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Climate change creates threats to pest management in Bangladesh: way forward

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Abstract

Bangladesh, with its large population and heavy reliance on agriculture, is particularly vulnerable to the impacts of climate change. These changes complicate traditional pest management strategies, as pests that were once seasonal or localized may now thrive year-round or spread to new areas. Unpredictable weather conditions can affect pest control practices, including the effectiveness of chemical treatments and the timing of pest monitoring. This article explores the impact of climate change on pest management in Bangladesh, focusing on the vulnerabilities of the agricultural sector and the need for adaptive strategies. It discusses how climate-induced changes in temperature, rainfall, and humidity can facilitate the spread of pests, the introduction of invasive species, and the outbreak of pest populations. These changes also enhance the reproduction of pests like rice stem borers, aphids, and fruit flies, which are already damaging key crops. As pests become difficult to control with conventional methods, leading to greater reliance on chemical pesticides, which carry long-term environmental and health risks. Agricultural production and food security in Bangladesh are at serious risk due to the spread of these arthropod pests and diseases. Global warming, irregular rainfall, and extreme weather events are disrupting current pest management methods, such as cultural, biological, and chemical approaches. Therefore, promoting sustainable agricultural practices like integrated pest management, climate-smart agriculture, and biotechnological approaches is essential for mitigating the impacts of climate change on pest outbreaks. Priority should be given to the development of resistant varieties, conservation of natural enemies and development of effective forecasting models.

Keywords: Climate change, food security, global warming, pest outbreak, resistant variety

Introduction

Climate change is rapidly transforming environmental conditions across the globe, and Bangladesh, with its vast agricultural sector and high population density, faces significant threats to food security and agricultural sustainability. The country's agriculture is particularly vulnerable to climate-induced changes, especially in relation to pest management, as rising temperatures, erratic rainfall, and extreme weather events create favorable conditions for pests to thrive. One of the major biotic stressors in agriculture is pests, whose populations and behavior are directly influenced by climate change and weather disruptions. Rising temperatures accelerate pest reproduction, survival, and spread while also altering interactions between pests, their environment, and natural predators (Prakash *et al*. 2014). Conventional strategies, which primarily rely on chemical pesticides, are not only becoming less effective due to evolving pest resistance but also pose environmental and health hazards, making sustainable alternatives essential. Global warming, which has reached record-breaking levels as evidenced by unprecedented increases in atmospheric temperature and sea levels, further intensifies these challenges (Field *et al*. 2014). Climate change creates new ecological niches that allow insect pests to establish themselves in previously uninhabitable regions, leading to geographic shifts and unpredictable outbreaks (FAO 2020).

The increasing levels of CO_2, fluctuating precipitation, and the migration of non-native insect species further complicate pest-plant interactions, making Integrated Pest Management (IPM) strategies harder to predict and implement effectively (Trumble and Butler 2009). Changes in agro-ecosystems may also lead to new challenges, such as greenhouse pests becoming more problematic in open fields and pastures. According to Morris (2008), the population growth and longevity of short-lived pest species may increase under warming conditions, while reduced cold constraints could enable pests to expand into new regions and extend their active seasons in existing areas (Diffenbaugh *et al*. 2008). A longer growing season may further exacerbate pest infestations,

requiring adaptive management strategies to minimize agricultural losses. To mitigate these risks, farmers must adopt climate-resilient pest management approaches that reduce reliance on chemical pesticides while ensuring long-term agricultural sustainability (Ziska 2014; Rosenblatt and Schmitz 2014). The objective of this review article is to analyze the impact of climate change on pest dynamics in Bangladesh and assess the challenges faced in existing pest management strategies. It aims to explore sustainable, climate-resilient pest control methods, including Integrated Pest Management (IPM) and eco-friendly alternatives. Additionally, the article seeks to provide policy recommendations and practical solutions to enhance pest management while ensuring environmental sustainability and food security. Lastly, it emphasizes the importance of farmer education and capacity-building initiatives to help agricultural communities adapt to evolving pest threats in a changing climate.

Climate change effects on agricultural insect pests

Effect of temperature increase: Climate change directly impacts pest reproduction, development, survival, and dispersal while also influencing interactions within and between insect species and their environment. Temperature fluctuations significantly affect insect physiology, doubling metabolic rates for every 10 °C increase (Dukes *et al*. 2009). Higher temperatures enhance feeding, performance, and dispersal, altering population dynamics (Shrestha 2019). Global warming boosts insect populations, leading to earlier infestations and crop damage. Increased overwinter survival of pests like the corn earworm and cotton bollworm has expanded their range, complicating pest control (Nayak *et al*. 2020). Additionally, warmer conditions shorten developmental times, increasing generations per season and shifting pest-host relationships. Lehmann *et al*. (2020) observed varied responses of insect pests to climate warming, with the majority of case studies showing increased pest impact. Figure 1, present, the impact of increased temperature on insect pests.

Here in Table 1, the dynamic impact of increased atmospheric temperature on crop pest dynamics is shown.

Effect of elevated CO_2 concentration: As CO_2 levels rise, leaves produce more carbohydrates but have lower nitrogen levels. This reduces the plant's defense hormone, jasmonic acid (JA), while increasing salicylic acid (SA) (Delucia *et al*. 2012). Elevated CO_2 (ECC) can affect insect pests by changing their food intake, growth, fertility, and population size (Table 2). For example, ECC increases aphid numbers but does not impact their parasitism rate.

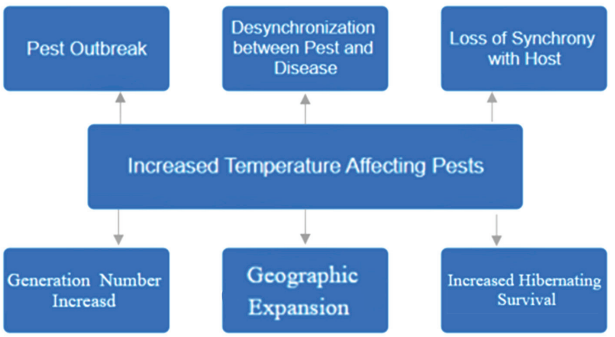


Figure 1. Impact of increased temperature on insect pests.

Table 1. Effect of enhanced atmospheric temperature on crop pest dynamics

Increasing effect	Decreasing effect
Insect extinctions	Effectiveness of insect biocontrol by fungi
Insect developmental rates and oviposition	Reliability of economic threshold levels
Potential for insect outbreaks	Insect diversity in ecosystems
Invasive species introductions	Parasitism

These changes may require adjusting crop management, such as altering planting and harvest times, to avoid peak pest activity.

Effect of changeable precipitation pattern: The survival and reproduction of many insect pests depends on rainfall, which affects their population levels. There is clear evidence of amplification of the global hydrological cycle, which is strongly influenced by changes in temperature (Figure 2). Heavy rain can help by washing away small pests like aphids, mites, jassids, and whiteflies. However, dry soil weakens plants, making them more vulnerable

to diseases and pests (Zayan 2019). Additionally, sap-feeding insects tend to thrive on trees that experience occasional water stress rather than constant.

Table 2. Effect of increasing atmospheric carbon dioxide on plant insect interaction

Increasing effect	Decreasing effect
Food consumption by caterpillars	Insect development rates
Reproduction of aphids	Response to alarm pheromones by aphids
Predation by lady beetle	Parasitism
Carbon based plant defenses	Effect of transgenic *Bacillus thuringiensis*
Effect of foliar application and *Bacillus thuringiensis*	Nitrogen-based plant defense

Effects on introduction of invasive alien species: Invasive alien species are organisms introduced outside their native range, either intentionally or accidentally. Studies suggest that climate change may expand their range, increase population density, and shorten generation time, harming agriculture (Ratnayake 2014). Climate change also influences their spread by affecting traits like adaptability to daylight shifts. As ectotherms, insects may adapt through behavioral changes that regulate energy metabolism (Gonzalez *et al.* 2020). The increase in temperature and the shifting of agro-ecosystems create favorable conditions for pests that were once limited by colder climates, such as the *fall armyworm*, which has spread to rice and maize fields in Bangladesh in recent years.

Effects on efficacy of bio-pesticides and synthetic insecticides: Temperature, humidity, and UV radiation are key environmental factors affecting the survival, spread, and virulence of entomopathogenic fungi. High temperatures drastically reduce conidial viability, while high humidity promotes conidial germination. *Beauveria bassiana* strains germinated faster at 95.5% RH (20 h) than at 90% RH (72 h) at 25 °C. Extreme winter (10-15°C) and summer (35-40 °C) temperatures slowed their germination and growth (Sen *et al*. 2009). Additionally, elevated CO_2 significantly reduced the germination and growth rate of *B. bassiana*. The high temperatures, particularly for long periods, decrease the viability of *Bacillus thuringiensis*, and the larvicidal activity was either undetectable or very low within 3 to 10 days after application. Higher temperatures can accelerate the

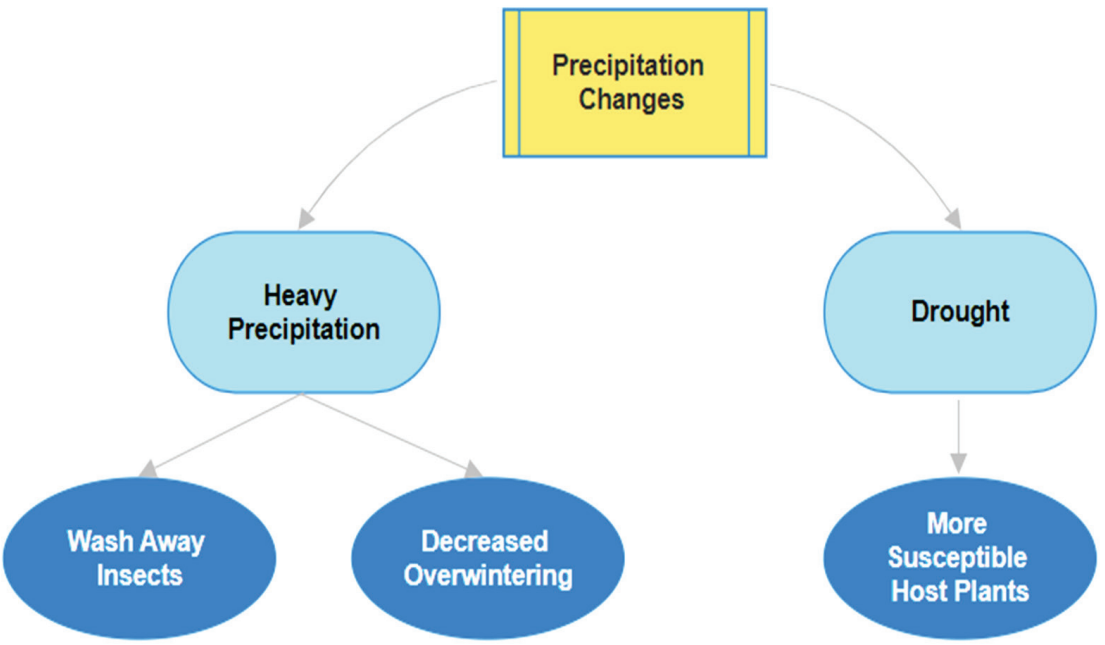


Figure 2. Impact of the changes in precipitation on insect pests.

chemical breakdown of pesticides, reducing their residual effectiveness and shortening the time they remain active in the environment. Additionally, extreme weather events like heavy rainfall can wash away pesticides before they have a chance to work, while dry conditions may limit their spread or effectiveness.

Yield loss of some major crops by insect pests: A study on rice diseases revealed that bacterial leaf blight and nematode are a great threat to rice production throughout the country, and about 4–14% of rice yield is also lost by bug pests annually (Mondal 2010). Moreover, several other crop yields are also undermined by pests and diseases because of climate change (Table 3).

Table 3. Estimated yield loss from insect pests for major crops

Crops	Yield Loss (%)
Rice	16.0
Maize	20.0
Wheat	11.0
Pulses	25
Sugarcane	20.0
Jute	15.0

Challenges in existing pest management strategies: Climate change poses significant challenges to existing pest management strategies, including chemical pesticides, biological control methods, and Integrated Pest Management (IPM).

Chemical pesticides: As the temperature rises, pesticide efficacy decreases due to increased volatilization, a process in which the pesticides turn into gas after application. This results in a higher risk of inhalation, reduced effectiveness, and contamination as the pesticides drift away from the intended area.

Biological control: Variations in CO_2 levels, temperature, and water availability are expected to impact different species within a biocontrol system in unique ways. Milder winters may fail to limit insect reproduction, allowing pests like aphids and thrips to multiply, while predators struggle to control their numbers. Warmer temperatures can lead to various effects, including changes in invertebrate feeding habits, altered pathogenicity of fungi, and often increased survival rates of parasitized hosts. Extreme weather events often lead to pest population surges due to the loss of natural predators. Parasitoids, being more sensitive than their hosts, typically recover more slowly, further reducing their effectiveness in controlling pest populations.

Integrated pest management: While IPM integrates various pest control methods, the unpredictability of climate-induced changes in pest behavior makes it harder to implement effectively. Climate induced changes, such as rising temperatures, can accelerate pest reproduction and resistance to control methods, including biological and chemical components of IPM, reducing their effectiveness. Climate change alters the dynamics between pests, crops, and natural enemies, making it harder to maintain the balance that IPM relies on.

Monitoring and forecasting: Shifting weather patterns, unpredictable temperature fluctuations, and extreme weather events disrupt pest behavior, making it more difficult to predict when and where pest outbreaks will occur. Additionally, climate change may alter the migration patterns and life cycles of pests, leading to unexpected pest invasions in new region. This unpredictability hampers the ability to track pest populations accurately and plan interventions in advance. As a result, existing monitoring systems and forecasting tools may no longer be reliable, undermining the effectiveness of pest management strategies such as Integrated Pest Management (IPM). Enhanced, climate-resilient monitoring technologies and better forecasting models are needed to keep pace with the evolving challenges posed by climate change.

Potential pest management strategies to overcome climate change effects: Managing insect pests under climate change requires a multi-faceted approach (Figure 3) that considers the evolving environmental conditions and the need for sustainable and resilient agricultural practices. These following strategies can be followed in the context of changing climate for better pest management:

Pest-resistant crop varieties: Developing and planting pest-resistant crop varieties one of the most effective long-term solutions to climate-induced pest pressures.

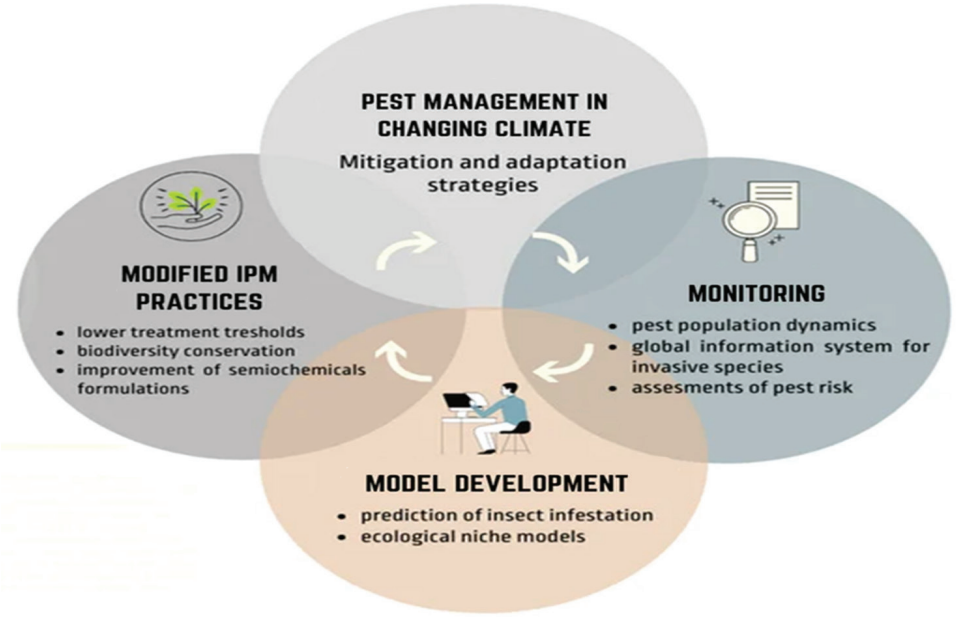


Figure 3. Potential pest management strategies for mitigation and adaptation.

These crops are bred to naturally resist or tolerate specific pests, reducing the need for chemical interventions. With changing climate conditions, pest-resistant varieties can help reduce crop losses and increase resilience against unpredictable pest outbreaks. Breeding for pest resistance can be an effective long-term strategy, especially in changing climates (Kumari *et al*. 2022). Research into climate-resilient varieties, such as drought-tolerant and pest-resistant crops, is critical for adapting to new pest challenges.

Biological control agents: Biological control involves using natural predators, parasites, or pathogens to manage pest populations. These agents, such as beneficial insects (e.g., ladybugs, parasitoid wasps) or biocontrol microorganisms, can effectively reduce pest numbers without harming the environment. Climate change may alter the effectiveness of biological control, but adapting bio-control agents to new climate conditions can offer a sustainable alternative to chemical pesticides. In some cases, introducing or strengthening native predators can help control pest populations more naturally and effectively. *Trichogramma* and *Telenomus* are the most active biological control agents, which parasitized the Fall armyworm eggs and other key pests (Zang *et al*. 2021).

Eco-friendly pest management strategies: Eco-friendly pest management involves a combination of cultural, physical, and mechanical practices that reduce the reliance on chemical pesticides. Techniques such as crop rotation, intercropping, mulching, and using pest-repellant plants can disrupt pest life cycles and reduce pest habitats. Additionally, using physical barriers like nets or traps, and promoting soil health through organic farming, can help prevent pest infestations. These strategies, when integrated with IPM, create a holistic approach that promotes long-term agricultural sustainability and reduces environmental impact.

Modified integrated pest management practices: Modified IPM practices adapt to climate change by incorporating climate-sensitive monitoring, crop diversification, and enhanced biological control methods. These practices focus on using climate data for better pest forecasting, reducing chemical pesticide reliance, and promoting sustainable farming techniques like crop rotation and pest-resistant varieties. By training farmers in climate-smart pest management, these practices aim to balance effective pest control with environmental sustainability, ensuring resilience to climate induced pest challenges.

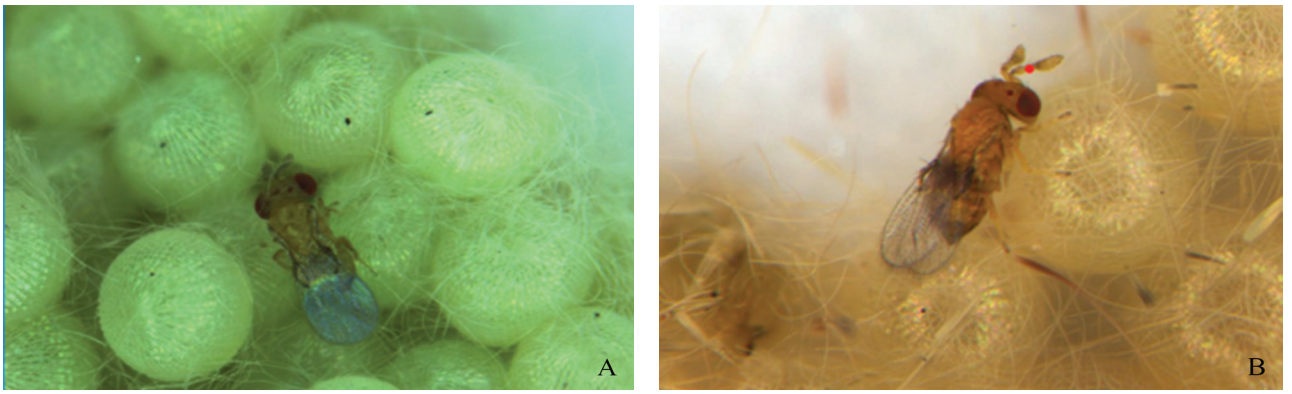


Figure 4. *Trichogramma* species parasitizing the egg mass of fall armyworm, *Spodoptera frugiperda.* (A) *Trichogramma pretiosum*, (B) *Trichogramma chilonis*.

Climate-responsive pest management and climate-smart agriculture in pest control: To address the challenges of climate change on agriculture, Bangladesh needs to combine climate-responsive pest management with climate-smart agriculture. This involves improving early warning systems, enacting climate-responsive policies, and engaging local stakeholders like governments, CBOs, and NGOs (Bodrud-Doza 2022). Figure 5 indicates Climate-smart agriculture enhances productivity and resilience, helping farmers adapt to shifting pest patterns by promoting sustainable practices that reduce pest risks. By integrating these strategies, Bangladesh can better manage pest outbreaks, minimize environmental impact, and ensure long-term agricultural sustainability.

Climate forecasting and model development: An effective early warning system (Figure 6) plays a crucial role in mitigating the impacts of weather extremes by providing timely and accurate information to communities, governments, and organizations. Climate forecasting and model development are essential for predicting how pests will respond to climate change. By using climate data and projections, these models help anticipate pest

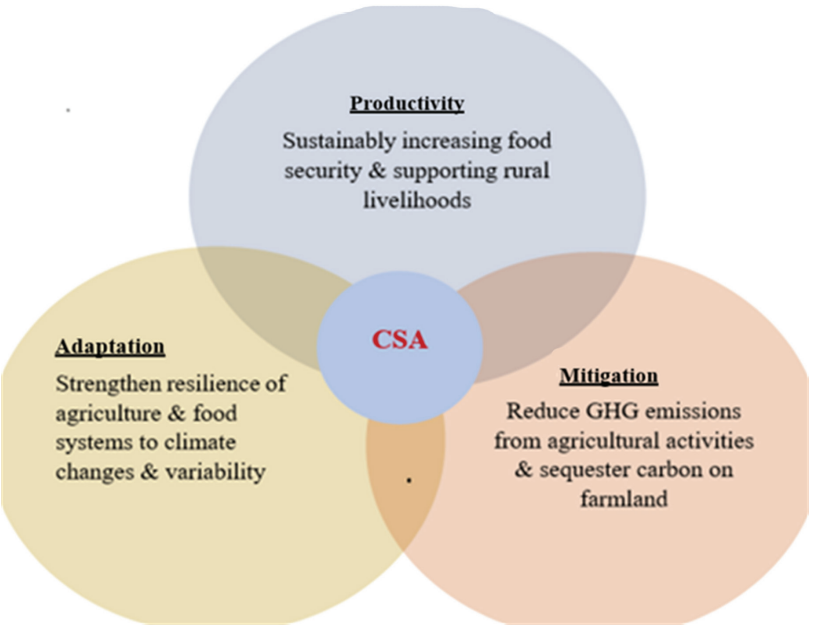


Figure 5. Pillars of climate smart agriculture.



Figure 6. Early warning systems.

outbreaks and identify vulnerable areas. They also enable the development of climate-resilient pest management strategies, allowing farmers and policymakers to better prepare for climate induced pest risks. Modelling the pest risk together with the responses of its plant hosts to climate change can therefore increase the ability to predict the outcome of an insect infestation (Raza *et al*. 2015).

Monitoring abundance and distribution: Without essential baseline data, it becomes challenging to accurately assess changes in pest populations due to climate change and predict future dynamics. Long-term monitoring of pest populations and behavior, especially in climate sensitive regions, is crucial as it can offer valuable insights into how pests biologically respond to shifting climate patterns. (Heeb *et al*. 2019).

Agroecological practices: Agroecological practices, such as polyculture, agroforestry, and conservation tillage, create more diverse and resilient farming systems that naturally control pests. These methods increase biodiversity and strengthen ecosystems, making crops more resistant to pest outbreaks. Agricultural practices, including water management, soil conservation, and carbon sequestration, can also help farmers adapt to changing climatic conditions while managing pest threats in a sustainable manner.

Disaster risk management: The disaster risk management cycle (Figure 7) in pest management includes prevention, preparedness, response and recovery. It involves proactive measures like pest-resistant crops and early warning systems, preparing farmers through training and monitoring, responding quickly with control measures during outbreaks, and recovering by restoring agriculture and refining strategies for future resilience. This cycle helps reduce pest impacts and strengthen food security.

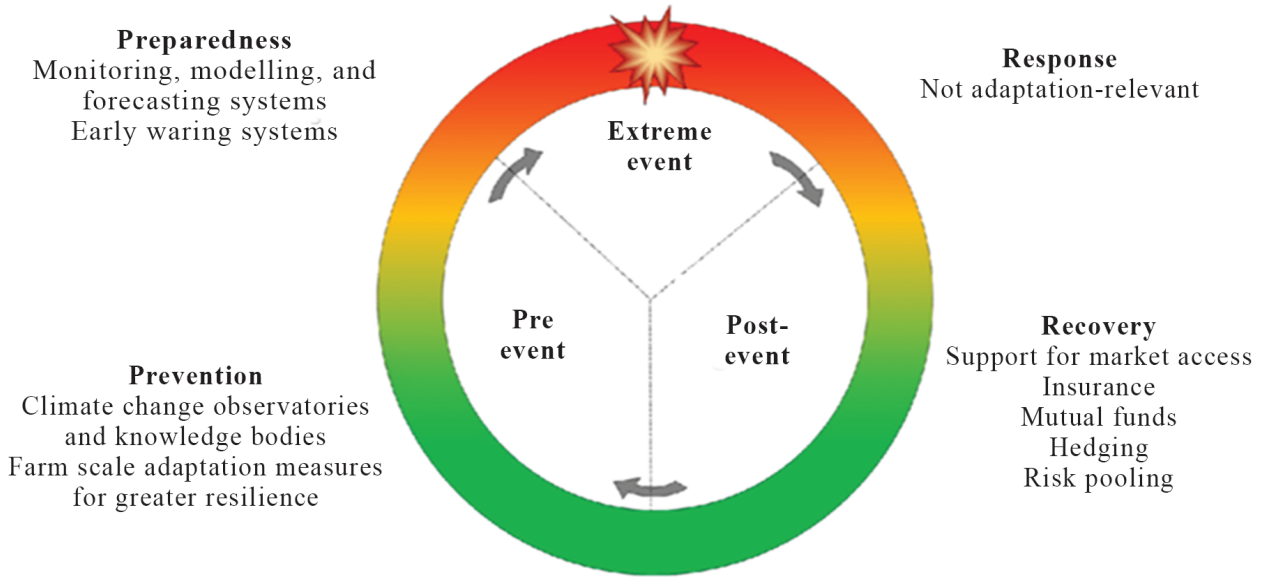


Figure 7. Disaster risk management cycle.

Policy recommendations for improved pest management in Bangladesh: To address the growing challenges posed by climate change on pest management, a coordinated effort involving government agencies, agricultural institutions, and farmers is essential. Below are actionable policy recommendations aimed at improving pest management strategies in Bangladesh while ensuring environmental sustainability and food security:

Promote research and development of climate-resilient pest control solutions: The government should invest in research to develop pest-resistant crop varieties and climate-adapted biological control agents. Agricultural institutions should focus on breeding pest-resistant and climate tolerant crops, as well as identifying native biocontrol agents that can thrive under changing environmental conditions.

Strengthen integrated pest management framework: The government should establish policies that encourage the adoption of IPM, includes providing training and extension services to farmers on IPM techniques, including pest monitoring, biological control, and eco-friendly alternatives to chemical pesticides. Policymakers should also create incentives, such as subsidies or tax breaks, for farmers who adopt sustainable pest management practices and reduce pesticide usage.

Support sustainable agricultural practices: The government should promote agroecological and climate-smart farming practices through financial support, technical guidance, and public awareness campaigns.

Enhance climate-smart extension services and farmer education: Agricultural extension services should be strengthened to educate farmers about climate change impacts on pest dynamics and teach them adaptive pest management strategies. Training programs should include practical workshops on pest forecasting, biological control methods, and the use of climate-resilient crop varieties.

Implement early warning systems for pest outbreaks: The government should invest in the development of digital platforms that provide real-time pest monitoring and forecasts. This would allow farmers to take timely action, such as applying targeted biological controls or adjusting planting schedules, to minimize pest-related crop damage.

Promote public-private partnerships (PPP): Collaboration between the public and private sectors can help accelerate the development and dissemination of innovative pest management technologies. Public-private partnerships could also improve access to financing for smallholder farmers to adopt climate-resilient pest management practices.

Enforce stronger regulations on pesticide use: The government should enforce laws that limit the use of harmful pesticides and promote the safe handling, storage, and disposal of chemicals. Most farmers overuse insecticides indiscriminately, often applying excessive doses, yet still struggle with pest issues (Amin and Islam 2020). So strict regulations should be implemented to prevent the misuse of pesticides that contribute to pest resistance and environmental degradation.

Strengthen data collection and monitoring systems: To improve pest management strategies, the government should invest in data collection and monitoring systems that track pest populations, weather patterns, and the effectiveness of control measures.

Conclusion

Climate change poses significant challenges to pest management in Bangladesh, threatening agricultural productivity and food security. Rising temperatures, unpredictable rainfall, and extreme weather events disrupt pest life cycles and create favorable conditions for pest outbreaks, making traditional control methods less effective. To address these challenges, Bangladesh must adopt climate-resilient pest management strategies that integrate climate-smart agriculture and modified Integrated Pest Management (IPM) practices. These strategies should include climate-sensitive monitoring, enhanced biological control, and reduced reliance on chemical pesticides. Strengthening early warning systems and providing farmer education on adaptive pest management are also essential. Additionally, collaboration between local governments, NGOs, and agricultural stakeholders is crucial for creating effective policies and ensuring community engagement. By embracing these adaptive measures, Bangladesh can improve agricultural sustainability, reduce pest risks, and secure food production in the face of climate change.

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