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REVIEW ARTICLE

AI-Driven Innovations in Smart Farming: Transforming Agriculture Practices

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ABSTRACT
Agriculture, which is an essential component of human existence, is presented with a number of challenges that are brought about by the growth of the human population, the depletion of resources, and the diversity in climates from season to season. The inclusion of artificial intelligence into traditional agricultural practices has resulted in the creation of the concept of smart farming, which is a response to the incorporation of AI into agricultural operations. This paradigm shift toward the inclusion of technology, in particular via technologies such as machine learning, holds immense potential in terms of increasing the agricultural sector's capability to preserve sustainability and ensure food security when it comes to the provision of food. An investigation of the many uses of AI in agriculture is presented in this research study. These applications include precision farming, predictive analytics, automated equipment, and decision support systems. This paper investigates the advantages, disadvantages, and possible future applications of AI in smart agriculture. It highlights the potential of these technologies to solve global food security concerns and to assist sustainable agricultural practices.
Keywords: *Artificial Intelligence, IoT, Smart Agriculture, Crop Management, Irrigation method.*

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INTRODUCTION

In a broad sense, the word "innovation" is applied in the context of the technical development. Whatever the case may be, it has been expanded to include any and all changes that may occur. By bridging these conceptions that an innovation is a thought, protest, or behavior that seems to be fresh or an improvement over the one that is already being used by people from a social context, we provide an alternative. The real trick is the component that comprises the focal component of an invention, and it often shows up in a material frame, which is the second element of it. Agriculture is not about cultivating crops and managing them for the sake of personal use and some market consumption. It has evolved into a complicated process that involves regulating the environment as well as the many forces that either support or oppose the output. As a result of these considerations, farmers have been compelled to advance agriculture by a significant margin in order to satisfy the demand and the requirement. This has only been achieved as a result of technology advancements and technical breakthroughs, which have been assisting farmers in the development of the most effective contemporary agricultural techniques [1].

In the 21st century, the only thing that can be noticed is change, whether it be in the circumstances of the climate, in the requirements and demands of humans, or in the life cycle. Unseasonal climate swings are also a factor. The farmers might be forced to endure intolerable losses and poor revenues as a result of their agricultural activity if these dangers are allowed to continue. A consequence of this is that farmers are losing interest in the agricultural work they do, and as a result, they are quitting the business. Utilizing current research and technology development should be a part of agricultural operations in order to overcome these challenges and increase productivity using the land that is already available for agricultural purposes. One of the primary goals of this study is to identify a method that is more effective in dealing with crop diseases, agricultural pests, and pests. This research study present the smart farming innovation like crop monitoring, irrigation management, weather forecasting and forecasting of groundwater and dam reservoir levels methods by using the AI technology.

AI IN AGRICULTURE: AN OVERVIEW

Conventional agriculture has used many AI technologies to address issues. These difficulties include diagnosing weeds, illnesses, and pests. Machine learning requires laborious feature extraction, classification, and image preparation. Due to the growing number of agricultural illnesses and pests and the similarities in their visual features, it is a difficult procedure to identify the individual characteristics of the many insects and diseases that affect crops [2]. The various areas of the agriculture where the AI is used are shown in the figure 1 and discussed in the next sections.

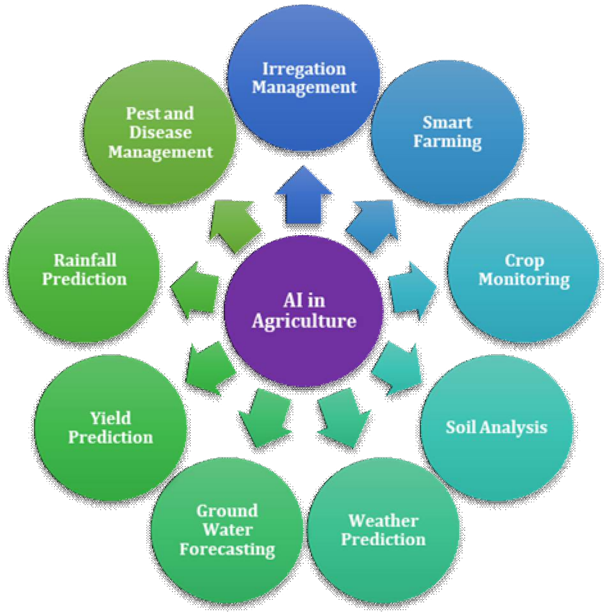

Figure 1: Uses of AI in Agriculture field

Smart Farming

In order to meet the issues that are associated with agricultural production, such as those pertaining to productivity, environmental impact, food security, and sustainability, smart farming is very necessary. For the purpose of addressing these issues, it is required to conduct an analysis and get an understanding of the agricultural ecosystems, which need continuous monitoring of a variety of factors. Smart farming generates vast volumes of data, which must be stored and analyzed in real time for some processes. Some procedures need this. New scientific disciplines have emerged, such as agri-technology and precision farming, which are commonly referred to as digital agriculture. These fields make use of data-intensive methods to increase agricultural output while simultaneously reducing the effect that agriculture has on the environment. The data that is created by contemporary farm operations provides a variety of sensors that provide a better knowledge of the operational environment (which is an interplay of dynamic crop, soil, and weather variables) and the operation itself (machinery data), which ultimately results in decisions that are more accurate and can be made more quickly [3].

Since quite some time ago, the agricultural industry has been significantly impacted by the introduction of digital technology. In light of this new development, the notions of smart farming and precision agriculture may be accurately described. The use of agricultural machinery that is controlled by an automated system, the monitoring of crop yields, and the use of a variety of seed drilling and fertilizer distribution techniques are all components of precision agriculture. When soil and field data, aerial photography, and historical weather and yield data are taken into consideration, it is possible to estimate the appropriate quantity of seeds and fertilizers, as well as the amount of irrigation that is required. Agronomy, human resource management, staff deployment, purchasing, risk management, warehousing, logistics, maintenance, marketing, and yield computation are all integrated into a single system via the use of smart farming. The effect of digitization is not confined to the conventional aspects of agriculture; rather, it encompasses the growing advancements in the livestock sector that are made possible by sensor technologies and robotics [4] [5].

Crop Monitoring and Management

In the modern day, one of the most essential aspects of agricultural management is the management and monitoring of crops throughout the many phases of farming. Crop management may be thought of as an interaction between the general management of agriculture and the management of crops. There are a number of different approaches that may be used for crop monitoring, including field mapping, precision agriculture, and remote sensing image analysis. The study of data that has been remotely sensed is referred to as remote sensing. This technique makes use of algorithms and key designs using Artificial Neural Networks (ANN) [6].

Soil Analysis

A crucial step that must be taken before to planting is the preparation of the soil. Excessive or insufficient usage of fertilizer has a substantial impact on the amount of crop that is produced. It is also necessary for crops to have nutrients that are properly dispersed in order for them to flourish. For the purpose of increasing production, the application of inorganic fertilizer to the soil may result in unfavorable impacts due to the fact that these chemicals alter the nutritional pattern of the soil over time.

The features of the soil are analyzed using data mining methods. An example of this would be the means method, which employs GPS-based approaches in conjunction with other methods to classify soils. The NDVI was the first method that was developed to predict dryness in rice fields. Fuzzy data were found during the period of time when cropping was not taking place. In order to determine the difference between precipitation and evaporation, meteorological circumstances that caused drought were first assessed [7]. Agriculture is a means of subsistence, and the production of crops is influenced by a variety of biological and seasonal elements; yet, unpredictability in the environment may cause farmers to be thrown off balance. The dangers were determined by using statistical methods to data about the soil, the weather, and the yields that had been produced in the past. Farmers are able to choose a plant for crop yield production with the assistance of the expected agricultural data, which was made possible by the advent of data mining.

PREDICTIVE ANALYTICS

One of the most sophisticated types of data analytics is known as predictive analytics, and its purpose is to answer the question, "What could possibly occur in the future?" It is the purpose of Predictive Analysis in Smart agricultural to investigate the uses of computational engineering methods in the field of agricultural development. For the purpose of smart agricultural engineering, recent technologies like as cloud computing, the internet of things, big data, and machine learning are being given priority.

Weather Prediction

The concept of weather forecasting using artificial intelligence can be defined in a simplified manner as a method with a particular approach in which, based on the previously observed pattern or behavior of weather over a given area and timeline, taking into consideration n number of factors as well as their dependencies, the weather conditions of the future time are predicted. This is done in order to forecast the weather conditions that will occur in the future. The dependability of the models that are used is given a higher amount of attention by testing them on a consistent basis with the aid of testing datasets. As soon as the model proves that it is trustworthy enough based on the accuracy measure, the model is then ready to be trained using the training dataset based on the results of the accuracy measure. In order to conduct research and make forecasts about the future based on historical data, weather forecasting systems need to be intelligent enough to read statistical data and produce patterns and rules. This is necessary for the goal of conducting research and making predictions about the future. It may be possible to make use of a numerical weather prediction model in order to effectively illustrate the relevance of forecasting on a global scale. Sub grid lakes were used in the process of global forecasting in order to reduce the number of prediction mistakes that occurred at high latitudes, particularly during the months of spring and summer [8].

Ground Water and Dam Reservoir Level Forecasting

In a great number of developing nations, groundwater is among the most precious natural resources that such nations possess. The extraction process is less expensive, it needs minimal treatment, and it is less susceptible to the effects of catastrophic occurrences. It is dependable during dry seasons or droughts. It is possible that groundwater will serve as the principal source of supply for household, agricultural, and industrial reasons in regions that have low or medium rainfall. These regions are characterized by minimal or medium rainfall. Physical hydrogeological features and system boundary conditions, such as climatic variability and pumping, are the factors that govern the dynamics of groundwater. On the other hand, it is often difficult to define nonlinear interactions, geographical heterogeneity, and temporal delays between these processes in global systems [9].

Yield Prediction

It is generally agreed that agriculture is the science of plant cultivation, and it has been an extremely important contributor to the well-being of mankind. The area of agribusiness, on the other hand, is progressively deteriorating as a result of the creation of original and contemporary innovative technologies and approaches [10]. Rich growth individuals have focused their attention on manufacturing counterfeit things that are half and half items that inspire an unwanted existence. This is because of the factors that have been mentioned and discussed.

In the field of machine learning, the Fuzzy C Means (FCM) method has historically been used for the purpose of classifying and describing different types of soil. When it comes to the generalization and grouping of unclear soil data, FCM is a very effective method. On the other hand, the ANN modeling is combined with artificial intelligence in order to overcome its limitations. These constraints include the need of a large training set. This method is used in agriculture for the classification of cotton production data and the rule mining classification technique utilized in agriculture. In addition, Artificial Neural Networks are often used for the purpose of training soil data in order to investigate soil properties and soil shear strength. In particular, the Multilayer Perceptron model, which is utilized as an artificial neural network (ANN) for predicting wheat production based on the inputs of sensors and fertilizers. In the subsequent step, the Radial Basis Function and Support Vector Regression were used [11].

Rainfall Prediction

In the field of agriculture, predicting rainfall is a job that is both necessary and hard. It provides assistance to farmers in planning their agriculture and reorienting it in order to maximize the advantages that may be obtained from heavy rains. It is possible for farmers to introduce new agricultural practices or revitalize existing ones with the assistance of rainfall information. India's agricultural sector relies heavily on rainfall as a source of water. The ability to accurately forecast rainfall is essential for a wide range of agricultural activities, including flood management, forest fires, hydrology, irrigation, vegetation, soil, settlement, animal health, and natural changes in ecosystems. For the purpose of acquiring any type of information about rainfall, it is essential to possess precisely calibrated instruments and measurements. Individual farmers are unable to accurately estimate rainfall due to the unpredictability of the weather and the unexpected shifts in climate, which necessitates the development of more advanced weather forecasting technologies. Inaccuracy and significance of the farm are both diminished as a result of the fact that public weather stations are not easily accessible and are located in a location that is far away from the farm [12].

DECISION SUPPORT SYSTEMS

Pest and Disease Management

Changes in climatic circumstances, such as rainfall, temperature, and soil fertility, may cause fungus, bacteria, and viruses to infect crops. These infections can be particularly harmful to crops. Because of this, they make use of pesticides and herbicides that are appropriate for the plants in order to avoid illnesses, as well as to boost the productivity and quality of the product. Visual observation patterns on the plants are utilized in order to detect and analyze the diseases that affect plants. The early detection of plant diseases will be advantageous since the illness may be controlled if it is caught in its early stages. When it comes to reducing losses in production and enhancing the quality of agricultural products, the identification of plant diseases is the key to success [13].

A significant amount of significance is placed on agricultural automation, as well as the automatic identification of plant illnesses and the development of productive crops. It is possible to define the word "plant disease" as any impairment that occurs to the normal physiological function of a plant, which results in the manifestation of recognizable symptoms. Within the realm of crop diseases, the study of the visually apparent patterns of a specific crop leaf is referred to as crop disease research [14]. When it comes to the successful cultivation of crops, the identification of the crop, its leaves and stems, as well as the detection of any illnesses or pests, or the proportion of each, has been shown to be quite useful. The manual observation method is often used by farmers for the purpose of detecting and identifying illnesses that affect their crops. In order to do this, continual monitoring is required, which is a challenging task for farmers that operate vast farms. Expertise was acquired. With the use of imaging technology, crop disease detection systems are able to automatically identify the symptoms that manifest on the leaves and stem of a crop [15]. This assists in the cultivation of healthy crops on a farm. With the use of an image technology system, variations will be automatically detected and also communicated to the user. These variations will be seen on components such as leaves and stems, and any variation that is observed from its distinguishing traits will be identified [16].

Irrigation Management

In addition to accomplishing water-saving techniques to compensate for the unpredictability of rainfall and the impact of water shortages as a consequence of drought in many areas of the globe, sustainable precision irrigation is an essential approach that must be taken in order to achieve the goal of obtaining food security. This not only provides a decrease in other indirect costs incurred from energy consumption, such as the use of electricity or fossil fuel for pumping, but it also provides a reduction in other indirect costs, which is necessary for optimal cost-effectiveness [17].

BENEFITS OF AI IN SMART FARMING

Through the use of innovations for modern agricultural systems, it has been possible to reduce the amount of waste produced, increase productivity, and monitor a diverse range of capital. The farmer is continuously away from the field, evaluating the reputation of the land, while they are engaged in traditional farming. It has become more challenging for farmers to maintain harmony in their operations as a result of the expansion of their farms [18].

Smart farming devices need to be able to manage agricultural output and monitor vital growth components like moisture, fertilizer, or cloth content in order to guarantee that the production of the anticipated crop is dependent on its condition . Over the course of the complete system, the sensors screen and software program are responsible for controlling everything from the farm to the fork. This results in a reduction in the average expenses, an increase in normal production and delivery quality, and ultimately an improvement in the farmer's experience . These benefits are summaries in the figure 2.

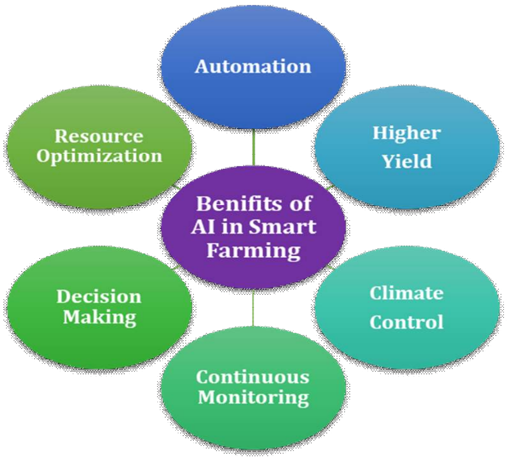

Figure 2: Benefits of AI in Smart Farming

CHALLENGES AND LIMITATIONS

Concerns concerning data privacy and security are raised as a result of the fact that AI systems depend on vast volumes of data. Fearing that their data may be misused or accessed without their permission, farmers may be reluctant to share their information with technology companies. The AI technology requires effective data management. The quantity of data that is generated and the procedures that are necessary for its administration become substantial when one considers a world in which everything is continually linked to one another and exchanging data. A rising number of people are turning to data aggregation, which is a technique that involves gathering and providing data in a uniform style. Statistical analysis may benefit from the use of this information [19]. The challenges of AI in agriculture are summaries in table 1.

A great number of AI innovative gadgets are designed to be used in the smart farming. It is necessary to provide physical protections for Internet of Things devices and networks after they have been deployed in order to protect costly technology from natural catastrophes such as hurricanes and floods. This is because smart farming makes use of a broad range of linked devices and sensors; hence, the development of an intelligent control framework is necessary in order to locate and modify each equipment. Numerous AI devices might be supported by gateways and protocols that are already in existence [20].

When it comes to smart farming, connecting several sensor nodes requires a lot of time and work. On the other hand, sensor batteries have a limited capacity, and sensors carry out significant calculations that call for varied degrees of strength. Consequently, the generator that is determined to be the most effective and powerful for record transmission may be used in settings that have very little environmental issues and in rural locations [21].

Table 1: Challenges of AI in agriculture.

S. No.	Challenge	Description
1.	Data Privacy and Security	AI systems rely on vast amounts of data, raising concerns about data privacy and security. Farmers may be hesitant to share their information with technology companies due to fears of misuse or unauthorized access.
2.	Effective Data Management	The continuous generation and exchange of data in AI-driven agriculture require effective data management. The volume of data and the complexity of managing it are significant challenges in a connected environment.
3.	Data Aggregation	Data aggregation involves collecting and providing data in a standardized format, which is crucial for statistical analysis but presents challenges in ensuring consistency and accuracy across diverse sources.
4.	Physical Protection of IoT Devices	AI and smart farming involve the deployment of IoT devices that require physical protection from natural disasters like hurricanes and floods to safeguard the technology.
5.	Intelligent Control Framework	The diversity of connected devices and sensors in smart farming necessitates the development of an intelligent control framework to manage and modify equipment effectively. Existing gateways and protocols may support multiple AI devices, but ensuring seamless connectivity remains a challenge.
6.	Sensor Connectivity and Battery Limitations	Connecting multiple sensor nodes in smart farming is time-consuming, and sensor batteries have limited capacity. Sensors perform complex calculations, requiring varying levels of power, making it challenging to ensure effective and reliable operation in remote or environmentally challenging locations.
7.	Implementation and Maintenance Costs	Implementing AI in agriculture involves significant costs, including the purchase of essential hardware (IoT gateways, devices, sensors, base station infrastructure) and ongoing maintenance expenses, such as data management and centralized services for data collection.

When it comes to implementing the innovation in the agriculture industry, there are two challenges that need to be conquered: implementation and continuing maintenance expenses. The initial expenditure takes into account the cost of all of the essential gear, which includes the IoT gateways, devices, and sensors, as well as the infrastructure of the base station. There are a number of services that are included in the operating expenses, including the administration, the exchange of records, and other services. Additionally, there are centralized services that gather data and information.

CONCLUSION

Agriculture is a vital sector that significantly contributes to the economic development and social progress of any nation. To address the growing global population and adapt to unpredictable changes in climate and soil composition, researchers worldwide are diligently developing sustainable agricultural practices. The study's findings indicate significant progress in transforming traditional farming practices into intelligent, efficient, and environmentally friendly systems. This is achieved through the integration of artificial intelligence technology into agricultural practices. Employing this technology not only enhances production but also aids in safeguarding the global food supply. However, the application of artificial intelligence in agricultural settings is fraught with challenges. Numerous challenges, such as data privacy issues, substantial implementation expenses, and the necessity for a comprehensive infrastructure for smart farming, must be addressed. This study significantly enhances our understanding of the evolution of smart farming and underscores the necessity of artificial intelligence technology to address contemporary agricultural challenges. Further research is necessary to expand the application of artificial intelligence technology in the agricultural sector. Future research may explore innovative methodologies for data collection and analysis, alongside the integration of drone technologies and precision agriculture techniques. Furthermore, efforts must be undertaken to enhance initiatives that build capacity and establish channels for knowledge transfer to ensure the widespread adoption of AI solutions among farmers.

CONFLICT OF INTEREST

The authors claim no conflicts of interest because none financial support was received from any government, non-government agency or organization to conduct this research work.

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