Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 5, No.9, May : 2024

# ARTIFICIAL INTELLIGENCE IN SUSTAINABLE AGRICULTURE: ENHANCING EFFICIENCY AND REDUCING ENVIRONMENTAL IMPACT

**Dattatray Raghunath Kale,** Assistant Professor, Dept.Of Computer Science & Engineering, MIT Art Design and Technology University, Pune India.
**Dr.Jagannath Nalvade,** Associate Professor, Dept.Of Computer Science & Engineering, MIT Art Design and Technology University, Pune India.
**Pradnya S Randive,** Assistant Professor, Dept.Of Computer Science & Engineering, Modern Education Society's Wadia College of Engineering Pune, India.
**Dr.Sumit Hirve,** Assistant Professor, Dept.Of Computer Science & Engineering, MIT Art Design and Technology University, Pune India.

## ABSTRACT
A revolutionary strategy for tackling the problems of environmental sustainability and global food security is the application of artificial intelligence (AI) in agriculture. AI technologies that optimize agricultural practices, minimize resource consumption, and minimize environmental impacts include machine learning, computer vision, and predictive analytics. This study examines the numerous uses of AI in sustainable agriculture, such as resource management, pest and disease control, crop monitoring, and precision farming. The conversation focuses on the advantages and difficulties of implementing AI in agriculture, highlighting how it can improve productivity and sustainability in the field.

**Keywords**:
Artificial Intelligence, Sustainable Agriculture, Crop Monitoring

## I. Introduction
Despite the fact that 64% of India's cultivated area is dependent on the monsoons, India's agricultural production ranks second in the world. Approximately 85% of water is used for irrigation, however during that process, nearly 60% of the water is lost. Precision agriculture is "the use of current information technology to provide, process, and analyze multi-source data of high geographical and temporal resolution for the purpose of decision making and operations in the management of crop production," according to one definition of the term. This precise agriculture may result in an increase in crop productivity, a deterioration of the soil, more efficient use of water, a reduction in the amount of chemical fertilizer and pesticides used for cultivation, and the spread of modern farming practices that improve the quality, quantity, and cost of producing crops. By adding agriculture IoT solutions, the goal is to assist farmers in bridging the supply-demand gap, which may be accomplished by assuring high yields, maximizing profits, and minimizing negative impacts on the environment. Precision agriculture is a technique that uses the Internet of Things (IoT) technology to assure the optimal allocation of resources, hence increasing agricultural yields while simultaneously lowering operating costs [1,2,3]. The Internet of Things has several applications in precision agriculture, but the most important ones are crop water management, pest control and management, precise detection and nutrients management, and safe storage management.
In the twenty-first century, agriculture is faced with the twin challenges of reducing its environmental impact and supplying the expanding global population's food needs. Even though they are effective, traditional farming methods frequently result in substantial resource waste and environmental damage. In order to solve these problems, sustainable agriculture—which places a strong emphasis on resource conservation, a decrease in chemical inputs, and an improvement in ecosystem health—becomes essential.
Artificial Intelligence (AI) integration in sustainable agriculture offers a large potential to improve productivity and lessen environmental impact [1][2]. Artificial Intelligence (AI) has the potential to

enhance food production and supply chains, track soil conditions, identify pests and diseases, and raise crop yields [3]. Farmers are able to make data-driven decisions to support sustainable practices and guarantee food security in the face of population growth and climate change by utilizing AI tools such as drones, sensors, and predictive analytics. The goal of green artificial intelligence (AI) is to create ecologically friendly AI systems that will reduce the carbon footprint of AI technologies and help society move toward a more sustainable future. All things considered, the application of AI to sustainable agriculture not only increases output and efficiency but also significantly reduces environmental impact and fosters long-term sustainability.

Artificial Intelligence (AI) has the potential to significantly improve agricultural sustainability and efficiency in this regard. A variety of technologies, such as machine learning, computer vision, and predictive analytics, are included in artificial intelligence (AI) and can be used to optimize different agricultural practices. AI-driven solutions have the potential to completely transform the agricultural industry. Examples of these include precision farming, which enables the precise application of pesticides, fertilizers, and water, and sophisticated crop monitoring systems, which can identify health problems early on. Here figure 1 displays a graphical depiction of AI applications in agriculture.

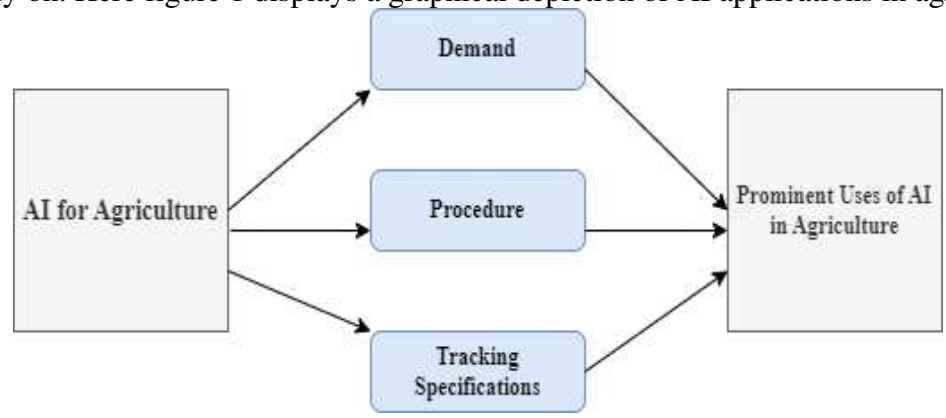


Figure1: Graphical depiction of AI applications in agriculture

Increasing productivity and lessening the environmental impact of farming practices are two benefits of integrating AI into agriculture. AI has the potential to greatly advance modern agriculture's sustainability objectives by enabling more efficient use of resources, reducing waste, and enabling proactive management of pests and diseases. Notwithstanding, there exist certain obstacles to the implementation of these technologies, such as the availability of data, the requirement for extensive training for farmers, and the need to attend to ethical and social concerns.

AI is transforming the agricultural sector by giving farmers access to cutting-edge tools. Technologies powered by AI can predict yield, assess crop health, and provide insights into field conditions. AI is useful for tracking livestock behavior, predicting crop yields, detecting pests, optimizing fertilizer use, and monitoring and controlling irrigation systems. Artificial Intelligence (AI) can also be used to evaluate soil data and make decisions about when and where to plant, as well as which seeds to use in different areas of a field. The size of the global AI market for agriculture was estimated at USD 1.25 billion in 2022 and is projected to grow at a compound annual growth rate (CAGR) of 26.7% from 2022 to 2032, when it will reach USD 13.33 billion as shown in figure2. A report by Allied Market Research details how the AI in Agriculture market is expected to grow at a compound annual growth rate (CAGR) of 26.7% by 2032. According to this research, the market for artificial intelligence in agriculture is anticipated to grow quickly as a result of things like the growing use of precision farming methods, the incorporation of IoT devices, and developments in machine learning and predictive analytics technologies in the agricultural industry.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 5, No.9, May : 2024

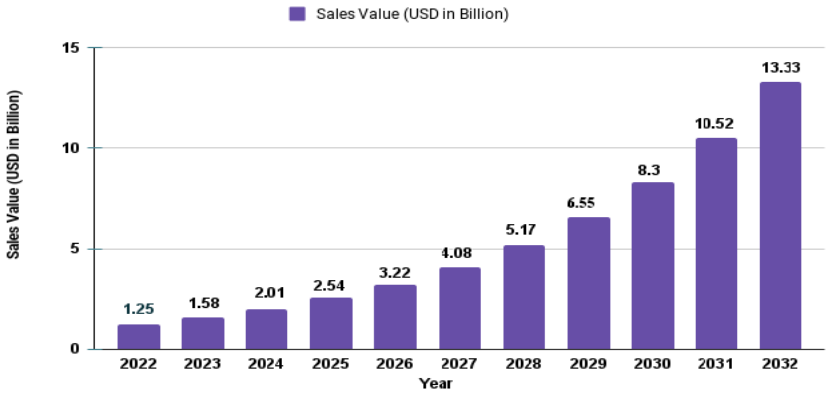


Figure2: Global AI in agriculture market size

This paper examines the numerous uses of artificial intelligence (AI) in sustainable agriculture, emphasizing the ways in which these tools can improve productivity while minimizing negative environmental effects. The advantages and difficulties of implementing AI in the agriculture industry are also covered, with a focus on how crucial it is for stakeholders to work together in order to fully realize AI's potential to support sustainable farming methods.

## II. Related Work

In sustainable agriculture, artificial intelligence (AI) is essential for increasing productivity and minimizing environmental impact [4] [5]. AI technologies have the potential to improve food production, track supply chains, distribute extra food, and assist circular economy projects—all of which will contribute to the creation of a more just and sustainable food system overall [6]. Furthermore, through lowering greenhouse gas emissions, protecting natural resources, and enhancing societal sustainability as a whole, AI can support environmental sustainability [7]. Farmers may monitor soil conditions, identify pests and diseases, and implement sustainable agricultural practices by utilizing AI tools such as drones, sensors, and biosensors. This will increase crop productivity [8]. In addition to addressing the issues brought on by population expansion and climate change, the use of AI in agriculture ensures food security and economic expansion.

The practice of precision agriculture entails managing crop variability through the use of technology. Based on research, precision agriculture powered by AI has the potential to greatly increase crop yields and decrease resource usage. AI in precision agriculture (PA) improves farming practices by utilizing technologies with cognitive capacities comparable to those of humans [9]. It entails using artificial intelligence (AI) to evaluate enormous volumes of data gathered from field sensors in order to automatically make wise decisions. To integrate data from multiple sensors for tasks like microclimate prediction and crop density per square meter, data fusion techniques like CNN-based algorithms are used [10]. Through the provision of accurate insights and recommendations based on real-time data analysis, artificial intelligence (AI) applications in Pennsylvania seek to enhance the productivity, sustainability, and profitability of farming operations. Farmers' confidence in AI solutions for precision agriculture can be increased by AI developers by tackling issues such as model transparency, accountability, fairness, and data privacy.

Applications of AI are essential to agricultural pest management and crop monitoring. Smart systems can efficiently identify and categorize pests by combining artificial intelligence (AI) with deep learning technologies, like convolutional neural networks (CNNs) [11]. By assisting in the early identification of dangerous insect species like the Brown Marmorated Stink Bug (BMSB), these systems allow for prompt crop quality protection measures [12]. Furthermore, AI-based methods improve pest monitoring's precision and effectiveness while decreasing the need for expensive and time-consuming traditional methods [13]. AI also makes it easier to predict pest outbreaks by taking into account a

variety of environmental factors, which results in timely pesticide applications and better pest management techniques. In general, AI technologies maximize crop health and reduce financial losses from pests, providing creative solutions for sustainable agriculture.
By utilizing machine learning techniques and real-time data, artificial intelligence (AI) plays a pivotal role in agricultural resource optimization. To improve fertigation, irrigation, and general farm management, artificial intelligence (AI) systems can evaluate crop data, soil properties, and weather patterns [14]. By predicting rainfall, scheduling irrigation, and effectively managing resources, these systems can increase crop yields while saving a substantial amount of energy, water, and fertilizer [15]. Agriculture becomes more sustainable when AI and machine learning models are combined to enable intelligent irrigation management [16]. Furthermore, by enabling automation and data-driven decision-making, AI technologies like robotics, cameras, and sensors are revolutionizing agriculture. Artificial General Intelligence (AGI) holds great promise for agriculture, providing improved crop yields and water scarcity as well as solutions to issues like climate change and food security.

## III. Existing System

### 3.1 John Deere's Precision Farming Solutions

John Deere provides a range of AI-driven precision farming instruments, such as self-governing tractors and unmanned aerial vehicles for monitoring fields. Utilizing machine learning algorithms, these systems maximize the efficiency and minimize the waste of resources during planting, watering, and harvesting processes.
Innovative technologies are incorporated into John Deere's Precision Farming Solutions with the goal of transforming agriculture[17]. These solutions help farmers distinguish between high-quality and low-quality grains during harvesting by addressing complicated issues like crop classification[18]. The company's emphasis on integrating artificial intelligence into conventional farm vehicles highlights the importance of AI in agriculture, which goes beyond autonomous driving to complex jobs like crop analysis[19]. Furthermore, through effective resource management and optimized farming inputs, the use of precision agriculture technologies significantly increases farm profitability while lowering environmental risks[20]. John Deere's precision agriculture initiatives demonstrate how cutting-edge technologies can be integrated to power efficient and sustainable food production systems, mirroring the industry's move toward smart agriculture [21].

### 3.2 IBM Watson Decision Platform for Agriculture

As with the platforms covered in the given contexts, the IBM Watson Decision Platform for Agriculture integrates multiple data sources to improve precision agriculture decision-making. Modern technologies like data analysis, image processing, and machine learning are incorporated into it[22]. In order to help with tasks like soil nutrient estimation and moisture content analysis, this platform makes it possible to collect, visualize, and analyze soil data from a variety of sources. In agricultural enterprises, it also improves operational efficiency, lowers expenses, and streamlines decision-making processes [23]. Improved productivity and sustainability are possible with intelligent agriculture thanks to the platform's intelligent features, which include remote control of agricultural systems, crop growth monitoring, and timely decision-making based on gathered data.

### 3.3 Blue River Technology

The goal of Blue River Technology, as it is presented in the research papers, is to transform agriculture through artificial intelligence. In the end, this technology improves sustainable agriculture in India by being a major factor in demand forecasting, machine learning, and precision farming [24]. Furthermore, farmers can now more easily receive vital information on grain storage technology thanks to the widespread use of Bluetooth wireless technology built into entry-level phones [25]. Water management in agriculture is crucial, and assessments of the Duero River Basin's water footprint emphasize the effects of green, blue, and grey water use on crop cultivation and sustainability [26]. Blue River Technology seeks to use creative solutions to address issues facing agriculture, such as the rising demand for food brought on by population growth.

John Deere's subsidiary Blue River Technologies employs AI to precisely control weeds. By using computer vision to identify and target weeds specifically, their "See & Spray" technology reduces the need for herbicides by up to 90%. This strategy reduces the use of chemicals and improves environmental health.

## IV. Proposed System

### AI-Enhanced Sustainable Agriculture Platform (AISAP)

AI technologies are integrated into an AI-Enhanced Sustainable Agriculture Platform (AISAP) to support sustainable agricultural practices[27]. Through the use of AI models, this platform can help with advanced crop care, weed control, resource management, and crop outcome prediction. In addition, AISAP can monitor soil conditions, identify diseases, and determine the best times to plant based on meteorological data using sensors and drones. Additionally, the platform can provide data-driven insights for decision-making, which can help to improve supply chains and productivity in the agricultural industry. Support from the government and inclusive policy interventions are essential to ensuring accessibility for small and marginal farmers. Overall, by addressing issues and boosting sustainability through creative and affordable digital inventions, AISAP represents a major step towards accomplishing Sustainable Development Goals in agriculture.

A comprehensive system for sustainable farming is to be created by integrating multiple AI technologies through the proposed AI-Enhanced Sustainable Agriculture Platform (AISAP). Key components include, Advanced Crop Monitoring: AISAP provides real-time insights into crop health, growth patterns, and potential problems by analyzing multispectral satellite imagery and drone footage using deep learning algorithms. Early disease detection, nutrient deficiencies, and pest infestations are all detectable by the system.

Precision Resource Management: In order to optimize irrigation and fertilization schedules based on current soil moisture data, weather forecasts, and crop requirements, the platform integrates AI-driven models. By ensuring effective use of fertilizers and water, this lessens waste and its negative effects on the environment.

Integrated Pest Management (IPM): AISAP has an AI-based integrated pest management (IPM) module that forecasts pest outbreaks based on past data and present circumstances. The system recommends focused interventions, reducing the use of pesticides, and encouraging environmentally friendly behaviors.

Autonomous Farm Machinery: To automate field operations, AISAP interfaces with autonomous machinery, including drones and tractors driven by artificial intelligence. These devices increase operational efficiency and lower labor costs by precisely completing tasks.

## V. Case Studies

This case study looks at how a commercial farm in California is using the AI-Enhanced Sustainable Agriculture Platform (AISAP). The 1,000-acre farm is mostly used to grow lettuce, tomatoes, and almonds. Over the course of one growing season, the impact of AISAP on crop yield, resource efficiency, and environmental sustainability was to be assessed.

The commercial farm chosen for this case study has been using both traditional and modern agricultural methods for more than 20 years. The farm is a perfect candidate to test the capabilities of AISAP because it faces difficulties with pest control, soil nutrient management, and water scarcity. The following results observes,

1. Crop yield increased by 15% overall after AISAP was put into place as opposed to the previous growing season.
2. Water consumption was reduced by 25% as a result of precision irrigation. During the course of the season, the farm saved about 500,000 gallons of water by optimizing irrigation schedules based on real-time data.

3. The IPM strategy powered by AI cut down on pesticide use by 40%. Early disease and pest identification made it possible to respond quickly and precisely, reducing the need for broad-spectrum chemical treatments.
4. A 20% decrease in total input costs was achieved. Reduced use of chemicals and water, along with increased operational effectiveness from autonomous machinery, resulted in savings.
5. A smaller environmental footprint resulted from water conservation and chemical usage reductions. Local biodiversity and ecosystem health were enhanced by healthier soil conditions and reduced chemical runoff.

## VI. Future Directions

**6.1 Strengthening Interoperability and Data Integration** Improving data integration from multiple sources, such as IoT devices, satellite imagery, and weather stations, should be the main focus of future research. Better data format standardization and improved interoperability amongst various AI systems will enable smoother information flow and more precise decision-making.

**6.2 AI Algorithm Advancement** It is imperative to develop more advanced AI algorithms that can manage intricate agricultural scenarios and offer more accurate recommendations. This involves creating algorithms that can adjust to shifting environmental conditions and enhancing machine learning models for increased prediction accuracy.

**6.3 Increasing Accessibility Worldwide** AI technology accessibility should be prioritized, particularly for smallholder farmers in developing nations. This entails creating affordable solutions, offering guidance and assistance, and encouraging the exchange of knowledge.

## VII. Conclusion

Artificial Intelligence has the potential to transform sustainable agriculture by improving productivity and lessening its environmental impact. The suggested AI-Enhanced Sustainable Agriculture Platform (AISAP) shows notable gains in environmental sustainability, resource optimization, and crop yield. In order to ensure environmental preservation and global food security, a sustainable agricultural future will require ongoing research and development in addition to addressing ethical and social issues.

## References

[1] Helen, Onyeaka., U, Nwauzoma., Taghi, Miri., Ogueri, Nwaiwu., Adenike, A., Akinsemolu. (2023). Using Artificial Intelligence to Tackle Food Waste and Enhance the Circular Economy: Maximising Resource Efficiency and Minimising Environmental Impact: A Review. Sustainability, doi: 10.3390/su151310482
[2] Rashmi, Mathur. (2023). Artificial Intelligence in Sustainable Agriculture. International Journal For Science Technology And Engineering, doi: 10.22214/ijraset.2023.54360
[3] Akriti, Taneja., Gayathri, Nair., Somesh, D., Sharma., Anet, Režek, Jambrak., Elena, Roselló-Soto., Francisco, J., Barba., Juan, Manuel, Castagnini., Noppol, Leksawasdi., Yuthana, Phimolsiripol. (2023). Artificial Intelligence: Implications for the Agri-Food Sector. Agronomy, doi: 10.3390/agronomy13051397
[4] Helen, Onyeaka., U, Nwauzoma., Taghi, Miri., Ogueri, Nwaiwu., Adenike, A., Akinsemolu. (2023). Using Artificial Intelligence to Tackle Food Waste and Enhance the Circular Economy: Maximising Resource Efficiency and Minimising Environmental Impact: A Review. Sustainability, doi: 10.3390/su151310482
[5] Environmental sustainability with artificial intelligence. EPRA international journal of multidisciplinary research, doi: 10.36713/epra13325
[6] Dr., Anil, Kumar, Pandey. (2023). Development and deployment of green artificial intelligence. International journal of mathematics and computer research, doi: 10.47191/ijmcr/v11i4.03
[7] Rashmi, Mathur. (2023). Artificial Intelligence in Sustainable Agriculture. International Journal For Science Technology And Engineering, doi: 10.22214/ijraset.2023.54360

[8] Vivek, Raj., Cynthia, Xavier, De, Carvalho. (2023). A Perspective on the Application of Artificial Intelligence in Sustainable Agriculture with Special Reference to Precision Agriculture. SDMIMD journal of management, doi: 10.18311/sdmimd/2023/33006
[9] Gardezi, Maaz, et al. "Artificial intelligence in farming: Challenges and opportunities for building trust." Agronomy Journal (2023).
[10] Singh, Vatsala, and Gulab Singh. "Development of AI Enabled Solution for Efficient Feature Enrichment from Multiple Data Sources: An Application in Precision Agriculture." 2023 International Conference on Artificial Intelligence and Applications (ICAIA) Alliance Technology Conference (ATCON-1). IEEE, 2023.
[11] Pendo, John, Mahenge, Michael., Mkwazu, Hussein., A., S., Camilius., Raphael, Madege, Richard., Mwaipopo, Beatrice., Maro, Caroline. (2023). Artificial intelligence and deep learning based technologies for emerging disease recognition and pest prediction in beans (phaseolus vulgaris l.): A systematic review. African Journal of Agricultural Research, doi: 10.5897/ajar2022.16226
[12] Amin, Kargar., Mariusz, P., Wilk., D, Alejandro, Zorbas., Michael, T., Gaffney., Brendan, Q'Flynn. (2022). A Novel Resource-Constrained Insect Monitoring System based on Machine Vision with Edge AI. doi: 10.1109/IPAS55744.2022.10052895
[13] Rahman, Shaik Moizur, and Gollapelly Ravi. "Role of artificial intelligence in pest management." (2022): 64-81.
[14] Ishimwe, Viviane. (2023). AI Based Real-Time Weather Condition Prediction with Optimized Agricultural Resources. European journal of technology, doi: 10.47672/ejt.1496
[15] Ahmed, Karmaoui. (2022). Network Analysis on Artificial Intelligence in Agriculture, a Bibliometric Review. doi: 10.1007/978-3-031-15420-1_20
[16] Guoyu, Lu., Sheng, Li., Gengchen, Mai., Dajiang, Zhu., Lilong, Chai., Haixing, Dai., Ning, Liu., Rui, Xu., Daniel, J, Petti., Changying, Li., Tianming, Liu. (2023). AGI for Agriculture. arXiv.org, doi: 10.48550/arXiv.2304.06136
[17] Mérta, Alexy., Tamás, Haidegger. (2022). Precision Solutions in Livestock Farming – feasibility and applicability of digital data collection. doi: 10.1109/ICCC202255925.2022.9922883
[18] (2022). Precision Solutions in Livestock Farming – feasibility and applicability of digital data collection. doi: 10.1109/iccc202255925.2022.9922883
[19] Pranoday, Pramod, Dingare. (2023). Precision agriculture technology. doi: 10.1016/b978-0-443-18953-1.00013-1
[20] Tekla, S., Perry. (2020). John Deere's quest to solve agricultures deep-learning problems - [Spectral Lines]. IEEE Spectrum, doi: 10.1109/MSPEC.2020.8976885
[21] Olaf, Deininger. (2022). Precision Farming für alle. Agrarzeitung, doi: 10.51202/1869-9707-2022-17-016
[22] Flavio, Piccoli., S., Locatelli., Raimondo, Schettini., Paolo, Napoletano. (2023). An Open-Source Platform for GIS Data Management and Analytics. Sensors, doi: 10.3390/s23083788
[23] Supunya, Swarnakantha., Bhagyani, Chathurika., K., V., Weragoda., W., M., I., K., Bowatte., E.V, Thalawala., Madhuri, Bandara. (2022). Decision-Making Platform for SMART Plantation Agriculture Using Machine Learning and Image Processing. doi: 10.1109/i2ct54291.2022.9825063
[24] Suraj, Panpatte., C., Ganeshkumar. (2021). Artificial Intelligence in Agriculture Sector: Case Study of Blue River Technology. doi: 10.1007/978-981-15-9689-6_17
[25] Dieudonne, Baributsa. (2022). Potential of Bluetooth Wireless Technology as a Tool for Agricultural Extension. Journal of agricultural science, doi: 10.5539/jas.v14n12p28
[26] Á., De, Miguel., M., Kallache., Eloy, García-Calvo. (2015). The Water Footprint of Agriculture in Duero River Basin. Sustainability, doi: 10.3390/SU7066759
[27] Rashmi, Mathur. (2023). Artificial Intelligence in Sustainable Agriculture. International Journal For Science Technology And Engineering, doi: 10.22214/ijraset.2023.54360