CURRENT ADVANCES AND FUTURE PROSPECTS IN AGRICULTURE ENGINEERING

Abstract:

Agricultural engineering has essential role in handling the growing problems the agricultural sector is facing globally, including food security, sustainability, and environmental impact. This chapter explores the future trends in agricultural engineering, with a focus on emerging technologies and innovative practices that have the potential to transform conventional farming systems. It investigates key areas such as bee vectoring technologies, indoor vertical farming, precision agriculture, farm management software, livestock farming technologies, real-time kinematic (RTK) technology, farm automation, laser scarecrows, minichromosome technology, water management technology, robotics and automation, data analytics and agricultural informatics, biotechnology, and the integration of the Internet of Things (IoT) and blockchain in agriculture. By shedding light on these future trends, this chapter seeks to offer insightful information to researchers, stakeholders, and policymakers, assisting them to envision and embrace sustainable and technologically advanced solutions for the future ofagriculture which is also in consonance the Sustainable Development Goal 2 (SDG 2).

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Authors

Vatsala Tyagi
Department of Life Sciences
Gargi College. University of Delhi
Delhi, India
tyagi.vatsala11@gmail.com

Rashmi Saini
Department of Zoology,
Gargi College, University of Delhi
Delhi, India
dr.rashmisaini@gmail.com

I. INTRODUCTION

As the global population continues to surge, the agricultural sector faces unprecedented challenges to supply food to the growing global population while mitigating the environmental impact. Agricultural engineering, at the nexus of science, technology, and sustainability, has a crucial role in transforming traditional farming practices into modern, efficient, and sustainable systems. In this context, this chapter delves into the future trends of agricultural engineering, exploring cutting-edge technologies and innovative practices that hold the potential to revolutionize agricultural productivity, resource management, and resilience. The world is witnessing a paradigm shift in agricultural practices driven by advancements in science and technology. Precision agriculture, vertical farming, livestock farming, bee-vectoring technologies, the integration of robotics, data analytics, and biotechnology are reshaping the agricultural landscape. Moreover, the emergence of Internet of Things (IoT) and block chain technologies opens up new possibilities for optimizing supply chains and ensuring transparency in the agricultural sector. This comprehensive review aims to provide a holistic perspective on the potential of these future trends in agricultural engineering. By examining each key area in detail, we seek to shed light on the transformative impact of technological innovations and sustainable practices on global food security and environmental sustainability. By fostering a deeper understanding of these trends, this chapter endeavours to inspire collaborative efforts among researchers, policymakers, and stakeholders, driving the adoption of cutting-edge agricultural engineering practices to ensure are silient and food-secure future. The diverse technical interventions to make agriculture sustainable in accordance with Sustainable Development Goal-2 (SDG-2) have been summarized in Fig 1.

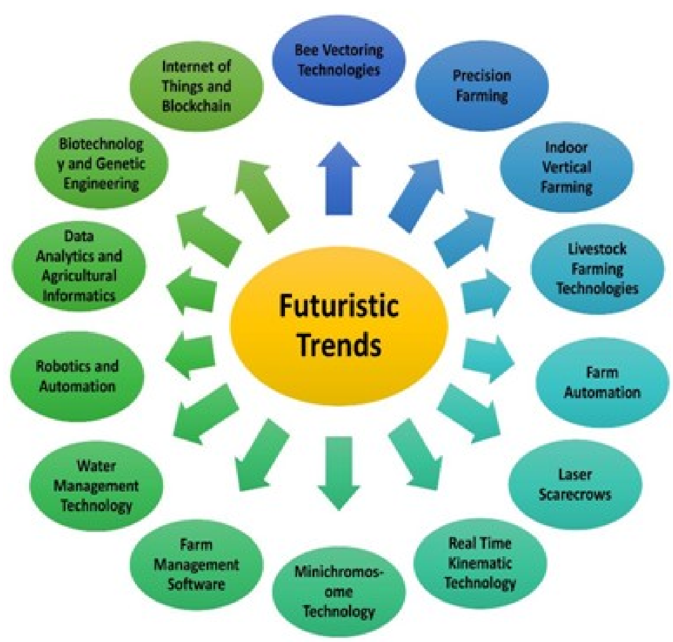

Figure 1: Futuristic trends of Agricultural Engineering

II. BEE VECTORING TECHNOLOGIES:

In the realm of U.S. crop production, honey bees play a pivotal role, contributing a staggering $20 billion in value. These tiny creatures are indispensable for human survival, and as a result, there is a growing emphasis on developing agricultural tools that safeguard bees and enhance their ability to pollinate. One noteworthy innovation in this area is employed by BVT (Bee Vectoring Technology), which utilizes commercially bred bees to implement targeted controls for crops by means of pollination. This approach replaces the need for chemical pesticides with an environmentally friendly system to protect crops. Unlike traditional methods involving water spraying or tractors, BVT's system operates differently. A bumblebee hive has been carefully built to allow bees to accumulate a little bit of pest control powder on their legs. As the bees travel throughout the fields, they naturally spread this powder, ensuring effective crop protection. The implementation of this advanced agricultural technology not only promotes sustainable farming but also leads to increased crop yields and enhanced soil quality. The BVT method may be successfully used on farms of any size, is adaptable, and ideal for a variety of crops including blueberries, sunflowers, apples, and tomatoes (Hokkanen et al., 2015).

III. PRECISION FARMING

Precision agriculture is a cutting-edge approach to managing agricultural resources effectively. It involves gathering, processing, and analysing data to provide valuable insights that help farmers enhance soil quality and increase productivity on their farms. Key agricultural decisions now heavily rely on data points derived from precision agriculture. This technology aims to optimize various aspects of farming, including resource usage efficiency, sustainability, profitability, productivity, and overall crop quality. At the core of this agricultural innovation is the use of big data, which assists in making informed management decisions. Farmers can precisely control variables that impact crop yields, such as moisture levels, soil conditions, and microclimates, in order to maximize output. Leveraging technologies like remote sensing systems, drones, robotics, and automation, and precision agriculture enhances crop health and optimizes the allocation of agricultural resources, ultimately leading to increased productivity. According to Grand View Research, the global precision farming market is projected to reach a value of $16.35 billion by 2028, experiencing a robust compound annual growth rate (CAGR) of 13.1%. This growth is expected to be driven by increasing government support for precision agriculture initiatives and the rising demand for efficient crop health monitoring techniques (Sharma et al., 2020).

IV. INDOOR VERTICAL FARMING

Indoor vertical farming presents a game-changing solution to the traditional limitations of rice cultivation, which typically yields between three and six tonnes per hectare. By adopting this innovative farming method, farmers can transcend these constraints and significantly enhance their crop production. Indoor vertical farming involves growing agricultural produce in stacked layers within a controlled and enclosed environment. The key to its success lies in the use of vertically mounted growing shelves, which efficiently utilize limited spaces to increase crop yield.

Notably, indoor vertical farms often eliminate the need for traditional soil-based cultivation. Instead, two primary methods are utilized:

1. **Hydroponics:** This gardening practice nurtures plants in water infused with essential nutrient solutions. By removing the dependency on soil, hydroponics promotes more efficient nutrient absorption and accelerated plant growth.

2. **Aeroponics:** In this approach, the crops' roots are suspended in the air, and water and nutrient emitters intermittently spray the roots. This method further optimizes nutrient delivery and encourages healthy plant development. Through indoor vertical farming, growers gain precise control over various environmental factors, including light exposure, temperature, water supply, and, in some cases, carbon dioxide levels. Such meticulous control enables farmers to create optimal conditions for their crops, resulting in healthier and more substantial yields.

   Additionally, indoor vertical farming offers a range of valuable benefits:

   - **70% Less Water Usage:** Compared to conventional farming, this method significantly reduces water consumption, leading to more efficient resource utilization and energy conservation.

   - **Reduced Labor Costs:** The integration of automation and robotic systems for tasks like harvesting and planting decreases labour requirements, streamlining farming operations and potentially lowering overall costs. Overall, indoor vertical farming represents a sustainable and technologically advanced approach that holds the potential to revolutionize agricultural practices, especially in areas with limited arable land or unfavourable growing conditions. By maximizing crop productivity and resource efficiency, this innovative technique offers promising solutions to future food security challenges (Mahmud et al., 2020).

V. LIVESTOCK FARMING TECHNOLOGIES

The agricultural landscape is witnessing a transformation through the emergence of data-driven livestock technologies, empowering farmers to revolutionize their farm management, enhance animal care, and ultimately boost productivity. Various innovations are redefining the way livestock farming is approached (Schillings et al., 2021), these are as follows:

1. **Automated Dairy Installations:** These advanced setups enable cows to be milked automatically without any human intervention. Moreover, milk sensors play a crucial role in monitoring the quality of the milk being produced.

2. **Automated Cleaning Systems:** Waste removal is made efficient with automated cleaning systems, which contribute to maintaining cleaner and disease-free environments for the livestock.

3. **Armenta's Non-Antibiotic Treatment:** For bovine mastitis, a costly cow disease causing annual losses of over $6 billion in Europe and U.S, Armenta introduces acoustic pulsetechnology (APT) as a non-antibiotic treatment (Leitner al., 2018).

4. **Automated Feeder Systems:** These systems offer tailored feeding mixtures to animals, considering their individual needs and providing the right amount of nutrition.

5. **Faromatics' Integration of Robotics, A.I., and Big Data:** Faromatics utilizes cutting-edge technologies like robotics, artificial intelligence (A.I.), and big data to significantly enhance farm productivity and animal welfare. By incorporating these innovative livestock technologies, farmers can make data-informed decisions that lead to more efficient and sustainable livestock farming practices. These advancements not only improve the well-being of the animals but also have the potential to boost agricultural industry productivity and profitability (Jagatheesaperumal et al., 2022).

VI. FARM AUTOMATION

Farm automation is a comprehensive integration of various technologies, including agricultural machinery, computer systems, chemical sensors, electronics, which are all examples of data management, aimed at optimizing equipment operations and decision-making while minimizing human errors and involvement. There are a number of advantages to this technology that have led to its widespread adoption, including, reduced labour time, higher yields, and efficient resource utilization. The use of robotic harvesters, drones, self-driving tractors, seeding, and weeding systems by farmers has totally changed the way they grow crops. By automating repetitive and mundane tasks, the technology liberates farmers to focus on more critical aspects of their work. Similar to other industries, automation in agriculture streamlines processes and saves time, as it reduces the need for manual intervention in various tasks. As a result, farmers can now allocate more time to spend with their families and engage in activities beyond the farm, enhancing their overall work-life balance (Zang and Pierce, 2013).

VII. LASER SCARECROWS

Protecting crops from pesky birds and rodents has been a longstanding challenge for farmers in open fields. In the past, traditional scarecrows were the primary defence, but advancements in technology have led to the adoption of high-tech solutions featuring motion sensors to deter these hungry invaders. Researchers from the University of Rhode Island made a remarkable discovery: birds are particularly sensitive to the color green. Leveraging this knowledge, they helped develop a laser scarecrow that emits green laser light. In sunlight, this light is undetectable to humans, yet it can travel up to 600 feet over a field, startling birds and deterring them from approaching and damaging crops. Initial tests of the laser scarecrow have shown promising results. By effectively reducing the bird population around farmlands, these devices have the potential to minimize crop damages by an impressive 70% to 90%. This innovative and environmentally friendly approach is proving to be a highly effective way to protect valuable crops from avian threats, ensuring better yields and a more secure harvest for farmers (Brown and Brown, 2020).

VIII. REAL-TIME KINEMATIC (RTK) TECHNOLOGY

Robert Salmon, an arable farmer from the UK, made a significant discovery when he decided to confine the movement of farming machinery to specific permanent lanes on his land. By doing so, he noticed a remarkable reduction in soil damage. Allowing farming machines to travel freely across the entire land often results in extensive soil compaction, affecting both drainage and soil structure. Farmers like Robert intended to change his 4,800-acre farm to a 12-meter controlled traffic system, where all agricultural machinery would use the same designated traffic lane, in order to address this problem. The implementation of a regulated traffic system, however, necessitates precise methods, which proved difficult to do with conventional GPS systems that lacked the necessary accuracy. The solution came in the form of RTK (Real-Time Kinematic) technology, offering centimetre-level accuracy in positioning. With RTK technology, farmers can accurately map their fields and ensure that vehicles strictly adhere to the same traffic lane consistently. The system transmits precise positioning information to tractors via radio signals, enabling them to maintain their trajectory while moving. This technological innovation not only preserves oil health and structure but also enhances overall productivity, allowing for increased output with fewer resources. By adopting the controlled traffic system facilitated by RTK technology, farmers like Robert Salmon made significant strides in sustainable agriculture, optimizing yields while minimizing the environmental impact on their land (Hefner et al., 2019).

IX. MINICHROMOSOME TECHNOLOGY

As the world's population and food demand continue to rise, farmers face the challenge of increasing crop production by at least 23% to sustain current living standards. However, one major obstacle is the significant loss of yields due to pest damage, which becomes increasingly concerning as global population growth continues. While genetically modified food has shown promise in boosting crop yields, it has also faced criticism in recent years. Studies have suggested potential links to allergic reactions and the inclusion of harmful toxins, raising concerns about human health risks. Additionally, genetically modified food production can interfere with natural biodiversity and also discharge toxins into the soil, posing environmental challenges. Fortunately, there is a promising solution on the horizon. Agricultural geneticists have developed minichromosomal technology, a ground breaking approach that enhances a plant's desirable traits without altering its genes. Small amounts of genetic material found in minichromosomes enable the selective enhancement of pest and drought resistance in crops without impairing the growth of the plant. Minichromosome technology enables genetic engineers to develop crops that require fewer fertilizers, insecticides, and fungicides, thereby minimizing the use of hazardous chemicals. Moreover, this technology enables bio-fortification, enhancing the nutritionalcontent of crops. By harnessing the potential of minichromosomes, farmers can foster sustainable agriculture practices that address the challenges of increasing food production while minimizing the negative impacts on human health and the environment (Cody et al., 2015).

X. FARM MANAGEMENT SOFTWARE:

Farming can be an overwhelming endeavour, especially for those managing large farms with limited assistance. However, in the digital age, the advent of Software-as-a-Service (SaaS) has brought a solution to this challenge— It functions as an integrated platform, providing information and real-time data similar to a digital check list. It helps farmers keep track of their day-to-day tasks and provides valuable insights for informed decision-making across all operations. One such solution is Farm ERP, an enterprise resource planning software tailored for farms. It empowers agricultural enterprises to streamline their processes and facilitates seamless collaborations. From managing procurement and supply chain to handling finances and processing, Farm ERP brings all essential aspects under a single, centralized hub. As internet-enabled devices become increasingly widespread, the capabilities of farm management software is likely to expand further. Experts predict substantial growth in this field, with Mordor Intelligence projecting a robust Compound Annual Growth Rate (CAGR) of 11.2% for the farm management software market in the decade leading up to 2026. With the aid of farm management software, farmers can better organize their operations, optimize efficiency, and effectively tackle the challenges of modern agriculture, ultimately contributing to increased productivity and success in the industry (Klerkx et al., 2019).

XI. WATER MANAGEMENT TECHNOLOGY

Water management technology plays a crucial role in transforming agricultural practices, particularly in dry lands with limited rainfall. Traditionally, irrigation has been the key method to provide water to arid regions, enabling farming in areas that would otherwise be unsuitable for cultivation. However, many farmers still employ outdated and wasteful flood irrigation techniques, reminiscent of practices use dover 4,000 years ago by the Mesopotamians. Unfortunately, flood irrigation not only squanders a significant amount of water, with over two-thirds of it going to waste, but it can also have negative impacts on plant growth. Excessive water can overwater plants, leading to stunted growth and reduced crop quality. Additionally, the excess water can carry harmful fertilizers and chemicals into nearby lakes and streams, contaminating precious freshwater sources. Thankfully, advancements in agriculture are offering more sustainable alternatives for providing water to crops. One such innovation is the N-Drip micro drip irrigation system. This technology allows water to be delivered slowly and directly to the roots of plants, creating an optimal environment for crop growth. By reducing water usage by up to 50%, N-Drip not only conserves this valuable resource but also improves the overall quality of the crops produced. With water management technologies like N-Drip, farmers can embrace more efficient and eco-friendly irrigation methods, promoting sustainable agriculture and responsible water usage while ensuring the successful growth of their crops (Patle et al., 2020).

XII. ROBOTICS AND AUTOMATION

The integration of robotics and automation is reshaping agriculture. This section investigates the potential of autonomous tractors, weeding robots, and drones in enhancing farm operations, as well as the challenges associated with their adoption (Krishnan et al., 2020).

XIII. DATA ANALYTICS AND AGRICULTURAL INFORMATICS

Leveraging Big Data, Data analytics and agricultural informatics play a crucial role in transforming agriculture. This section delves into the applications of big data, machine learning, and artificial intelligence in crop yield forecasting, disease detection, and decision-making for farmers.

XIV. BIOTECHNOLOGY AND GENETIC ENGINEERING

Enhancing Crop Potential- Biotechnology is a key driver of crop improvement. This section discusses recent trends in genetic engineering, gene editing techniques like CRISPR-Cas9, and their potential in creating crops with better features such as disease resistance and higher nutritional value.

XV. INTERNET OF THINGS (IOT) AND BLOCKCHAIN

Advancing Agricultural Systems IoT and blockchain technologies offer novel opportunities in agriculture. This section examines how IoT devices can enhance farm management and livestock tracking, while blockchain provides transparency and traceability in the agricultural supply chain (Torky and Hassanein, 2020).

XVI. CONCLUSION

Amidst mounting environmental concerns and growing fears of climate change, the urgency of sustainable farming has never been greater. The ever-expanding global population, coupled with wind ling land and water resources, poses a significant risk to the future of humanity. While political progress may seem slow and uncertain, agriculture technology start ups are taking proactive measures to address these challenges. Innovation in agriculture technology is revolutionizing the way we farm, offering solutions to create a more sustainable and secure future. Precision agriculture, genetics, agricultural automation, and water management advancements pave the way for smarter, safer, and more productive farming practices. Initiatives like Mass Challenge provide a platform for new start-ups in the Agtech (Agriculture Technology) industry to collaborate with rising talent. By connecting with experts, corporations, and communities in the agricultural sector, these start-ups can tap into the latest trends and cutting-edge agricultural technologies. This collaboration not only transforms their businesses but also holds the potential to shape the future of our world by promoting sustainable farming methods that are good for both the environment and the farmers. In this age of pressing environmental challenges, embracing innovative agriculture technology is a critical step towards ensuring a resilient and thriving future for generations to come. Through collective efforts and partnerships, the agriculture industry can drive positive change and contribute to a more sustainable and secure world.

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