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Changing Climate and Emerging Insect Threats: Is Indian Agriculture Prepared?

Rittik Sarkar*, Ram Keval, Rohit Raman, Prince Gond and **Adarsh Kumar**
Department of Entomology and Agricultural Zoology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi 221005, India.
**Corresponding author - rittikrnj197@gmail.com*

Abstract

Climate change is rapidly reshaping insect ecology across Indian agroecosystems. Rising temperatures, erratic rainfall, prolonged dry spells, and extreme weather events are altering the distribution, survival, and outbreak potential of insect pests. Several invasive pests such as fall armyworm, rugose spiralling whitefly, and tomato pinworm have expanded rapidly under favourable climatic conditions, threatening crop productivity and food security. At the same time, beneficial insects including pollinators and natural enemies are also being affected. This article discusses how changing climate is influencing insect dynamics in India, the emerging risks for agriculture, current preparedness measures, and the urgent need for climate-smart pest management and policy interventions for sustainable crop protection.

Keywords

Climate change; emerging insect pests; invasive species; integrated pest management; pest dynamics

Introduction

Climate change is no longer a distant environmental concern; it has become a direct agricultural challenge affecting crop productivity, pest behaviour, and farming sustainability across the globe. In India, where agriculture supports millions of livelihoods, rising temperatures, irregular rainfall, prolonged droughts, unseasonal rains, and extreme climatic events are increasingly influencing insect ecology and pest outbreaks. Insects, being cold-blooded organisms, are highly sensitive to environmental changes, and even small shifts in temperature and humidity can alter their development, survival, migration, and feeding behaviour.

Over the last decade, farmers across several Indian states have witnessed sudden outbreaks of invasive pests, changing pest calendars, and increased pesticide dependency. The rapid spread of fall armyworm in maize, rising incidence of whiteflies in cotton, increased stem borer activity in rice, and outbreaks of sucking pests during warmer winters clearly indicate that climate change is reshaping insect dynamics in Indian agriculture. These changes are now

challenging existing pest management practices and demanding more adaptive, climate-resilient crop protection strategies.

Climate Change and Insect Ecology

Climate directly influences insect growth, reproduction, survival, voltinism, and geographical distribution. Increasing temperature accelerates insect metabolism and shortens developmental periods, allowing many pests to complete more generations within a single cropping season. Warmer winters also improve overwintering survival of pests that were previously restricted by low temperatures.

Recent studies have shown that climate warming may increase the abundance and spread of several economically important insect pests (Singh *et al.,* 2026). Elevated atmospheric carbon dioxide levels also modify plant nutritional quality and influence plant-insect interactions. In many cases, reduced nitrogen concentration in plant tissues compels herbivorous insects to consume more foliage, resulting in greater crop damage.

Erratic rainfall patterns further complicate pest dynamics. High humidity and intermittent rainfall often favour sap-feeding insects such as aphids, whiteflies, and planthoppers, while drought conditions weaken crop defence mechanisms and increase susceptibility to insect attack. Climate change also disrupts synchrony between pests and their natural enemies, reducing the effectiveness of biological control agents and increasing the likelihood of pest outbreaks.

Emerging Insect Threats in Indian Agriculture

Fall Armyworm: A Climate-Driven Invasion

The invasion of fall armyworm, *Spodoptera frugiperda*, into India represents one of the most significant examples of climate-linked pest emergence in recent years. Originally native to the Americas, this highly destructive pest was first reported in India during 2018 and spread rapidly across maize-growing regions due to favourable temperature and humidity conditions.

Its high reproductive capacity, migratory behaviour, and adaptability to different agro-climatic regions enabled rapid establishment across the country. Studies suggest that warmer climatic conditions have accelerated its spread and increased the number of generations per year (Sorahia *et al.,* 2025). Today, fall armyworm has become a major threat not only to maize but also to sorghum, millets, and several other crops.

Figure 1. Fall armyworm infestation in maize has emerged as a major invasive pest problem under favourable climatic conditions in India.

Changing Dynamics of Rice Pests

Rice ecosystems are also experiencing shifts in pest incidence due to climate variability. Increased temperatures and humidity favour brown planthopper outbreaks, while changing rainfall patterns influence stem borer populations and leaf folder incidence. Unseasonal weather conditions frequently disturb the ecological balance between pests and natural enemies in rice fields.

Warmer conditions may also enhance pest migration and survival, resulting in severe outbreaks in areas previously considered low risk. Climate induced changes in rice pest dynamics are now emerging as a major concern for food security in Asia.

Cotton Ecosystems Under Stress

Cotton cultivation in India is increasingly affected by climate driven pest resurgence. Whiteflies, jassids, pink bollworm, and mealybugs are showing altered seasonal occurrence patterns due to changing temperature regimes. Mild winters and prolonged warm conditions favour survival and rapid multiplication of these pests.

In recent years, pink bollworm has re-emerged as a serious challenge in Bt cotton-growing regions. Scientists have linked this resurgence partly to changing climatic conditions and evolving pest adaptation mechanisms. Increased pesticide applications against sucking pests have also disturbed beneficial insect populations, leading to secondary pest outbreaks.

Horticultural Crops and Invasive Pests

Fruit and vegetable crops are becoming increasingly vulnerable to invasive insect pests under changing climate scenarios. Tomato pinworm (*Tuta absoluta*), rugose spiralling whitefly, fruit flies, and thrips are expanding their distribution in several parts of India.

Elevated temperatures allow faster multiplication and increased survival of these pests. Horticultural ecosystems, with their year-round crop availability and favourable microclimatic conditions, often support rapid pest population growth. Climate variability also influences vectorborne plant diseases transmitted by insects such as whiteflies and thrips, further increasing crop losses.

Table 1. Major Climate-Driven Emerging Insect Pests in Indian Agriculture

Crop Ecosystem	Major Pest	Climate Influence	Major Impact
Maize	Fall armyworm	Warm temperatures	Severe defoliation
Rice	Brown planthopper	High humidity	Hopper burn
Cotton	Pink bollworm	Mild winters	Boll damage
Tomato	Tuta absoluta	Extended warm season	Leaf and fruit mining
Mango	Fruit fly	Elevated temperature	Fruit infestation

(Source adapted from Sorahia *et al.,* 2025)

Impact on Pollinators and Beneficial Insects

Climate change is not affecting only harmful insects; beneficial insects are equally vulnerable. Pollinators such as bees and butterflies are

experiencing habitat loss, phenological mismatches, and reduced floral availability due to shifting climatic conditions.

Extreme heat events, pesticide exposure, and irregular flowering patterns are contributing to pollinator decline across several ecosystems. Similarly, parasitoids and predators used in biological control may fail to synchronize with pest populations under altered climatic conditions, reducing their effectiveness.

Disruption of these ecological interactions weakens natural pest suppression and threatens ecosystem stability. Since pollinators contribute significantly to crop productivity and biodiversity conservation, their decline poses serious long-term implications for sustainable agriculture.

Climate Change and Pest Distribution

One of the most visible consequences of climate change is the geographical expansion of insect pests into new ecological regions. Many insects are now shifting towards higher altitudes and latitudes in response to warming temperatures.

Several pests previously confined to tropical and subtropical regions are now establishing populations in cooler agro-climatic zones. This expansion increases the vulnerability of new cropping systems and creates additional challenges for pest surveillance and quarantine systems.

Climatedriven migration also increases the risk of invasive alien species introduction through trade and transportation networks. Once established, these pests become difficult and expensive to manage.

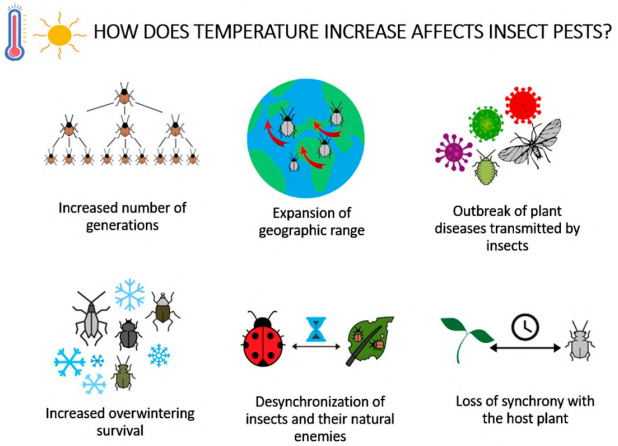

Figure 2. Impact of Climate Change on Insect Pest Dynamics (Skendžić*et al.,* 2021).

India's Preparedness and Existing Initiatives

India has initiated several programmes aimed at climate-resilient agriculture and pest management. The National Innovations in Climate Resilient Agriculture (NICRA) programme by ICAR has played a significant role in studying climate impacts on agriculture and developing adaptive technologies.

Digital pest surveillance systems, remote sensing tools, artificial intelligence-based forecasting models, and mobile advisory platforms are gradually being integrated into pest monitoring programmes. Climate-smart Integrated Pest Management (IPM) approaches emphasizing resistant varieties, biological control, cultural practices, and need-based pesticide use are also receiving greater attention.

Government initiatives promoting drone-based surveillance, precision agriculture, weather-based agro-advisories, and pest forecasting models are helping improve preparedness. However, implementation gaps still exist at the

field level, especially among small and marginal farmers.

Major Policy Gaps and Challenges

Despite increasing awareness, India's preparedness for climate-driven insect threats remains inadequate in several areas. Pest surveillance systems are still fragmented and often reactive rather than preventive. Long-term insect monitoring databases are limited, making accurate prediction of future pest outbreaks difficult.

There is also insufficient integration of climate science with pest management planning. Many farmers continue to rely heavily on chemical pesticides, which may provide short-term relief but often lead to resistance development, ecological imbalance, and destruction of beneficial insects.

Climate-smart pest management technologies are not equally accessible across all farming communities. Lack of region-specific advisories, limited extension support, and inadequate biosecurity measures further increase vulnerability to invasive pests. Recent studies have emphasized the urgent need for stronger climate linked pest forecasting systems and adaptive policy frameworks for sustainable crop protection.

The Way Forward

Indian agriculture must now move from reactive pest control to proactive climate-resilient pest management. Strengthening national pest surveillance systems, integrating climate forecasting with pest advisories, and promoting ecological approaches to crop protection are essential steps for future preparedness.

Greater investment is needed in artificial intelligence, remote sensing, GIS-based pest prediction, and real-time digital advisory systems. Conservation of pollinators and natural enemies should become an important component of climate-smart agriculture.

Farmers must also be trained in climate-adaptive IPM strategies, pest identification, and safe pesticide use. Stronger quarantine regulations and early warning systems are crucial to prevent the establishment of invasive alien species.

Climate change is transforming insect ecology at an unprecedented pace. The future resilience of Indian agriculture will depend not only on increasing crop productivity but also on strengthening preparedness against emerging insect threats through science-based policies, technological innovation, and sustainable pest management approaches.

Conclusion

Changing climatic conditions are significantly altering insect pest dynamics in Indian agriculture. Rising temperatures, erratic rainfall, and extreme weather events are increasing pest outbreaks, expanding pest distribution, and affecting beneficial insects. Invasive species such as fall armyworm and tomato pinworm are emerging as major agricultural threats under favourable climatic conditions. Although India has initiated climate-resilient agricultural programmes and digital pest surveillance systems, significant policy and implementation gaps remain. Strengthening climate-smart Integrated Pest Management, improving pest forecasting systems, conserving beneficial insects, and promoting sustainable crop protection strategies will be critical for

safeguarding Indian agriculture against future insect threats.

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