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AI-Driven Decision Support System for Smart Agriculture Using IoT Sensors

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Abstract:

Agriculture is a vital sector that significantly contributes to the economy and food security of many countries, including India. However, traditional farming methods often depend on manual observations and experience, leading to inefficient use of resources such as water, fertilizers, and pesticides. To address these challenges, this project proposes an **AI-Driven Decision Support System (DSS) for Smart Agriculture using Internet of Things (IoT) sensors**. The system continuously monitors environmental and soil parameters, including temperature, humidity, soil moisture, pH level, and rainfall, through a network of IoT sensors. The collected data is transmitted to a cloud platform, where Machine Learning algorithms analyze the information and generate intelligent recommendations for irrigation scheduling, crop selection, fertilizer application, and early disease prediction. By integrating IoT, Artificial Intelligence, and Decision Support Systems, the proposed framework enables real-time monitoring, predictive analytics, and data-driven decision-making for farmers. The system aims to improve crop productivity, optimize resource utilization, reduce operational costs, and promote sustainable and precision farming practices.

Index: Artificial Intelligence (AI), Internet of Things (IoT), Decision Support System (DSS), Smart Agriculture, Machine Learning, Precision Farming.

I. INTRODUCTION

Agriculture is one of the most important sectors contributing to the economic growth and food security of many countries, especially India. A significant portion of the population depends on agriculture for their livelihood. However, the agricultural sector faces numerous challenges, including climate change, water scarcity, soil degradation, unpredictable weather conditions, pest infestations, and increasing food demand. Traditional farming practices mainly rely on manual observation and farmers' experience, which often leads to inefficient utilization of resources and reduced crop productivity.

Recent advancements in Information and Communication Technologies (ICT), particularly Artificial Intelligence (AI) and the Internet of Things (IoT), have created new opportunities for transforming conventional farming into smart and precision agriculture. IoT technology enables the deployment of various sensors in agricultural fields to continuously monitor environmental and soil conditions such as temperature, humidity, soil moisture, pH level, and rainfall. These sensors generate real-time data that can be transmitted to cloud platforms for storage and analysis.

Artificial Intelligence and Machine Learning techniques can process the collected data, identify patterns, and generate predictive insights. Decision Support Systems (DSS) utilize these insights to provide intelligent recommendations related to irrigation scheduling, fertilizer management, crop selection, and disease prediction. Such recommendations assist farmers in making informed and timely decisions, thereby improving productivity and reducing resource wastage.

The proposed AI-Driven Decision Support System for Smart Agriculture integrates IoT sensors, cloud computing, and Machine Learning algorithms to develop an intelligent and automated agricultural management framework. The system continuously monitors field conditions, analyzes the collected data, and provides actionable recommendations through a user-friendly interface. By enabling real-time monitoring and data-driven decision-making, the proposed system aims to enhance agricultural productivity, optimize the use of water and fertilizers, reduce operational costs, and promote sustainable and precision farming practices.

Specific Objectives:
The primary objective of the proposed AI-Driven Decision Support System for Smart Agriculture Using IoT Sensors is to develop an intelligent and automated platform that assists farmers in making data-driven decisions for efficient crop management and sustainable farming practices. The specific objectives of the project are:

- To collect real-time agricultural data such as soil moisture, temperature, humidity, pH level, and rainfall using IoT sensors.
- To develop a cloud-based agricultural database for storing, managing, and processing the collected sensor data.
- To apply Machine Learning algorithms for analyzing agricultural data and generating intelligent predictions and recommendations.
- To provide intelligent irrigation scheduling based on real-time soil and environmental conditions, thereby reducing water wastage.
- To recommend suitable crops and fertilizers according to soil characteristics and environmental parameters.
- To predict crop diseases at an early stage using data-driven analysis and predictive models.
- To optimize the utilization of resources such as water, fertilizers, and pesticides through precision farming techniques.
- To improve agricultural productivity and efficiency by enabling farmers to make timely and informed decisions.
- To reduce operational costs and increase profitability through intelligent monitoring and automated decision support.
- To promote sustainable and precision agriculture by integrating Artificial Intelligence, IoT, and cloud technologies into modern farming practices.

II. PROBLEM STATEMENT

Agriculture plays a crucial role in ensuring food security and economic development. However, traditional farming practices primarily depend on manual observation, experience, and conventional methods of crop management. These approaches often result in inefficient utilization of resources such as water, fertilizers, and pesticides. Farmers frequently face challenges including irregular rainfall, climate variability, soil degradation, lack of real-time field monitoring, and delayed detection of crop diseases.

The absence of accurate and timely information makes it difficult for farmers to make informed decisions regarding irrigation scheduling, crop selection, and nutrient management. Consequently, these limitations lead to reduced agricultural productivity, increased operational costs, and unnecessary wastage of valuable resources.

Therefore, there is a need for an intelligent and automated agricultural system that can continuously monitor field conditions, analyze real-time data, and provide timely recommendations to farmers. An **AI-Driven Decision Support System integrated with IoT sensors** can address these challenges by enabling real-time monitoring, predictive analytics, and data-driven decision-making, thereby improving resource management, increasing crop productivity, and promoting sustainable and precision agriculture.

III. PROPOSED SYSTEM

The proposed system is an **AI-Driven Decision Support System (DSS) for Smart Agriculture** that integrates **Internet of Things (IoT) sensors, cloud computing, and Machine Learning techniques** to provide intelligent recommendations for agricultural management. The system is designed to continuously monitor environmental and soil conditions, analyze real-time data, and assist farmers in making informed decisions related to irrigation, crop selection, fertilizer management, and disease prediction.
The system consists of four major layers:
1. Data Collection Layer
This layer comprises various IoT sensors deployed in the agricultural field to collect real-time data. The sensors used include:

- Soil Moisture Sensor
- Soil pH Sensor
- Temperature Sensor
- Humidity Sensor
- Rainfall Sensor

These sensors continuously monitor field conditions and generate accurate environmental and soil data.
2. Communication Layer
The collected sensor data is transmitted to the cloud platform using wireless communication technologies such as:

- Wi-Fi
- LoRaWAN
- GSM/GPRS

This layer ensures reliable and real-time data transfer from the agricultural field to the processing server.
3. Processing Layer
The received data is stored and processed in the cloud environment. Data preprocessing techniques are used to remove noise and handle missing values. Machine Learning algorithms are then applied to analyze the data and generate predictions. The algorithms used include:

- Random Forest
- Support Vector Machine (SVM)
- Decision Tree

These algorithms help in identifying patterns and making intelligent predictions based on historical and real-time data.

4. Decision Support Layer

Based on the analysis results, the Decision Support System generates actionable recommendations for farmers, including:

- Intelligent Irrigation Scheduling
- Fertilizer Recommendations
- Suitable Crop Selection
- Early Disease Prediction and Prevention

The recommendations are delivered to farmers through a user-friendly mobile application or web dashboard, enabling timely and data-driven decision-making.

The proposed system provides real-time monitoring, predictive analytics, and automated decision support, thereby improving agricultural productivity, optimizing resource utilization, reducing operational costs, and promoting sustainable and precision farming practices.

IV. LITERATURE SURVEY

The rapid advancement of **Internet of Things (IoT)** and **Artificial Intelligence (AI)** technologies has transformed conventional farming into smart and precision agriculture. According to the **Ministry of Agriculture and Farmers Welfare (2024)**, increasing food demand, water scarcity, and climate variability require the adoption of intelligent technologies to improve agricultural productivity and ensure sustainable farming practices **[1]**. Traditional farming methods are often inefficient due to their dependence on manual observation and experience, creating a need for automated monitoring and decision-support systems.

Singh and Kumar (2023) discussed the major challenges faced by modern agriculture, including inefficient irrigation, excessive fertilizer usage, soil degradation, and unpredictable climatic conditions. Their study emphasized the importance of integrating advanced technologies to improve decision-making and resource utilization **[2]**. Similarly, **Sharma et al. (2023)** demonstrated that precision agriculture using IoT-based monitoring systems can significantly reduce water consumption while improving crop productivity through intelligent irrigation scheduling **[3]**.

Several researchers have developed IoT-based monitoring systems for agriculture. **Farooq et al. (2023)** proposed an IoT-enabled smart farming system that continuously monitors environmental and soil parameters using wireless sensor networks. Their work demonstrated that real-time monitoring enables timely agricultural decisions and improves overall farm management **[4]**. Likewise, **Bhanu et al. (2023)** designed an automated irrigation system using soil moisture sensors that optimizes water usage and reduces wastage by supplying water only when required **[5]**.

The choice of hardware plays a vital role in agricultural IoT systems. **Chen et al. (2023)** compared various IoT microcontrollers and concluded that the ESP32 provides excellent processing capability, integrated Wi-Fi, low power consumption, and cost-effectiveness, making it highly suitable for smart agriculture applications **[6]**. The **ICRISAT Research Team (2023)** further demonstrated the effectiveness of IoT-based field monitoring through the LeasyScan project, which enabled precise crop monitoring and improved agricultural research using sensor networks **[7]**.

Sensor technologies have also undergone significant improvements. The **DHT22 Temperature and Humidity Sensor** provides reliable environmental measurements for agricultural monitoring **[8]**, while the **MQ135 Gas Sensor** is widely used for detecting harmful gases and monitoring air quality in agricultural environments **[9]**. Similarly, modern **Capacitive Soil Moisture Sensors** offer improved accuracy, corrosion resistance, and longer operational life compared to traditional resistive sensors, making them ideal for long-term soil moisture monitoring **[10]**.

A comprehensive review conducted by **Kumar and Desai (2023)** compared various agricultural monitoring systems and highlighted the benefits of integrating sensing technologies, wireless communication, and cloud computing into a unified platform **[11]**. However, **Wang and Johnson (2023)** pointed out that many existing IoT implementations still suffer from limitations such as poor scalability, high power consumption, communication delays, and inefficient data management, indicating the need for more intelligent and integrated systems **[12]**.

Artificial Intelligence has become an essential component of precision farming. **Okonkwo and Chen (2023)** demonstrated that AI and Machine Learning algorithms significantly improve crop disease detection, crop recommendation, and yield prediction by analyzing large volumes of agricultural data **[13]**. **Martinez (2023)** emphasized that edge computing reduces communication latency and improves system reliability by processing data closer to the agricultural field rather than relying entirely on cloud computing **[14]**. Furthermore, **Williams and Park (2023)** evaluated several Machine Learning algorithms, including Random Forest, Decision Tree, and Support Vector Machine (SVM), and reported that these techniques provide high prediction accuracy for agricultural decision-support applications **[15]**.

Environmental monitoring also contributes to sustainable agriculture. **Thompson (2023)** discussed the application of gas sensors for monitoring environmental pollution and greenhouse gases affecting crop growth **[16]**. **Anderson and Kumar (2023)** demonstrated the use of Firebase cloud services for real-time data synchronization, remote monitoring, and mobile application development in smart agriculture **[17]**. More recently, **Das et al. (2025)** developed the **AgriSense AI Dashboard**, an IoT-enabled smart agriculture platform that integrates cloud computing, Artificial Intelligence, and interactive visualization to provide intelligent recommendations and real-time farm monitoring **[18]**.

Although considerable progress has been made in IoT-enabled smart agriculture, existing systems still face challenges related to integrated monitoring and control, efficient utilization of AI resources, scalable edge-cloud architectures, and user-friendly interfaces for farmers. Therefore, the proposed **AI-Driven Decision Support System for Smart Agriculture Using IoT Sensors** aims to overcome these limitations by integrating IoT sensing, cloud computing, Machine Learning, and intelligent decision support into a unified platform for sustainable and precision agriculture.

V. IMPLEMENTATION

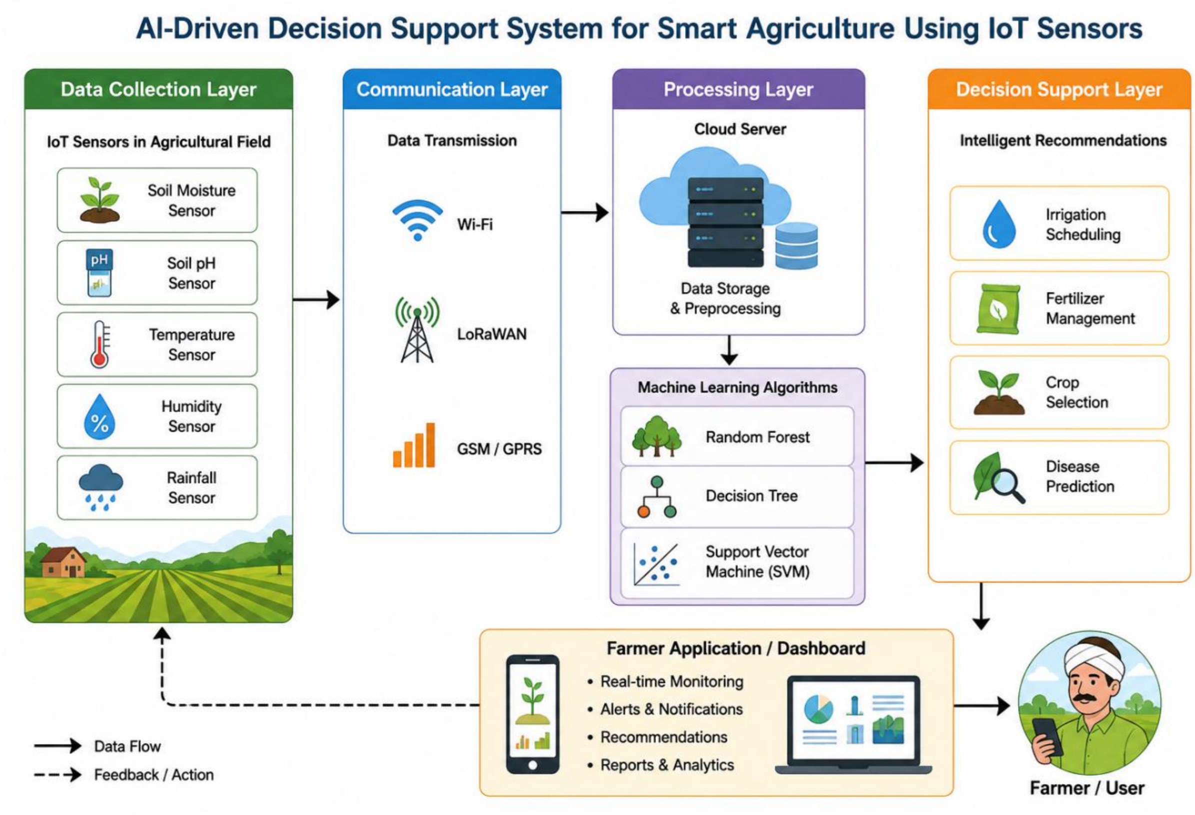

Fig. 6.1 AI-Driven Decision Support System for Smart Agriculture Using IoT Sensors

The block diagram illustrates the overall architecture and working principle of the **AI-Driven Decision Support System for Smart Agriculture Using IoT Sensors**. The system is divided into six major modules that work together to collect field data, analyze it, and provide intelligent recommendations to farmers.

1. Agricultural Field (IoT Sensors)

The first block represents the agricultural field where multiple IoT sensors are installed to continuously monitor environmental and soil conditions. The sensors include a **Soil Moisture Sensor**, **Temperature Sensor**, **Humidity Sensor**, **Soil pH Sensor**, and **Rain Sensor**. These sensors collect real-time information about the field and generate accurate data required for agricultural decision-making.

2. IoT Controller (ESP32)

The sensor outputs are connected to the **ESP32 microcontroller**, which acts as the central data acquisition unit. The ESP32 reads data from all sensors, performs basic preprocessing such as filtering and formatting, and prepares the information for wireless transmission. Its built-in Wi-Fi capability enables efficient communication with cloud servers.

3. Communication and Cloud Server

The processed sensor data is transmitted to the cloud using communication technologies such as **Wi-Fi**, **LoRaWAN**, or **GSM/GPRS**. The cloud server stores the incoming data in a database and performs preprocessing operations such as removing noise, handling missing values, and organizing the data for further analysis.

4. Machine Learning Processing Unit

After preprocessing, the data is analyzed using Machine Learning algorithms including **Random Forest**, **Decision Tree**, and **Support Vector Machine (SVM)**. These algorithms identify hidden patterns in the agricultural data and generate predictions related to irrigation requirements, fertilizer recommendations, crop suitability, and disease occurrence.

5. Decision Support System (DSS)

Based on the Machine Learning results, the Decision Support System generates intelligent recommendations for farmers. The DSS provides guidance on:

- Irrigation scheduling based on soil moisture and weather conditions.
- Suitable crop selection according to soil properties.
- Fertilizer recommendations to improve soil fertility.
- Early disease prediction and preventive measures.

These recommendations enable farmers to make informed and timely decisions, improving agricultural productivity while reducing resource wastage.

6. Farmer Mobile Application/Web Dashboard

The final block represents the user interface through which farmers access the generated recommendations. The mobile application or web dashboard displays real-time sensor readings, alerts, reports, irrigation schedules, crop recommendations, fertilizer suggestions, and disease warnings. Farmers can remotely monitor field conditions and take immediate corrective actions based on the information provided.

Overall Operation

The complete workflow of the system follows the sequence:

Agricultural Field (IoT Sensors) → ESP32 Controller → Wireless Communication (Wi-Fi/LoRa/GSM) → Cloud Database → Machine Learning Analysis → Decision Support System → Farmer Mobile Application/Web Dashboard.

This integrated architecture enables continuous field monitoring, intelligent data analysis, and real-time decision support, resulting in improved crop productivity, efficient resource utilization, reduced operational costs, and sustainable precision agriculture.

Flowchart Explanation

Explanation of the Flow Chart

The flow chart represents the working process of the **AI-Driven Decision Support System for Smart Agriculture Using IoT Sensors**. The system follows six major stages to collect field data, analyze it, and provide intelligent recommendations to farmers.

Step 1: Data Collection (IoT Sensors)

Various IoT sensors are deployed in the agricultural field to continuously monitor environmental and soil conditions. These sensors measure:

Soil Moisture Sensor: Measures the amount of water present in the soil.
Soil pH Sensor: Determines the acidity or alkalinity of the soil.
Temperature Sensor: Monitors the surrounding temperature.
Humidity Sensor: Measures the moisture content in the air.
Rainfall Sensor: Detects rain intensity and precipitation.
The collected data provides real-time information about the condition of the agricultural field.

Step 2: Data Transmission

The sensor data is transmitted from the field to the cloud server using wireless communication technologies such as:

- Wi-Fi
- LoRaWAN
- GSM/GPRS

This communication layer enables remote monitoring and real-time accessibility of agricultural data.

Step 3: Data Storage and Preprocessing

The received data is stored in a cloud database. Before analysis, the data undergoes preprocessing operations, including:

- Data storage in the cloud database
- Data cleaning to remove errors and noise
- Data preprocessing and normalization

These operations improve data quality and prepare it for Machine Learning analysis.

Step 4: Machine Learning Analysis

The processed data is analyzed using Machine Learning algorithms:

Random Forest: Used for crop recommendation and disease prediction.

Decision Tree: Used for agricultural decision-making and classification.

Support Vector Machine (SVM): Used for prediction and classification tasks.

The algorithms identify patterns and generate intelligent insights from the collected agricultural data.

Step 5: Decision Support System (DSS)

- Based on the analysis results, the Decision Support System generates recommendations related to:
- Irrigation Scheduling
- Fertilizer Recommendation
- Crop Selection
- Disease Prediction

These recommendations help farmers make informed and timely decisions.

Step 6: Output to Farmer

The generated recommendations are displayed to farmers through:

- Mobile Application
- Web Dashboard

The farmer can monitor field conditions, receive alerts and notifications, view reports, and take appropriate actions based on the system recommendations.

Feedback Loop

After implementing the recommendations, the field conditions change. The sensors again collect updated information, and the entire process repeats continuously. This feedback mechanism enables **real-time monitoring, continuous learning, and adaptive decision-making**, leading to improved crop productivity, optimized resource utilization, and sustainable precision agriculture.

Overall Flow:

IoT Sensors → Data Transmission → Cloud Storage & Preprocessing → Machine Learning Analysis → Decision Support System → Farmer Application → Feedback to Field Conditions

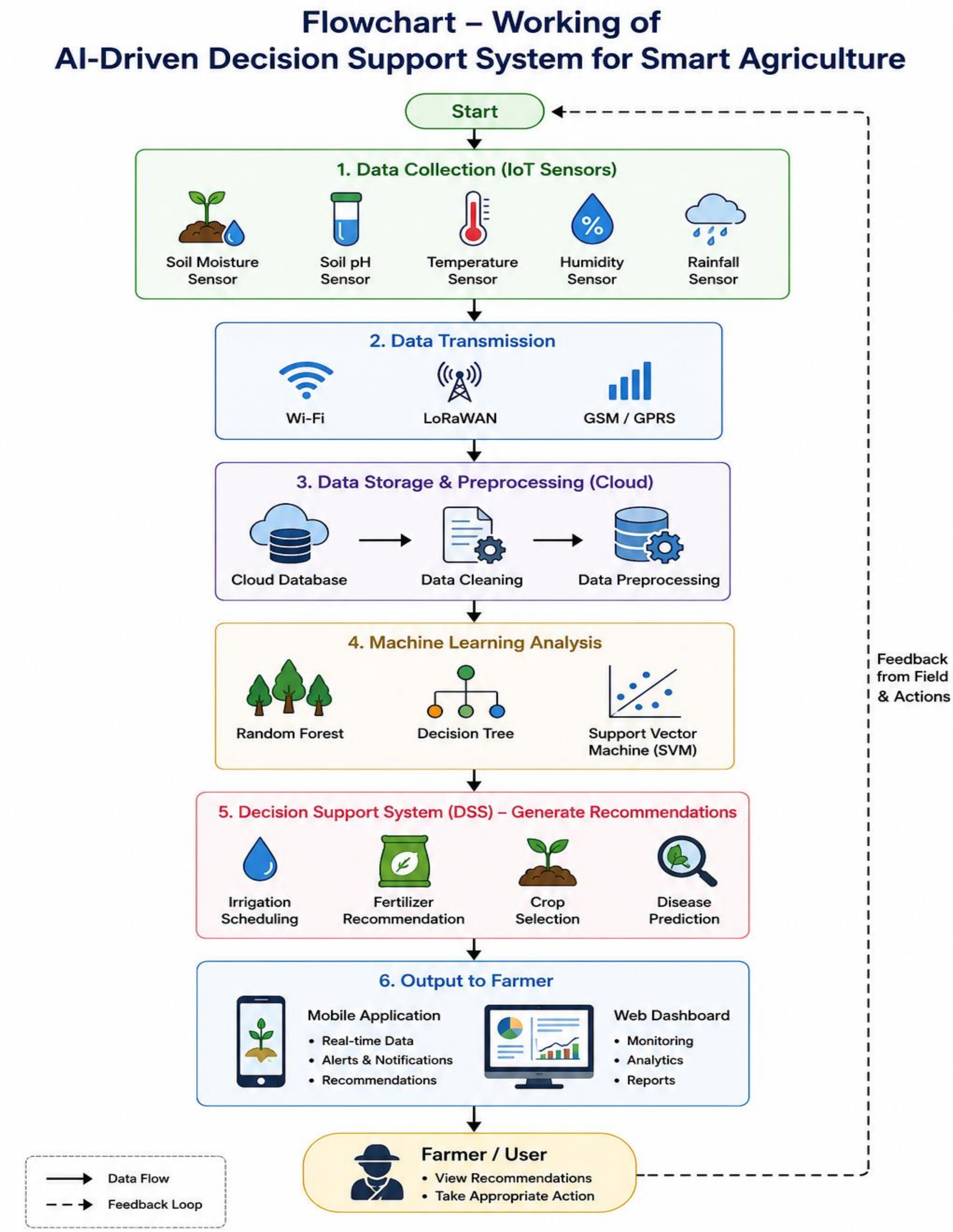

Fig. 6.2 : Flow chart AI-Driven Decision Support System for Smart Agriculture Using IoT Sensors

VI. HARDWARE AND SOFTWARE REQUIREMENT'S

Hardware Requirements

Sl. No.	Hardware Component	Description
1	ESP32 Development Board	Main microcontroller used for data acquisition and wireless communication.
2	Soil Moisture Sensor	Measures the moisture content present in the soil.
3	DHT11 Temperature and Humidity Sensor	Monitors environmental temperature and relative humidity.
4	Soil pH Sensor	Measures the acidity or alkalinity of the soil.
5	Rain Sensor	Detects rainfall and precipitation levels in the field.
6	Wi-Fi/LoRa/GSM Module	Provides wireless communication between the field and cloud server.
7	Power Supply/Battery	Supplies electrical power to sensors and the ESP32 controller.
8	Smartphone/Computer	Used by farmers to access recommendations through a mobile application or web dashboard.

Hardware Specifications

- **Controller:** ESP32 Dual-Core Microcontroller
- **Operating Voltage:** 3.3V–5V
- **Communication:** Wi-Fi, LoRaWAN, GSM/GPRS
- **Sensors:** Soil Moisture, pH, Temperature, Humidity, Rainfall Sensors
- **Power Source:** Rechargeable Battery or DC Power Supply

Software Requirements

Sl. No.	Software	Purpose
1	Arduino IDE	Programming and uploading code to ESP32.
2	Python	Data processing and Machine Learning implementation.
3	Jupyter Notebook	Development and testing of Machine Learning models.
4	MySQL	Storage and management of agricultural data.
5	TensorFlow	Development of Artificial Intelligence and prediction models.
6	Scikit-learn	Implementation of Machine Learning algorithms such as Random Forest, Decision Tree, and SVM.
7	ThingSpeak Cloud Platform	Cloud-based storage, monitoring, and visualization of sensor data.
8	Web Dashboard/Mobile Application	Displays recommendations, alerts, and real-time monitoring information to farmers.

Software Specifications

- **Programming Languages:** Python, Embedded C/C++
- **Machine Learning Libraries:** TensorFlow, Scikit-learn
- **Database:** MySQL
- **Cloud Platform:** ThingSpeak
- **Development Environment:** Arduino IDE, Jupyter Notebook
- **Operating System:** Windows/Linux

VII. Results and Discussion

The proposed **AI-Driven Decision Support System for Smart Agriculture Using IoT Sensors** was designed to continuously monitor agricultural field conditions and provide intelligent recommendations to farmers. The IoT sensors successfully collected real-time environmental and soil parameters, including soil moisture, temperature, humidity, soil pH, and rainfall data. The collected data was transmitted to the cloud platform, where Machine Learning algorithms processed the information and generated recommendations related to irrigation scheduling, fertilizer management, crop selection, and disease prediction.

The system demonstrated the following outcomes:

- Real-time monitoring of agricultural field conditions.
- Accurate collection and storage of sensor data.
- Intelligent irrigation recommendations based on soil moisture and weather conditions.
- Suitable crop and fertilizer recommendations according to soil characteristics.
- Early prediction of crop diseases using Machine Learning techniques.
- Remote monitoring through a mobile application and web dashboard.
- The expected performance improvements of the proposed system are:
- Reduction in water consumption by approximately **20–30%**.
- Improvement in crop yield by approximately **15–25%**.
- Reduction in excessive fertilizer usage and operational costs.
- Better utilization of available agricultural resources.
- Enhanced decision-making through predictive analytics.

The implementation of IoT and Artificial Intelligence technologies significantly improves the efficiency of traditional farming practices. Continuous monitoring of environmental conditions enables farmers to understand the real-time status of their agricultural fields and take appropriate actions promptly.

The integration of Machine Learning algorithms such as **Random Forest, Decision Tree, and Support Vector Machine (SVM)** provides intelligent analysis of the collected data and generates data-driven recommendations. These recommendations assist farmers in optimizing irrigation schedules, selecting suitable crops, and applying fertilizers more efficiently.

The cloud-based architecture enables remote access to agricultural information and allows farmers to monitor field conditions using mobile devices or web applications. The feedback mechanism continuously updates field information, making the system adaptive to changing environmental conditions.

Overall, the proposed system demonstrates that combining IoT sensors, cloud computing, and Artificial Intelligence can improve agricultural productivity, reduce resource wastage, lower operational costs, and promote sustainable precision farming practices. The system provides an effective framework for intelligent agricultural management and supports farmers in making informed and timely decisions.

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