

Agri Sense Farming: Soil-Crop Recommendation & Prediction System

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Abstract:

Agriculture plays a vital role in economic development, food security, and sustainable living. However, traditional agricultural practices often face challenges such as irregular climate conditions, inefficient irrigation, crop diseases, pest infestations, poor soil management, and fluctuating market prices. Farmers frequently lack access to real-time agricultural intelligence and personalized recommendations, leading to reduced productivity and inefficient resource utilization. Recent advancements in Artificial Intelligence (AI), Machine Learning (ML), image processing, Internet of Things (IoT), and Large Language Models (LLMs) have created new opportunities for developing intelligent smart farming systems capable of improving agricultural efficiency and decision-making. This research proposes AgriSense, a hybrid AI-based smart agriculture platform designed to provide intelligent agricultural assistance through real-time environmental monitoring, crop recommendation, disease detection, irrigation management, fertilizer guidance, pest-control analysis, and market demand prediction. The proposed system integrates rule-based agricultural algorithms, image-processing techniques, weather analytics, and Large Language Models within a unified and scalable architecture. One of the major strengths of the proposed architecture is its hybrid AI design, where rule-based algorithms provide scientific accuracy and deterministic calculations while LLMs provide contextual reasoning and expert-level agricultural recommendations. This combination improves reliability, adaptability, scalability, and fault tolerance.

Keywords: Smart Agriculture, Hybrid AI, Machine Learning, Large Language Models, Image Processing, Crop Recommendation, Precision Farming.

INTRODUCTION

AGRICULTURE is one of the most important sectors contributing to economic growth, food production, employment generation, and sustainable development. A significant portion of the global population depends directly or indirectly on agriculture for livelihood and economic stability. However, traditional farming practices continue to face several challenges such as unpredictable climate conditions, irregular rainfall, soil degradation, water scarcity, pest infestations, crop diseases, and fluctuating market prices. These problems often reduce agricultural productivity, increase operational costs, and negatively affect farmer profitability [8], [18], [20].

Conventional agricultural systems mainly rely on manual observation, historical experience, and generalized farming methods for crop cultivation and resource management. Such traditional approaches

are often insufficient for addressing modern agricultural challenges that require real-time analysis, environmental monitoring, and intelligent decision-making. Farmers frequently lack access to accurate agricultural guidance regarding crop selection, irrigation scheduling, fertilizer usage, disease management, and market planning. As a result, improper farming decisions may lead to crop failure, resource wastage, environmental damage, and financial losses [9], [17],[22].

In recent years, advancements in Artificial Intelligence (AI), Machine Learning (ML), IoT, image processing, cloud computing, and data analytics have significantly transformed the agricultural sector. Technologies such as weather monitoring, soil analysis, crop prediction, automated irrigation, and disease detection are increasingly being integrated into precision agriculture systems. Machine Learning algorithms such as Decision Trees, Random Forests, Support Vector Machines (SVM), and Neural Networks have been widely used for crop recommendation, yield prediction, and disease detection [11], [16], [19].

Recently, Large Language Models (LLMs) have introduced new possibilities in agricultural intelligence systems. LLMs can generate context-aware agricultural recommendations, provide expert-level farming guidance, and support natural language interaction through AI- powered chatbots. These systems improve accessibility by enabling farmers to receive real-time assistance regarding fertilizers, pest control, crop management, and market trends. Despite these advancements, existing agricultural systems still suffer from several limitations. Many systems focus only on individual agricultural activities such as irrigation management or disease detection without providing an integrated smart farming ecosystem [14], [15],[21].

LITERATURE REVIEW

The rapid growth of Artificial Intelligence (AI), Machine Learning (ML), Internet of Things (IoT), cloud computing, and data analytics has significantly transformed the agricultural sector in recent years. Researchers and agricultural experts have proposed various intelligent farming systems to improve crop productivity, optimize resource utilization, reduce environmental impact, and support farmers in making accurate decisions. Smart agriculture systems integrate technologies such as weather forecasting, soil analysis, disease detection, irrigation automation, and market prediction to enhance overall farming efficiency. However, many existing systems still face limitations related to scalability, contextual understanding, real-time adaptability, and reliability [8], [14], [20].

Several studies have focused on the use of Machine Learning algorithms for crop recommendation and yield prediction. Algorithms such as Decision Trees, Random Forest, Support Vector Machines (SVM), and Artificial Neural Networks have been widely applied for analyzing soil nutrients, climatic conditions, rainfall, temperature, and historical agricultural data. These systems can predict suitable crops and estimate expected production levels based on environmental parameters. Although Machine Learning models provide high predictive accuracy, they require large amounts of labeled training data and frequent retraining to adapt to changing environmental conditions. In addition, many ML-based systems operate as black-box models, making it difficult for farmers to understand the reasoning behind recommendations [9],[17], [20].

Researchers have also explored IoT-based smart irrigation systems for water management and precision agriculture. These systems use sensors to monitor soil moisture, humidity, temperature, and water levels in real time. Based on collected sensor data, automated irrigation systems can optimize water usage and reduce wastage. Such approaches improve irrigation efficiency and support sustainable farming

practices, especially in water- scarce regions. However, IoT systems often depend heavily on hardware infrastructure, stable internet connectivity, and sensor maintenance, which may increase implementation costs for small-scale farmers.

Plant disease detection has become another major research area in smart agriculture. Deep Learning and image-processing techniques such as Convolutional Neural Networks (CNNs) have been used to identify plant diseases from leaf images. These systems analyze visual symptoms including discoloration, spots, and texture changes to detect diseases at an early stage. While image- based disease detection systems improve accuracy and reduce manual effort, many existing models are limited to specific crops or diseases and may fail under varying environmental conditions or poor image quality [11], [16], [19].

Recent advancements in Large Language Models (LLMs) have introduced new possibilities in agricultural intelligence systems. LLMs can simulate expert agronomist reasoning and generate context-aware recommendations using natural language interaction. Unlike traditional ML models, LLMs can provide detailed explanations, contextual advice, and conversational assistance to farmers. Agricultural chatbots powered by LLMs answer farming-related questions, suggest fertilizers, and identify pest control strategies. However, LLMs may sometimes generate inaccurate or hallucinated responses, especially when precise numerical calculations are required. To overcome individual approach limitations, hybrid systems combine rule-based algorithms for scientific calculations and LLMs for contextual reasoning [15], [21], [24].

PROBLEM STATEMENT

Agriculture plays a vital role in economic development, food security, and employment generation. However, farmers continue to face multiple challenges that negatively affect agricultural productivity, profitability, and resource management. Traditional farming practices mainly depend on manual observation, historical experience, and generalized cultivation methods, which are often insufficient for solving modern agricultural problems such as climate change, irregular rainfall, soil degradation, pest infestations, crop diseases, water scarcity, and fluctuating market prices [8], [18], [20].

One of the major limitations of existing agricultural systems is the lack of integrated decision-support platforms capable of analyzing multiple agricultural and environmental factors simultaneously. Most current solutions focus only on a single agricultural activity such as crop recommendation, irrigation management, or disease detection, without providing a complete smart farming ecosystem. Farmers often need to use multiple disconnected applications and services for different agricultural tasks, which increases complexity and reduces usability. In addition, many existing systems fail to provide recommendations based on local environmental conditions, soil quality, climate variations, and market demand .

Traditional Machine Learning-based agricultural systems also suffer from several drawbacks. These models require large amounts of labeled training data, continuous retraining, and complex feature engineering for maintaining prediction accuracy. In rural agricultural environments, collecting high-quality datasets is expensive and difficult. Moreover, many ML models operate as black-box systems, making it difficult for farmers to understand the reasoning behind generated recommendations, which may reduce trust and adoption. Similarly, systems based entirely on LLMs may face reliability and numerical accuracy issues in scientific agricultural tasks [14].

PROPOSED SYSTEM

The proposed system, AgriSense, is an intelligent hybrid AI-based agricultural assistance platform designed to support smart farming and precision agriculture using AI, image processing, weather analytics, and Large Language Models (LLMs). The primary objective of the system is to provide farmers with accurate, real-time, and context-aware agricultural guidance for improving productivity and resource utilization [14], [20], [24].

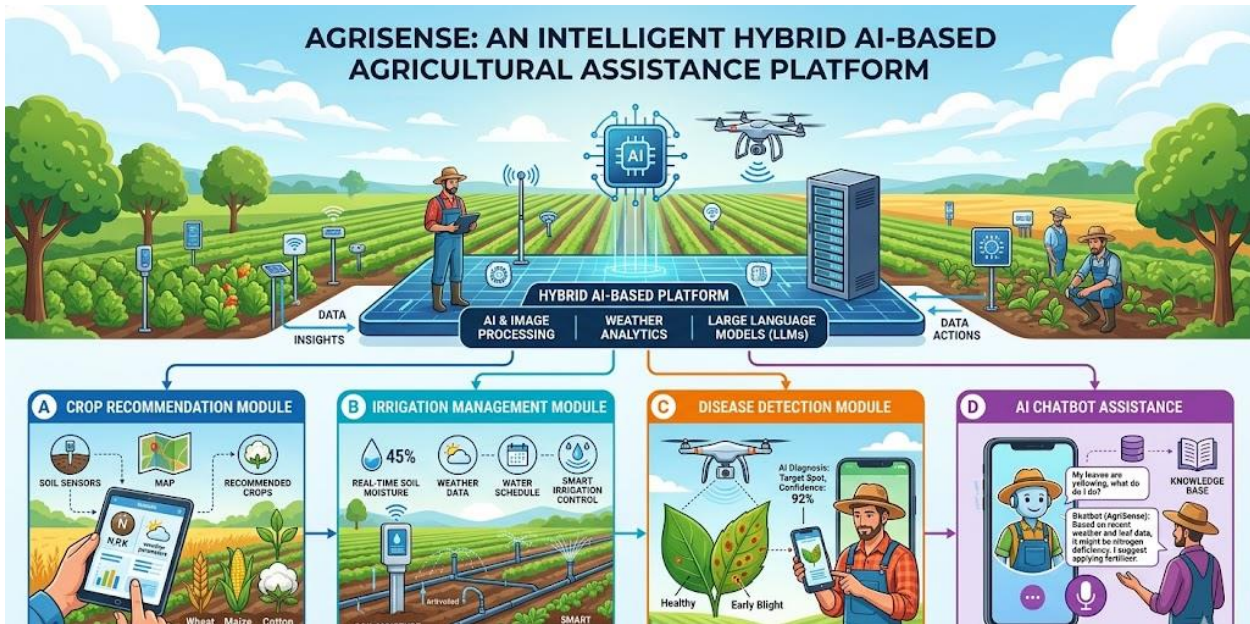


Fig. 1. Overall System Architecture demonstrating hybrid integration of rule-based and AI models

A. Crop Recommendation Module

The Crop Recommendation Module analyzes soil nutrients such as Nitrogen (N), Phosphorus (P), Potassium (K), pH value, humidity, rainfall, and temperature conditions to identify crops that are most suitable for cultivation. Rule-based agricultural calculations and AI-driven recommendation techniques are used to improve crop selection accuracy and reduce crop failure risks [9], [17], [22].

B. Irrigation Management Module

The Irrigation Management Module provides intelligent irrigation recommendations by analyzing soil images, moisture conditions, weather information, and crop water requirements. This module helps optimize water usage and supports sustainable irrigation practices, especially in drought-prone agricultural regions [10], [18], [20].

C. Disease Detection Module

The Disease Detection and Plant Growth Monitoring Module uses AI-based image-processing techniques to analyze uploaded crop images and identify diseases such as fungal infections, leaf discoloration, spots, and abnormal growth patterns. The system generates treatment recommendations and preventive measures to minimize crop damage [11], [16], [19].

D. AI Chatbot Assistance

To improve contextual agricultural assistance, the platform integrates Large Language Models through OpenRouter APIs. The AI chatbot module provides real-time farming guidance, fertilizer recommendations, pest-control suggestions, and market intelligence through natural language interaction. The chatbot acts as a virtual agricultural expert capable of assisting farmers in real time [15], [21].

TABLE I. SOIL ANALYSIS PARAMETERS AND IMPORTANCE
 [cite: 1]

Nutrient	Measurement	Standard Range	Significance
Nitrogen (N)	mg/kg	50 - 150	Vegetative Growth
Phosphorus (P)	mg/kg	20 - 60	Root Development
Potassium (K)	mg/kg	100 - 250	Disease Resistance
pH Value	pH Scale	6.0 - 7.5	Nutrient Availability
Moisture	%	40 - 70	Irrigation Timing

SYSTEM ARCHITECTURE

The architecture of the proposed AgriSense system is designed as a modular, scalable, and hybrid AI-based agricultural intelligence platform. The system integrates AI, ML, image processing, weather analytics, market intelligence, and rule-based agricultural algorithms to provide real-time assistance. Communication between users, AI services, and agricultural modules is managed through integrated backend services. [14], [20],[24].

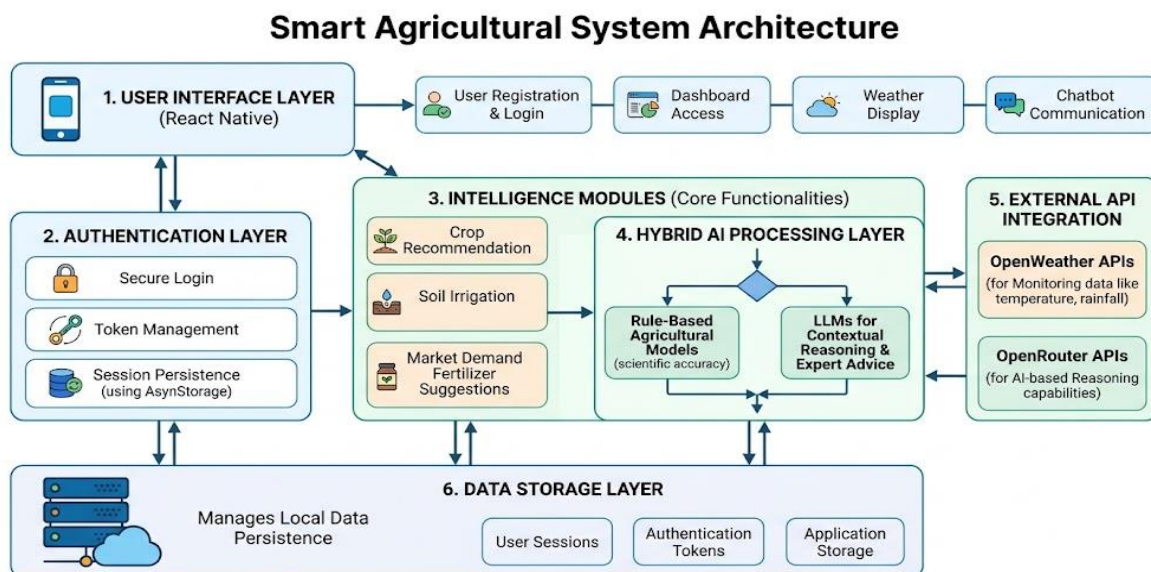


Figure 2: Complete System architecture of proposed system

The architecture consists of several key layers:

1. User Interface Layer: Developed using React Native, managing user registration, dashboard access, weather display, and chatbot communication.
2. Authentication Layer: Responsible for secure login, token management, and session persistence using AsyncStorage.
3. Intelligence Modules: Core functionalities for crop recommendation, soil irrigation, market demand analysis, and fertilizer suggestions.
4. Hybrid AI Processing Layer: Combines rule-based agricultural models for scientific accuracy with LLMs for contextual reasoning and expert advice.
5. External API Integration: Connects to Open Weather APIs for monitoring and OpenRouter APIs for AI-based reasoning.
6. Data Storage Layer: Manages local data persistence, user sessions, authentication tokens, and application storage [cite: 1].

METHODOLOGY

The AgriSense platform follows a systematic data collection and analysis workflow.

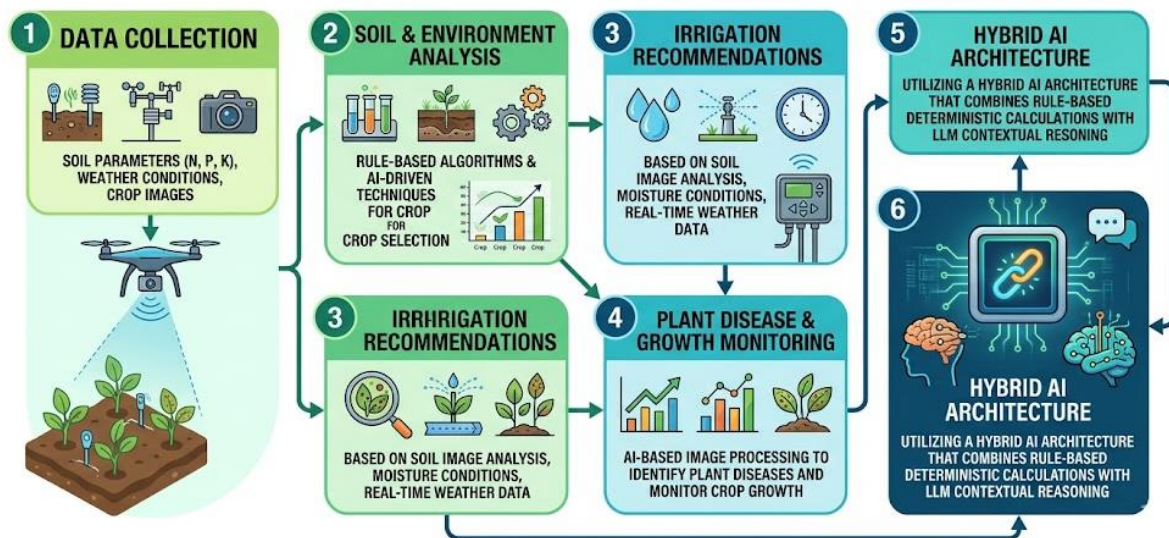


Figure 3 : shows the workflow of system

The methodology involves six key stages:

1. Data collection from soil parameters (N, P, K), weather conditions, and crop images.
2. Analysis of soil quality and environment using rule-based algorithms and AI-driven techniques for crop selection.
3. Generating irrigation recommendations based on soil image analysis, moisture conditions, and real-time weather data.
4. Applying AI-based image processing to identify plant diseases and monitor crop growth from uploaded plant photos.
5. Analyzing market trends, crop demand, and seasonal price variations to recommend crops with better market value.

6. Utilizing a hybrid AI architecture that combines rule-based deterministic calculations with LLM contextual reasoning [2], [10], [13].

MODEL AND IMPLEMENTATION

The proposed system uses a hybrid combination of rule-based agricultural algorithms, image-processing techniques, and Large Language Models. Rule-based models are used for deterministic scientific agricultural calculations such as yield estimation and nutrient thresholds. For intelligent reasoning, the system integrates Large Language Models through OpenRouter APIs, specifically utilizing the openai/gpt-oss-120b:free model. This model is responsible for AI chatbot assistance, fertilizer suggestions, and contextual expert advice. This hybrid architecture ensures numerical accuracy and expert reasoning while improving system adaptability and fault tolerance .

FRONTEND IMPLEMENTATION

The frontend is developed using React Native to provide a user-friendly and interactive mobile application. The visualization layer allows farmers to input soil parameters, upload plant images, and view recommendations generated by the backend. Key features include a real-time dashboard for weather updates, specific modules for crop prediction and disease analysis, and multi-language support. Communication with the backend is achieved through REST APIs using Axios, ensuring clear and actionable responses for implementable farming scenarios [3], [4].

ALGORITHMS USED:

AgriSense utilizes a hybrid suite of algorithms to ensure reliability and accuracy. Rule-Based Agricultural Algorithms analyze environmental and soil conditions using predefined scientific formulas. The Large Language Model (openai/gpt-oss-120b:free) processes prompts to generate natural language expert advice. Image Processing Algorithms analyze symptoms such as discoloration and spots in crop images. The hybrid strategy combines rule-based mathematical models with LLM-based qualitative insights. In the Market Controller, yield prediction follows scientific formulas, while qualitative assessments like risk levels and market trends are derived from LLM analysis. Geolocation and weather algorithms provide location-specific recommendations, while JWT and AsyncStorage manage secure sessions [14], [15], [21].

RESULTS AND DISCUSSION

The proposed AgriSense system was successfully implemented and evaluated. The Crop Recommendation Module produced effective suggestions based on soil chemistry and climate, reducing crop failure probability. The Irrigation module demonstrated water management efficiency by generating schedules based on moisture data fusion. Disease Detection effectively identified pathogens from leaf images, enabling early treatment recommendations. The AI Chatbot provided contextual expert advice through natural language interaction, enhancing information accessibility. The Hybrid AI Architecture improved reliability and fault tolerance through fallback mechanisms during API disruptions [10], [18], [20]. The proposed system offers several benefits for modern agriculture: 1. Real-time intelligent agricultural guidance. 2. Improved crop productivity through accurate soil-climate matching. 3. Optimized water usage via efficient irrigation scheduling. 4. Early identification of plant diseases minimizing crop damage. 5. Expert expert-level recommendations for fertilizers and pest control. 6.

Market-aware financial planning based on demand trends.

6. Reliable hybrid architecture ensuring scientific accuracy. 8. Accessible mobile application for farmers. 9. Integration of weather and geolocation monitoring. 10. Secure user authentication and local data persistence [12], [23], [27].

AgriSense can be applied across multiple agricultural domains: - Smart farming and precision agriculture decision support. - Irrigation management for water conservation in water-scarce regions. - Plant disease identification and growth monitoring. - Intelligent nutrient management and fertilizer application. - Profitable crop planning based on market demand analysis. - Virtual expert agronomist services through AI chatbots. - Academic research for soil conditions and disease patterns .

CONCLUSION:

The AgriSense system presents an integrated smart agriculture platform designed to address major challenges faced by modern farmers. By combining rule-based algorithms with Large Language Models and image processing, the system improves scientific accuracy and contextual reasoning. The hybrid architecture ensures reliability through fallback mechanisms, contributing toward sustainable agriculture, improved productivity, and data-driven precision farming. The research confirms that hybrid AI systems can efficiently transform traditional farming into intelligent modern agriculture .

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