

Buzzing into silence: A geographical analysis of Colony Collapse Disorder

Vijaylaxmi¹, Dr. H N Koli²

¹ Research Scholar, Department of Geography, Government Arts College, Kota, University of Kota, Rajasthan, India

² Professor, Department of Geography, Government Arts College, Kota, University of Kota, Rajasthan, India

Abstract

Colony Collapse Disorder (CCD) represents a critical ecological and agricultural crisis with far-reaching implications for biodiversity, food security, and rural livelihoods. First reported in the United States in 2006, CCD is characterized by the sudden disappearance of worker bees, leaving colonies unable to function. While initially observed in developed nations, CCD has now emerged as a global concern, particularly in countries like India where pollinator-dependent crops form a major part of agricultural production.

This paper adopts a geographical framework to explore the spatial dimensions of CCD, emphasizing the interconnected roles of land use change, pesticide dependency, climate variability, and ecological governance. Using secondary datasets from FAO, IPBES, ICAR, and IARI (2010–2025), it examines trends in honeybee colony numbers, pesticide intensity, and crop pollination dependence. Findings reveal that states such as Punjab and Maharashtra, with intensive pesticide use, report significantly higher CCD incidence compared to diversified regions like Kerala and Himachal Pradesh. Globally, neonicotinoid pesticides account for approximately 35% of CCD cases, while varroa mites, habitat fragmentation, and climatic anomalies add further stress.

The socio-economic impacts are considerable—high-value crops including apples, mustard, cardamom, and cucurbits are at risk, resulting in estimated annual economic losses of thousands of crores. Beyond agriculture, CCD disrupts vital ecosystem services and rural livelihoods. The study concludes by advocating Integrated Pest Management (IPM), habitat diversification, farmer–beekeeper digital coordination, and GIS-based monitoring as crucial pathways for sustainable mitigation.

Keywords: Colony Collapse Disorder, pollinators, agricultural geography, pesticides, sustainable agriculture

Introduction

Pollinators, particularly honeybees, are rightly called the “unsung heroes of agriculture.” According to Klein *et al.* (2007) [7], nearly 75% of the world’s food crops depend to some degree on pollinators. Bees not only sustain ecosystems but are fundamental to human nutrition and rural livelihoods. The Food and Agriculture Organization (FAO, 2023) defines pollination as a critical ecosystem service essential for biodiversity maintenance and global food security.

The phenomenon of Colony Collapse Disorder (CCD)—marked by the sudden and mysterious disappearance of worker bees while leaving behind a queen, brood, and food reserves—has emerged as one of the most pressing ecological crises of the 21st century. Initially detected in the United States in 2006, CCD has since been reported from Europe, Brazil, China, and India, underlining its global reach.

A geographical perspective is vital because CCD manifests differently across regions depending on climatic, agricultural, and policy factors. Potts *et al.* (2010) demonstrated that stricter pesticide regulations in Europe helped stabilize bee populations, whereas unregulated pesticide use and monocropping in developing nations have intensified pollinator decline. Thus, CCD must be analyzed as a socio-ecological phenomenon, shaped by environmental, economic, and governance contexts rather than merely a biological disorder.



Source: Public Domain (for Educational Purposes)

Fig 1: Colony Collapse Disorder Indicators in Honeybee Brood Frames.

Study Area

The study focuses primarily on India, a country of immense agroecological diversity, encompassing tropical, subtropical, and temperate zones. India’s agricultural system is highly pollinator-dependent, particularly for crops such as mustard, apples, cucurbits, and cardamom.

States such as Punjab, Maharashtra, Rajasthan, Himachal Pradesh, and Kerala were analyzed due to their distinct cropping systems and variations in pesticide intensity. These states represent contrasting agricultural geographies—from the pesticide-intensive cotton belts of Punjab and Maharashtra to the diversified horticultural systems of Kerala and Himachal Pradesh—making them ideal for studying spatial variability in CCD vulnerability.

Methodology

This paper relies exclusively on secondary data derived from multiple credible sources: FAO, IPBES, ICAR, and IARI (2010–2025), along with peer-reviewed scientific literature.

Key indicators include

- Pesticide usage intensity (kg/ha)
- Honeybee colony numbers and decline rates
- Crop-wise pollination dependence
- Economic valuation of pollination services

Spatial and temporal analyses were conducted to identify CCD trends globally and within India. Data are represented through comparative tables and figures to illustrate regional

disparities. The methodology also includes cross-referencing of climatic, agricultural, and ecological datasets to identify correlations between anthropogenic stressors and bee decline.

Results

1. Global Overview

CCD was first reported in the United States in 2006 and subsequently spread to Europe, South America, China, and India. Environmental governance appears to influence outcomes—Germany’s stringent pesticide bans have stabilized bee populations, while deforestation and warming trends in Brazil and China have worsened CCD. India reported its first CCD incidents in 2012, coinciding with rising pesticide dependency.

Table 1: Global Status of Colony Collapse Disorder (CCD) by Country, Year of First Report, and Major Causes

Country	Year First Reported	Current Status	Major Cause
United States	2006	Severe, ongoing	Pesticides, mites
Germany	2008	Stabilized	Stringent pesticide regulations
Brazil	2010	Increasing	Deforestation, rising heat waves
India	2012	Growing concern	Insecticide overuse, monoculture
China	2011	Deteriorating	Pollution, shortage of pollinators

Source: Potts *et al.* (2010); IPBES (2017) [6]; FAO (2023)

2. Drivers of CCD

A synthesis of international research identifies neonicotinoid pesticides as the largest contributor to CCD

(35%), followed by varroa mites (20%), habitat fragmentation (15%), and climate variability (15%).

Table 2: Primary Global Drivers of Colony Collapse Disorder (CCD) and Their Estimated Impact

Factor	Description	Estimated Global Impact (%)
Neonicotinoid Pesticides	Impair bee cognition and immunity	35%
Varroa Mites	Parasitic vectors transmitting viral infections	20%
Habitat Fragmentation	Urban sprawl, intensive mono cropping	15%
Climate Variability	Alters flowering seasons and bee physiology	15%
Pathogens	Fungal and viral diseases (e.g., Nosema, DWV)	10%
Pollution & Noise	Disrupts foraging and communication behavior	5%

Source: Potts *et al.* (2010); ICAR (2023)

Table 2 identifies pesticides, particularly neonicotinoids, as the single largest contributor to CCD, impairing bee cognition and immunity with an estimated global impact of 35%. Varroa mite infestations account for 20%, revealing the biological dimension of the crisis. Habitat fragmentation and climate variability each add 15%, emphasizing that CCD is driven by both anthropogenic and natural stressors. The table underscores the multifactorial nature of CCD, where ecological, climatic, and chemical drivers converge.

Source: Public Domain (for Educational Purposes)

Fig 2: Visual Comparison of healthy and CCD Affected Hives

3. India’s Vulnerability

Spatial patterns in India reveal that states with higher pesticide use report greater CCD incidence. For example, Punjab and Maharashtra exhibit colony losses of 20–25%, compared to 10–12% in Kerala and Himachal Pradesh.

Table 3: State-wise Pesticide Use and CCD Losses in India

State	Pesticide Use (kg/ha)	CCD Incidence (% Loss)	Dominant Crops
Punjab	1.33	25%	Cotton, Wheat
Maharashtra	1.18	21%	Cotton, Horticulture
Kerala	0.85	10%	Spices, Coconut
Himachal Pradesh	0.65	12%	Apples, Vegetables
Rajasthan	0.72	15%	Mustard, Bajra

Source: Directorate of Plant Protection, Quarantine & Storage (DPPQS) 2023; Indian Council of Agricultural Research (ICAR) 2023

Table 3 highlights spatial disparities within India, linking intensive pesticide use to higher CCD incidence. Punjab and



Maharashtra, with pesticide consumption above 1 kg/ha, report colony losses exceeding 20%. By contrast, Himachal Pradesh and Kerala, with relatively lower pesticide usage, record lesser losses. Crop profiles also matter: cotton and horticultural monocultures amplify CCD risk, whereas diversified systems like spices and coconut in Kerala are somewhat more resilient.

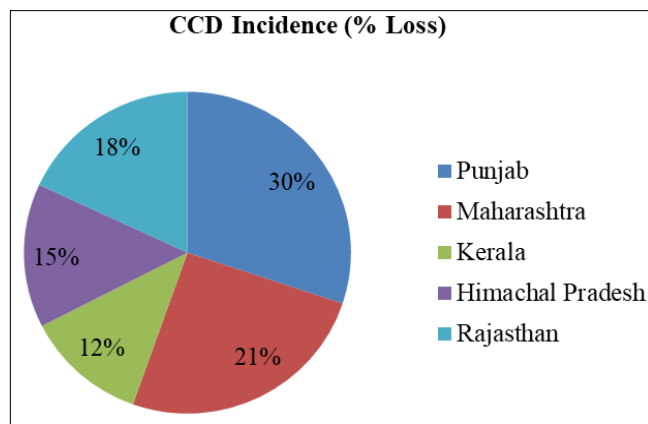
India’s total bee colony numbers fell from 1.5 million (2010) to 0.92 million (2023)—a nearly 40% decline in just over a decade, peaking during years of extreme climate events and intensified pesticide application.

Table 4: Estimated Bee Colony Numbers and Annual Decline Rates, 2010–2023

Year	Estimated Bee Colonies (in millions)	Annual Decline (%)
2010	1.5	—
2015	1.3	13.30%
2020	1.05	19.20%
2023	0.92	12.40%

Source: FAO 2023; Indian Council of Agricultural Research (ICAR) 2023

Table 4 tracks the declining trend in bee colonies over the last decade. India’s bee population dropped from 1.5 million colonies in 2010 to less than 1 million in 2023. Annual decline rates peaked in 2020 at 19.2%, coinciding with intensified pesticide use and erratic climatic conditions. This temporal data reveals a persistent downward trajectory, signaling the erosion of pollination services at a national scale.



Graph 1: State-wise Percentage Loss Due to Colony Collapse Disorder (CCD) in India

4. Impact on Food Systems

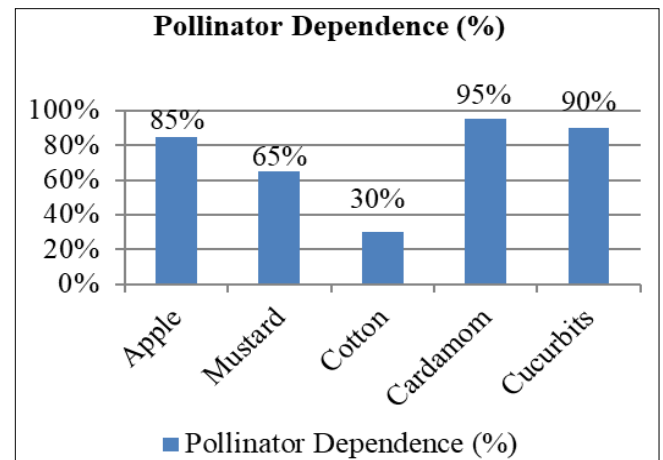
Crops with high pollinator dependence—such as apple (85%), cardamom (95%), and cucurbits (90%)—face serious yield losses. The economic valuation indicates annual losses worth ₹14,000 crore across selected crops.

Table 5: Estimated Bee Colony Numbers and Annual Decline Rates (2010–2023)

Year	Estimated Bee Colonies (in millions)	Annual Decline (%)
2010	1.5	—
2015	1.3	13.30%
2020	1.05	19.20%
2023	0.92	12.40%

Source: FAO 2023; Indian Council of Agricultural Research (ICAR) 2023

Table 5 further elaborates the degree of crop dependency on pollinators. It reveals that a significant proportion of India’s horticultural and cash crops are heavily reliant on bees and other pollinators. This reinforces the critical role of pollination in sustaining national food security and rural livelihoods.



Graph 2: Crop-wise Dependence on Pollinators in India (%)

Discussion

Spatial and temporal evidence clearly links CCD with chemical-intensive agricultural systems. The excessive use of neonicotinoids and other pesticides weakens bees’ immune systems, disrupts navigation, and increases vulnerability to pathogens. Regions like Punjab and Maharashtra typify this pattern, where pesticide density correlates directly with colony loss.

Environmental stressors such as habitat fragmentation, monoculture cropping, and deforestation further diminish forage diversity. Climate variability—manifested through heat waves and irregular flowering—disrupts synchronization between bees and crops, aggravating CCD effects.

From a socio-economic perspective, smallholders often lack training on safe pesticide practices or alternatives like IPM. Poor coordination between farmers and beekeepers results in hive exposure during pesticide spraying periods. Therefore, CCD must be recognized as both an ecological and socio-technical challenge, necessitating integrated, multi scalar responses.

Conclusion

Colony Collapse Disorder is a geographical indicator of ecological imbalance. The study’s findings affirm that CCD emerges from the complex interplay between agrochemical dependency, habitat degradation, climate stress, and governance gaps. The phenomenon threatens not only pollinators but also India’s food sovereignty and rural livelihoods.

The spatial evidence shows that diversified agricultural landscapes offer resilience, while monocultures intensify vulnerability. Hence, region-specific strategies—rather than uniform national policies—are essential. Promoting Integrated Pest Management (IPM), floral diversification, floral corridors, and bee–farmer collaboration platforms can directly mitigate risks. Strengthening pesticide regulation, as evidenced by the EU’s successful neonicotinoid ban, offers a viable policy model for India.

Ultimately, safeguarding bees equates to securing biodiversity and food systems. An integrated approach combining ecological insight, technological monitoring, and participatory governance is essential for ensuring pollinator sustainability and agricultural resilience.

References

1. Sunil V, Dubey VK, Laskar N, Mareppa K. Colony Collapse Disorder in Honeybees and Its Management. *Vigyan Varta*,2022;3(3):1–5.
2. Centre for Agroecology, University of Calcutta. Economic Benefits of Animal Pollination to Indian Agriculture. *Indian Journal of Agricultural Sciences*,2017;87(7):861–867.
3. Chaudhary OP, Chand R. Impact of Insect Pollinators on Quantitative and Qualitative Improvement in Agricultural Crops, A Review. *Journal of Pharmacognosy and Phytochemistry*,2023;12(1):221–227.
4. To Protect India’s Bees, We Need to Understand Their Impact on Agricultural Practices. *Down To Earth*, 2023. www.downtoearth.org.in/blog/india/to-protect-india-s-bees-we-need-to-understand-their-impact-on-agricultural-practices-89333.
5. Indian Council of Agricultural Research, ICAR. All India Coordinated Research Project on Honey Bees and Pollinators, AICRP-HB and P. ICAR, 2025. aicrp.icar.gov.in/honeybee/.
6. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, IPBES. Assessment Report on Pollinators, Pollination and Food Production. IPBES Secretariat, 2017.
7. Klein AM, Vaissière BE, Cane JH, Steffan-Dewenter I, Cunningham SA, Kremen C, *et al.* Importance of Pollinators in Changing Landscapes for World Crops. *Proceedings of the Royal Society B, Biological Sciences*,2007;274(1608):303–313.
8. Kleczkowski A, Ellis C, Goulson D, Hanley N. Ecological-Economic Modelling of Interactions between Wild and Commercial Bees and Pesticide Use. *arXiv preprint*, 2015. arxiv.org/abs/1509.03734.
9. Narcia-Macias CI, Singh A, Patel P, Rawat S, Choudhary R, *et al.* IntelliBeeHive: An Automated Honey Bee, Pollen, and *Varroa destructor* Monitoring System. *arXiv preprint*, 2023. arxiv.org/abs/2309.08955.
10. Hubli S, Singh H, Sharma R, Meena RS. Effect of Indigenous Bee Attractants on Berseem Seed Yield and Role of Geospatial Tools in Agriculture. *ICAR-NRCSS Annual Report*,2024:2023–24:76–82.
11. United Nations Environment Programme, UNEP. Global Pollinator Initiative. UNEP, 2022.
12. European Commission. Ban on Neonicotinoid Pesticides. European Commission, 2018.