilization, resulting in higher yields, improved fruit size, and enhanced nutritional quality. The study observed that crops with abundant floral resources, such as mustard and sunflower, attracted higher numbers of pollinators and demonstrated better productivity. In contrast, crops with limited floral appeal showed reduced pollinator activity and lower productivity.

From an economic perspective, pollination services provided by insects represent a significant contribution to global agriculture. These services reduce the need for artificial pollination and increase farm profitability by improving crop output. In areas where natural pollinator populations have declined, farmers often rely on managed pollinators, which increases production costs and may not fully compensate for the loss of wild pollinator diversity. Therefore, conserving natural pollinator populations is essential for maintaining cost-effective and sustainable agricultural systems. Beyond agriculture, pollinators play a vital role in maintaining ecosystem balance. By enabling plant reproduction, they support the growth and regeneration of diverse plant species, which form the foundation of terrestrial ecosystems. This, in turn, supports a wide range of organisms, including herbivores, predators, and decomposers, thereby maintaining ecological stability. Pollinators also contribute to the preservation of biodiversity by ensuring the survival of both wild and cultivated plant species. The ecological significance of pollinators extends to soil conservation, water regulation, and climate stability. Healthy

plant communities, supported by effective pollination, help prevent soil erosion, enhance water retention, and contribute to carbon sequestration. The decline of pollinators can disrupt these processes, leading to environmental degradation and reduced ecosystem resilience.

Conservation Strategies

The decline in pollinator populations observed globally necessitates the adoption of effective conservation strategies to ensure their sustainability within agroecosystems. The findings of the present study emphasize the importance of integrating ecological principles into agricultural practices to support pollinator diversity and abundance. One of the most effective strategies for pollinator conservation is the adoption of organic farming practices. Organic farming minimizes or eliminates the use of synthetic pesticides and fertilizers, thereby reducing the exposure of pollinators to harmful chemicals. This creates a safer and more favorable environment for pollinator survival and reproduction. Additionally, organic farming promotes biodiversity by encouraging the growth of wild plants and flowering weeds, which provide essential nectar and pollen resources for pollinators throughout the year. Habitat protection is another critical component of pollinator conservation. The preservation and restoration of natural habitats within and around agricultural landscapes are essential for providing nesting sites, food resources, and shelter for pollinators. Features such as hedgerows, flower strips, grasslands, and forest patches serve as important refuges for pollinator species. Maintaining these habitats enhances ecological connectivity, allowing pollinators to move freely across the landscape and access diverse resources. The creation of buffer zones and ecological corridors can further support pollinator populations by reducing habitat fragmentation and promoting genetic diversity.

The implementation of sustainable agricultural practices, such as crop diversification and intercropping, can also contribute to pollinator conservation. Diverse cropping systems provide a continuous supply of floral resources, supporting a wider range of pollinator species. Integrated pest management (IPM) practices can reduce the reliance on chemical pesticides by promoting the use of biological control methods and environmentally friendly alternatives. These practices not only protect pollinators but also enhance overall ecosystem health. Policy interventions play a crucial role in promoting pollinator conservation at a larger scale. Governments and regulatory bodies should implement policies that encourage sustainable farming practices and restrict the use of harmful pesticides. Providing financial incentives and subsidies for farmers adopting pollinator-friendly practices can facilitate the transition towards sustainable agriculture. Additionally, research and monitoring programs should be supported to assess pollinator populations and evaluate the effectiveness of conservation strategies. Public awareness and education are equally important in promoting pollinator conservation. Farmers, communities, and stakeholders need to be informed about the importance of pollinators and the impact of agricultural practices on their populations. Training programs and extension services can help disseminate knowledge and encourage the adoption of best practices.

Conclusion

The present study provides valuable insights into the diversity and distribution of pollinator insects in agroecosystems and highlights their critical role in supporting ecological and agricultural sustainability. The findings demonstrate that pollinator diversity is strongly influenced by factors such as crop diversity, habitat availability, climatic conditions, and agricultural practices. Bees were identified as the dominant pollinators, contributing significantly to crop productivity and ecosystem functioning. The study reveals that agroecosystems with diverse cropping patterns and minimal chemical inputs support higher pollinator diversity compared to monoculture and pesticide-intensive systems. Seasonal and spatial variations also play an important role in determining pollinator activity, with higher abundance observed during favorable climatic conditions and in areas with abundant floral resources. These findings emphasize the importance of maintaining habitat heterogeneity and ecological balance within agricultural

landscapes. Pollinators provide essential ecological and economic services, including crop yield improvement, biodiversity conservation, and ecosystem stability. However, their populations are under threat due to unsustainable agricultural practices, habitat loss, and environmental changes. This highlights the urgent need for effective conservation strategies.

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