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Intelligent farming system leveraging IoT powered by AI Technology

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***Abstract*—Agriculture is a key sector that supports the economy and ensures food security, particularly in developing countries where many people depend on farming for their livelihood. However, traditional farming methods are still widely practiced and mainly depend on manual observation and farmers' experience. This often leads to inefficiencies and challenges, such as unpredictable weather conditions, poor irrigation practices, soil degradation, and plant diseases. As a result, farmers frequently face reduced crop yields and financial losses.**

To overcome these challenges, modern technologies like the Internet of Things (IoT) and Artificial Intelligence (AI) are being introduced into agriculture. This project presents a Smart Agriculture System that integrates IoT and AI to improve farming efficiency and productivity. The system uses IoT sensors installed in fields to continuously monitor key environmental factors such as soil moisture, temperature, and humidity. The collected data is transmitted to a cloud platform, where it is stored and analyzed in real time.

AI algorithms process this data to evaluate soil conditions and seasonal patterns, helping farmers select the most suitable crops for cultivation. In addition, an AI-based image processing system detects plant diseases from crop images and provides recommendations for appropriate fertilizers and pesticides. This helps in early detection and prevention of crop damage.

A user-friendly mobile application allows farmers to access real-time data, receive crop suggestions, get disease alerts, and learn about government schemes. Overall, this system reduces manual effort, improves resource management, increases productivity, and promotes sustainable farming practices.

***Index Terms*—Keywords: Internet of Things (IoT), Artificial Intelligence (AI), Smart Agriculture, Digital Farming, Precision Farming, Farm Automation, Wireless Sensor Systems, Soil Condition Monitoring, Environmental Sensing, Real-Time Monitoring, Crop Yield Estimation, Smart Irrigation System, Plant Disease Detection, Convolutional Neural Networks (CNN), Image-Based Plant Analysis, Agricultural Data Analysis, Cloud-Enabled Farming System, IoT-Driven Monitoring, Decision Support Systems, Sustainable Agriculture Technologies.**

I. Introduction

Agriculture is one of the most important sectors that contributes significantly to the development of both rural and urban economies. In rural areas, it is often the primary source of income and employment, while in urban regions, it supports food supply chains[1], industries, and markets. A stable and productive agricultural system ensures food security, economic stability, and overall national growth. Despite its importance, farmers face numerous challenges that affect their productivity and income[19]. Some of the most common issues include water scarcity, irregular rainfall patterns, pest attacks[2], soil degradation, and lack of access to modern farming knowledge and resources. These problems make farming a risky and uncertain activity.

One of the major limitations of traditional agriculture is its dependence on manual observation and experience. Farmers usually inspect their fields physically to check soil conditions, crop health, and irrigation needs. While experience plays an important role, it does not always provide accurate or timely information. For example[18], a farmer may not detect early signs of plant disease or may over-irrigate or under-irrigate crops due to lack of precise data. Such inefficiencies can lead to reduced crop yield, wastage of resources, and financial losses. Additionally, unpredictable climate changes further complicate decision-making, making it difficult for farmers to plan their activities effectively.

In recent years, technological advancements have opened new possibilities for improving agricultural practices. Smart farming, also known as digital or precision agriculture, is an innovative approach that uses modern technologies to enhance farming efficiency and productivity. Two key technologies driving this transformation are the Internet of Things (IoT) and Artificial Intelligence (AI)[17]. IoT involves connecting physical devices, such as sensors, to the internet so that they can collect and share data in real time. In agriculture, IoT sensors can be installed in fields to monitor various environmental parameters, including soil moisture, temperature, humidity, and even nutrient levels. This real-time data provides farmers with accurate insights into the condition of their crops and soil. Artificial Intelligence complements IoT by analyzing the collected data and generating useful recommendations. AI algorithms can process large amounts of data quickly and identify patterns that may not be visible to humans. For instance, AI can analyze soil data and weather forecasts to suggest the most suitable crops for a particular season[20]. It can also predict potential risks, such as drought or pest outbreaks, allowing farmers to take preventive measures. By combining IoT and AI, farming becomes more data-driven, reducing the reliance on guesswork and improving decision-making.

The integration of IoT and AI also enables automation in agriculture. Automated irrigation systems, for example, can use sensor data to determine when and how much water is needed, ensuring optimal water usage. This not only conserves water but also promotes healthy crop growth. Similarly, AI-based image processing systems can detect plant diseases by analyzing images of crops[21]. Early detection allows farmers to apply the right treatment at the right time, minimizing damage and improving yield quality.

The main objective of the proposed project is to design a smart agriculture system that takes advantage of these technologies to support farmers. The system continuously monitors soil conditions using sensors, ensuring that farmers have up-to-date information about their fields. It also includes a disease detection mechanism that identifies plant health issues using image analysis. Based on the collected data, the system recommends suitable crops that are most likely to thrive under given conditions.

To make the system accessible and easy to use, a mobile application is developed. Through this application, farmers can view real-time data, receive alerts, and access recommendations directly on their smartphones. This eliminates the need for constant physical monitoring and allows farmers to manage their fields more efficiently. Additionally, the app can provide information about best farming practices and government schemes, further supporting farmers in improving their productivity. Overall[23], this smart agriculture system aims to reduce the challenges faced by farmers by providing accurate, timely, and actionable information. It enhances productivity, reduces resource wastage, and promotes sustainable farming practices. By adopting such advanced technologies, agriculture can become more resilient, efficient, and capable of meeting the growing food demands of the population.

II. LITERATURE SURVEY

From 2019 onward, several researchers have contributed to the development of smart agriculture systems using modern technologies. In 2019, Patil et al[15]. explored the use of IoT sensors to monitor soil parameters such as moisture and temperature. This approach allowed farmers to remotely observe field conditions, but it lacked advanced features like crop selection and disease management.

In 2020, Sharma et al[14]. enhanced this system by integrating cloud computing with IoT. This improvement enabled real-time data storage and remote access, making it more convenient for farmers to monitor their fields. However, the system still did not include AI-based analysis or disease detection capabilities. By 2021, Kumar et al[13]. introduced AI-driven image processing techniques for identifying plant diseases. This marked a significant step toward intelligent farming, as it improved the accuracy of disease detection. Despite this advancement, the system operated independently and was not integrated with soil sensor data, limiting its effectiveness for overall farm management.

In 2022, Reddy et al[12]. combined IoT and AI technologies to recommend suitable crops based on soil conditions. While this addressed decision-making to some extent, the system lacked a user-friendly mobile interface and real-time advisory support. In 2023, Singh et al[15]. developed a mobile-based AI advisory system that provided disease identification and guidance to farmers. Although this improved accessibility, it did not incorporate IoT-based soil monitoring, field analytics, or integration with government schemes.

Overall, many researchers have worked on improving agriculture using technologies such as IoT and Artificial Intelligence. Some systems utilize IoT sensors to measure soil moisture[3], temperature, and humidity, helping farmers monitor their fields and manage irrigation. However, most of these systems focus only on data collection and display, without offering intelligent recommendations.

Other approaches involve the use of cloud technology for storing and accessing agricultural data[11]through mobile or web applications. While this simplifies monitoring, these systems often lack proper analysis and actionable insights. Additionally, several studies have focused on AI-based plant disease detection using image processing and machine learning techniques. These systems can accurately identify diseases from leaf images, but they typically function in isolation and are not integrated with real-time soil monitoring systems[9]. Crop recommendation systems have also been developed to suggest suitable crops based on soil and weather conditions. However, in many cases, these systems rely on manually entered data rather than real-time sensor inputs.

From the existing research, it is evident that most systems concentrate on a single aspect, such as monitoring or disease detection[24]. Only a few approaches attempt to integrate multiple functionalities into one platform. Therefore, the proposed system aims to combine IoT and AI technologies to deliver a comprehensive smart agriculture solution[10], including real-time monitoring, disease detection, crop recommendation, and a user-friendly mobile application for farmers.

III. PROPOSED SYSTEM

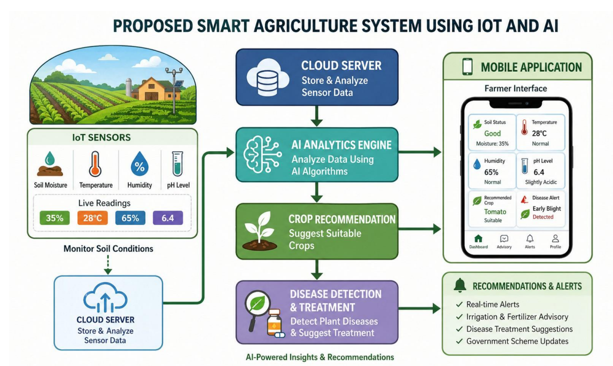

Fig. 1. Proposed smart system using IOT and AI

The proposed system combines both hardware and software components to deliver smart farming assistance. IoT sensors are deployed in the field to continuously track soil conditions such as moisture, temperature, and other parameters. This data is transmitted to the cloud through wireless communication technologies for storage and processing.

AI algorithms then analyze the collected data to suggest suitable crops based on soil quality and seasonal factors. Additionally, an AI-driven image processing model is used to identify plant diseases from images captured in the field. Based on the detected diseases, the system recommends appropriate treatments[4], including the use of fertilizers and pesticides.

A mobile application serves as the user interface, allowing farmers to easily access all information. It displays real-time data, crop recommendations, disease alerts, and necessary guidance, making the system practical and user-friendly.

IV. SYSTEM ARCHITECTURE

The system architecture is designed as a multi-layered structure, where each layer performs a distinct and essential role to ensure the smooth functioning of the smart agriculture system. This layered approach helps in organizing the overall workflow, improving efficiency, and enabling seamless integration of different technologies such as IoT, cloud computing, and artificial intelligence.

At the foundation of the system lies the IoT sensor layer, which is responsible for collecting real-time environmental data directly from the agricultural field. Various sensors are deployed to monitor key parameters such as soil moisture, temperature, humidity, and pH levels. These sensors continuously observe field conditions and generate data at regular intervals. This real-time monitoring enables farmers to gain an accurate understanding of the current state of their crops and soil, which is crucial for making informed decisions.

The data collected by the sensors is then passed to the microcontroller layer. The microcontroller acts as an intermediary processing unit that receives raw sensor data, performs basic preprocessing such as filtering or formatting, and prepares it for transmission. Once processed, the data is sent to the cloud through a communication module, which may use wireless technologies such as Wi-Fi, GSM, or LoRa[7]. This ensures that data from remote agricultural fields can be transmitted efficiently to centralized storage systems without requiring physical connectivity.

The cloud layer plays a vital role in the system by providing scalable storage and remote accessibility. All the sensor data transmitted from the field is securely stored in cloud servers, where it can be accessed anytime and from anywhere. This eliminates the limitations of local storage and allows farmers and agricultural experts to monitor field conditions [8]. Additionally, the cloud infrastructure supports data management, backup, and integration with other services, making it a central hub for the entire system.

Above the cloud layer is the AI layer, which brings intelligence to the system. In this layer, advanced algorithms and machine learning models analyze both the soil data and crop images. Soil parameters are evaluated to determine nutrient levels and environmental suitability, while image processing techniques are used to detect plant diseases or abnormalities. By combining these analyses, the system can generate valuable insights that go beyond simple data monitoring, enabling predictive and prescriptive decision-making.

The analytics layer further processes the insights generated by the AI models. It is responsible for transforming raw and analyzed data into meaningful reports, visualizations, and predictions. For example, it can generate crop recommendations based on soil health, forecast potential risks such as disease outbreaks, and provide irrigation or fertilizer suggestions. This layer ensures that complex data is presented in a simplified and understandable format, making it easier for users to interpret the results.

Finally, the mobile application layer serves as the interface between the system and the farmers. This layer presents all the processed information, including real-time data, alerts, recommendations, and reports, in a user-friendly manner. Farmers can easily access the application on their smartphones to monitor their fields, receive notifications, and take timely actions. The mobile app enhances usability and ensures that even users with limited technical knowledge can benefit from the system. In conclusion, the multi-layered architecture of the smart agriculture system integrates data collection, processing, storage, analysis, and user interaction into a cohesive framework. Each layer contributes to delivering accurate, timely, and actionable information, ultimately helping farmers improve productivity and make better agricultural decisions.

A. Explanation:

The Smart Agriculture System based on IoT and AI enables farmers to manage their crops more effectively and efficiently. In this system, various sensors are installed in the agricultural field to monitor important parameters such as soil moisture, temperature, and humidity. These sensors continuously collect data and send it to a microcontroller[6], which gathers and organizes all the information.

The collected data is then transmitted to the cloud using communication technologies like Wi-Fi or GSM through the internet. Within the cloud environment, the data is stored securely and further processed. An AI-based system analyzes this information to provide valuable insights, such as recommending suitable crops based on soil conditions and identifying possible plant diseases.

Once the analysis is complete, the system generates reports and displays the results through a mobile application. Farmers can easily access this app to monitor real-time field conditions and receive actionable suggestions, such as when to irrigate or take preventive measures against diseases. Overall, this system helps save time, reduce water usage, minimize costs, and improve crop yield, making farming more productive and sustainable.

V. METHODOLOGY

The research methodology is carried out through a well-defined and systematic approach. Initially, key agricultural challenges were identified to understand the problems faced by farmers. After that, suitable IoT sensors were chosen and deployed in the field to monitor environmental conditions. Data collection was conducted continuously using these sensors, which were connected to a microcontroller for initial processing.

The gathered data was then transmitted to a cloud server, where it was securely stored for further use. Machine learning algorithms were designed to provide crop recommendations

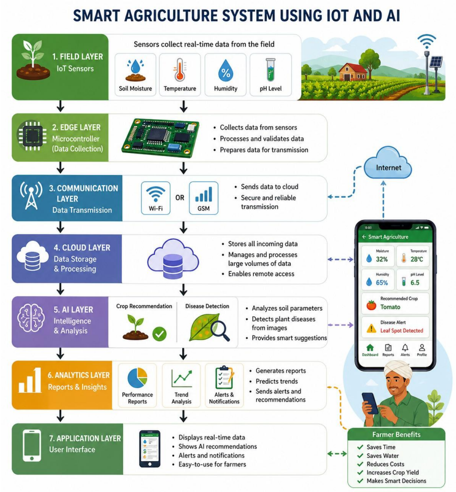

Fig. 2. SMART AGRICULTURAL SYSTEM

based on the collected data. In addition, deep learning models were trained using plant disease image datasets to enable accurate disease detection.

These AI models were integrated with the cloud platform to ensure efficient data processing and analysis. A mobile application was also developed to offer a simple and user-friendly interface for farmers. Finally, the entire system was tested in various agricultural environments to assess its performance and effectiveness.

VI. IMPLEMENTATION

The hardware implementation of the smart agriculture system is designed using a combination of sensors, processing units, and communication modules to ensure efficient data collection and transmission. Key components include soil moisture sensors, which measure the water content in the soil, and DHT sensors that monitor environmental parameters such as temperature and humidity. These sensors are strategically placed in the agricultural field to capture real-time data continuously. A microcontroller, such as Arduino or ESP8266, acts as the central processing unit of the system. It interfaces with all the sensors and is responsible for collecting both analog and digital signals generated from the field. The microcontroller may also perform basic preprocessing tasks, such as filtering noise or converting analog signals into digital form for easier handling.

To enable remote monitoring, communication modules like Wi-Fi or GSM are integrated into the system. These modules transmit the collected data from the microcontroller to a cloud-based platform over the internet. This ensures that the data is accessible from anywhere, allowing farmers and researchers to monitor field conditions without being physically present.

On the software side, cloud platforms such as Firebase or AWS are used for secure data storage, management, and retrieval. These platforms provide scalability and reliability, making them suitable for handling large volumes of agricultural data. Machine learning models are developed using Python, a widely used programming language in data science. These models are trained using agricultural datasets to analyze patterns and provide intelligent recommendations, such as suitable crop selection or irrigation planning.

Furthermore, deep learning techniques, particularly Convolutional Neural Networks (CNNs), are utilized for plant disease detection and classification. These models are trained on image datasets of plant leaves and can accurately identify diseases at an early stage. This integration of hardware and software components creates a powerful and efficient system that supports modern, data-driven farming practices.

A. HARDWARE SETUP:

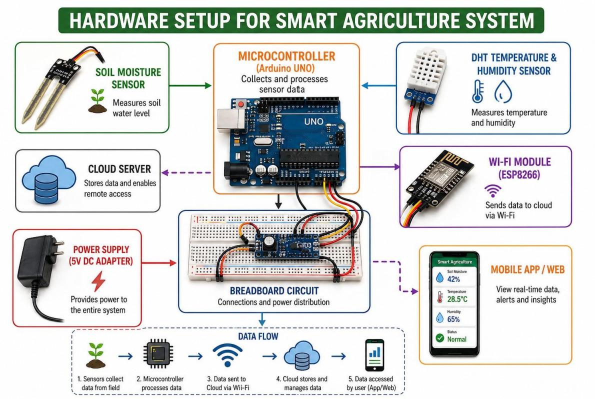

Fig. 3. HARDWARE SETUP FOR SMART AGRICULTURAL SYSTEM

Explanation: The hardware configuration of the Smart Agriculture System is made up of several electronic components that work together to monitor agricultural conditions effectively. Soil moisture sensors are embedded in the ground to measure the level of water in the soil, helping determine whether it is dry or adequately moist. In addition, a temperature and humidity sensor is used to monitor environmental conditions such as air temperature and moisture levels. All these sensors are connected to a microcontroller, such as an Arduino, which serves as the central unit of the system. It collects data from the sensors and performs basic processing.

The components are assembled on a breadboard, which allows easy connections without the need for soldering. A power supply is provided to ensure continuous operation of the microcontroller and sensors. To enable internet connectivity, a Wi-Fi module like the ESP8266 is integrated with the microcontroller. This module sends the collected sensor data to a cloud server.

The cloud server is responsible for storing and processing the received data for further analysis. Through this process, real-time information from the farm is collected and transmitted to an online platform. Farmers can then access this data using a mobile application to monitor field conditions and make informed decisions. Overall, this setup enhances farming efficiency, reduces manual work, and supports better irrigation and crop management practices.

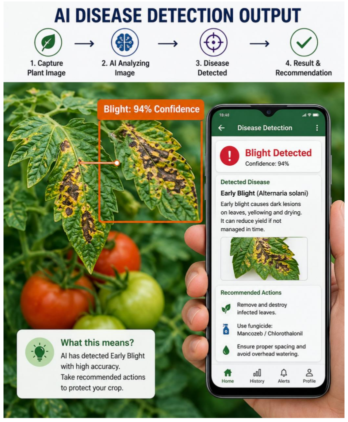

Fig. 4. AI DISEASE DETECTION OUTPUT

B. AI DISEASE DETECTION OUTPUT:

This image illustrates the working of an AI-based plant disease detection system within a Smart Agriculture framework. In this process, the farmer uses a mobile application to capture a clear image of a plant leaf showing possible signs of damage or infection. The image is then processed by an AI model[6], typically trained using machine learning and image recognition techniques, to analyze patterns, colors, and textures associated with various plant diseases.

In the example shown, the system successfully identifies the disease as "Blight" with a high confidence level ranging from 94% to 99%, indicating strong accuracy in detection. Along with the disease name, the application provides a confidence score, which helps the farmer understand how reliable the prediction is. Additionally, the system offers detailed information about visible symptoms, such as the presence of yellowing and brown spots on the leaves, which are common indicators of Blight infection.

The application also suggests appropriate remedial measures, including spraying suitable fungicides and removing infected leaves to prevent further spread. This timely guidance allows farmers to take immediate and effective action, reducing crop damage and improving overall yield. By using such AI-powered tools, farmers can make informed decisions without requiring expert knowledge, ultimately enhancing productivity and promoting sustainable farming practices.

C. MOBILE APP SCREEN SHOT:

Explanation: The Smart Agriculture System mobile application is designed to make farming more efficient and data-driven by allowing farmers to monitor their fields in real time. Through an easy-to-use interface, the app displays important soil parameters such as temperature, moisture levels, and humidity, helping farmers understand the current condition of their land. This information is continuously updated, enabling timely decisions for irrigation and crop management.

Based on the collected data, the application also provides intelligent crop recommendations. For example, if the soil and environmental conditions are suitable, it may suggest

Fig. 5. SMART AGRICULTURAL SYSTEM MOBILE E APP

growing tomatoes or other appropriate [5], which can improve productivity and reduce the risk of failure. Another important feature of the app is its ability to detect plant diseases. When a potential issue is identified, the system sends an alert, such as "Blight Detected," along with a warning that action is required. Farmers can then view detailed information about the disease, including its symptoms and possible treatments.

By combining monitoring, recommendations, and disease detection in one platform, the application helps farmers take quick and informed actions, ultimately improving crop health, yield, and overall farm management.

VII. RESULTS AND DISCUSSION

The integrated Smart Agriculture System demonstrated effective performance across all its components, making farming more efficient and technology-driven. The IoT sensors played a crucial role by continuously monitoring soil conditions such as moisture, temperature, and humidity in real time. This ensured that farmers always had up-to-date information about their field environment. The data collected by these sensors was transmitted reliably to the cloud without delays or loss, allowing seamless data storage and access from anywhere.

Based on this real-time data, the AI-based crop recommendation system analyzed soil parameters and suggested the most suitable crops for cultivation. This helps farmers choose crops that are more likely to grow successfully under current conditions, thereby increasing productivity. Additionally, the disease detection model showed high accuracy in identifying plant diseases from leaf images, enabling early diagnosis and prevention of further damage.

The mobile application served as a user-friendly interface, clearly displaying all the outputs such as soil data, crop suggestions, and disease alerts. Farmers could easily understand the information and take immediate action. Overall, this integrated system significantly reduced the need for manual field inspection, saved time and effort, and improved resource management, leading to better crop yield and sustainable farming practices.

RESULT GRAPH OR SCREEN SHOT Explanation: The

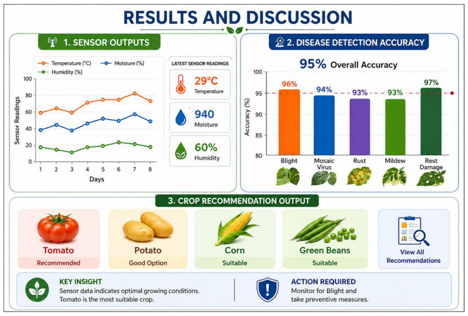

Fig. 6. RESULTS AND DISCUSSION

Results and Discussion section provides a comprehensive evaluation of how well the Smart Agriculture System functions in real-world conditions. The sensor output graph plays a crucial role by showing the changes in key environmental parameters such as temperature, soil moisture, and humidity over several days. These continuous readings allow farmers to observe patterns and fluctuations in their field conditions, helping them make timely decisions related to irrigation, crop care, and overall farm management. By having access to real-time and historical data, farmers can better understand how environmental factors influence crop growth.

The disease detection accuracy chart further highlights the effectiveness of the AI-based model integrated into the system. With an overall accuracy of around 95%, the model demonstrates strong capability in identifying different plant diseases, including blight, mosaic virus, rust, mildew, and pest damage. The high accuracy range of approximately 93% to 97% for individual diseases indicates that the system can reliably assist farmers in early disease detection, reducing the risk of crop loss and minimizing the need for extensive manual inspection.

In addition to monitoring and detection, the crop recommendation output enhances decision-making by suggesting suitable crops such as tomato, potato, corn, and green beans. These recommendations are based on the analyzed soil and weather conditions, ensuring better compatibility between crops and the environment. Overall, the results clearly show that the system integrates monitoring, analysis, and intelligent recommendations effectively, leading to improved productivity, efficient resource utilization, and more sustainable farming practices.

VIII. Conclusion

The Results and Discussion section provides a comprehensive evaluation of how effectively the Smart Agriculture System performs under real-world conditions. The sensor output graph plays an important role by illustrating variations in key environmental parameters such as temperature, soil moisture, and humidity over several days. These continuous readings enable farmers to observe patterns and fluctuations in field conditions, helping them make timely and informed decisions regarding irrigation, crop care, and overall farm management. With access to both real-time and historical data, farmers gain a deeper understanding of how environmental factors influence crop growth.

The disease detection accuracy chart further demonstrates the effectiveness of the AI-based model integrated into the system, achieving an overall accuracy of around 95%, The model shows strong capability in identifying various plant diseases, including blight, mosaic virus, rust, mildew, and pest damage, with individual accuracy ranging between approximately 93% and 97%. Additionally, the crop recommendation output supports better decision-making by suggesting suitable crops such as tomato, potato, corn, and green beans based on soil and weather analysis. Overall, the results highlight that the system successfully integrates monitoring, analysis, and intelligent recommendations, leading to improved productivity, efficient resource utilization, and more sustainable farming practices.

FUTURE ENHANCEMENT

The future development of smart agriculture systems can significantly improve farming efficiency and productivity. Advanced deep learning models will enhance the accuracy of plant disease detection, enabling farmers to identify issues earlier and take corrective action quickly. The integration of weather forecasting APIs will provide real-time climate data, helping farmers plan irrigation more effectively and avoid water wastage. Automated irrigation systems can further support this by supplying water precisely when needed, ensuring optimal crop growth while conserving resources.

For large-scale farming, drone-based monitoring can offer a practical solution for observing vast fields, detecting crop stress, and collecting detailed data from areas that are difficult to access manually. In addition, market price prediction systems can assist farmers in deciding the best time to sell their produce, maximizing profits. Blockchain-based supply chain tracking can improve transparency, ensuring that agricultural products are traceable from farm to market. Together, these advancements will make agriculture more intelligent, efficient, and sustainable.

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