

Artificial Intelligence in Agronomy: Transforming Crop Management for Sustainable Agriculture

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Agriculture is becoming more and more challenging due to climate crisis, soil depletion, scarcity of water, rising production expenses, and so on. In this regard, artificial intelligence (AI) provides a solution that allows farmers to enhance their farming processes with the help of data-driven decisions. Owing to machine learning, computer vision, remote sensing, and IoT technologies, AI can help in precision nutrient management, smart irrigation, weed mapping, crop monitoring, and forecasting. Thus, it is obvious that the introduction of AI technologies allows farmers to make their agriculture more sustainable, as these technologies enhance resource utilization efficiency, reduce expenditure, and ensure sustainable agriculture performance. Nevertheless, the problems associated with expensive introductory technology, the low rate of digitalization, and poor data quality remain in existence.

Key words: Artificial Intelligence, Agronomy, Precision Agriculture, Machine Learning, Crop Management, Sustainable Agriculture

Introduction

Agronomy studies the cultivation of plant crops, the condition of soil, and the provision of quality irrigation and fertilizer to plants. Traditional agriculture is based mainly on farmers' observations in the field and expert agronomic prescriptions. But the current climatic situation and properties of soil and crops demand thinking and acting more accurately and faster.

Artificial intelligence is based on the ability of the computer to analyze the information. The use of machine learning, deep learning, and computer vision for the agricultural industry is widely studied at the moment. Combined with satellite imagery, climate data, soil sensors, and geographic information systems, AI technologies enable agronomist to establish localized crop management systems and increase the efficiency and sustainability of agricultural practices.



Most Important Applications of AI in Agriculture

Precision Nutrient Management: Computer algorithms can combine a number of elements such as soil testing results, crop development data, and historical output records, in order to optimize the amount and type of fertilizer. Geographic nutrient management helps introduce improvements in fertilizer usage and avoid over-fertilization and maximize nutrient management. The introduction of AI diagnosis should be combined with soil testing data and field experimentation, so as to achieve the reliable results.

Smart Irrigation Management: Artificial Intelligence helps process data about soil moisture, weather, plant growth state, and evaporation, which is essential for creating an optimal irrigation plan. About the agricultural university that has been explored the important sector. Sensor systems allow the exact limiting the time and amount of watering.

Weed Identification and Control: In the process of employing computer algorithms, data concerning different factors like soil testing results, changes in crop growth and development, climate change effect, and previous output is used to make decisions about the kind and amount of fertilizer applied. The use of geographically specific nutrient management enables better use of fertilizers and avoidance of large losses of nutrients. AI diagnosis is necessitated by the necessity to combine soil testing and testing and field experiments.

Smart Irrigation Management: The use of AI enables the use of data connected to soil moisture, climate forecast, crop development phases, and evapotranspiration for aiming towards effective irrigation scheduling. The application of various sensor systems allows establishing precise timing and quantity of irrigation.

Prediction of Crop Growth Throughout Yield: Time series data analysis allows machine learning models to use data about previous years' crop production, amount of rainfall, temperature, soil features, crop's sowing dates, and satellite data to get estimates of crop productivity. Yield estimation can be used to perform harvesting as well as storage, marketing, and production planning. The accuracy of predictions would depend on the quality of a data set used for predicting yield as well as validation of the model used to carry out estimations.

Conceptual Framework Related to Crop Management Using AI

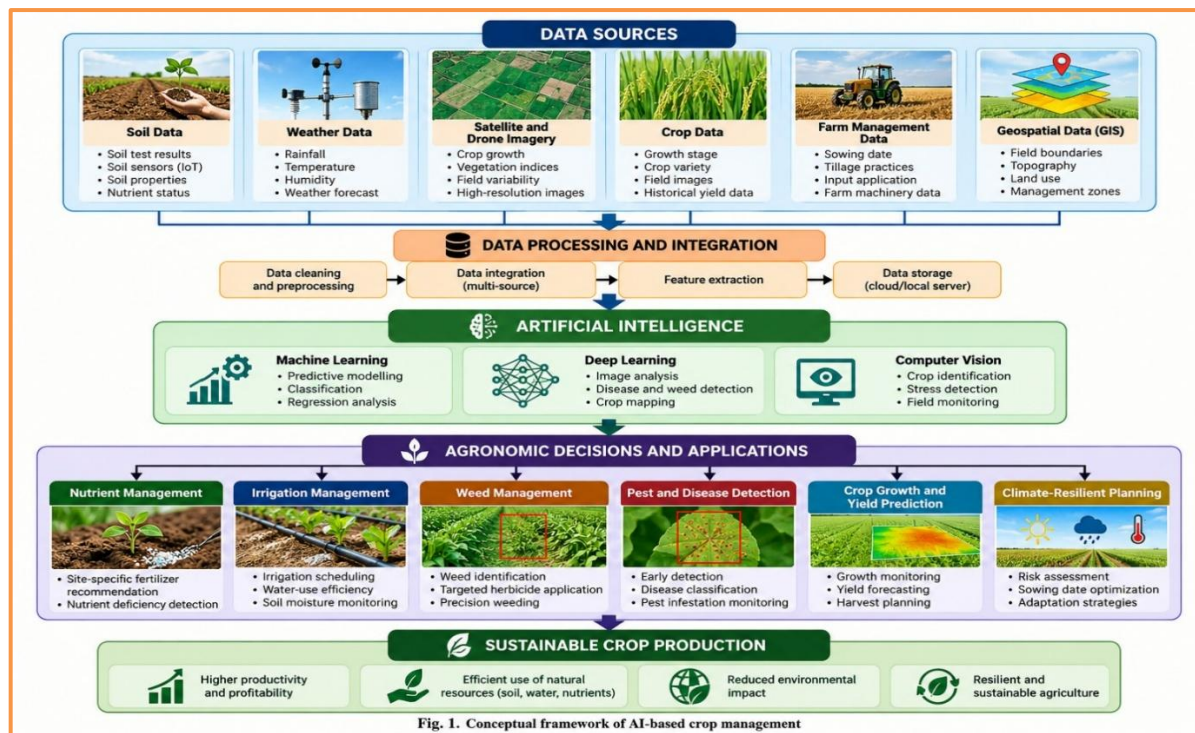


Fig. 1. Conceptual framework of AI-based crop management

AI crop management follows a framework of systematically gathering agricultural information, processing it into useful data, and then applying AI technologies to act on that data by making decisions which can later be checked against reality. Furthermore, different

types of data form the base for this framework. These data types include information on the soil, weather, crop and data gathered by means of satellite and drone technologies. The data are then subjected to various data analysis techniques including machine learning, deep learning, and computer vision.

AI in Sustainable Agriculture

Artificial intelligence plays a major role in sustainable agriculture as it ensures accuracy and timing in the execution of agricultural practices brought about by AI involvement. For example, investing in AI technology for nutrient management reduces the amount of chemical fertilizer lost, and implementing modern irrigation systems can also increase water efficiency. Furthermore, AI makes weed and pest management much more efficient, thus avoiding unnecessary chemical application. Finally, due to accurate weather prediction, AI improves the adaptation of farmers to climate change. Nevertheless, it is important to remember that the success of AI in achieving everything mentioned above depends on how accurate the AI recommendations are and how well they are executed. AI must be used only as a complementary means to reliable methods of agriculture, such as crop rotation, conservation agriculture, integrated nutrient management, and integrated pest management.

Table 1. Applications of AI in agronomy and their potential benefits

Application	Data Used	Potential Benefit
Nutrient management	Soil tests and crop data	Improved fertilizer efficiency
Irrigation management	Soil moisture and weather	Better water management
Weed detection	Field and drone images	Targeted weed control
Crop health monitoring	Plant images and vegetation indices	Early stress detection
Yield prediction	Historical yields and weather	Improved crop planning
Precision farming	GIS and sensor data	Site-specific management

Source: Author-developed synthesis.

Challenges and Future Prospects

The utilization of AI technology in agriculture encounters numerous difficulties such as huge initial cost, the absence of internet access, the lack of digital education, and absence of local representative data. Small farmers might be unable to utilize modern devices and internet-based platforms. Additionally, another issue is the confidentiality of information and the trustworthiness of AI recommendations. The future development would rely on the reduction of the cost of technology, the development of local language agricultural advisory tools, cost-effective agricultural datasets, and digital platforms for farmers.

Conclusion

The use of artificial intelligence in agriculture enables it to expand its operations and successfully implement advanced practices such as the effective use of nutrients, smart irrigation, weed detection, plant health monitoring, and yield prediction. Many agricultural data can be analyzed by means of advanced methods and technologies in order to better use resources and make the right decisions when it comes to organization of farming activities. Nonetheless, AI can be used only if a sufficient amount of reliable data is collected and correctly validated, technologies are affordable, and farmers are properly trained. AI must function as a tool that aids farmers in their decision-making rather than as a replacement of any sort.

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