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Agro Smart Hub: An IoT and AI-Based Smart Agriculture System

D Sumanth[#1], A Deepak Teja[#2], CH Mahendra Chowdary[#3],

Dr J Mercy Geraldine[#4]

Email: sumanthdaripalli03@gmail.com, deepakteja46@gmail.com, nanichidipothu45@gmail.com,

mercygeraldine@gmail.com

[#123]UG Student, Department of Computer Science and Engineering, School of Engineering and Technology, Dhanalakshmi Srinivasan University, Trichy–621112, Tamil Nadu, India

[#4]Professor and Head , Department of Computer Science and Engineering, Dhanalakshmi Srinivasan University, Trichy–621112, Tamil Nadu, India

Abstract : In the modern era, the integration of Internet of Things (IoT) and Artificial Intelligence (AI) has transformed traditional agricultural practices by enabling real-time monitoring, intelligent decision- making, and automated control. This paper presents Agro Smart Hub, an IoT- and AI-based smart agriculture system designed to improve agricultural productivity, resource efficiency, and rural market connectivity. The proposed system employs a network of sensors to continuously monitor environmental parameters such as soil moisture, temperature, and humidity. The collected data is analyzed using AI and machine learning techniques to optimize irrigation and farming operations automatically.

In addition to smart farming, Agro Smart Hub introduces a direct farmer-to-consumer model that eliminates intermediaries, ensuring freshness of agricultural produce and fair pricing for farmers. To address digital literacy challenges in rural areas, village- level support branches are incorporated to assist farmers in using the mobile application and managing long- distance customer interactions. The proposed system promotes sustainable agriculture, efficient water usage, and economic empowerment of rural communities.

Keywords : IoT, Artificial Intelligence, Smart Agriculture, Precision Farming, Rural Supply Chain, Farmer-to-Consumer Model

I.INTRODUCTION :

Agriculture remains the backbone of rural economies and plays a vital role in ensuring food security and economic stability. However, traditional farming practices often rely on manual observation and experience-based decision-making, which can lead to inefficient resource utilization, reduced crop yield, and increased dependency on unpredictable environmental conditions. With the rapid growth of population and increasing demand for food, there is a strong need to adopt advanced technologies that can enhance agricultural productivity while ensuring sustainability.[1]

The emergence of the Internet of Things (IoT) has enabled the deployment of smart sensing devices capable of continuously monitoring environmental parameters such as soil moisture, temperature, humidity, and weather conditions. When combined with Artificial Intelligence (AI), these technologies allow intelligent analysis of real-time data, enabling automated decision-making and precise control of agricultural operations. Such integration supports precision farming practices by optimizing irrigation,

reducing water wastage, and improving overall crop health.

In addition to production challenges, farmers in rural areas face significant difficulties in accessing markets and obtaining fair prices for their produce. The involvement of multiple intermediaries often reduces farmer income while compromising the freshness of agricultural products delivered to consumers. Moreover, limited digital literacy among farmers restricts the adoption of modern technological solutions, particularly mobile-based platforms designed for market connectivity.

To address these challenges, this paper proposes Agro Smart Hub, an IoT- and AI-based smart agriculture system integrated with a direct farmer-to-consumer supply model. The proposed system not only automates agricultural monitoring and control but also establishes a digital platform that connects farmers directly with customers. To ensure inclusivity and ease of adoption, village-level support branches are introduced to assist farmers in utilizing the application and managing long-distance transactions. This approach aims to improve agricultural efficiency, promote sustainable farming, and strengthen rural economic development.[1]

Despite the availability of modern technologies, agriculture in many rural regions continues to face several critical challenges. Traditional farming methods lack real- time monitoring mechanisms, resulting in inefficient use of resources such as water, electricity, and fertilizers. Farmers often depend on manual judgment to make irrigation and crop management decisions, which can lead to over-irrigation, crop stress, and reduced yield.[2]

Another major issue is the lack of intelligent systems that can analyze environmental data and provide automated responses. Existing agricultural practices rarely utilize predictive analytics or machine learning techniques to forecast crop requirements based on soil conditions and weather patterns.[3] This absence of data-driven decision- making limits productivity and increases operational costs for farmers.

In addition to production-related challenges, rural farmers face significant market accessibility problems. The presence of multiple intermediaries between farmers and consumers reduces profit margins for farmers and affects the freshness of agricultural produce. Farmers also experience difficulties in reaching long-distance customers due to the absence of reliable digital platforms and logistical support.

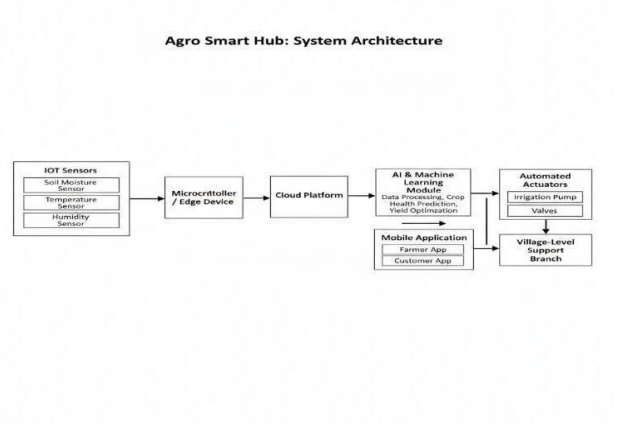


Fig. 1. Architecture of the Agro Smart Hub System

Furthermore, limited digital literacy among farmers acts as a barrier to adopting mobile applications and smart technologies.[4] Many farmers are unfamiliar with using smartphones or online platforms, making it difficult to implement fully digital solutions in rural areas. Therefore, there is a need for an integrated system that not only automates agricultural operations using IoT and AI but also provides a farmer-friendly interface and local support infrastructure to ensure effective adoption and market connectivity.

II. RELATED WORKS

Several studies have explored the application of Internet of Things (IoT) and Artificial Intelligence (AI) in smart agriculture to improve farming efficiency and resource management[1]. IoT-based agricultural systems primarily focus on real-time monitoring of environmental parameters such as soil moisture, temperature, and humidity using distributed sensor networks. These systems enable farmers to make informed decisions by providing continuous data on crop and soil conditions.

Previous research has demonstrated the effectiveness of automated irrigation systems that utilize soil moisture sensors to control water supply, thereby reducing water wastage and improving crop yield. Some studies have furtherintegrated weather forecasting data and machine learning algorithms to predict irrigation requirements and optimize farming operations.

While these systems enhance precision farming, they are often limited to monitoring and automation and do not address broader supply chain challenges Recent advancements have also introduced mobile and cloud-based agricultural platforms that allow farmers to access market information and sell produce online. However, many of these platforms face adoption challenges in rural areas due to limited digital literacy and lack of technical support. Additionally, the presence of intermediaries in traditional market structures continues to reduce farmer profit margins and affects the freshness of agricultural products delivered to consumers.

Unlike existing approaches, the proposed Agro Smart Hub system integrates smart agriculture monitoring with a direct farmer-to-consumer model and localized village-level support branches. This combined approach not only improves agricultural productivity through IoT and AI but also enhances market accessibility and technology adoption among rural farmers, addressing key limitations observed in previous works.

III. PROPOSED SYSTEM

The proposed Agro Smart Hub system is an integrated IoT- and AI-based smart agriculture platform designed to enable real-time monitoring, intelligent decision-making, and direct market connectivity for farmers. The system combines sensor-based data acquisition, cloud-based data processing, artificial intelligence analytics, and a mobile application supported by village-level service branches. The overall architecture is designed to ensure efficiency, scalability, and ease of use in rural environments.[2]

A. System Architecture

The system architecture consists of four main layers: the sensing layer, processing layer, application layer, and support layer. In the sensing layer, IoT sensors such as soil moisture sensors, temperature sensors, and humidity sensors are deployed in agricultural fields to continuously monitor environmental conditions. These sensors are connected to a central processing unit, such as a microcontroller or edge device, which collects and transmits data to the cloud.[3][2]

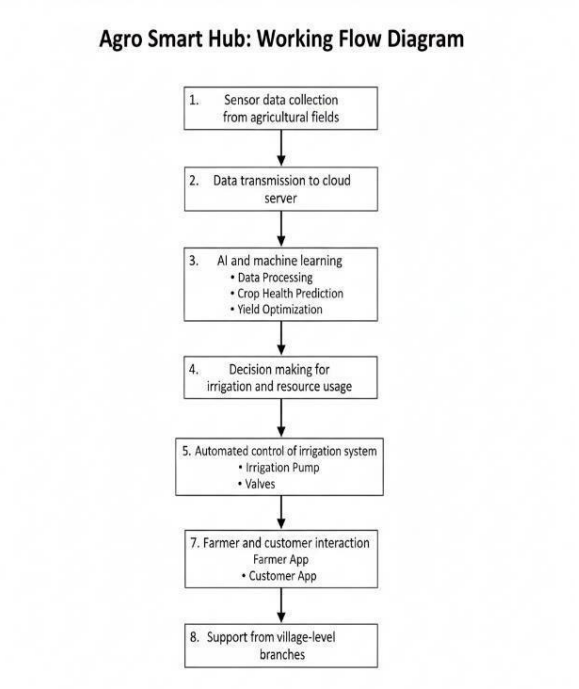


Fig. 2. Working Flow of the Agro Smart Hub System.

The processing layer is responsible for data storage, analysis, and decision-making. Sensor data is transmitted to a cloud server where artificial intelligence and machine learning algorithms analyze patterns and predict optimal actions, such as irrigation scheduling and resource allocation. Based on the analysis, control signals are generated and sent back to actuators, enabling automated control of irrigation systems.[4]

The application layer includes a mobile application designed for farmers and customers. Farmers can monitor field conditions, receive recommendations, and manage agricultural produce, while customers can view available products and place orders directly. To address usability challenges, the support layer introduces village-level branches that assist farmers in using the application, managing transactions, and coordinating logistics.

B. System Components

The major components of the proposed system include IoT sensors, actuators, a central processing unit, cloud infrastructure, AI and machine learning models, and a mobile application. Sensors continuously collect environmental data, while actuators such as water pumps and valves execute automated actions. The central processing unit acts as an interface between sensors and the cloud platform.

The cloud infrastructure provides scalable storage and computational resources for data processing. AI and machine learning algorithms analyze historical and real-time data to optimize farming operations. The mobile application serves as the primary user interface for both farmers and customers, enabling real-time monitoring, order management, and communication. Village-level support branches function as intermediaries to assist farmers with limited digital literacy.

C. Working Flow of the System

The working flow of Agro Smart Hub begins with the continuous collection of environmental data from sensors deployed in the field. The collected data is transmitted to the cloud through the central processing unit. AI algorithms analyze the data to determine optimal irrigation schedules and generate actionable insights. Automated control commands are then sent to actuators to regulate irrigation and other farming operations.[3]

Simultaneously, agricultural produce information is updated on the mobile application, allowing customers to place orders directly from farmers. Village-level support branches facilitate farmer participation by providing technical assistance and managing customer interactions. This integrated workflow ensures efficient agricultural management, reduced resource wastage, improved produce freshness, and enhanced farmer income.

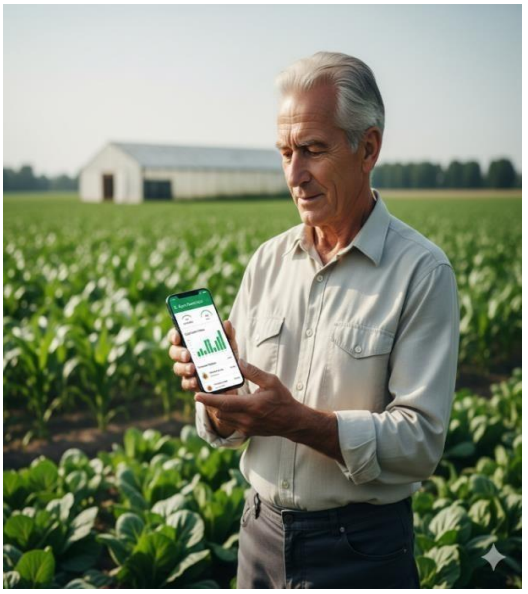
The Agro Smart Hub system consists of three main components:

1. IoT Sensor Network: A network of sensors and actuators monitors soil moisture, temperature, humidity, and other environmental parameters. The sensors are connected to a central processing unit for real-time data collection.

2. AI and Machine Learning Module:

Collected data is analyzed using machine learning algorithms to:

- Predict crop growth patterns
- Automate irrigation schedules
- Optimize resource usage and energy consumption



3. Rural Farmer Mobile Application:

A mobile application enables farmers to list their produce for direct sale to customers. Features include:

- Real-time inventory updates
- Order notifications
- Pricing optimization

Advanced Feature: Local branches are set up in rural areas to assist farmers in using the app, ensuring usability for long- distance customers and smooth transactions.

IV. METHODOLOGY

The implementation of the Agro Smart Hub system follows a structured methodology that integrates IoT-based data acquisition, cloud-based data processing, artificial intelligence analysis, and application-level interaction. The methodology is designed to ensure real-time monitoring, automated control, and seamless farmer-to-consumer connectivity.[5][4]

A. Data Acquisition Using IoT Sensors

The first phase of the methodology involves the deployment of IoT sensors in agricultural fields. Sensors such as soil moisture sensors, temperature sensors, and humidity sensors are used to collect real-time environmental data. These sensors are connected to a microcontroller or edge device, which continuously reads sensor values at predefined intervals. The collected data is pre-processed to remove noise and ensure accuracy before transmission.

B. Data Transmission and Cloud Storage

The processed sensor data is transmitted to a cloud server using wireless communication technologies such as Wi-Fi or cellular networks. The cloud platform provides scalable storage for both real-time and historical data. Secure data transmission protocols are used to ensure reliability and data integrity. The stored data serves as the input for further analysis and decision-making.

C. AI and Machine learning Based Analysis

Artificial intelligence and machine learning techniques are applied to analyze the collected sensor data. Historical and real-time data are used to identify patterns and predict irrigation requirements based on soil conditions and environmental factors. The machine learning model generates recommendations for optimal irrigation schedules and resource usage. These recommendations enable data-driven decision-making and support precision farming practices.

D. Automated Control Mechanism

Based on the AI-generated recommendations, automated control commands are issued to actuators such as water pumps and irrigation valves. This automation ensures timely and efficient irrigation without manual intervention. The control mechanism helps reduce water wastage and improves crop health by maintaining optimal soil moisture levels.

E. Mobile Application and Rural Support Implementation

A mobile application is developed to provide a user- friendly interface for farmers and customers. Farmers can view real-time field data, receive alerts, and manage agricultural produce, while customers can browse and purchase fresh produce directly. To overcome digital literacy challenges in rural areas, village-level support branches are established to assist farmers in using the application, managing orders, and coordinating logistics. This hybrid approach ensures technology adoption and effective system utilization.[6]

V. RESULTS AND DISCUSSION

The implementation of the Agro Smart Hub system demonstrates significant improvements in agricultural monitoring, resource management, and market connectivity. The results are discussed based on system functionality, efficiency, and practical impact on farmers and consumers.

The IoT-based sensing mechanism successfully enables continuous monitoring of environmental parameters such as soil moisture, temperature, and humidity. Real-time data collection ensures timely detection of field conditions, reducing dependency on manual observation. The automated irrigation mechanism responds effectively to AI-generated recommendations, leading to optimized water usage and prevention of over-irrigation.[1][2]

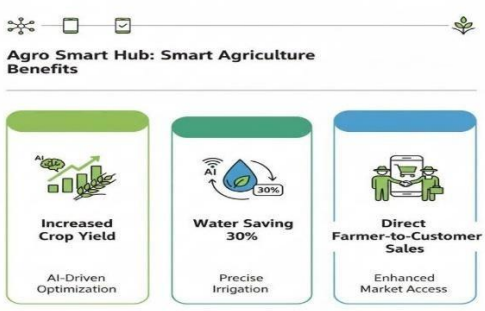
The application of AI and machine learning algorithms enhances decision-making by analyzing historical and real- time data patterns. The system provides accurate irrigation scheduling and resource optimization, which contributes to improved crop health and increased agricultural productivity. This data-driven approach supports precision farming practices and promotes sustainable agriculture.

The mobile application enables direct interaction between farmers and customers, eliminating intermediaries in the traditional supply chain. As a result, farmers experience improved profit margins, while customers receive fresher agricultural produce. The inclusion of village-level support branches plays a crucial role in improving system adoption by assisting farmers with limited digital literacy, ensuring effective utilization of the platform.[6] Overall, the proposed system demonstrates reliability, scalability, and practical feasibility for rural deployment.

The results indicate that Agro Smart Hub effectively integrates smart farming technologies with a direct market model, addressing both agricultural efficiency and rural economic challenges.

VI. CONCLUSION AND FUTURE SCOPE

This paper presented Agro Smart Hub, an integrated IoT- and AI-based smart agriculture system designed to enhance agricultural productivity, optimize resource utilization, and improve rural market connectivity. By combining real-time environmental monitoring, intelligent data analysis, and automated irrigation control, the proposed system supports precision farming practices and promotes sustainable agriculture. In addition to smart farming, Agro Smart Hub introduces a direct farmer-to-consumer supply model that eliminates Intermediaries and ensures freshness of agricultural produce. The incorporation of village-level support branches addresses digital literacy challenges and facilitates effective technology adoption among rural farmers. The results demonstrate that the proposed system is practical, scalable, and capable of improving both farming efficiency and farmer income.[5] The future scope of this work includes the integration of advanced machine learning models for improved prediction accuracy and the incorporation of weather forecasting APIs to enhance decision-making. Further enhancements may involve the use of blockchain technology for transparent transactions, real-time logistics tracking, and expansion of the system to support multiple crop types and larger agricultural regions. These advancements can further strengthen the role of Agro Smart Hub in modernizing agriculture and empowering rural communities.[2]



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