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SMART AGRICULTURAL MONITORING SYSTEM USING ESP8266, ANDROID APP AND POWER BI

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Abstract: This project introduces a Smart Agricultural Monitoring System that integrates IoT, mobile technology, and data analytics to enhance irrigation efficiency and environmental monitoring in agriculture. Utilizing the ESP8266 NodeMCU microcontroller, the system gathers real-time data from a DHT22 sensor for temperature and humidity and a soil moisture sensor. Based on the soil moisture levels, it automatically controls a water pump via a relay module to maintain optimal soil conditions. The collected data is transmitted to the ThingSpeak cloud platform and visualized through a custom Android application, enabling farmers to monitor field conditions remotely. Additionally, the system connects to Power BI for advanced data analysis and visualization, offering insights into environmental trends and supporting precision farming. This cost-effective and scalable solution aims to reduce water wastage, minimize manual labor, and promote sustainable farming practices through smart automation and real-time decision-making.

Keywords: soil moisture, temperature, humidity, and light intensity.

I. INTRODUCTION

Agriculture plays a crucial role in global food production and economic stability. However, the agricultural sector faces numerous challenges, including unpredictable weather conditions, inefficient water usage, and poor soil management. Traditional farming practices often rely on manual observation and experience-based decision-making, which may lead to inaccuracies in irrigation scheduling. As water scarcity becomes a growing concern, there is an urgent need for smart and automated solutions to ensure sustainable and efficient farming practices. Integrating modern technology into agriculture can significantly improve productivity, optimize resource utilization, and minimize environmental impact. One of the most critical factors affecting crop health and yield is soil moisture level. Over- irrigation can lead to waterlogging, root rot, and nutrient leaching, while under-irrigation can cause crop stress and yield reduction. Monitoring environmental parameters such as temperature, humidity, and soil moisture in real time can help farmers make informed decisions and maintain optimal growing conditions. The development of an IoT-based Smart Agricultural Monitoring System can provide a data-driven approach to farming, ensuring that crops receive the precise amount of water required at the right time. The proposed system integrates ESP8266, sensors, Thing Speak cloud, an Android application, and Power BI analytics to create a comprehensive monitoring and control system for farmers. The ESP8266 microcontroller collects real-time data from sensors measuring temperature, humidity, and soil moisture levels. Based on the moisture readings, the system automatically controls a water pump, reducing manual labor and improving irrigation efficiency. The collected data is transmitted to Thing Speak, a cloud-based IoT platform, for real-time monitoring and analysis. A key feature of this system is the Android application, which provides farmers with instant alerts and insights. Through the app, farmers can receive notifications about critical changes in soil conditions, temperature fluctuations, or irrigation status. This real-time connectivity ensures that farmers, even those working remotely, can monitor their fields and take necessary actions when needed. The user-friendly interface of the app makes it accessible to farmers with varying levels of technical expertise, bridging the gap between traditional agriculture and modern IoT technology.

II. RELATED WORK

Several researchers have explored the use of IoT in agriculture to enhance productivity and automate monitoring processes. Most smart farming systems utilize sensors to measure environmental parameters such as soil moisture, temperature, humidity, and light intensity. For instance, Patil and Kale (2016) proposed an IoT-based solution where sensor data was transmitted using Wi-Fi to support decision making in irrigation. Similarly, other studies have incorporated microcontrollers like the ESP8266 for wireless data transmission due to its low cost and built-in Wi-Fi

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capability. Android applications have also been widely used to provide farmers with real-time access to sensor data, enhancing mobility and ease of use. Furthermore, Power BI and other data analytics platforms have been employed to visualize agricultural data, enabling better analysis and trend prediction. These related works demonstrate the potential of integrating ESP8266, mobile apps, and cloud-based analytics to create an efficient, real-time agricultural monitoring system.

The methodology for the Smart Agricultural Monitoring System using ESP8266, Android App, and Power BI involves hardware setup, data acquisition, cloud communication, data analytics, and automated irrigation control. This section provides a detailed, step-by-step explanation of how the system is developed, implemented, and used for real-time agricultural monitoring.

The research methodology for the Smart Agricultural Monitoring System using ESP8266, an Android App, and Power BI involves a systematic approach combining hardware development, software integration, and data analysis. Initially, IoT-based sensors such as soil moisture, temperature, and humidity sensors are interfaced with the ESP8266 microcontroller to collect real-time environmental data. The ESP8266 is programmed to transmit the sensor readings over Wi-Fi to a cloud platform like ThingSpeak. An Android application is developed to retrieve and display the sensor data, providing farmers with on-the-go access to field conditions. Simultaneously, the collected data is also forwarded to Power BI for advanced visualization and analytics, allowing for trend analysis and informed decision- making. The methodology also includes testing the system in a simulated or real agricultural environment to validate accuracy, reliability, and usability. Data is collected over a period to assess system performance and demonstrate its effectiveness in supporting smart farming practices.

III. LITERATURE SURVEY

[1] K. G. Sanabia-Lizárraga, B. Carballo-Mendívil, A. Arellano-González, and A. Bueno- Solano, "Business Intelligence for Agricultural Foreign Trade: Design and Application of Power BI Dashboard," Sustainability, vol. 16, no. 21, p. 9576, 2024. This research paper explores the application of Power BI in enhancing agricultural foreign trade, focusing on the development of an interactive data visualization dashboard to monitor Mexico's agricultural exports. Conducted by Sanabia-Lizarraga et al. (2024), the study addresses the challenges faced by non-technical stakeholders in accessing and interpreting complex datasets related to agricultural commerce. By integrating real-time IoT sensor data, government export records, and economic indicators, the Power BI dashboard enables policymakers, traders, and agronomists to make informed, data-driven decisions. The study demonstrates how the platform improves trade efficiency by offering insights into export trends, market demands, pricing fluctuations, and geospatial trade patterns. Furthermore, the integration of AI-driven analytics and geographic mapping facilitates predictive forecasting and strategic planning, helping stakeholders optimize logistics, reduce wastage, and align production with market needs. The findings underscore the transformative potential of business intelligence tools like Power BI in modernizing agricultural trade and supporting sustainable supply chain practices.

[2] D. S. Waghole, H. S. Joil, P. R. Morey, P. H. Hadke, and S. R. Betageri, "Smart Agriculture System Using IoT and AI/ML: A Survey," International Journal of Engineering Research & Technology (IJERT), vol. 13, no. 5, pp. 1–9, 2024. This research paper provides a comprehensive analysis of the evolving landscape of smart agriculture, focusing on the integration of IoT, AI, and data analytics to enhance productivity, sustainability, and resource efficiency in modern farming. The study highlights the pivotal role of IoT devices such as sensors, drones, and automated irrigation systems in collecting real-time environmental and crop-related data. Leveraging cloud computing and edge processing, farmers can analyze this data instantly for timely and informed decision- making. Emphasis is placed on the use of data analytics and AI-driven forecasting models through platforms like Power BI, which enable predictive insights into weather patterns, pest outbreaks, and soil conditions, thereby supporting precision agriculture. The paper also addresses key challenges including high implementation costs, low digital literacy, and infrastructural limitations in rural areas, advocating for government support and policy intervention to promote adoption. Furthermore, the research explores the transformative impact of AI-powered automation on farm management, where robotic machinery and real-time dashboards streamline operations, reduce labor dependency, and enhance operational efficiency.

[3] J. Li, D. Chen, X. Qi, Z. Li, Y. Huang, D. Morris, and X. Tan, "Label-Efficient Learning in Agriculture: A Comprehensive Review," arXiv preprint arXiv:2305.14691, 2023. This research paper presents a comprehensive survey of recent advancements in IoT- based smart agriculture, emphasizing the integration of artificial intelligence (AI), machine learning (ML), and data analytics to transform traditional farming practices. The study categorizes smart agriculture into five key components: IoT-based sensor networks, AI- powered analytics, cloud computing, automation, and business intelligence dashboards.

It explores how real-time data collected from sensors—such as soil moisture, temperature, and pH—enables informed decision-making and enhances farm productivity. A significant focus is placed on the application of AI and deep learning models for crop disease detection, yield prediction, and irrigation optimization. These technologies facilitate early detection of crop stress and improve resource efficiency. The paper also highlights the role of Power BI in visualizing agricultural data, offering interactive dashboards for real-time monitoring, trend analysis, geospatial insights, and risk assessment. Precision farming emerges as a key benefit, allowing for targeted application of resources, which reduces costs and environmental impact. Supported by case studies, the paper demonstrates how smart, automated systems have led to improved yields and sustainable farming outcomes.

[4] M. Padhiary, K. Kumar, N. Hussain, D. Roy, J. A. Barbhuiya, and P. Roy, "Artificial Intelligence in Farm Management: Integrating Smart Systems for Optimal Agricultural Practices," International Journal of Smart Agriculture, vol. 3, no. 1, pp. 1–15, 2024. This research paper explores the role of IoT in shaping the future of smart agriculture, focusing on wireless technologies, AI integration, and automation. It provides an in-depth review of how IoT devices, such as soil sensors, weather stations, and automated irrigation systems, are transforming farming. The study highlights real-world applications of IoT-based smart farming, demonstrating its potential in enhancing productivity and sustainability. The paper emphasizes how IoT sensors work in real-time data collection, providing insights into soil health, temperature, humidity, and crop conditions. These sensors send data to cloud platforms, where AI and analytics tools—such as Power BI, Google Cloud AI, and AWS IoT— process information for better farm management. The research presents case studies where farmers used IoT-driven automation to reduce water wastage and increase crop yield. One of the key aspects of this paper is the discussion on connectivity challenges in rural farming. Since IoT devices rely on wireless networks, Wi-Fi, LoRa, and 5G, the paper explores how network coverage issues in remote agricultural areas affect adoption. The researchers suggest that edge computing and satellite-based IoT networks can provide solutions for connectivity gaps, making IoT accessible to farmers in rural and underdeveloped regions.

[5] R. J. Patil, I. Mulage, and N. Patil, "Smart Agriculture Using IoT and Machine Learning," Journal of Scientific Research and Technology, vol. 1, no. 3, pp. 47–59, 2023. This research paper presents a systematic literature review on the applications of artificial intelligence (AI) in agriculture, focusing on how machine learning (ML), deep learning, and AI-based automation are transforming modern farming practices. The study examines case studies and emerging trends that demonstrate the effectiveness of AI in crop monitoring, disease detection, yield prediction, and smart irrigation. AI-powered computer vision systems are shown to analyze aerial imagery and satellite data with high accuracy, enabling early identification of crop stress and soil conditions. A significant emphasis is placed on predictive analytics, where AI models process data on weather, soil, and market trends to support informed decision-making regarding planting schedules and irrigation planning. The integration of these insights with Power BI dashboards allows for real-time visualization and customized farm monitoring. The paper also highlights AI-driven automation technologies such as robotic farming systems, intelligent pest control, and self-regulating irrigation.

IV. PROPOSED WORK

MODULES:

1. Sensor Module
Components: Temperature, humidity, soil moisture, and light sensors.
Purpose: Collect real-time data from the agricultural field.

2. ESP8266 Wi-Fi Module
Purpose: Transmit sensor data to the cloud or a local server via Wi-Fi.
Functionality: Acts as a bridge between sensors and the cloud/Android app.

3. Android App
Purpose: Provide farmers with real-time monitoring and control capabilities.
Features:
- Real-time data visualization (temperature, humidity, soil moisture, light).
- Alerts and notifications for abnormal conditions.
- Remote control of agricultural equipment (e.g., irrigation systems).

4. Power BI Dashboard
Purpose: Provide advanced data analytics and visualization for better decision-making.
Features:
- Historical data analysis.

- Trend identification.
- Customizable reports and dashboards.

5. Cloud Platform
Purpose: Store and process data from the ESP8266 module.
Functionality: Enables remote access to data via the Android app and Power BI.

6. Automation Module
Purpose: Automate agricultural processes based on sensor data (e.g., automatic irrigation).
Functionality: Integrates with the ESP8266 and Android app to control equipment.

7. Notification System
Purpose: Send alerts to farmers via the Android app or SMS for critical conditions.
Functionality:Enhances responsiveness to environmental changes.

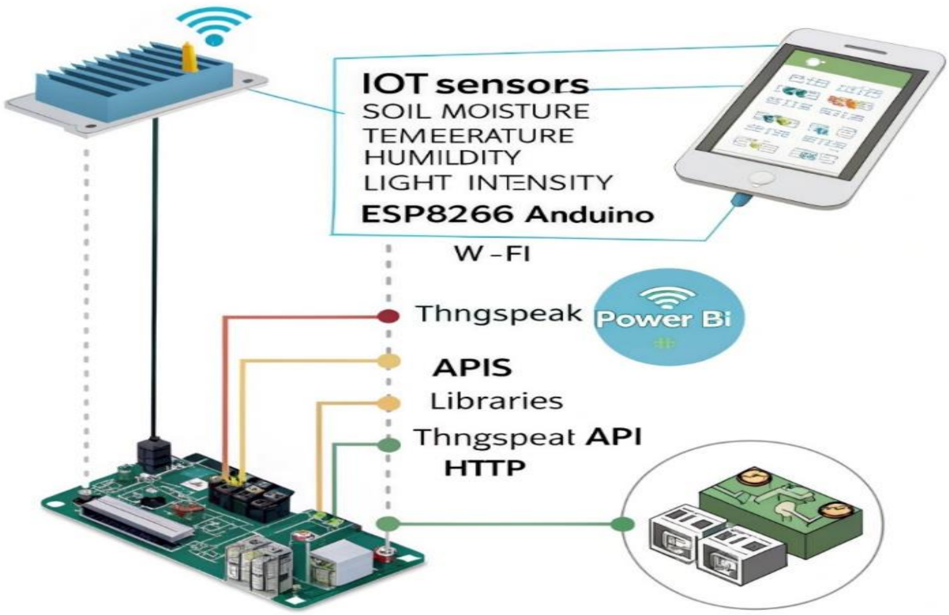

Fig: Workflow of Methodology

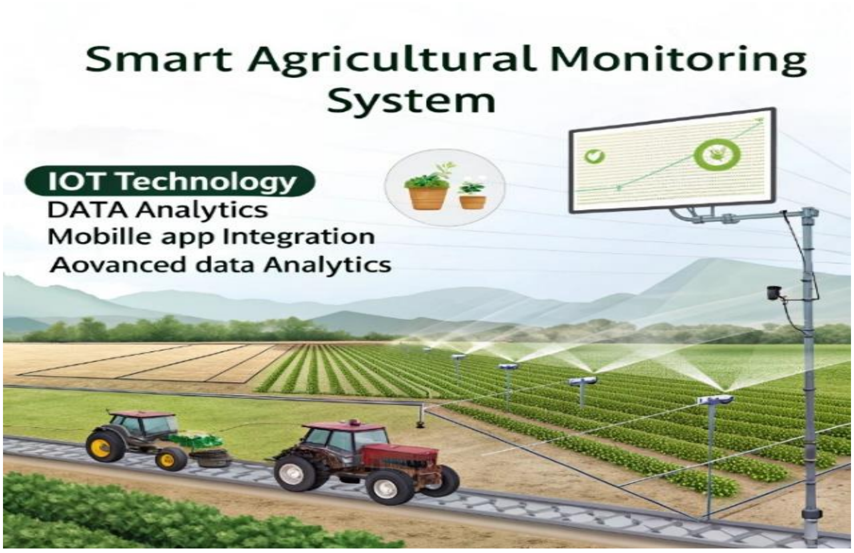

Fig: Proposed Model

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V. RESULTS

User Sign-Up Interface for Smart Farming ApplicationThe first image represents the sign-up screen of the Smart Farming mobile application. This screen is crucial for enabling new users, typically farmers or agricultural stakeholders, to register and gain access to the app's features. Interface Design and Elements: Header Section The header at the top of the screen is purple and displays system icons like battery status, time (20:57), network strength, and app notifications, indicating that the app is running on an Android device. App Logo The logo is placed in the center and contains the text "SMART FARMING" with a symbol representing technology integrated with agriculture. This visual identity builds trust and reinforces the app's branding. Text Fields

➢ The first field is a username input. In this example, the placeholder text is "hello", which seems to be a test input.

➢ The second field is a password input, masked with dots for security. This ensures that sensitive information is protected from shoulder surfing or onlookers. 5 Sign-Up Button A wide green button at the bottom labelled “Sign Up” is used to trigger the account creation process. This button is stylized with rounded corners and a clean modern design to align with the user-friendly theme. Purpose and Functionality

➢ This screen ensures that only authorized users can access the system by allowing account creation. ➢ It potentially connects to a Firebase, MySQL, or SQLite backend to store the new user credentials. ➢ Once the sign-up is successful, the user would typically be redirected to either a welcome page or directly into the app’s dashboard.

Relevance to Smart Farming: In a smart agriculture environment, data access must be secure and personalized. Sign-up functionality ensures user accountability and can be used to personalize data (such as showing farm-specific monitoring information). Additionally, it lays the groundwork for scalable and multi-user support—important for large or cooperative farming operations.

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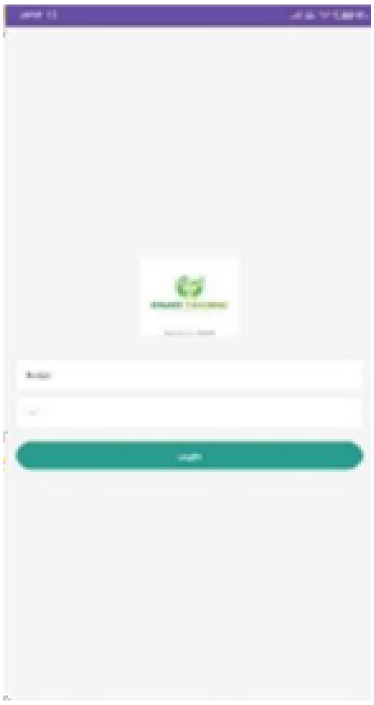

Fig Login Page

➢ On clicking "Login", the system likely checks the entered credentials against stored data in a database.
➢ If valid, the user is taken to the main dashboard where they can monitor key agricultural parameters like soil moisture, temperature, humidity, and motor control.
➢ If invalid, it displays "Invalid credentials
➢ The use of password masking enhances security.
➢ The clear minimalist UI design helps farmers and other users, including those with limited tech experience, navigate easily.
➢ Having a separate login screen makes the app more secure and scalable for future updates such as user roles, password recovery, or two-factor authentication. 5.1.2.7 Relevance to Smart Agriculture: Secure login systems ensure safe data handling and customized monitoring, which is vital in precision farming. Users can access real-time insights into their specific farm conditions, enabling data-driven decisions. It also helps in user accountability, where each farmer's usage and system alerts (like motor status changes or soil moisture drops) can be tracked individually.

Real-time Farm Monitoring Interface This image represents the main dashboard of the Smart Farming application, which displays real-time agricultural data after a successful login. This is the core screen where users can view critical environmental parameters that affect crop health and irrigation needs.

➢Real-time monitoring of soil and atmospheric conditions.
➢ Remote activation of irrigation via motor control.
➢ User-specific access with secure login/logout functionality.
➢ Visual clarity for farmers to make quick, data-driven decisions. Such systems help reduce water wastage, improve crop yield, and bring precision farming to rural and commercial agriculture. The visual indicators and easy-to-read layout make the app highly usable for non-technical users, such as stands for ON, while "0" would represent OFF

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Fig 5.3 Real-Time Farm Monitoring Interface

User Interaction

➢ Login Feedback Message: Below the monitoring card, a small popup-like message reads: "Login Successful!", confirming that the user has securely logged in and is now viewing personalized or secured farm data.

Relevance to Smart Farming This screen ties together the critical components of a Smart Agriculture system:

➢ Real-time monitoring of soil and atmospheric conditions.

➢ Remote activation of irrigation via motor control. ➢ User-specific access with secure login/logout functionality.

➢ Visual clarity for farmers to make quick, data-driven decisions. Such systems help reduce water wastage, improve crop yield, and bring precision farming to rural and commercial agriculture. The visual indicators and easy-to-read layout make the app highly usable for non-technical users, such as local farmers.

Fig 5.4 Thing Speak Data Visualization

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VI. CONCLUSION AND FUTURE SCOPE

The Smart Agricultural Monitoring System utilizing ESP8266, IoT sensors, an Android app, and Power BI has successfully demonstrated how technology can revolutionize traditional farming methods. By integrating real-time environmental monitoring, automated irrigation control, and data analytics, the system ensures optimal water usage, reduces manual labor, and enhances overall agricultural productivity. The results have shown that smart farming techniques can significantly improve soil moisture management, leading to healthier crops and increased yields. This project serves as a foundation for precision agriculture, allowing farmers to make informed decisions based on real-time and historical data insights rather than relying on traditional guesswork.

In conclusion, this Smart Agricultural Monitoring System serves as a crucial step towards sustainable and technology-driven farming. With global challenges such as climate change, water scarcity, and population growth, smart agriculture solutions are becoming more important than ever. This project demonstrates that by harnessing IoT, automation, and data analytics, farmers can achieve higher efficiency, increased productivity, and better resource management. The successful implementation of this system paves the way for future innovations in precision agriculture, making farming smarter, more efficient, and more sustainable for generations to come.

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