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REVIEW PAPER

An Analysis of the Decline in Bee Populations and Its Effects on Pollination

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Abstract

This study aims to identify the fundamental causes of the global decline in bee populations, its connection to climate change, and possible solutions. Review synthesized open access or peer-reviewed sources published between 2014 and 2024 from academic databases. It synthesizes data obtained from internationally recognized statistical databases such as the Food and Agriculture Organization (FAO), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), and the United Nations World Population Projections (UN WPP). Data on colony sizes are presented in graphs and tables at the continental level. The findings indicate that bee populations are affected by multiple factors such as habitat loss, intensive pesticide use in agricultural areas, various parasites, and climate change, with regional variation in impact. The data obtained shows that bee colonies are increasing in some parts of Europe while decreasing in North America. This situation potentially reflects the impact of protection policies implemented in Europe. However, focusing solely on honeybee populations may cause losses in wild bee populations to go unnoticed. Therefore, this study emphasizes the importance of developing comprehensive strategies that can encompass all ecosystems, highlighting the criticality of collective action to preserve ecological balance, ensure economic stability, and safeguard global food systems.

Introduction

Bees are essential pollinators that ensure biological diversity and continuity on our planet. The role bees play in pollinating plants supports the functioning of ecosystems and also supports modern agriculture. According to the IPBES (2016) report, the yield and quality of an average of 75% of food products worldwide depends on pollinators. These crops, representing 35% of global production, are produced dependent on the pollination services provided by butterflies, bats, birds, and more than 20 000 species of bees. Healthy bee populations support the production of fruit, vegetables, oilseeds, and livestock feed, ensuring that they are both healthy and abundant (Bugin et al., 2022).

Bee pollination is central to environmental systems in many ways and has a value of between $235 billion and $577 billion in the global economy (IPBES, 2016). In addition to pollination services, products directly produced by bees, such as honey, beeswax, propolis, pollen, and bee venom, are also valuable products used in various food, cosmetic, and medical fields (Aylanç et al., 2021; Phiri et al., 2022). From this perspective, the critical contribution of bees to the sustainability of agriculture and food security, both directly and indirectly through pollination, can be understood. Despite this critical value, bee populations have declined alarmingly over the past two decades (Zattara & Aizen, 2021). This decline is not only related to agricultural productivity or honey production; it also threatens biodiversity (Prendergast et al., 2020; Wagner, 2020). Multiple stressors drive these population losses. Intensive agriculture, excessive pesticide use, and monoculture practices degrade bee habitats. Parasites like *Varroa destructor*, climate change, and nutritional stress further threaten colonies. (Kline & Joshi, 2020; Lundin et al., 2015).

Furthermore, rising temperatures due to global warming cause irregular flowering, and extreme weather events negatively affect the natural life cycle of bees (Zattara & Aizen, 2021; Hemberger & Williams, 2024). A mismatch between flowering time and pollination activities is a significant factor that directly negatively affects pollination success. Heavy pesticide use can damage bees' orientation abilities and immune systems. In addition to all this, growing cities and expanding agricultural areas are reducing flower and nesting areas and decreasing the chances of bees finding nests (Motta et al., 2023; Okely et al., 2023). When all these situations are considered together, it is clear that the decline in bee populations is an ecological, economic, and social problem. These pressures reduce pollination success, lowering product quality. Consequently, prices fluctuate and food shortages may occur (Khalifa et al., 2021; Bugin et al., 2022). Protecting bees is critical not only for environmental sustainability but also for ensuring long-term economic stability (Delgado-Carrillo et al., 2024).

Theoretical Framework

The recent sharp decline in bee populations threatens not only biodiversity but also ecosystem services and global food security (Powney et al., 2019; Bugin et al., 2022; Phiri et al., 2022). The IPBES (2019) report clearly states that a significant portion of flowering plants and nutrient-rich agricultural products can only survive through the natural pollination services provided by bees. With this fundamental function, bees play a pivotal role in ensuring the security of food systems and ecosystems around the world (Delgado-Carrillo et al., 2024; Khalifa et al., 2021; Reilly et al., 2020). These losses in bee populations are not only reflected in reduced agricultural yields but also in decreased product diversity, lower product quality, and consequently, reduced market values. This situation additionally has severe negative impacts on agricultural economies (Bugin et al., 2022).

Significant bee losses can have serious consequences that could lead to the cascading collapse of natural ecosystems (Montero-Castaño et al., 2022). The survival, growth, and spread of many plant species depend on pollinators. Consequently, diminishing bee populations weaken vegetation, disrupt food webs, and threaten critical wildlife habitats (Prodanović et al., 2024; Tarakini et al., 2021).

Considering all these factors, these losses and disruptions may weaken the resilience of ecosystems to climate change and accelerate biodiversity loss by disrupting its continuity. This research aims to understand the underlying causes of the global diminishing populations. While paying particular attention to how climate change and various agricultural practices may affect this problem, it also addresses what can be done to reverse this trend.

To guide the research, the study poses the following questions:

1. What are the environmental and human factors most responsible for the decline in bee populations worldwide?

2. How does climate change affect bees' life cycles, pollination habits, habitats, and distribution?

3. What are the effects of declining bee populations on agriculture, food security, and economic sustainability?

4. What are the most frequently proposed conservation strategies and solutions in the current literature?

Background

The previous section outlined the role of bees in pollination services and their contributions to food production and agricultural sustainability. This review examines pollination services, the threats facing bee populations, and the potential consequences of these threats within the framework of the existing literature. We examine the effects of bees' pollination services on ecosystems and agriculture in the context of both managed and wild bee species, emphasizing the need for comprehensive conservation strategies.

Research indicates that approximately 75-90% of flowering plants and 70-85% of staple food crops benefit from bee pollination (Motta et al., 2023; Powney et al., 2019). Similarly, approximately 75% of 115 economically important agricultural products worldwide achieve increased yields facilitated by this process (Bugin et al., 2022). Pollination activity ensures the reproduction of wild flora. It also supports the healthier growth and spread of vegetables, fruits, and oilseeds (Prodanović et al., 2024; Tsadila et al., 2023). Thus, genetic diversity is preserved and supported, increasing the resilience of ecosystems.

In addition to their essential role in pollination, bees support the agricultural economy through the production of honey, beeswax, pollen, and propolis, which are of economic and medicinal value (Aylanç et al., 2021; Phiri et al., 2022). Researchers consider pollen a “nutritionally complete food”, and its unique composition makes it highly attractive for both the food industry and pharmaceutical applications (El Ghouizi et al., 2023). It is estimated that 9.5% to 35% of global food production is directly dependent on pollination services (Powney et al., 2019). Given these findings, bees play pivotal role in maintaining environmental balance and economic development.

Managed honeybee colonies, along with wild bee species, also make substantial contributions to the conservation of biodiversity through pollination activities. Studies suggest that wild bees may perform better than honeybees in pollinating certain plant species (Bugin et al., 2022; Reilly et al., 2020). This is generally attributed to factors such as the greater species diversity and different foraging behaviors of wild bees (Reilly et al., 2020). However, wild bees are sensitive to habitat fragmentation, pesticides, and changes in flowering patterns due to climate change.

This is because wild bees are dependent on specific nesting areas and flower species (Gérard et al., 2022; Straw et al., 2023). Despite their ecologically important roles, wild bees receive much less attention in conservation and monitoring efforts compared to honeybees (Scheper et al., 2023; Zattara & Aizen, 2021). In this context, effective conservation efforts must include both managed and wild pollinators to support the continuity of environmental services and the sustainability of food systems.

Despite their critical ecological value, bee populations face a serious global threat. Habitat degradation, intensive agriculture, monoculture farming practices, excessive pesticide use, parasites, and nutritional stress are among the many factors contributing to this situation (Cameron & Sadd, 2020; Khalifa et al., 2021; Kline & Joshi, 2020).

Climate change is a major stress factor among these factors. Sudden temperature increases, unseasonal rainfall, prolonged droughts, storms, and shifting flowering periods disrupt the life cycles of bees and reduce pollination success (Gérard et al., 2022; Hemberger & Williams, 2024; Okely et al., 2023). Increased CO_2 concentrations and changes in plant phenology can affect pollen and nectar quality, disrupting the nutritional balance of bees (Fantinato et al., 2017). Bee population losses pose major economic risks. The drop in agricultural yield and loss of quality are expected consequences of rising agricultural costs (Delgado-Carrillo et al., 2024). As pollination declines, crop yields also decrease, and the effort required to produce high-quality products increases (Khalifa et al., 2021; Reilly et al., 2020). Rising food prices and vulnerabilities in the supply chain can be cited as indicators of this situation (Powney et al., 2019). Therefore, bee protection must be recognized as a global priority in order to ensure food security, rural livelihoods, ecosystem health, and agricultural sustainability (Tarakini et al., 2021; Prodanović et al., 2024).

The main reasons for this decline in bee populations include habitat loss, intensification of agriculture, monoculture practices, pesticide use, diseases, parasites, and management factors (Figure 1) (Khalifa et al., 2021; Kline & Joshi, 2020; Lundin et al., 2015). Urban sprawl and intensive agricultural activities severely limit the life cycles of bees by limiting the flower sources and nesting sites (Okely et al., 2023). The toxic effects of pesticides, particularly on nectar and pollen, weaken bees' survival and navigation abilities (Motta et al., 2023). Furthermore, the prevalence of parasites and diseases leads to colony collapse and reduces the resilience of bee populations (Cameron & Sadd, 2020).

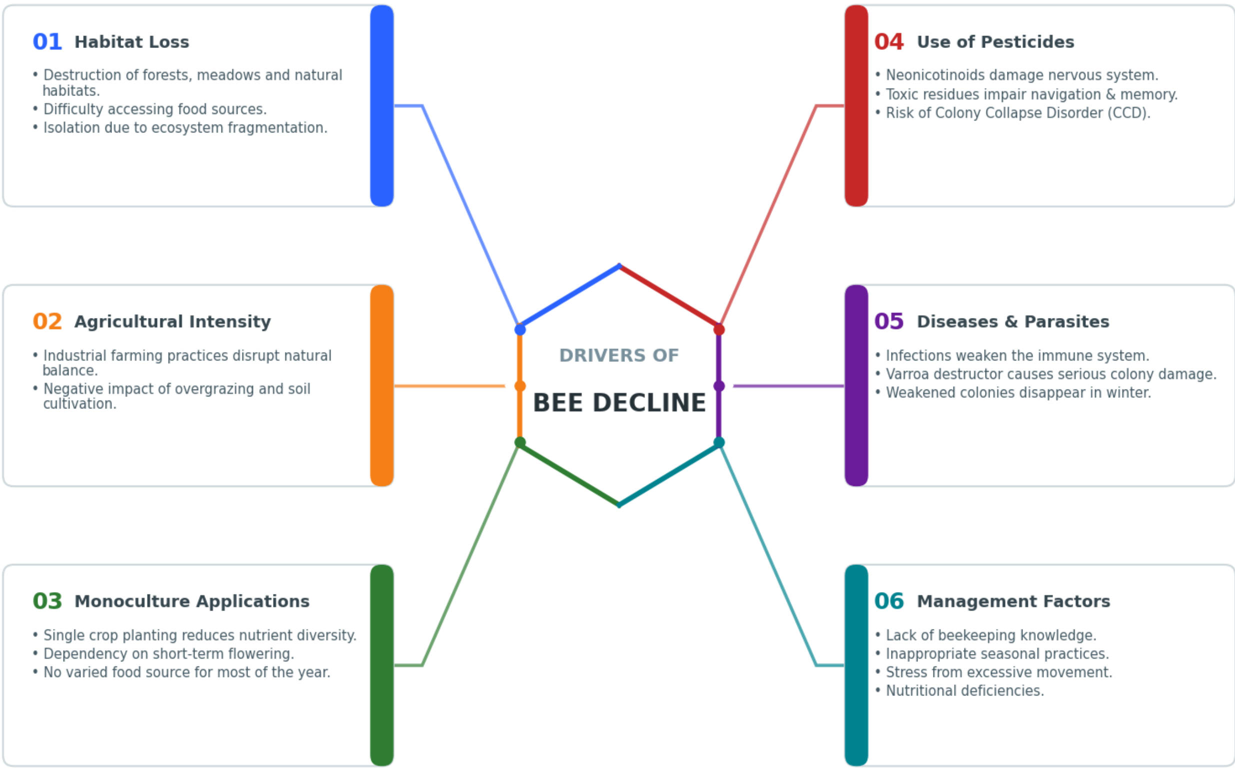

Figure 1. Main causes of decline in bee populations

These global threats manifest themselves with varying intensity in different regions. Countries with rich biodiversity, such as Türkiye, face similar challenges.

Beekeeping in Türkiye: Potential and Threats

Due to its climate conditions and rich vegetation, Türkiye has substantial potential in the beekeeping sector. Despite ranking among the top countries in the world with approximately 9.2 million colonies, the sector faces various structural and environmental challenges (FAOSTAT, 2023). Low hive productivity, diseases, insufficient export potential, marketing problems, and organizational deficiencies are among the key factors hindering the sector's development (Uysal, 2022).

The spread of parasites such as *Varroa destructor*, which cause serious damage to colony health and weaken the immune system of bees, represents one of the most harmful factors for beekeeping in Türkiye (Şengül & Saner, 2023). Changes in plant life cycles due to global warming limit the food sources available to bees and exacerbate environmental stress on bees (Usta, 2021; Yaman & Sağlam, 2023). In addition to these challenges, intensive agricultural practices, excessive pesticide use, and increasing global competition are also putting pressure on the sector (Çevrimli & Sakarya, 2018).

To overcome these challenges, it is recommended to implement techniques such as frequent comb replacement and prioritizing pollen and propolis production, encourage the use of biopesticides, and raise awareness of environmental risks by providing ecosystem-based training to beekeepers (Aydın et al., 2019; Şengül & Saner, 2023; Yaman & Sağlam, 2023).

Given the multifaceted impacts of bees on agriculture and ecosystems, the decline in their populations seriously threatens not only biodiversity but also economic sustainability and food security. Efforts to protect bees should therefore be considered beyond an ecological necessity and a global policy priority. Within this framework, this study aims to establish a scientific basis for conservation strategies by examining the scope of ecosystem services provided by bees and the factors threatening these services through a qualitative analysis based on a literature review.

Method

This study analyzes the natural and environmental factors causing the decline in bee populations, the effects of climate change on this decline, and possible solutions. We conducted a comprehensive literature review by compiling existing scientific studies and various policy documents and reports. Data from 2015 to 2024 were examined to provide a consistent analysis of current trends over the last decade. The announcement of the United Nations Sustainable Development Goals (SDGs) in 2015 has increased academic and political interest in biodiversity and ecosystem services. This has led to an increase in the number of high-quality peer-reviewed and current sources. Therefore, the review period begins in 2015. This ten-year period provides an important framework for examining declining bee population trends and migration patterns, as well as their broader ecological and socioeconomic impacts. Since official data for subsequent years has not yet been published by FAOSTAT, records from 2013 to 2023 have been used. This approach has helped maintain consistency across data sets and enabled comparisons of trends between regions and years.

The review utilized academic articles, institutional reports, and open-access statistical databases. Data was collected from reputable sources such as Google Scholar, ScienceDirect, SpringerLink, and Web of Science. Keywords and search terms included phrases such as “decline in bee populations,” “climate change and pollinators,” and “honeybee mortality rate.” In addition, data and publications from leading international organizations such as the FAO, IPBES, the European Commission Joint Research Centre, and the Bee Informed Partnership were incorporated into the study.

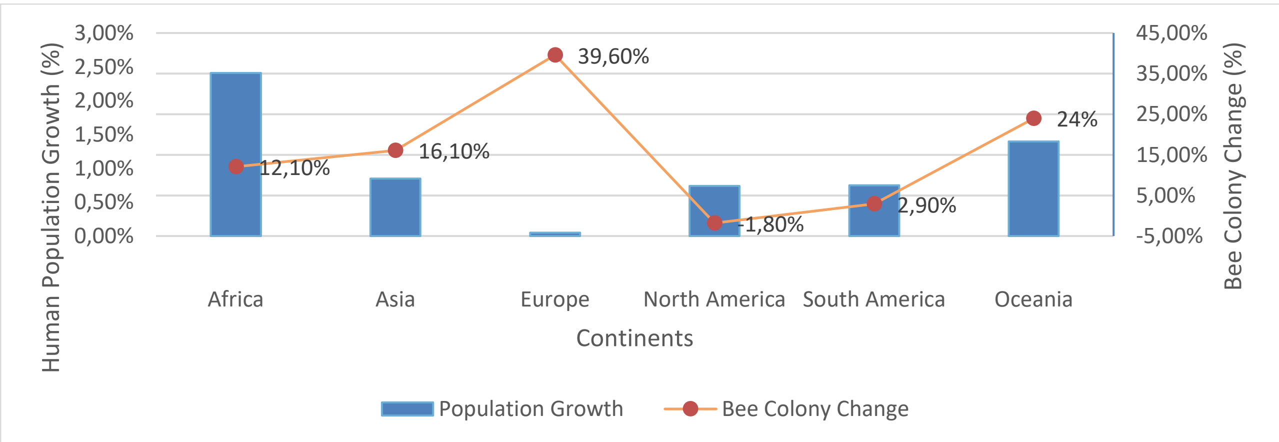

Figure 2. Comparison of Changes in the Number of Bee Colonies and Human Population by Continent (2013–2023)

The compiled data were evaluated using comparative trend analysis and comparative assessment methods. Regional changes in bee populations, the economic importance of pollination services, and climate change indicators were supported by data obtained from sources such as FAOSTAT (2023) and United Nations World Population Projections. The changes observed on a continental basis are shown in Table 1 and Table 2. Figure 2 shows the relationship between these two variables.

Table 1. Change in the Number of Bee Colonies by Continent Between 2013 -2023 (FAOSTAT, 2023)

Continent	2013 Colony Count (Millions)	2023 Colony Count (Millions)	Change %	Annual Average Increase (CAGR %)
Africa	16.4	18.4	+12.1%	+1.15%
Asia	39.1	45.4	+16.1%	+1.50%
Europe	18.2	25.4	+39.6%	+3.40%
North America	3.31	3.25	-1.8%	-0.18%
South America	5.16	5.31	+2.9%	+0.29%
Oceania	1.00	1.24	+24%	+2.17%

Table 2. Population Growth by Continent Between 2013 - 2023

Continent	2013 Population (Millions)	2023 Population (Millions)	Change (%)	Annual Average Increase (CAGR %)
Africa	1158	1480	+27%	+2.48%
Asia	4388	4778	+8.8%	+0.85%
Europe	741	745	+0.53%	+0.05%
North America	355	382	+7.6%	+0.74%
South America	402	433	+7.7%	+0.75%
Oceania	39	45	+15%	+1.44%

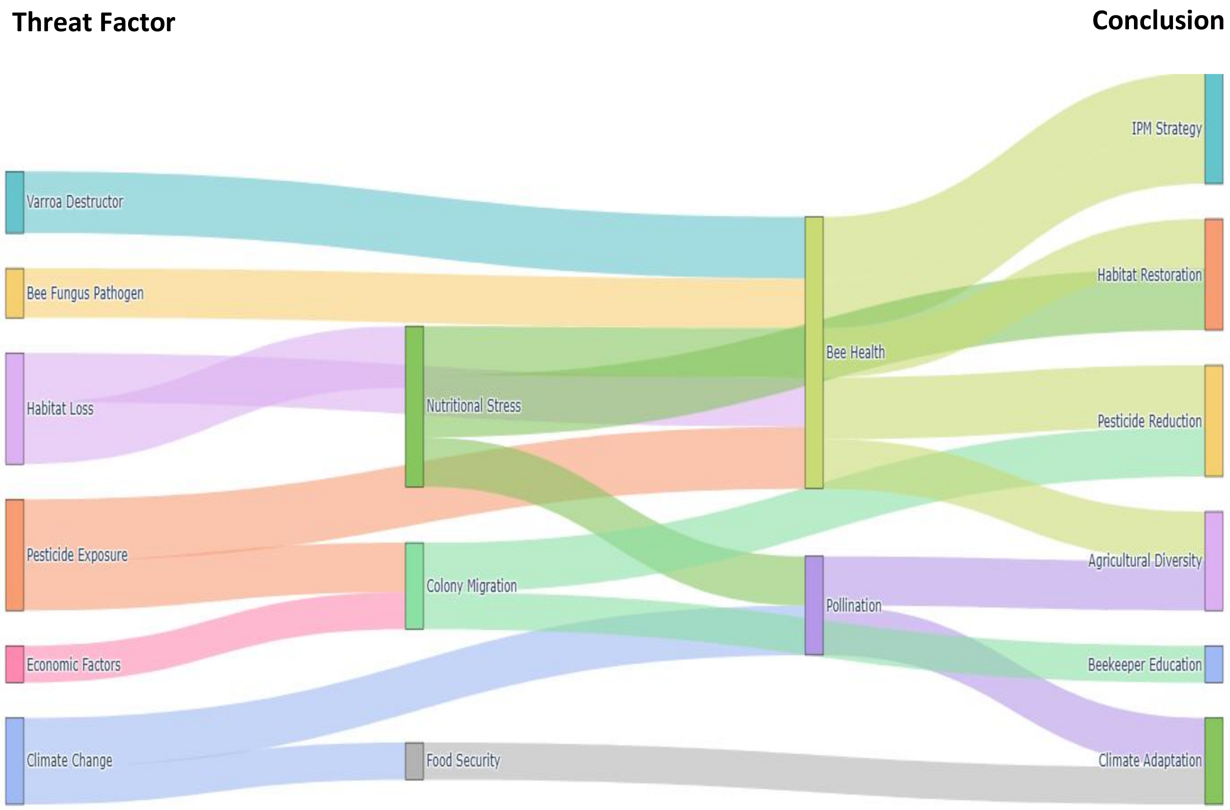

Figure 3: Cause-and-effect relationships of bee population decline

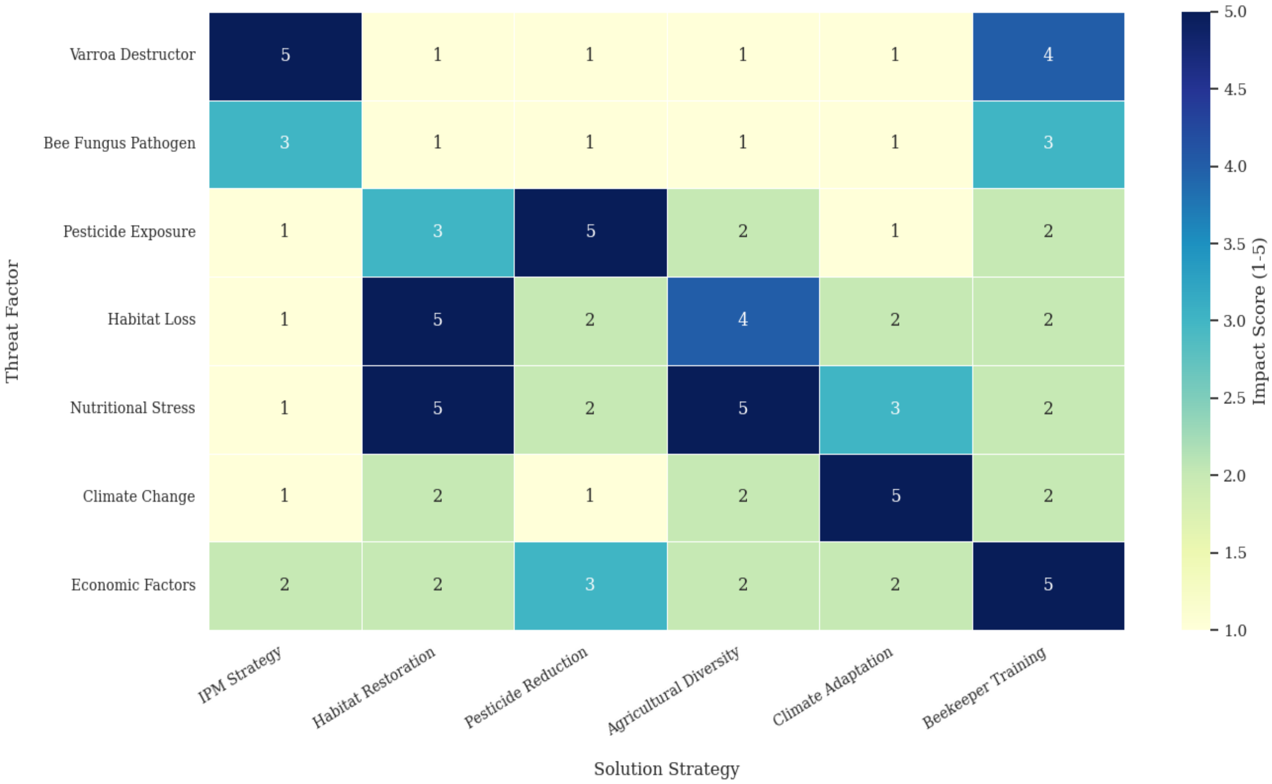

Figure 4. Relative Impact Map of Factors Threatening Bee Populations and Intervention Strategies

The complex environmental and human-induced relationships behind the decline in bee populations have been analyzed using a Sankey diagram in Figure 3. Based on 10-year trends, risks associated with pesticide use, habitat loss, and climate change, along with the effects of potential countermeasures, have been visualized using a heat map in Figure 4.

Results

The continuous population losses extend beyond biodiversity loss. With the increase in seasonal temperatures, it has become a global issue with direct impacts on agricultural productivity, food security, and rural livelihoods. Long-term trends and global data reveal these patterns.

Table 1, based on FAOSTAT data, summarizes changes in the number of bee colonies across different continents from 2013 to 2023. These trends vary significantly by continent. For example, notable increases were recorded in some regions such as Europe and Oceania, while declines occurred in other regions such as North America.

Table 2, which uses United Nations World Population Projections (UN WPP) data, reflects trends parallel to the increase in human population. As the global population has grown, so has the demand for pollination and agricultural production. Between 2013 and 2023, both bee colonies and human populations showed a marked increase in Africa and Asia. However, North America showed a contrasting trend: despite population growth, the number of bee colonies declined, which may indicate a gap between pollination needs and ecological capacity.

Figure 2 visually compares the growth of bee colonies and human populations across continents on the same axis. According to this visualization, pollinators show regional differences in their capacity to meet demographic demands. For example, regions where the growth of bee colonies lags behind (or is negative relative to) demographic growth, such as in North America, may face increasing pressure on food systems and ecosystem services.

According to FAOSTAT (2023) data, Europe recorded the highest growth in colony numbers, with a 39.6% increase. This growth reflects stricter pesticide regulations, agricultural diversification incentives, and improved colony registration practices in EU countries. Asia continues to be the region with the most colonies worldwide, reaching 45.4 million in 2023. This increase stems primarily from widespread commercial beekeeping activities in countries such as China and India.

The 12.2% increase in the number of colonies in Africa is a relatively modest figure compared to the continent's 27.8% population growth. This imbalance may reflect ecological stress factors in rural areas, habitat degradation, and infrastructure problems. The 23.9% increase observed in Oceania may be due to export-oriented honey production and advanced beekeeping management practices in Australia and New Zealand.

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In contrast, a 1.8% decline in colony numbers was observed in North America. Intensive pesticide use, *Varroa destructor* infestations, and climate pressures contributed to these losses. In South America, the growth of bee colonies was limited to only 2.9%, which may indicate a decline in investments in beekeeping or structural constraints within the sector.

Figure 3 illustrates a Sankey diagram summarizing the interconnected environmental and anthropogenic stress factors contributing to the decline in bee populations. It demonstrates how major factors such as pesticide exposure, habitat loss, climate variability, and economic pressures create intermediate effects such as nutritional stress, parasite infections (e.g., *Varroa destructor*, *Nosema* spp.), and increased colony migration or collapse, which ultimately affect pollination services and food security. The diagram emphasizes how these stress factors reinforce each other not independently, but through complex feedback loops.

Figure 4 presents a heat map evaluating the effectiveness of different mitigation strategies such as integrated pest management, habitat restoration, pesticide reduction, agricultural diversification, climate adaptation, and beekeeper training. Each strategy is rated on a scale from 1 (low impact) to 5 (high impact), and color gradients visually encode their relative effects on specific stress factors.

Impact scores have been determined based on recent studies and institutional reports. Research indicates that pesticides weaken the immune systems of bees and make them more susceptible to disease (Cameron & Sadd, 2020; Khalifa et al., 2021). Therefore, parasite infestations such as *Varroa destructor* can become more dangerous and more severe (Gusachenko et al., 2020). Integrated pest management systems contribute to the persistence of pollination services by reducing these negative effects (Bugin et al., 2022; Scheper et al., 2023). Similarly, studies by Scheper et al. (2023) and Zattara and Aizen (2021) show that habitat loss causes nutritional stress in bees, while habitat restoration and agricultural diversification provide mitigating effects at medium or high levels of loss. Hemberger and Williams (2024) emphasized the potential of phenological adaptation, artificial shading, and improved water access to reduce climate-related stress on colonies.

Beekeeper training is critical in areas such as increasing colony survival rates and strengthening disease management (Khalifa et al., 2021; Phiri et al., 2022). In addition, it has broader socioeconomic impacts such as increasing rural resilience, supporting cooperatives, and providing economic and social benefits through the integration of traditional and modern knowledge (Prodanović et al., 2024; Singh & Singh, 2024).

Overall, these findings confirm that bee populations are shaped by diverse and region-specific dynamics. The evidence highlights the complex relationship between climate stress, agricultural practices, and economic factors. Overcoming this global challenge requires integrated, data-driven responses adapted to regional contexts.

Discussion and Conclusion

This study examines the underlying causes of the global decline in bee populations, its impacts on ecosystem services and socio-economic systems, and current conservation strategies. The findings confirm that this decline is a complex, multi-causal phenomenon driven by interacting biological and anthropogenic stressors. The main threats to bee health, as summarized in Figure 1, are habitat loss, pesticide exposure, nutritional stress, climate change, parasite and pathogen pressure, and inadequate beekeeping practices. These factors interact in a mutually reinforcing manner, creating a multidimensional stress environment that weakens colony resilience at both local and global scales (Khalifa et al., 2021; Zattara & Aizen, 2021).

Climate change represents the most critical threat. Temperatures above seasonal norms are rapidly reshaping the geographic distribution of bee species, causing species adapted to cold climates to retreat from their southern boundaries and preventing them from expanding their northern boundaries (Hemberger & Williams, 2024; Kerr et al., 2015). Geographic shifts, altered flowering times, and extreme weather events intensify pressure on bee populations (Gérard et al., 2022; Okely et al., 2023). Therefore, integrated approaches must address synergistic interactions between stressors that consider the synergistic interactions between these stress factors.

The data also reveal significant regional differences. FAOSTAT data (Table 1; Figure 2) show that while population growth has stagnated in Europe, there has been a 39.6% increase in colony numbers between 2013 and 2023, while in North America, despite continued demographic growth, there has been a 1.8% decline. These trends may reflect the impact of region-specific policies and ecological pressures. In Europe, regulatory measures on pesticide use and subsidies promoting agricultural diversity have made a positive contribution (Kline & Joshi, 2020; Scheper et al., 2023). In contrast, North American declines reflect intensive agricultural chemical use, *Varroa destructor* infestations, and climatic instability.

Increases in managed honeybee colonies may mask the ongoing decline of wild bee species, creating a misleading perception of stability (Scheper et al., 2023; Zattara & Aizen, 2021). Wild bees are highly vulnerable to habitat fragmentation and loss of floral resources, and their decline may signal broader ecosystem degradation (Cameron & Sadd, 2020; McNeil et al., 2020). Therefore, strategies such as habitat restoration and agricultural diversification are essential for supporting wild bees (Kline & Joshi, 2020; Scheper et al., 2023).

The Sankey diagram in Figure 3 shows the causal pathways through which environmental and biological stress factors interact to affect pollination systems. Pesticide use, changes in land use, and climate variability can lead to biological responses such as nutrient deficiencies, pathogen proliferation (e.g., *Varroa destructor, Nosema* spp.), and colony migration or collapse. These situations can create significant impacts that impair bee health and reduce pollination efficiency.

Climate change can cause interconnected processes that interact with each other on bee populations (Rader et al., 2020; Zattara & Aizen, 2021). Larvae and queen bees, especially during their developmental stages, have low tolerance to heat stress. Therefore, above-normal temperatures can lead to morphological abnormalities and increased bee losses (Feuerborn et al., 2023; Gérard et al., 2022). Along with these direct effects, changes in plant flowering times are becoming out of sync with bees' foraging cycles and increasing foraging stress (Cameron & Sadd, 2020; Kline & Joshi, 2020). Such phenological mismatches can lead to the disruption of ecological balance and seriously compromise the sustainability of pollination services (Hemberger & Williams, 2024; Réquier et al., 2023).

From a regional perspective, data from Türkiye reflects global trends, but there are also local vulnerabilities. Türkiye's rich flora, suitable ecological conditions, and number of hives indicate significant beekeeping potential. However, despite this, significant declines in hive productivity have been observed (Çevrimli & Sakarya, 2018; Yaman & Sağlam, 2023). Monoculture farming, excessive pesticide use, and increasing climatic variability are known to exert substantial pressure on pollination services. (Khalifa et al., 2021). These challenges, combined with diseases such as *Varroa destructor* and *Nosema*, are considered severe dangers (Yaman & Sağlam, 2023). Beekeeping is a vital livelihood source for rural communities due to its low capital requirements and lack of land dependency (Aydın et al., 2019). These ecological pressures create socioeconomic vulnerabilities by reducing economic efficiency (Uysal, 2022).

Diminishing bee numbers affects not only biodiversity but also agricultural production and food security. Reduced pollination can lead to lower crop yields, decreased product quality, and increased food prices, particularly in regions with fragile agricultural systems. The results of this study underscore the need for comprehensive, multi-dimensional conservation strategies.

A visual assessment ranking the effectiveness of various intervention strategies against key stress factors is shown in Figure 4 using a heat map. Interventions such as integrated pest management, habitat restoration, agricultural diversification, climate adaptation, and beekeeper training are effective in managing the process, but none of these alone will be sufficient. According to the data, multi-layered, region-specific approaches are highly important. The successes observed in Europe provide compelling evidence of the effectiveness of ecological policy integration.

It is important for countries with intensive agricultural activity, including Türkiye, to adopt similar frameworks. These policies include strengthening pesticide regulations, promoting pollinator-friendly agriculture, and investing in capacity building for sustainable beekeeping. Establishing national pollinator databases and ecosystem-based conservation plans remains vital for long-term resilience.

In conclusion, protecting bee populations requires more than isolated interventions; it requires a comprehensive strategy that integrates ecological, economic, and social dimensions. By adopting systemic and adaptable policies, we can protect not only the health of bees, but also food systems, biodiversity, and rural livelihoods worldwide.

Measures and practices aimed at protecting and developing bee populations should be managed through comprehensive and multi-layered planning. Improving beekeeping practices requires regular, structured training programs for beekeepers. Collaborating with various research institutions and local organizations, continuously sharing information, and conducting regular monitoring studies can be considered measures that support colony health and sustainability.

Youth education about bees' environmental importance strengthens long-term conservation efforts. Integrating pollinator ecosystem services and nature-based activities into school curricula, combined with digital campaigns, engages students and raises awareness. This approach will support the development of a more environmentally conscious society in the future.

Integrating rural development policies with beekeeping is a valuable strategy that can provide economic and environmental benefits. Beekeeping is a sector that can contribute to the development of rural areas by supporting women's cooperatives and young entrepreneurs. Furthermore, combining beekeeping with rural tourism can create new opportunities for local economies while helping the community better understand the role of bees in ecosystem health. From a policy perspective, priorities include strengthening regulatory frameworks for pesticide use, supporting habitat restoration, and promoting pollinator-friendly agricultural practices. Media campaigns and community events build broader public support for conservation.

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Ethical Responsibility

As this study relies on secondary data analysis and literature review rather than primary data collection involving human or animal subjects, it does not require any ethical committee approval. However, all sources have been referenced in accordance with scientific ethical rules, and the principles of academic integrity have been strictly applied regarding citations and referencing.

The authors used an AI tool to translate the article into English. They then reviewed and edited the content and took full responsibility for the content of the publication.

Author Contributions

First Author: Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Writing – Original Draft, Visualization

Second Author: Conceptualization, Methodology, Investigation, Writing – Review & Editing, Validation, Supervision.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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