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Artificial Intelligence in Agricultural Entomology: Revolutionizing Insect Pest Detection and Management

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Insect pests destroy an estimated 20–40% of global agricultural output every year, making early and accurate detection one of the most decisive factors in crop protection. Artificial intelligence (AI) is transforming agricultural entomology by shifting pest management from a reactive, calendar-based practice to a proactive, data-driven discipline. Convolutional neural networks (CNNs), vision transformers, Internet of Things (IoT)-enabled smart traps, unmanned aerial vehicles (UAVs), hyperspectral imaging, and mobile diagnostic applications now allow pests to be identified, counted, and mapped in near real time, often before visible crop damage occurs. This article reviews the major AI technologies used in insect pest detection, highlights field-level case studies, and discusses the benefits, current limitations, and future directions of AI-assisted entomology for sustainable agriculture.

Introduction

Insects have shared humanity's fields for as long as agriculture has existed, and managing them has traditionally relied on manual scouting, pheromone traps checked by hand, and pesticide schedules based on the calendar rather than actual pest pressure. These methods are slow, labour-intensive, and often detect infestations only after economic damage has already occurred. Between 20% and 40% of global agricultural output is lost annually to insect pests, a scale of loss that keeps broad-spectrum insecticide use high despite its environmental and health costs (Islam *et al.*, 2026). Climate change is compounding the challenge by shifting pest ranges, accelerating breeding cycles, and introducing new invasive species into regions that previously did not face them. Artificial intelligence, and in particular deep learning-based computer vision, is now being deployed across the pest-management value chain - from the trap in the field to the dashboard on a farmer's phone. By automating the most time-consuming step in integrated pest management (IPM), namely the identification and quantification of insects, AI allows interventions to be targeted, timely, and proportionate to actual risk rather than applied uniformly across a field.

The Scale of the Pest Problem

Insect pests remain one of the most persistent threats to global food security. Broad-spectrum chemical insecticides, though widely used, are frequently reactive, environmentally damaging, and economically inefficient once an infestation has already established itself (a comprehensive survey on AI-based pest detection, 2026). A shift toward proactive, precise, and sustainable pest management has been made possible by recent advances in deep learning, computer vision, and IoT, which together allow infestations to be flagged while populations are still small enough to manage with targeted treatment (a comprehensive survey on AI-based pest detection, 2026).

Computer Vision and Deep Learning in Pest Identification

The foundation of AI-driven entomology is computer vision paired with deep learning. Convolutional neural networks (CNNs) and, increasingly, vision transformers are trained on large libraries of insect images and learn to recognise a pest from its wing pattern, body shape, or colouration in a fraction of a second. Such systems can distinguish pests such as aphids from beneficial insects with roughly 95% accuracy and can classify life stages - larvae, pupae, or adults - directly from leaf or drone imagery (WiccaGrow, 2026). Purpose-built architectures are also emerging for specific crop-pest problems; for example, an enhanced YOLO-based model has been developed specifically for detecting insect pests in field crop imagery (Wang *et al.*, 2025, as cited in the deep-learning survey on crops, fisheries, and livestock). Reported accuracies can be very high under controlled conditions - one CNN developed for identifying aquatic insects achieved 98.7% accuracy - though performance often declines on noisy, real-world images and lightweight field devices, a gap that remains an active area of research (Islam *et al.*, 2026).

Smart IoT-Enabled Insect Traps

A practical application of this technology is the smart trap - a conventional pheromone or sticky trap fitted with a camera and a wireless connection. Rather than requiring a technician to visit and count insects manually every few days, the trap photographs itself continuously and transmits images to the cloud for automatic identification and counting. Commercial deployments already exist: one insect-trap manufacturer uses narrowband cellular connectivity to send pest-count data directly to a farmer's app, while other agri-tech firms have raised dedicated funding to further develop networked smart-trap systems (industry reporting on IoT-enabled insect traps, 2026). These systems, often paired with sensors tracking temperature and humidity - two major drivers of pest population growth - can flag rising risk before an outbreak occurs rather than after.

Drones, UAVs, and Remote Sensing

Ground-level traps and handheld scanners capture only part of the picture, which is why unmanned aerial vehicles (UAVs) and multispectral or hyperspectral imaging have become valuable additions to the AI entomologist's toolkit. A camera-equipped drone can survey hundreds of acres in a single flight - far more than any ground crew could cover in the same time - and hyperspectral sensors can detect subtle, early stress signatures in plant tissue that are invisible to the human eye and often appear before visible leaf damage (industry reporting on UAV-based crop monitoring, 2026). When this imagery is processed by a trained AI model, infestation hot-spots can be flagged while they are still small enough to be managed with a targeted, localised treatment instead of blanket spraying across an entire field.

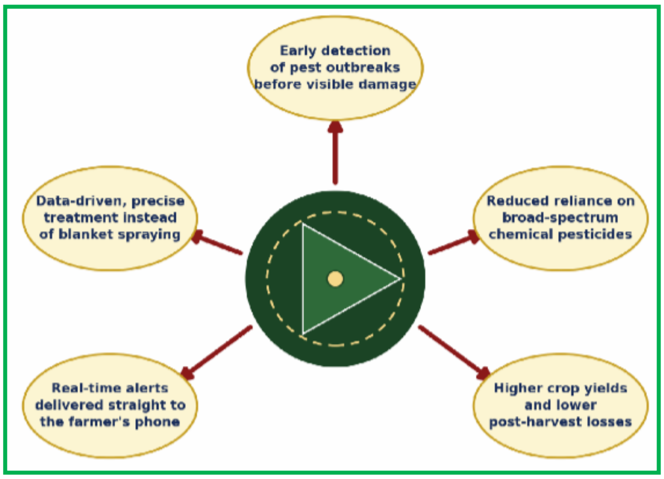

Figure 1. Key benefits of AI-assisted insect pest detection and management for farmers and the broader agri-food system.

Mobile Applications for Farmer-Level Diagnosis

Not every pest problem is caught by a fixed trap or a scheduled drone flight; often, a farmer is the first to notice chewed leaves or curling shoots. AI is supporting this pathway as well: mobile applications built on deep learning can now analyse a photograph or short video of a suspect insect and return a species-level identification within seconds, by comparing wing shape, colouration, and body structure against extensive reference databases (innovations in AI insect identification for 2026). For farmers in remote regions with limited access to trained entomologists, this kind of instant, expert-level diagnosis can be the difference between an early, low-cost intervention and the loss of an entire season's crop.

Field Deployment: A Case Study from Vietnam

These technologies are already moving from research papers into working farm tools. In Vietnam's Bình Định Province, a system known as T-Pest integrates AI, IoT, and geographic information system (GIS) data to monitor rice fields for both diseases and harmful insects. Using an enhanced YOLOv5-based model, the system identifies multiple rice diseases and monitors key pests such as the brown planthopper and stem borer, delivering real-time alerts through a web dashboard (TMA Solutions, 2026). The pilot has performed well enough that plans are already underway to expand the system nationwide, offering a practical illustration of how AI-based entomology can scale from a single province to an entire country's rice sector.

Benefits and Current Limitations

The benefits of AI-assisted pest detection are substantial: earlier detection allows for smaller, cheaper interventions; reduced reliance on broad-spectrum sprays protects pollinators and natural predators; and continuous monitoring replaces guesswork with data. Industry analysts report that AI-based pest detection can reduce pesticide costs by as much as 30%, a figure that matters both for farm economics and for environmental sustainability (WiccaGrow, 2026). These systems are not yet a complete solution, however. Models trained on clean, curated datasets can struggle with the noise of real field conditions - dust on camera lenses, overlapping foliage, and inconsistent lighting all reduce accuracy (Islam *et al.,* 2026). Poor rural connectivity can bottleneck cloud-dependent systems, and the upfront cost of drones, smart traps, and sensors remains a barrier for many smallholder farmers. Closing these gaps through lighter, on-device models and more affordable hardware is a major focus of current research.

Conclusion

Artificial intelligence is reshaping agricultural entomology from a reactive discipline into a proactive, precision-driven one. Computer vision, deep learning, IoT-enabled smart traps, UAVs, and mobile diagnostic tools together allow pests to be identified and acted upon earlier, more accurately, and with far less blanket chemical use than traditional scouting methods allow. Continued investment in affordable, field-robust AI systems - particularly for smallholder farmers in the regions most affected by pest-driven crop loss - will be essential to translating these research gains into measurable improvements in food security and sustainable farming.

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