Chapter 14

Beyond Pesticides: Sustainable Pest Management in AgTech

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Abstract

Agtech is highlighted in the review as a major driver for a sustainable future in food production as it explores sustainable food systems with an emphasis on social justice, ecological harmony, and financial sustainability. Crop breeding and production are made possible by the application of machine learning and advanced analytics in digital transformation for trend analysis. This technology empowers farmers and ensures customized products for consumers by predicting appropriate features and genetics for maximum crop output. A lack of workers, lower productivity, and economic difficulties threaten the agriculture industry. Increased production, resource conservation, and labor stability are the primary objectives of AgTech, a movement driven by investments, inventions, and entrepreneurial endeavors. Major agricultural input businesses' decrease in innovation, especially in seeds and crop protection products, is a serious issue for the agricultural industry as a whole because innovation is crucial for addressing the challenges brought about by population expansion. Scouting, pest identification, sampling techniques, spatially variable rate technologies, and integrated pest management (IPM) are covered in this chapter. It emphasizes the significance of precision and IPM in pest management. Technology-enabled agriculture, or "agtech," is necessary for solving problems along the value chain. In addition to facilitating access to modern resources, it lets farmers to monitor produce quality, utilize resources like water and agrichemicals efficiently, and obtain enhanced inputs. A lack of education and integration within integrated programs confronts biopesticides with issues such as inadequate understanding, individual testing, and uncertainties regarding affordability and efficiency. The development of biopesticides is being influenced by biotechnology, necessitating a thorough reorganization of the way government and private sectors collaborate. To acquire a better understanding of exposures and hazards, current regulations are being modified. The application of cutting-edge technologies, diverse approaches, and auxiliary devices like unmanned aerial vehicles (UAVs) for crop observation and yield maximization in farming is covered in this review.

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Keywords

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1. Introduction

With its numerous applications, agtech—a fusion of technology and agricultural methods—is transforming agriculture and strengthening productivity and prosperity [1]. The global food production sector is confronted with issues that call for cooperation between government, business, and technology in order to find sustainable solutions that increase productivity, enhance production capacity, minimize adverse environmental effects, and lower greenhouse gas emissions [2]. AgTech's digital revolution has encouraged data-centric, sustainable solutions while also influencing conventional approaches. Analyzing the drivers and barriers and emphasizing the necessity for stakeholders to implement digital methods with the objective to establish a more productive, eco-friendly, and efficient agriculture industry [3]. Technologies utilized in precision agriculture are redefining crop management and transforming the AgTech sector. Robotics promotes production and minimizes the demand for agrochemicals, while the Internet of Things (IoT) streamlines the distribution and collection of resources. Adopting digital transformation trends is crucial for farmers and food producers to drive agriculture towards unparalleled prosperity [4]. A transition from traditional innovation frameworks, consumer requirements, digital technology adoption, collaboration, and innovation promotion are all necessary for agricultural input enterprises to adapt to growing food demand and remain competitive in the industry [5]. Agtech operations are incorporating AI technologies in an effort to reduce operating costs, optimize resource usage, and address market imbalances. The incorporation of AI is further supported by growing affordability and accessibility of mobile connectivity, as well as the advancements in big-data analytics, computational capabilities, cloud-based storage solutions, and hardware efficiencies that have made AI commercially viable [6]. Agricultural solutions, especially pest management, are being revolutionized by AI and automation. Machine learning techniques provide excellent crop security decision-making at an affordable rate by facilitating the efficient detection and monitoring of pests [7]. Precision farming is increasing farm productivity by combining sensors, IoT, real-time data collection, and predictive modeling. Integrating sensors, IoT, AI, bigdata, and robotics, Agriculture 4.0, or digital agriculture, promises to transform India's food system cycle. Agriculture still stagnates behind industrial advancements [8]. An image of autonomous field robot is shown in figure 1 below. By changing agriculture from a statistical to a quantitative approach, the IoT has entirely transformed the industry, disrupting established agricultural procedures while presenting opportunities in the face of adversities [9].

2. Sustainable Pest Management

A sustainable food supply is required due to climate change and population expansion worldwide. Scientific and technological improvements have boosted the productivity of farmers and supply chain partners; nonetheless, to address the difficulties of today's agriculture, equivalent innovation is necessary [10]. Biological management is becoming a competitive alternative to pesticides, presenting concerns to farmers. With competitive price and environmental preservation, efforts should be made to encourage adoption. Owing to their ingrained worldview, farmers confront challenges [11]. Agri-food systems are progressively incorporating robotics and artificial intelligence (AI) for automating processes that have

Figure 1. Autonomous field robots

historically required human expertise [12]. The global market share of biopesticides, also known as biocontrol, has grown dramatically and currently stands at 10% worldwide. It is imperative that new herbicides be developed, however bioherbicides still make up a minor part of the market because of technical difficulties and cost concerns [13]. Crop yields and quality can be improved by employing biopesticides, which grow crops more quickly than chemical pesticides. Compared to chemical pesticides, they are less dangerous to non-target organisms, decrease chemical residues, postpone insect resistance, provide shorter field re-entry times, are biodegradable, and utilize agricultural raw resources [14]. Precision in Pest Management (PPM) focuses on microlevel control employing tools like GIS/GPS, Remote Sensing (RS), and Variable Rate Technology (VRT) for monitoring, prevention, and suppression. Integrated pest management (IPM) incorporates pest control into agricultural output [15]. Biopesticides and botanical pesticides are two examples of natural pest management technologies that are gaining popularity because of concerns about the toxicity and detrimental effects of synthetic agrochemicals on human health. Issues about consumers, compiling regulations, and managing resistance effectively are challenges in crop protection. Conventional chemical pesticides hurt the environment and make plant infections more resilient [16]. Food produced without residue is aided by the application of biopesticides in agriculture, however worldwide regulation must establish regulatory parameters. Small and medium-sized businesses require assistance from producers, researchers, and regulatory agencies [17]. Figure 2 below showcases different varieties of Biopesticides that can be applied for effective pest control, thus

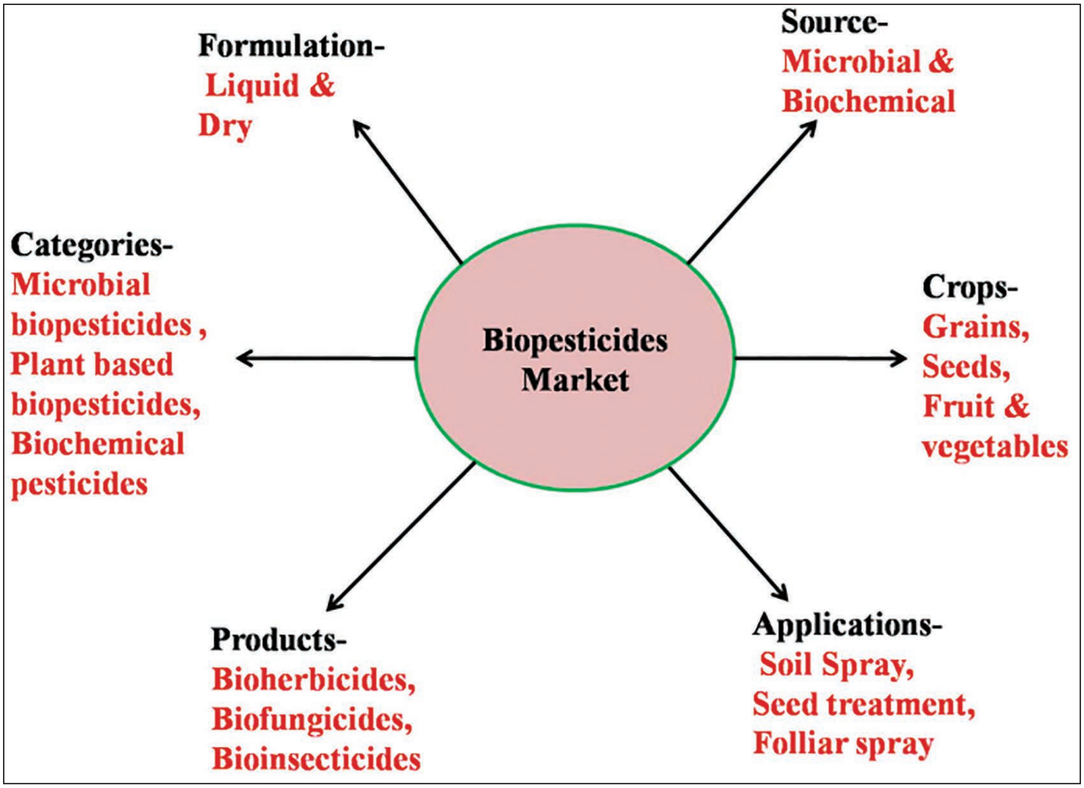

Figure 2. Various types of Biopesticides that can be employed for effective pest control

enhancing productivity and sustainability. Innovations in agricultural technology have been accelerated by digital technologies, which provide farmers with advantages such as cloud-based devices and sensors. Though independence and dependability are crucial for continuous output during emergencies, these solutions are the primary objective of scientific publications [18]. Leveraging visual data for safe path selection and navigation, research on autonomous robots for agricultural applications focuses on developing sensing, mapping, localization, trajectory planning, and obstacle avoidance techniques [19]. Agro-ecology and ag-tech are encouraging avenues that could enhance farming in the future. Agro-ecology prioritizes diversified planting systems, inadequate resource inputs, and indigenous knowledge, while agro-tech is applicable cutting-edge approaches for bettering the food chain. Though ag-tech has historically focused on large-scale agribusinesses, initiatives attempt to integrate both approaches, with a focus on small, resource-constrained farmers and a promotion of social progressivism [20]. AgriTech is transforming the agricultural industry by integrating cutting-edge approaches to sustainability, resource management, and food production. Robotics, hydroponics, precision farming, IoT devices, vertical farming, and hydroponics all optimize utilization of resources, while genetic engineering and biotechnology strengthen crop characteristics and resistance to pests and illnesses [21]. Modifications in the environment are driving a rising demand for innovation in agricultural technologies. With their extensive data collection on crop yields, soil health, and moisture content, farms are turning into data hubs. Analytics and big data assist farmers in making intelligent choices [22]. The emergence of autonomous field robots (AFR) in combination with autonomous vehicles is revolutionizing both the automotive and agricultural industries. User acceptability is essential for their success, but broad adoption is nonetheless dubious [23]. Big data is being employed by the AI and computer vision-driven food business for developing predictive models, dynamic training, and smart machines that operate in real time [24].

3. Recommendation

After thoroughly examining the literature and processes currently employed in Sustainable Pest Management in AgTech, we propose following recommendations.

- For the purpose of leveraging the potential of digital agriculture, public organizations should create databases, dynamic agroecosystem models, data analytics platforms, algorithms, and communication channels with farmers and industry.
- A multi-stakeholder strategy integrating government agencies, non-governmental organizations, universities, trade associations, and food producers is necessary for AgTech innovation. It needs to concentrate on emphasizing advantages, stimulating customers' interest, and fostering trust.
- Agronomists will become data analysts, AgTech businesses will turn technology enablers, governments will support digital infrastructure, and farmers will move into managerial positions—all of which will bring about huge changes to global agriculture.
- The agricultural sector needs to create revenue streams by employing AI and Big Data analytics to engage with farmers, offer real-time farm advisories, update based on dynamic agronomy, and create agricultural value chains.
- As the agricultural industry increasingly integrates robotics and people and the demands of climate change increase, it is imperative that responsible persons understand their responsibilities.
- To reconcile innovations in technology with environmental stewardship, social equality, and economic viability, sustainable agriculture necessitates the application of agroecological principles, ethical considerations, and community engagement.
- Venture capital investments in the agtech space are increasing in emerging nations because of reduced expenses, the promotion of scalable product and service enterprises, and additional financial inflows.

Conclusion

With an emphasis on food processing, farming, plant data analysis, smart irrigation, and next-generation farming, this article investigates the application of Industry 4.0 technologies, including computer vision and artificial intelligence (AI), in agriculture. Urban areas are being created on fertile land as a result of the growing global population's demand for food. To accommodate this demand, cutting-edge technologies are required. Despite advancements in techniques, there is still a communication breakdown between buyers, sellers, farmers, and retailers. In order to connect with small farmers in developing markets, agribusinesses are utilizing AI to develop practical business models. Funds from the private sector might be directed toward accomplishing the Sustainable Development Goals pertaining to agriculture as deal activity increases. A diverse network of stakeholders and supportive systems are necessary for technological innovation, which is essential for agricultural sustainability and resilience.

Farmers need to be encouraged to embrace new technology, and customers must have trust in their advantages and reliability.

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