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Climate-Smart Entomology: AI as a Farmer's Potential Ally

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Climate change is not merely altering weather patterns; it is reshaping the very biology and behavior of insects that interact with crops. In this evolving scenario, farmers are increasingly confronted with unpredictable pest outbreaks, new invasive species, and declining effectiveness of conventional pest control methods. Climate-smart entomology emerges as a necessary paradigm shift one that blends ecological understanding with adaptive technologies. Among these, Artificial Intelligence (AI) stands out as a transformative ally. Beyond being a tool, AI represents a decision-making partner that enhances farmers' capacity to anticipate, interpret, and respond to insect-related challenges. This article presents a more reflective and analytical exploration of AI in climate-smart entomology, emphasizing its practical relevance, socio-ecological implications, and future potential in sustainable agriculture.

Introduction

Agriculture has always been a delicate balance between human intervention and natural processes. Insects, as one of the most dynamic components of agroecosystems, often determine the success or failure of crops. However, climate change has disrupted this balance, creating conditions where pest populations thrive unpredictably. From a farmer's perspective, pest management is no longer a routine practice it has become a constant struggle against uncertainty. Traditional calendars for pest control are losing relevance as insects respond more to microclimatic variations than seasonal norms. In such a context, relying solely on experience or conventional knowledge may no longer suffice. Artificial Intelligence introduces a new dimension to this challenge. It does not replace the farmer's wisdom but augments it, offering insights derived from patterns hidden within complex datasets. AI transforms pest management from a reactive approach to a proactive and predictive system, aligning perfectly with the principles of climate-smart agriculture.

Climate Change and the Changing Face of Insects

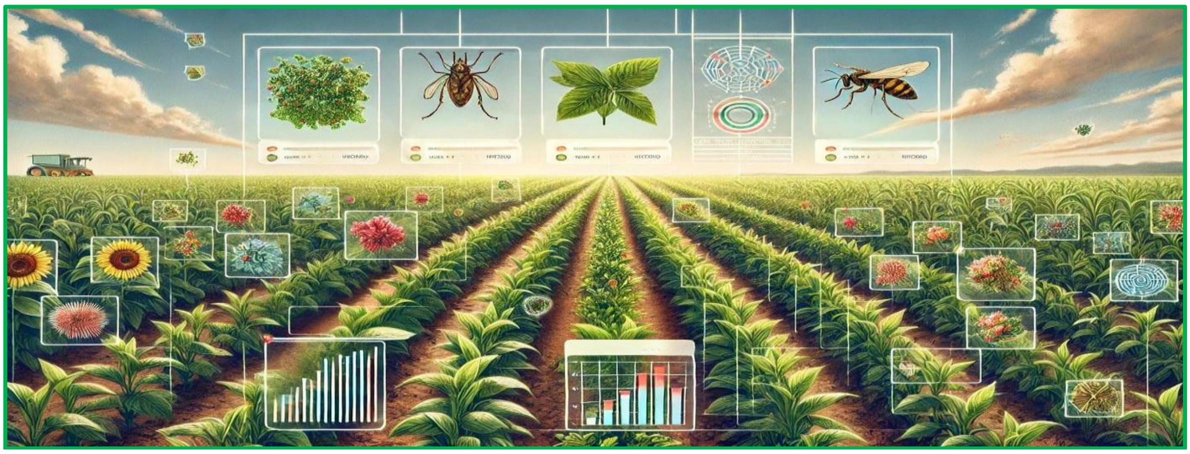
The relationship between climate and insects is deeply intertwined. Even slight variations in temperature can significantly influence insect metabolism, reproduction, and survival. As global temperatures rise, insects are not just increasing in number they are changing in behavior, distribution, and ecological roles. One of the most noticeable impacts is the geographical expansion of pests. Regions that were once unsuitable for certain insect species are now becoming favorable habitats. This exposes farmers to unfamiliar pests, often without established management practices. For instance, tropical pests are gradually moving into temperate zones, while local pests are becoming more aggressive. Another critical concern is the increase in the number of generations per year. Faster life cycles mean that pest populations can build up rapidly, overwhelming crops before farmers can respond. This intensification of pest pressure often leads to excessive pesticide use, creating a vicious cycle of resistance development and environmental degradation. Moreover, climate change disrupts the synchronization between pests and their natural enemies. Beneficial insects, such as predators and parasitoids, may not adapt at the same pace as pests, weakening natural biological control mechanisms. This imbalance further amplifies the vulnerability of agricultural systems.

Climate-Smart Entomology: A Conceptual Shift

Climate-smart entomology is not just about controlling pests it is about understanding and managing insect dynamics within a changing climate framework. It emphasizes adaptability, sustainability, and resilience. This approach recognizes that insects are not merely adversaries but integral components of ecosystems. Therefore, pest management strategies must aim to restore ecological balance rather than disrupt it further. It calls for a shift from chemical-intensive practices to knowledge-intensive systems. In this context, AI acts as an enabler of informed decision-making. It bridges the gap between complex scientific data and practical field-level actions. By integrating climate data, insect behavior, and crop responses, AI helps design strategies that are both effective and sustainable.

AI as a Cognitive Partner for Farmers





Artificial Intelligence, in the context of agriculture, should not be viewed merely as a technological upgrade. It represents a shift toward **augmented intelligence**, where human experience and machine learning complement each other. For farmers, especially smallholders, decision-making often relies on observation and intuition. AI enhances this process by providing real-time, evidence-based insights. For example, a farmer can use a smartphone application to identify a pest instantly, something that previously required expert consultation. AI also introduces the concept of anticipation in pest management. Instead of waiting for an outbreak, farmers can receive early warnings based on predictive models that analyze weather patterns and historical pest data. This proactive approach reduces crop losses and minimizes unnecessary interventions. Furthermore, AI democratizes access to knowledge. It brings advanced scientific tools to the fingertips of farmers, reducing dependence on centralized advisory systems. In doing so, it empowers farmers to become active participants in decision-making rather than passive recipients of recommendations.

Practical Applications in Climate-Smart Entomology

Intelligent Pest Surveillance

AI-powered surveillance systems use drones, cameras, and sensors to monitor pest populations continuously. These systems provide a level of precision and consistency that manual scouting cannot achieve.

Predictive Pest Forecasting

By analyzing climatic variables, AI models can forecast pest outbreaks with remarkable accuracy. This enables farmers to plan interventions in advance, reducing both economic and environmental costs.

Precision Pest Control

AI-guided systems ensure that pesticides are applied only where needed and in optimal quantities. This not only reduces input costs but also minimizes environmental contamination.

Integration with IPM

AI strengthens Integrated Pest Management (IPM) by optimizing the use of biological, cultural, and chemical methods. It ensures that interventions are timely, targeted, and sustainable.

Socio-Economic and Ethical Dimensions

While the technological benefits of AI are evident, its adoption raises important socio-economic questions. Will smallholder farmers have equal access to these technologies? Can digital tools be adapted to local languages and contexts? These questions are crucial for ensuring inclusive development. There is also the issue of data ownership. Agricultural data generated through AI systems must be managed responsibly, ensuring that farmers retain control over their information. Ethically, AI should be designed to support sustainable practices rather than promote excessive input use. The goal should be to enhance ecological balance, not disrupt it further.

Challenges in Real-World Implementation

Despite its potential, AI in climate-smart entomology faces several practical challenges. Infrastructure limitations, such as poor internet connectivity in rural areas, can hinder adoption. Additionally, the accuracy of AI models depends heavily on the quality of data, which may not always be available. Another challenge lies in bridging the gap between technology and user understanding. Farmers may require training to effectively use AI tools. Without proper capacity building, even the most advanced systems may fail to deliver desired outcomes.

Future Outlook: Toward Intelligent Agroecosystems

The future of climate-smart entomology lies in the development of **intelligent agroecosystems**, where AI seamlessly integrates with other technologies such as remote sensing, robotics, and biotechnology. Imagine a farming system where sensors detect early signs of pest infestation, AI models predict its spread, and drones execute targeted interventions all with minimal human intervention. Such systems are not distant possibilities but emerging realities. In the long term, AI could also contribute to ecological restoration by promoting biodiversity and strengthening natural pest control mechanisms. It has the potential to transform agriculture into a more resilient and self-regulating system.

Ms. Simran Mahapatra receives Best Poster Award at the International Symposium Organized by CCSA and SOADU, Bhubaneswar

Topic : CLIMATE SMART ENTOMOLOGY : AI AS A FARMER'S POTENTIAL ALLY

Ms. Simran Mahapatra (Ph.D. Scholar, Department of Entomology, FAS-SOADU) secured First Position in the Best Poster category presented under Theme 1: *Enhancing Resource Use Efficiency and Agricultural Productivity* at the International Symposium on *Artificial Intelligence in Shaping Agriculture and Allied Sectors for Sustainable Food Security*, held during 10–11 March 2026 at Bhubaneswar. The symposium was organized by the Centre for Climate Smart Agriculture (CCSA), Faculty of Agricultural Sciences (FAS), Siksha 'O' Anusandhan Deemed to be University (SOADU).

The achievement was accomplished under the esteemed guidance of **Dr. Prajna Pati**, Assistant Professor, SOADU, and **Dr. Raghu S.**, Scientist (Plant Pathology), Crop Protection Division, ICAR–National Rice Research Institute (NRRI), Cuttack. The poster was evaluated and presented by eminent dignitaries including **Prof. (Dr.) P. K. Nanda**, Vice-Chancellor, SOA; **Prof. R. K. Panda**, Director, Centre for Climate Smart Agriculture (CCSA); and **Prof. S. K. Rout**, Dean, Faculty of Agricultural Sciences (FAS), SOADU.

Conclusion

Climate change has introduced unprecedented complexity into insect–crop interactions, making traditional pest management approaches increasingly inadequate. Climate-smart entomology offers a holistic framework to address these challenges, emphasizing adaptability, sustainability, and resilience. Artificial Intelligence, as a farmer's potential ally, plays a pivotal role in this transformation. It enhances the ability to predict, monitor, and manage pest dynamics with precision and efficiency. More importantly, it empowers farmers with knowledge and confidence in an uncertain climate. However, the success of AI-driven entomology will depend on inclusive access, ethical implementation, and continuous learning. When combined with traditional knowledge and ecological principles, AI can truly redefine pest management—making it smarter, safer, and more sustainable.

GLIMPSE OF THE POSTER

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