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. Machine learning and advanced analytics are used in digital transformation for crop breeding and production, empowering farmers and ensuring 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. AgTech aims for increased production, resource conservation, and labour stability through investments, inventions, and entrepreneurial endeavours. The decline in innovation in major agricultural input businesses, particularly in seeds and crop protection products, is a significant issue for the industry. This chapter covers topics like scouting, pest identification, sampling techniques, spatially variable rate technologies, and integrated pest management. Precision and IPM are crucial in pest management, and technology-enabled agriculture (agtech) is essential for solving problems along the value chain, allowing farmers to monitor produce quality, efficiently use resources like water and agrichemicals, and obtain enhanced inputs. Biopesticides face challenges like inadequate understanding, individual testing, and affordability uncertainties due to inadequate education and integration within integrated programs. Biotechnology influences their development, necessitating a reorganization of government-private sector collaboration. This review discusses the modification of current regulations to better understand exposures and hazards, focusing on the use of advanced technologies, diverse approaches, and UAVs for crop observation and farming yield maximization.

Keywords

Agtech, Biopesticides, Microlevel Control, Precision in Pest Management, Biological Management, Bioherbicides

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1. Introduction

Agtech, a combination of technology and agricultural methods, is revolutionizing agriculture by increasing productivity and prosperity through its numerous applications [1]. The global food production sector faces challenges requiring collaboration between government, business, and technology to find sustainable solutions that boost productivity, increase production capacity, minimize environmental impacts, and reduce greenhouse gas emissions [2]. AgTech's digital revolution promotes sustainable, data-centric solutions, challenging traditional approaches. It highlights the need for stakeholders to adopt digital methods for a more productive, eco-friendly, and efficient agriculture industry [3]. Precision agriculture technologies are revolutionizing crop management and the AgTech sector. Robotics boosts production and reduces agrochemical demand, while IoT streamlines resource distribution. Adopting digital transformation trends is crucial for farmers and food producers to achieve 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].

Figure 1. Autonomous field robots

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, disrupted established agricultural procedures while presented 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 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]. Table 1 describes the technologies in sustainable pest management.

Figure 2 below showcases different varieties of Biopesticides that can be applied for effective pest control, thus 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

Table 1. Biopesticides and Digital Technologies: Transforming Sustainable Pest Management

	Topic	Details
1	Biopesticides Market Share	Biopesticides account for 10% of the global market, but bioherbicides remain underutilized due to technical and cost challenges [13].
2	Advantages of Biopesticides	Improve crop yields and quality, are safer for non-target organisms, leave fewer residues, biodegrade faster, and use agricultural raw materials [14].
3	Precision in Pest Management (PPM)	Utilizes GIS/GPS, Remote Sensing (RS), and Variable Rate Technology (VRT) to control pests at the micro level, integrated into IPM strategies [15].
4	Natural Pest Management Technologies	Botanical pesticides and biopesticides are gaining traction due to concerns over synthetic agrochemicals' toxicity and environmental impact [16].
5	Regulation and Support Needs	Global regulatory frameworks are essential to standardize biopesticide use; small and medium enterprises need support from producers and agencies [17].
6	Digital Technologies in Agriculture	Innovations like cloud-based tools and sensors empower farmers, ensuring dependability and independence for consistent production [18].

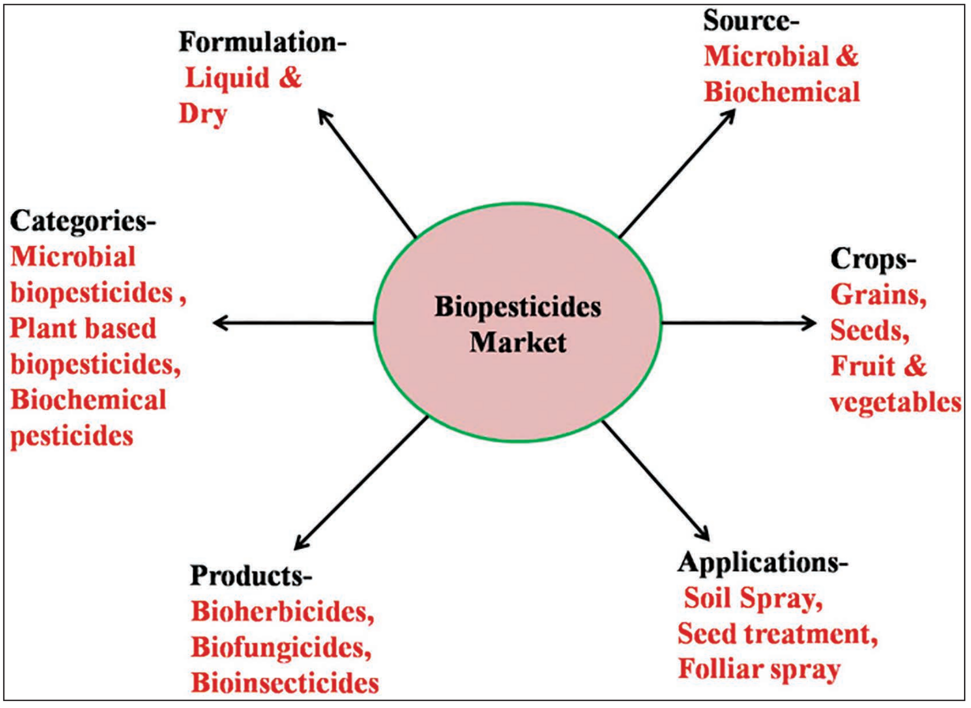

Figure 2. Various types of Biopesticides that can be employed for effective pest control

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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