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Review Article

Evaluation of Honey Bees within the Scope of Sustainable Development Goals and Ecosystem Services

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ABSTRACT

Beekeeping is one of the significant activities that contribute to sustainability in environmental, social, and economic aspects. Honeybees provide multifaceted contributions to humanity, with 90% attributed to pollination services and 10% to bee products (honey, propolis, wax, etc.). The preservation of these services plays a key role in achieving ecological and economic sustainability, ensuring a healthy future for human life. According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) under the United Nations, more than 80 million beehives contribute to an estimated annual honey production of 1.6 million tons. Honeybees can travel distances ranging from 600 meters to 11.3 kilometers to pollinate in bee forests. The bee products obtained from these areas provide income sources for forest communities, supporting sustainable development. According to the Food and Agriculture Organization of the United Nations (FAO), one-third of global food production relies on pollination services by bees. Pollination services are critical for maintaining food security and increasing agricultural productivity. These services create a significant impact on biodiversity support, landscape diversification, enrichment of forest cover, and expansion of wildlife habitats, as well as erosion control—effects that are often imperceptible to humans. Bees contribute to human well-being and cultural sustainability by providing food, medicine, genetic resources, and related materials. The ecosystem services provided by bees make substantial contributions to achieving Sustainable Development Goals (SDGs) including No Poverty (SDG1), Zero Hunger (SDG2), Good Health and Well-being (SDG3), Affordable and Clean Energy (SDG7), Decent Work and Economic Growth (SDG8), Responsible Consumption and Production (SDG12), Climate Action (SDG13), and Life on Land (SDG15). This study discusses the importance of beekeeping and bee products in terms of ecosystem services for sustainable development and addresses environmental risks.

Keywords: *Beekeeping, climate change, sustainable development, ecosystem services, life on land.*

Bal Arılarının Sürdürülebilir Kalkınma Hedefleri ve Ekosistem Hizmetleri Kapsamında Değerlendirilmesi

ÖZET

Arıcılık, çevresel, sosyal ve ekonomik açılardan sürdürülebilirliğe katkıda bulunan önemli faaliyetlerden biridir. Arılar, insanlığa çok yönlü katkılarda bulunur, bunların %90'ı tozlaşma hizmetlerine ve %10'u da arı ürünlerine (bal, propolis, balmumu, vb.) atfedilir. Bu hizmetlerin

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korunması, ekolojik ve ekonomik sürdürülebilirliği sağlamak, insan yaşamının sağlıklı bir geleceğini garanti altına almak için kilit bir rol oynar. Birleşmiş Milletler bünyesindeki Biyoçeşitlilik ve Ekosistem Hizmetleri Üzerine Hükümetler Arası Bilim-Politika Platformu'na (IPBES) göre, 80 milyon arı kovanı yılda tahmini 1,6 milyon ton bal üretimine katkıda bulunuyor. Arılar, arı ormanlarında tozlaşma yapmak için 600 metre ila 11,3 kilometre arasında mesafeler kat edebilirler. Bu alanlardan elde edilen arı ürünleri, orman toplulukları için gelir kaynakları sağlayarak sürdürülebilir kalkınmaya destek olur. Birleşmiş Milletler Gıda ve Tarım Örgütü'ne (FAO) göre, küresel gıda üretiminin üçte biri arıların tozlaşma hizmetlerine dayanmaktadır. Tozlaşma hizmetleri, gıda güvenliğini sürdürmek ve tarımsal verimliliği artırmak için hayati öneme sahiptir. Bu hizmetler, biyoçeşitliliği destekleme, manzara çeşitlendirmesi, orman örtüsünün zenginleştirilmesi ve vahşi yaşam habitatlarının genişletilmesi, ayrıca erozyon kontrolü gibi, genellikle insanlar için fark edilemeyen etkiler yaratır. Arılar, gıda, ilaç, genetik kaynaklar ve ilgili materyaller sağlayarak insan refahına ve kültürel sürdürülebilirliğe katkıda bulunur. Arılar tarafından sağlanan ekosistem hizmetleri, Yoksullukla Mücadele (SDG1), Açlıkla Mücadele (SDG2), İyi Sağlık ve İyi Olma Hali (SDG3), Uygun ve Temiz Enerji (SDG7), İnsana Yakışır İş ve Ekonomik Büyüme (SDG8), Sorumlu Tüketim ve Üretim (SDG12), İklim Eylemi (SDG13) ve Kara Hayatı (SDG15) dahil Sürdürülebilir Kalkınma Hedefleri'ne önemli katkılarda bulunur. Bu çalışma, arıcılığın ve arı ürünlerinin ekosistem hizmetleri açısından sürdürülebilir kalkınma için önemini ve çevresel riskleri ele almaktadır.

Anahtar Kelimeler: *Arıcılık, iklim değişikliği, sürdürülebilir kalkınma, ekosistem hizmetleri, karada yaşam.*

I. INTRODUCTION

The mutualistic relationship between bees and people has a crucial importance for sustainability. Bees provide essential ecosystem services through pollination, which directly benefits human agriculture and food production. Bees play a vital role in pollinating plants, including many of the crops that make up a significant portion of our food supply. In turn, humans have historically cared for and benefited from bees by cultivating hives for honey and other bee products. This relationship has evolved over thousands of years and is often referred to as mutualism, where both species gain benefits. Without bees and other pollinators, these services would be severely compromised. The decline in bee populations, as reported by Potts et al. in 2016, is indeed a cause for concern [1].

Bees and flowering plants have co-evolved over millions of years [2]. This co-evolution has resulted in intricate relationships between bees and various plant species, leading to specialized pollination mechanisms that benefit both bees and plants. Bees have evolved to gather nectar and pollen, while plants have developed strategies to allure and reward them for their pollination services. Bees's role as pollinators doesn't exclusively pertain to crops; it extends to wild and native plants, fostering biodiversity and enhancing ecosystem resilience. Safeguarding and conserving bee populations is imperative for maintaining robust ecosystems and providing essential ecosystem services, such as pollination.

While humans directly manage only a modest fraction of bee species (approximately 50 out of around 20,000 documented species), the larger group of bees holds a critical position in ecosystem functionality. There are potentially around 5,000 bee species that are yet to be scientifically described [3]. Fifty bee species are managed by people, of which around 12 are managed for crop pollination [4]. Their dominance among pollinators and their importance in crop pollination underscore their vital contributions to both natural ecosystems and human well-being [5]. Acknowledging and preserving these crucial species is fundamental for sustainable development and environmental conservation.

The decline in natural habitats significantly impacts bee colonies. Profound impact of habitat loss and the destruction of natural environments on bee colonies, which, in turn, can have significant ecological

and agricultural consequences. In Millennium Ecosystem Assessment (MEA) (2005); globally, human-induced changes in land use are a major cause of species endangerment. The primary causes of environmental degradation include monoculture farming, reduced biodiversity, overgrazing, extensive irrigation, and deforestation. The extinction of natural flora poses a threat to bee colonies, as bees rely on diverse and interconnected floral habitats. Small, fragmented habitats limit bees' foraging range, nesting opportunities, and access to food sources [6],[7].

The decline in bee populations can be attributed to various factors including habitat loss, pesticide application, increasing prevalence of parasites, changes in the availability and diversity of forage, changes in land use and climate, and increased species competition [8],[9],[10]. These factors interact in intricate ways. For instance, intensified agricultural practices driven by market demands have restricted bees' access to forage resources while simultaneously heightening their exposure to potentially harmful agrochemicals [9],[10]. Both managed and wild pollinators are inevitably affected by the wide-ranging impacts of industrial agriculture, as they grapple with the dual challenges of habitat destruction resulting from agricultural activities and the detrimental consequences of intensive farming practices, given that the natural habitats of pollinators often intersect with industrial agricultural landscapes [11],[12],[13].

People have the potential to make a positive impact on ecosystem functioning by implementing bee-friendly policies and participating in efforts to conserve bees [1],[14],[15]. In addition to their role in food production, bees offer a diverse array of advantages to society [14]. For instance, they support the livelihoods of farmers and beekeepers, embody social and cultural significance, and contribute to sustaining ecosystem stability [16].

There is literature discoursing the decline in bee populations and the effects on agriculture. We argue that the broader significance of bees in fostering connections between the planet and humanity remains relatively understudied, particularly in the context of broader Sustainable Development Goals (SDGs) and Ecosystem Services (ESs).

Ecosystems offer numerous advantages to human beings in the form of various goods and services, including ecosystem processes and components. These ESs can be either direct, such as regulation functions (e.g. gas, climate, disturbance prevention,water regulation, soil retention, water supply, soil formation, nutrient regulation, pollination, biological control), habitat functions (e.g. suitable living place, suitable reproduction habitat), productions functions (e.g. food, rawmaterials, genetic resources), information functions (e.g.aesthetic, cultural, spiritual recreation, science and education) [17],[18],[15]. Biodiversity and ESs can serve as the foundation for strategies aimed at climate change adaptation and reducing disaster risks. Because they can offer advantages and enhance people's ability to withstand and recover from the impacts of climate change. The presence of bees contributes to the diversity and resilience of local plant populations, thereby enhancing their capacity to withstand the impacts of severe weather conditions and other environmental pressures. Bees as pollinators can provide food for a large number of animals, which is extremely important for biodiversity [19].

The SDGs, the Convention on Biological Diversity, and the Committee on World Food Security are identified as avenues for promoting the integration of pollinators and pollination in mainstream discussions. The Aichi targets set by the Convention on Biological Diversity further emphasize the necessity of including pollinators and pollination in policymaking. Among these targets, Target 2 focuses on integrating biodiversity considerations into strategies and processes, Target 7 emphasizes sustainable agriculture, and Target 14 underscores the restoration and protection of ESs, all of which hold particular relevance for the conservation of pollinators and pollination [16].

The biosphere is the foundation for all SDGs. But biodiversity conservation remains a persistent global challenge [21],[22]. Exploring how a specific group of organisms (honey bees) from the extensive global biodiversity can contribute to achieving the SDGs has the potential to bridge sustainable development policies with conservation efforts through the development of integrated solutions. Indeed, the decline

in bee populations has led to an increase in research efforts directed toward understanding the causes of this decline and its effects on the provision of ESs [23].

SDGs can be grouped into six thematic areas: Dignity, People, Planet, Partnership, Justice and Prosperity. These themes, especially planet and prosperity, are comprehensive in achieving sustainability goals. ESs provided by bees, which play an important role in the continuity of biodiversity, significantly affect these scopes. In particular, food production and biodiversity are supported through pollination services.

Given the reliance of humans on bees for crucial ecosystem services, it is important to recognize the reciprocal dependence of bees on humans for their own survival. Many factors that influence the delicate balance of wild bee-human systems are driven by human activities [14]. The SDGs explains these balance, influence and interactions within scope of Dignity, People and Prosperity. Actions taken to access these goals support provisioning, regulating and cultural ESs. In context of sustainable conservation solutions, bee polinations offers opportunities at reduced costs in agriculture. Regulating ESs is important especially, about SDG- 2 Zero hunger. Despite cultural ESs enables people to understand the importance of bees on the world and to establish relationships with bees at the level of belief and need. But, these ESs are not taken consideration. Whereas, when this pollinators known, conservation start by people. Relationship between SDGs and ESs has been given in shown Figure 1.

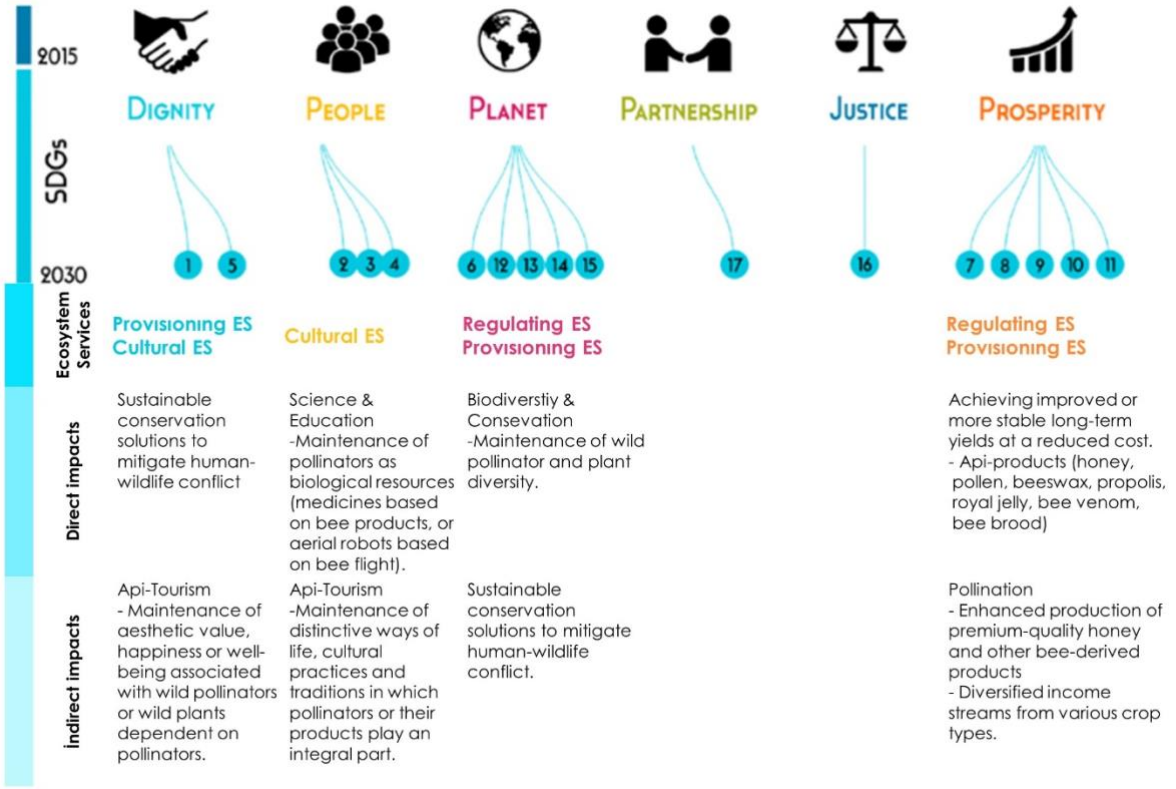

Figure 1. Relationship between Sustainable Development Goals and Ecosystem Services provided by honey bee (Prepared with modifications from IPBES,2017; Leal Filho et al., 2018 and Aryal et al., 2020) [16],[22],[15].

We investigate the interrelations between bees, and human communities within the framework of the SDGs and ESs. In this study highlight that the diversity of honey bees has crucial ecological, economic and social importance and crop pollination.

II. METHOD

We conducted a thorough search of articles through Scopus, Web of Science and Google Scholar using search terms that exclude sustainable honeybees managed, pollination services including ESs and studies of bees with human interaction. Journals had selected in different fields of biochemistry, chemistry, engineering, genetics, molecular biology and environmental.

The report for the SDGs was examined in detail with its themes and sub-goals. Interpretations were made based on reports and articles to define the relationships of beekeeping activities in line with the SDGs. Therefore, publications was analysed based on bee–human interaction and its corresponding services or benefits, its use of livelihood, the social context where bees are found, and benefits from the bees based on SDGs.

We evaluated linkages between SDGs and ESs taken from the Millenium Ecosystem Assessment ESs typology. The services of bees, especially for pollination activities, are arranged and tabulated according to this classification. But the reports of other relevant organizations were examined. These organizations: Ecosystem Services Partnership (ESP), The Economics of Ecosystems and Biodiversity (TEEB), Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES), UN Sustainable Development Solutions Network (SDSN), and Institute International Sustainable Development. We explained whether the research was examining human and bee interactions through the livelihoods framework and ESs.

III. RESULTS AND DISCUSSION

Bees contribute either directly or indirectly to most of the SDGs. While maintaining the planet's life support systems, bees offer various ESs that enhance human well-being [14]. ESs inherently contribute to achieving SDGs [24]. Based on literature review, the extent to which bees contribute towards the achievement of the full suite of the SDGs has not been explored in detail.

In literature existing research has highlighted the importance of pollinators in achieving multiple SDGs through the regulation of natural cycles, biological pest control, pollination, seed dispersal, and even as bio-inspiration [25],[26]. Wood et al. (2018) in their study; respondents evaluationed across SDGs and ESs. The most frequently evaluated services were provision of food and water, habitat & biodiversity maintenance, and water quality services (SDG-1 No Poverty, SDG-2 Zero Hunger, SDG-6 Clean Water, and SDG-15 Life on Land) [24]. These substances, which are associated with provisioning and regulating services, can be maintained through pollination. Pollination has been identified as directly contributing to food security (SDG-2) and biodiversity (SDG-15). Bees are important in both food production and economic systems. Bee pollination services effectively have the potential to help meet some of the key SDGs in economics. (SDG-1 (No Poverty), SDG-2 (Zero Hunger), and SDG-8 (Decent Work and Economic Growth)). SDGs linked to bees's services are summarized in Table 1.

Table 1. *Explaining the Relationship Between Ecosystem Services(ESs) and Sustainable Development Goals(SDGs) and Literature Connections*[3]

SDGs	Contributions bees' in achieving the SDG targets	Supported ESs	Some supported literature
1. No Poverty	1.1: Beekeeping can provide economic diversity by offering an additional source of income 1.4: Potential to promote equitable access to economic and natural resources for both men and women	Provisioning ESs and Cultural ESs	[27], [28].

	1.5: Beekeeping can aid in establishing resilient livelihoods for impoverished and vulnerable communities.		
2. Zero hunger	2.2: Enhances the nutritional value of fruits, vegetables and seeds 2.3: Bee pollination increases crop yield	Provisioning ESs and Cultural ESs	[1], [7], [29],[30].
3. Good health and well-being	3.4: Utilized in both traditional and modern medicine for treating non-communicable diseases, including cancer, due to their potent bioactive compounds 3.8: Bee products offer safe and cost-effective medicinal resources 3.9: Bee pollination potentially contributes to the proliferation and variety of plants that play a crucial role in enhancing air quality	Regulating ESs, Provisioning ESs and Cultural ESs	[31], [32], [33].
4. Quality education knowledge)	4.3, 4.4 and 4.5: Providing vocational training on beekeeping equally for men, women and locals and improving job opportunities	Cultural ESs	[28], [34] [35]
5. Gender equality	5.5: Keeping bees as a hobby or being involved in beekeeping by women can in economic, social and political decision-making processes	Cultural ESs	[28], [34] [35]
6. Clean water and sanitation	6.6: Pollination by bees is important for biodiversity in ecosystems. Appropriate planting studies and designing the urban open-green space system with patch-corridor-matrix approach allow bee activities. Thanks to this design, regional water supply is also supported.	Regulating ESs, Provisioning ESs	[31]
7. Affordable and clean energy	7.2: Bee pollination enhances the yield of oilseed crops used in biofuel production, such as sunflower, canola, and rapeseed	Regulating ESs, Provisioning ESs	[36], [37]
8. Decent work and economic growth	8.1: Bee pollination may contribute to the gross domestic product (GDP) of nations 8.6: Beekeeping can be increased livelihood opportunities in rural areas 8.9:Support nature-based tourism initiatives	Regulating ESs, Provisioning ESs	[38], [28] [30]
9. Industry innovation and infrastructure	Bees are ecosystem services human innovations (e.g., airplane design and computer algorithm development) and new honey-related products	Regulating ESs, Provisioning ESs	[39]
10. Reduced inequality	10.1: Improved livelihoods from beekeeping can support sustainable income growth for lower-income groups 10.2: Promoting social, economic and institutional development.	Regulating ESs, Provisioning ESs	[40], [34]
11. Sustainable cities and communities	11.6: Bees can be useful in air quality in urban ecosystems. Such as pollination of urban green areas can provide improved local air quality. 11.7: Bees can enhance pollination and sustainability of urban green areas and urban open spaces.	Regulating ESs, Provisioning ESs	[41], [42], [43]

12. Responsible consumption and production	12.3: Pollination can contribute to reducing food waste by improving visual shape, size and colour of food and increasing shelf life. 12.b: Beekeeping can be marketed as sustainable tourism for regional growth.	Regulating ESs, Provisioning ESs	[44]
13. Climate actions	13.3: Bees can improve understanding of climate impacts on the environment.	Regulating ESs, Provisioning ESs	[45]
14. Life below water	14.4: Bees can serve to production of plant-based sources eaten by fish.	Regulating ESs, Provisioning ESs	[46]
15. Life on land	15.5: Bees contribute to biodiversity by pollinating. 15.1: Beekeeping can contribute to especially honey forest conservation. 15.9: Integrating beekeeping in local planning processes may support reforestation activities based on sustainable regional development.	Regulating ESs, Provisioning ESs	[7], [47]

Assessment Regulating Ecosystem Services with Sustainable Development Goals

Pollinators have the greatest share in preserving food and increasing productivity. Moreover; In addition to productivity, the quality of the product due to pollination is also positively affected [48]. This contributes to the regulatory services that bees provide for ecosystems and humans. Today, in conditions where approximately 20 million people are at risk of hunger, ending hunger, safe food and sustainable agricultural activities are aimed within the scope of SDG-2 (Zero Hunger). With this service provided by bees in pollination activities, important solutions can be offered to the safe food problem experienced nowadays. Beyond agricultural pesticides, production and efficiency are possible with natural methods.

Forest ecosystems are areas where pollinator services are most active, especially with the presence of species that attract bees. Preserving these areas where services such as biodiversity, water cycle and carbon sequestration occur is important for sustainability [31]. Especially, within the scope of SDG-15 (Land on Life); Pollinator services of these areas should be supported to achieve the goals of ensuring sustainable forest management and preventing biodiversity loss [29]. Moreover; this pollinator regulating service also indirectly contributes to the supply of non-timber forest products [49]. In this direction, SDG – 8 can be accomplished by rural livelihoods with beekeeping [15].

The issue of efficiency of biofuels in pollination services (SDG-7) has been little noticed. It has been observed that the productivity of oilseed crops, such as canola, increases when pollinated by bees [37].

Bee pollination can be active not only in natural areas but also in the urban open-green space system [50]. The patch-corridor-matrix approach should be adopted in urban planning and design processes and bee-attracting species should be included in these corridor transitions at the planting level. These practices provide a transition within the scope of pollination in achieving the goals of sustainable cities (SDG-11). Such as; the United Kingdom's Protection of Pollinators Bill was proposed to develop a national network of wildflower corridors. Thanks to bee pollination, this corridor can supported SDG-11 and SDG-15 in urban areas [51].

Assessment Provisioning Ecosystem Services with Sustainable Development Goals

Provisioning services are services used by people as resources. Products obtained from beekeeping activities not only provide these services, but also support the SDG-1 (income diversity) target. People's

use of services from bees dates back thousands of years. It is used in many areas such as food, cosmetics, medicine and fuel. Some bee products are honey, pollen, beeswax, propolis, royal jelly, bee venom, bee brood. In this context; transforming beekeeping activities into a source of income for small farmers will enable the goal to be achieved [15].

Choosing an economy based on bee products directly contributes to the per capita income at home. In line with SDG-8, targeted rural areas can be increased income opportunities in rural areas [3]. Moreover; sustainable tourism activities can be carried out by adding social value other than economy through the initiatives of local people. It provides additional livelihood opportunities through increased tourism activities. For example; Initiatives suitable for these tourism activities are carried out in Slovenia. This offers opportunities to create and purchase original crafts using bee products [38].

Assesment Cultural Ecosystem Services with Sustainable Development Goals

According to literature, the relationship between bees and humans dates back to the Stone Age period [3]. Throughout history, bees have been mentioned in religious texts, mythology, cosmology and iconography.

The existence of bees has become an important figure in many cultures. Beeswax has been used for at least 4000 years. It has been observed that Aboriginal people prefer this product in rock art. It has been determined that the Greek people included bees in their beliefs about life. Immortality is expressed with the bee symbol. In England, in the 19th century, bees were used to tell important events such as birth, death, marriage or long journeys [3].

The most important point in achieving the sustainability goals of cultural services (SDG-1, 4, 5, 8) is education, employment and entrepreneurship. Providing training on beekeeping and providing employment to entrepreneurial farmers should be encouraged with a focus on sustainability. These activities must support gender equality [34].

Pressures on Activities of Bees

According to the literature; there are studies explaining that bee populations are decreasing due to global pollination crises. Reasons such as habitat fragmentation due to land use change, competition between native and invasive species, agricultural activities and climate change negatively affect bee populations [1]. This situation creates pressure towards decreasing efficiency in food production and species losses in biodiversity [15]. These pressures on bees have far-reaching effects that intersect with the SDGs. It is vital to protect and sustain bees, considering the indirect impact they will have on the economy, welfare and the planet.

Land cover changes: Increasing urbanization causes the destruction of the habitat required for nesting of fodder in pollination [52]. Destroyed and fragmented many natural habitats prevent bees from nesting and transitioning between species. Apart from the change in open-green areas due to urbanization, the change in aquatic systems also changes bee movements. Bees, which use aquatic plants for pollination, may lose their movement corridor due to changes such as drying of water, being placed under urban construction, or changing their location. Moreover; the loss of plant species specific to the aquatic system due to this change also means the extinction of pollinator species [52].

Agricultural activities: One of the most common pressures on pollinators is spraying due to agricultural activities. Exposure to pesticides in intensive agricultural activities and monoculture cropping patterns reduce species richness [52].

Climate change: Bee habitats are affected by seasonal changes, extreme weather events and increasing disasters. There is a suitable climate range for each species to survive. It has been demonstrated that those living at the edges of the climate range become more vulnerable to population decline or even extinction. Bees have difficulty in synchronizing and performing spatial displacements because sudden and temporal changes in seasonal transitions also affect migration times. Additionally, this phenological mismatch can lead to pollinator losses.

IV. CONCLUSION

Pollination services sustain all terrestrial ecosystems, being crucial for the reproduction of numerous plants that serve as the foundation of ecosystems worldwide. Therefore, the conservation of pollinators directly or indirectly contributes to most of the SDGs, fostering a more balanced, sustainable, and socially just world. In this context;

- Creating and restoring habitats for pollinators can mitigate the combined impacts of agricultural intensification, climate change, and to some extent, pesticides and pathogens.
- A major challenge during strategic planning at the landscape level is to develop suitable incentives for land managers to collaborate and ensure an effective spatial and temporal network of food and nesting sites for pollinators.
- Urban landscape planning and design should incorporate initiatives to encourage wildlife-friendly gardening and beekeeping, providing better support for pollinators.
- Bee habitats should incorporate a diversity of food sources in both time and space.
- Sowing flowering plants is necessary to minimize temporal and spatial gaps in pollinators' resources.

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