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Review Article

IMPACT OF CLIMATE CHANGE ON HONEYBEE IN VIEW OF SUSTAINABLE LIFE

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Abstract: The sustainability of life is greatly enhanced by honeybees. For sexual reproduction, as well as the development of many agricultural products, honeybees' pollination services are essential. The ability of bees to contribute to the sustainable development aim highlights the interdependence between bees, people, and the environment. In the last ten years, all natural systems have experienced major problems as a result of climate change and global warming. The number of stigmas visited each minute was most significantly impacted by temperature. For the six fly and bee taxa that were tested, the number of stigmas visited each minute increased as the temperature climbed. Honey bee populations increased with rising light levels, decreased humidity, and higher temperatures (25°C) than lower temperatures (20°C). Honey bee population. With increasing radiation exposure, the number of honey bees increased until it peaked at levels more than 2.5 MJ. The locomotor activity of bee workers reduced when CO_2 concentration increased from 20% to 60%. Bees are unable to navigate normally due to the radiation from mobile phones, which also stops them from returning to the colony. Given these localised increases in rainfall, it will be crucial to comprehend the effects on plant-pollinator interactions, which have important ecological and economic importance, both positive and negative. This review focuses on the varied effects of climate change and global warming on bee health, their foraging behaviour, flower architecture, pollen quality, and their pollination activity, which ultimately destroys the natural resources.

Keywords: *Climate change, Global warming, Bee health, Pollination, Sustainable life*

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Introduction

Honey bees commitment to agricultural produce and sustainable natural resource management, in addition to tremendous economic benefit, arise a real blessing to humankind. The pollination services that honey bees provide are crucial for sexual reproduction including for elevating the calibre and production of many agricultural crops. Averaging 13% of floral visits across all networks, biological pollinators (*Apis* sp.) are the most frequent floral pollinators in natural habitats worldwide and are necessary for the pollination of 33 out of the key 53 crops (range 0–85 percent). The potential contributions of bees to fulfilling the sustainable development goals, emphasize the interconnectedness of bees, people, and the environment from the viewpoint of an integrated system. Global warming triggered by climate change has become a problem in recent decades.

Global warming associated with climate change has become a serious concern for the existence of life on Earth in recent decades [1]. Global temperature has risen during the previous century, while humidity, precipitation, and atmospheric Carbon dioxide concentration have all substantially increased and will double in 2100. This change is attributed largely to natural and anthropogenic causes, which have led to abnormal weather events like modified rainfall patterns, frequent droughts, and floods, increased heat and cold wave intensity and frequency, outbreaks of insect pests and diseases, *etc.*, which have a profound influence on a variety of biological systems and ultimately on people. The population of bees could be significantly damaged by such climatic and weather changes both intrinsically and extrinsically [2]. Changes in phenology, dispersion, community makeup, foraging behavior, colony development, floral biology, and ecosystem dynamics are just a few examples of how the direct effect generally affects the pest population and eventually resulted in the extermination of bees. There are eco-friendly solutions to this issue, such as habitat management, reduced pesticide use, and educating local traditional people on bee ecology, which can reduce the consequences of the parasitic environment and improve pollen quality while gradually resolving the issue since humans are the only species that is the most adaptable to change.

The Function and Value of Bees in Sustainable Life

Seven percent of the world's flora, or 45,000 kinds of plants and shrubs, are found in the world. *Apis cerana, Apis mellifera, Apis florea, and Apis dorsata*, the four species of honey bees found on the Indian subcontinent, provide most of the honey [3]. States with high concentrations of *Apis mellifera* beekeeping include Punjab, J&K, H.P., Haryana, U.P., Bihar, and W.B. The existence of life as we know it on planet Earth is supported by honeybees, an extraordinary and incredibly helpful insect species. The value of the delectable food produced by beekeepers' honey bees each year is more than $6 million. Here are some listed below [Table-1] [4].

Climate and Climate Change

Climate

The term climate is typically used to refer to the average weather or, more precisely, to the statistical description of important parameters over timescales ranging from months to thousands or millions of years. The following definitions show that although the terms "climate change" and "global warming" are frequently used indiscriminately, they do not actually represent the same thing. The National Academy of Sciences, however, considers that the term "climate change" is more favoured over the term "global warming" since it conveys the concept that a shift could occur.

Climate Change

Climate change is defined as it is events in the climate that are attributed directly

Table-1 *The function and value of bees in sustainable life*

SN	Sustainable Developments through bees	Details Contribution
1	Reduced Poverty	Beekeeping provides economic diversity as an income source, assisting vulnerable and underprivileged individuals in creating durable livelihoods. while conceivably giving both men and women equal access to economic and natural resources.
2	Zero hunger	Fruits, vegetables, and seeds have higher nutritional content thanks to bee pollination, which also increases crop yield.
3	Good health and well-being	Strong bioactive components found in bee products make them safe and economical sources of medicine utilised in both traditional and modern medicine to treat non-communicable disorders like cancer. Bee pollination may help plants develop and become more diverse, which is crucial for better air quality.
4	Quality Education	Beekeeping training programmes can improve chances for men, women, and indigenous people with traditional knowledge to pursue employment, education, and entrepreneurship.
5	Gender Equality	Even in societies where women are denied the ability to own property, having bees as a hobby or engaging in beekeeping might increase opportunities for women to participate in economic, social, and political decision-making.
6	Clean water and sanitation	Mountains and forests, which also include water-related ecosystems, may benefit from bee pollination's expansion and diversity. Appropriate afforestation activities could substantially improve the regional water supply while supplying new resources for commercial bee operations.
7	Sustainable cities and communities	Bees are helpful in monitoring the quality of the air in cities since they pollinate the flora there, which contributes to improved regional air quality. Bees can enhance the sustainability and pollination of urban gardens [5].

or indirectly to human activity that modifies the composition of the global atmosphere and that is added to natural climate variability observed throughout the corresponding time periods.

Causes of Climate Change

The earth's climate is dynamic and always changing through a natural cycle. The society is more concerned about the fact that man-made activities have hastened the changes currently taking place. The causes of climate change can be divided into two categories-those that are due to natural causes and those that are created by man (Anthropogenic) [6].

Natural factors

A variety of natural processes contribute to climate change. The earth's tilt, comets, meteorites, ocean currents, and continental drift are a few of the more noticeable ones. Let us examine them more closely.

Continental drift

According to scientists, the continents were once all interlinked by a single enormous landmass and the world did not look as it does today. The uniformity of fossilized plant and animal remains as well as the existence of broad rock belts on the western and eastern coasts of Africa and South America serve as evidence for this. The split between the continental masses altered the direction of winds and ocean currents, which had an impact on the climate. Even today, the continents are still drifting apart; as a result of the slow but persistent displacement of the Indian landmass toward the Asian land mass, the Himalayan range is rising by around 1 mm (millimetre) annually.

Volcanoes

When a volcano erupts, sulphur dioxide (SO_2), water vapour, dust, and ash are discharged in huge quantities into the atmosphere. Even though volcanic activity may only last a few days, the massive amounts of gases and ash can have a long-lasting impact on climatic patterns. A significant eruption can release millions of tonnes of sulphur dioxide gas into the stratosphere, the uppermost part of the atmosphere. In April 1991, Mount Pinatubo, which is in the Philippine Islands, erupted and sent hundreds of tonnes of gases into the atmosphere.

Earth's inclination

Each year, the earth accomplishes one complete orbit around the sun. It is 23.5° inclined with respect to the plane perpendicular to its orbit. The northern hemisphere tilts toward the sun during the summer months for one-half of the year. The earth is inclined away from the sun in the other half during the winter. Seasons would not have been if there had been no tilt. The ferocity of the seasons can change depending on how inclined the earth was; a tilt that is greater results in warmer summers and harsher winters; a tilt that is less results in cooler summers and milder winters.

Ocean currents

A significant part of the climate system is the oceans. They occupy about 71 percent of the planet's surface and take in roughly twice as much solar radiation as the atmosphere or the land. Huge amounts of heat are transported across the earth by ocean currents – about equivalent to what the atmosphere does. However, because the oceans are encircled by land, heat is transferred through the water through channels.

Caused by people

Fossil fuels were significantly used for industrial processes during the 19th century Industrial Revolution. People migrated from rural to urban areas as a result of the jobs that these enterprises produced over time. Even today, this pattern is still present.

Everything mentioned here has aided in the increase of greenhouse gases in the atmosphere. Oil, coal, and natural gas are the primary sources of energy used to power homes, businesses, and transportation infrastructure. About 34 of the carbon dioxide emissions, 1/5 of the methane emissions, and a significant amount of nitrous oxide are brought on by the energy sector. Furthermore, it generates carbon monoxide (CO) and nitrogen oxides (NOx), which are not greenhouse gases but do have an impact on the chemical cycles in the atmosphere that produce or destroy greenhouse gases.

Sources of greenhouse gases

Without a doubt, the most prevalent greenhouse gas in the atmosphere is carbon dioxide. A rise in the emission of carbon dioxide is a consequence of various factors, including changes in land use patterns, deforestation, clearing of land, agriculture, and other activities. Fields of rice or paddy that are inundated during the planting and maturation phases also release methane. When soil is submerged in water, it depletes its oxygen supply and becomes anaerobic. Since rice is the main food in Asia, about 90% of the world's paddy-growing land is situated there. Between them, China and India have 80-90% of the world's rice-growing lands.

In cities, electricity serves as the primary energy source. These thermal power plants emit enormous volumes of greenhouse gases and other pollutants because they burn fossil fuels, primarily coal. In most of our cities, cars, buses, and trucks are the main modes of transportation for both people and commodities. These are mostly powered by fossil fuels like gasoline or diesel. We produce a lot of plastic waste, which harms the ecosystem by lingering there for a very long time. In both schools and offices, we use a lot of paper in our work. Have you ever considered how many trees you use each day? Large amounts of wood are required for house construction, necessitating the clearing of vast tracts of forest. There are increasingly more mouths to feed as the population grows. Due to the restricted amount of land that can be used for agriculture (which is expanding due to ecological deterioration), high-yielding crop types are being planted to maximize the amount of food produced from a particular plot of land.

However, these high-yielding crop varieties need a lot of fertilizers, and more fertilizer means greater nitrous oxide emissions from both the field where it is applied and the fertilizer industry. Furthermore, fertilizer runoff into water bodies leads to pollution.

Impact of Climate Change on Honey-Bees

There are two main categories for how climate change affects bees: (1) Direct Effects on Bee Life; (2) Indirect Effects

Direct: Behaviour, foraging, reproduction, lifecycle, and dispersal of honeybees
For survival, honeybees have biological and genetic traits that allow them to adapt to climate change over hundreds of millions of years.

Indirect: Habitats comprise plants that serve as sources of nectar and pollen, as well as places where animals can find food and water. Parasites and pathogens including wax moths, small hive beetles, mites (Varroa destructor, Tropilaelaps species), and mites (*Varroa* spp.). Predators including weasels, bears, wasps, dragonflies, spiders, mantises, toads, and spiders [7].
Herbicides, pesticides, and fungicides
The agricultural system, land usage, policy, and social perception are examples of social-economic factors.

The Impact of Climate Change on Bees

Temperature's Impact on Bees

Beekeepers are worried about the potential conflict between the phenology of plants and honeybees as well as the introduction of new cultivars of annual crops developed in response to a changing climate. The mass spring emergence of worker bees came halfway through or later into the winter oilseed rape flowering season in recent years, as honeybee colonies were unable to form early in the year. This encourages bees to swarm, which significantly diminishes the honey crop by dividing existing colonies into new ones. Honeybees may therefore need to get started early in order to benefit from spring nectar flows. The first cleansing flight that bees make after the winter is the earliest phonological sign of spring activity in a honeybee colony. This date is based on the temperature in the late winter, according to our research [8].

On Bee Behaviour

Of the behavioural factors looked at, temperature had the biggest impact on how many stigmas were visited per minute. The number of stigmas visited per minute for the six fly and bee taxa studied increased as the temperature rose.

Abundance

Honey bees showed increased abundance with rising light intensity and decreasing humidity, and were more abundant at high temperatures (25°C) than at low temperatures (20°C). In contrast, the short-tongue bumblebee population peaked between 12 and 21 degrees Celsius, and that of native bees between 17 and 30 degrees.

Effect on Foraging Activity

Most bees' foraging activity was found to positively correlate with temperature. On the other hand, neither the relative humidity nor the wind speed had an impact on foraging activity. Each species' activity is influenced by a wide variety of elements, including abiotic variables, body size, visitor behaviour, and the availability of floral resources throughout the day [9]. The lack of floral resources produced by most plants after a specific time of the day may prompt bees to forage in the flowers early the next day, possibly before the time when the abiotic conditions are truly favourable. Production losses are the percentage of a crop's annual yield that comes from the initial harvest.

Radiation Influence on Bee Abundance

The number of honey bees rose with radiation exposure, reaching its maximum level with readings > 2.5 MJ. Only during midday observations may a relatively lower number of honey bees be active at a very low light intensity of 0.5 MJ. There were no clear correlations between radiation and the abundance of flowers for other bee taxa (short-tongued bumblebees, Leioproctus bees, and Lasiolossum bees), and bees were frequently numerous over a wide range of radiation levels.

Impact of Increasing CO_2 in Flowers

Pollen quality impact

North American bee pollen sources had less protein due to rising CO_2 levels. The impact of rising CO_2 on bees' nutrition. Bee food is no longer as nutrient-dense as it once was, according to Jeffrey Dukes. With the rise in CO_2 concentration from 20% to 60%, the locomotor activity of bee workers decreased [10]. The workers remained still, moving only once with their heads, antennae, or legs while breathing more quickly. All employees who were given different CO_2 in N_2 concentrations displayed deep anaesthesia.

Rainfall's Impact on Bees

Numerous intricate interactions occur at various dimensions, both microscopic and macroscopic, when it comes to the impact of rain on pollination. The phenology, physiology, animal behaviour, and energetics of the plant-pollinator connection are all impacted by these effects [11]. This review highlights areas that could use further study and highlights gaps in our existing understanding of the connection between rain and pollination. Many of these information gaps include how some species may be more vulnerable to the effects of rain contact and how this may influence pollinator preferences and behaviour, including flower destruction, nectar dilutions, and the various ways floral signals may be weakened. There are examples that could be studied with basic tools, even though some may be difficult to implement and large in scope.
There are some examples that could be researched using straightforward experimental techniques, even though some may be complex to implement and broad in scope. On a larger scale, it would be useful to test the robustness of networks exposed to these effects and to understand how the structure of plant-pollinator communities' networks is changed by changes in rainfall patterns. The timing of phonological phases may change as a result of changes in rainfall patterns. These changes may also increase the likelihood of pollen deterioration and nectar dilution, all of which are harmful to the fitness of the plant, the pollinator, or both. Mechanical and energy restrictions, disturbance of feeding patterns, and interference with sensory signals could all have an impact on pollinators. One such environmental factor that could have a negative impact is rainfall. One such environmental factor that may have an impact on plant-pollinator interactions is rainfall. Rainfall may have a direct physical impact on flowers and the pollinators who visit them, as well as interfere with the timing of pollinator visits.

Effects on plants Threats to flower-pollen degradation, floral architecture

Successful pollen transport from one bloom to another is necessary for biotic pollination, which enables sexual reproduction in plants [12]. Through a variety of processes, rain can thwart this pollen transport and hence impede flowering plants' attempts at reproduction [13]. According to the Intergovernmental Panel on Climate Change, it is a "virtual certainty" that as mean global surface temperatures rise, precipitation will likewise rise globally, with a persistent trend for some places for precipitation to fall as rain rather than snow [14]. Understanding the impacts on plant-pollinator interactions, which have significant ecological and economic relevance, both positive and negative, will be vital considering these localised increases in rainfall [15]. When combined with the global reduction in pollinator diversity and abundance, the likelihood of localised rainfall increases is made more worrying.

Electromagnetic Radiation's Impact on Bees

Disrupt the Bees Navigational System

One major natural tragedy, the global extinction of honeybees, may be caused by the radiation emitted by mobile phones. The radiation from mobile phones disrupts the bees' ability to navigate and prevents them from returning to the colony; this condition eventually results in issues with their reproductive system and their demise. The world is witnessing the extinction of honeybees [16].

Disturbing life cycle and increasing Colony Collapse disorder

This environmental catastrophe has been linked to several factors, including pesticides, fungi, and other pathogens as well as radiation from mobile phones, particularly considering the recent exposure of wild animals to microwave and radio frequency radiation from a variety of sources, including wireless phones. Bees can use their own compass to navigate thanks to a special organ that senses magnetic forces. According to the research, cell phone radiation disrupts the life cycle of honeybees and has an impact on their ability to reproduce and produce honey.

Effect on the activities of foraging

Temperature and brightness were the two primary abiotic parameters on which the majority of the common bee species depended. For the species of bees whose foraging behaviour substantially connected with luminosity. The two primary abiotic parameters controlling bees' feeding behaviours were brightness and temperature [17]. Each species' activity is influenced by a variety of elements, including abiotic variables, body size, visitor behaviour, and the availability of floral resources throughout the day. The lack of floral resources produced by most plants after a particular time of the day can encourage bees to forage in the flowers early the following day, which may happen before the time when the abiotic conditions are genuinely favourable.

Shift in Species Distribution Range

Most bee species are expected to continue declining as climate change intensifies, according to predictions based on models of species distribution, with the rare exceptions being widespread, widespread species with strong dispersal ability. Most of the bee species that have been examined so far are temperate or tropical species, however many environments are expected to become more arid as a result of climate change. We must thus comprehend how pollinator species are likely to react. Here, we provide species distribution models for the *Ceratina australis* Perkins, 1912, Australian little carpenter bee (Apidae: Xylocopinae) under forecasted climate change circumstances for 2070 from the Intergovernmental Panel on Climate Change (IPCC) (Representative Carbon Pathway 8.5). They used the Random Forest, Generalized Linear, Generalized Additive, and Maximum Entropy techniques. Overall, our models indicate that as climate change advances, this bee will have a larger region of acceptable habitat, including a larger range inside protected areas. However, if it becomes more urbanised and more inhabited, its potential range will expand into coastal regions.

Future challenges

The honeybee population, which pollinates more than 90 commercial crops, has decreased by 30% during the past 20 years. The production of agricultural goods has been greatly hampered by this. Critical levels of bee species diversity and/or population abundance over which certain SDG targets are much more difficult to achieve. When determining whether certain species will adapt while others will suffer, it is necessary to consider how the phenological shifts and variations in abundance vary between species. If we want to see a future where bees continue to contribute to the sustainable development of society, we must work to restore balance and reverse bee decline trends. Poor management of colonies is made possible by a lack of qualified bee workers and honeybee professionals. One of the main issues in beekeeping is the depletion of floral resources due to the expansion of concrete jungles. Many beekeepers complain that the price of the equipment is too exorbitant, which will deter businesspeople from entering this industry. Increasing daily the effects of very high frequency electromagnetic waves from mobile devices and other technologies on bees, especially *Apis cerana*. The fact that few economic indicators have undergone significant change in the years after the emergence of colony collapse disorder points to beekeeping reforms. Human alteration of natural ecosystems to ensure the stability and permanence of interactions between plants and pollinators. Due to human effects, species extinction rates today are 100 to 1000 times greater than they should be. Most of the future biodiversity loss will probably be accounted for by insects, as 40 percent of invertebrate pollinator species, mainly bees and butterflies, are in danger of going extinct. Vertebrate pollinators (16.5%) are likewise globally threatened with extinction, albeit to a lower extent.

Adaptation Method to Protect Bees from Climate Changes

Strategies for conservation and restoration

Strategies for conservation and restoration that aim to maintain biodiversity should consider the various forms of land use as well as the socioeconomic development of the area. In order to generate additional revenue while protecting pollinator species, it is advised to utilise strategies for agroecosystems that are favourable to biodiversity, practise beekeeping, and promote ecotourism in certain locations.

Biodiversity

For indigenous species
Preserve indigenous honeybees
Select and breed good subspecies
Apply appropriated methods for honey hunting

For exotic species: *Apis mellifera*

Select and preserve good ecotypes to breed
Import selected drone's semen to increase biodiversity by Artificial Insemination

Proactive risk evaluation approach

It can assist countries to plan against losses of pollination services due to climate change.

Need to change pollination research emphasis

Need to Change towards both resolving the floral constancy problem and retaining a focus on species with potential to remain abundant into future climate scenarios.

Cross-pollinated crop production must be sustainable

Applied pollination, pollinator management, and managed pollination are the common efforts recently being practiced for maximization of production in cross pollinated crops and to bring the pollinator to the target crop.

Modern genomics methods

Modern Genomics methods made possible by the recent sequencing of the bee genome, are expected to play a prominent role in discovering the vital stress factors for these species.

Management of Habitats

Create a foraging environment that is also secure for honeybees [18].
Develop reforestation
Using pesticides/fungicides/herbicides in right compounds and direction to minimize harmful for honeybees.

Increasing community understanding of beekeeping

Propagate role of honeybees and beekeeping
Diversify traditional beekeeping models
Educate beekeeping in selected schools, agricultural colleges and universities
Multimedia: TVs, Books, Posters, Leaflets, Newspapers, Organize seminars, workshop, events about honeybees and beekeeping

Governmental

Promulgate policies to protect the honeybees and floral sources; regulations for using pesticides, beekeeping preservation, good beekeeping practice.
Enhance capacity of lab to control quality
Support for training courses, beekeeping extension, marketing, free or low tax for beekeeping
Grant for bee research and development
Assist private beekeeper to set up organizations (cooperative, association)
Encourage developing traditional beekeeping models (log hives, top-bar hives) with *Apis cerana*.

Conclusion

Seed crops are pollinated by insects under a highly diverse range of weather circumstances. In terms of other pollinators, honey bees are currently the most prevalent species on these crops, and temperatures above 25 degree celsius tend to increase their domination even further. These results suggest that, if sufficient numbers are still available, their pollination efficiency should not be negatively impacted by rising temperatures per se [19]. Honey bee availability for crop pollination depends on effective management tactics to combat the varroa mite and associated bee health problems. It may be possible to conserve or restore species biodiversity and ensure the ecosystem services provided by pollinators, as well as increase the economic output and welfare of the local population, under climate change scenarios, assuming the same or very similar crops are still grown. The current stable but diverse range of insect species providing pollination services may also change in species composition. Working with communities to lessen their susceptibility to the disasters rendered worse and more frequent by climate change is one of the practical steps in battling it. impacts of climate change on at-risk communities, empowering people to take concrete steps in support of strong and urgent local, national, and global change [20].

Application of research: Study of various effects of climate change and global warming on bee health, their foraging behaviour, flower architecture, pollen quality, and their pollination activity, which ultimately destroys the natural resources and how it can be managed and developing a future in a sustainable way elaborate here.

Research Category: Apiculture - Beekeeping

Abbreviations: FAO-Food and Agriculture Organisation
SDG-Sustainable Development goal, MG-Millijoule
IPCC-Intergovernmental Panel on Climate Change

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