

AgroSphere: A Terra-to-Trade Intelligent Decision Support Framework for Precision Agriculture Using Machine Learning and Real-Time Analytics

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Abstract— Agriculture is a significant contributor to global food and economic development, yet modern farming continues to face significant challenges such as unpredictable climatic conditions, inappropriate crop selection, fluctuating market prices, increasing cultivation costs, and limited access to agricultural guidance. Existing digital agricultural solutions often address these challenges independently, resulting in fragmented decision-making and reduced operational efficiency. To overcome these limitations, this paper proposes AGROSPHERE: A Terra-to-Trade Intelligent Decision Support Framework for Precision Agriculture Using Machine Learning and Real-Time Analytics. The proposed framework integrates crop recommendation, real-time weather monitoring, market intelligence, cost-profit analysis, and crop hygiene assessment into a unified web-based platform that supports farmers throughout the entire agricultural lifecycle.

The framework employs the Random Forest machine learning algorithm to recommend suitable crops based on soil and environmental parameters. Real-time weather information and agricultural market prices are retrieved through external APIs to facilitate informed cultivation and marketing decisions. In addition, a cost-profit prediction module assists farmers in estimating cultivation expenses, expected revenue, and profitability, while a crop hygiene assessment module provides preventive recommendations for maintaining crop

health. The system is implemented using a FastAPI backend with a responsive web interface, ensuring scalability, accessibility, and efficient service delivery.

By integrating agronomic, environmental, and economic intelligence within a single platform, AgroSphere enables data-driven decision-making, improves resource utilization, reduces agricultural risks, and enhances farm productivity. The proposed framework offers an affordable and scalable solution for promoting sustainable precision agriculture, particularly for small and medium-scale farmers, while providing a

strong foundation for future integration of advanced AI technologies and smart farming applications.

Key Words: Precision Agriculture, Smart Farming, Machine Learning, Random Forest, Decision Support System, Real-Time Analytics, Crop Recommendation, Sustainable Agriculture.

1. INTRODUCTION

Agriculture has been the foundation of human civilization and continues to play a pivotal role in ensuring global food security, economic stability, and sustainable development. In many developing countries, particularly India, agriculture serves as the primary source of livelihood for a significant portion of the population while contributing substantially to the national economy. However,

the agricultural sector is increasingly challenged by climate change, declining soil fertility, unpredictable rainfall patterns, water scarcity, pest infestations, and fluctuating market prices. These factors directly influence crop productivity and farmer income, making agricultural decision-making more complex than ever before.

Traditionally, farmers rely on personal experience, inherited knowledge, and local agricultural practices to make decisions regarding crop selection, irrigation, fertilizer application, disease management, and harvesting. Although these conventional approaches have supported farming for generations, they often fail to address the dynamic challenges of modern agriculture. Decisions made without scientific analysis of soil characteristics, environmental conditions, and market demand can lead to reduced crop yields, inefficient resource utilization, and significant financial losses.

Recent advancements in Artificial Intelligence (AI), Machine Learning (ML), cloud computing, and data analytics have created new opportunities for transforming conventional agriculture into an intelligent, data-driven ecosystem. Precision Agriculture utilizes these technologies to collect, process, and analyze agricultural data, enabling farmers to make informed decisions based on scientific evidence rather than assumptions. Machine learning algorithms can identify complex relationships among soil properties, climatic conditions, and crop performance, thereby improving crop recommendation, yield prediction, and resource optimization. Similarly, real-time weather forecasting and agricultural market intelligence enable farmers to reduce risks associated with environmental uncertainty and market volatility.

Despite these technological advancements, most existing agricultural applications focus on individual aspects of farming, such as crop recommendation, weather forecasting, disease diagnosis, or market price monitoring. As a result,

farmers are often required to access multiple independent platforms, manually interpret information, and combine recommendations before making cultivation decisions. This fragmented approach increases complexity, consumes valuable time, and limits the effectiveness of digital agriculture solutions, particularly for small and medium-scale farmers with limited technical resources.

To address these challenges, this research proposes AgroSphere: A Terra-to-Trade Intelligent Decision Support Framework for Precision Agriculture Using Machine Learning and Real-Time Analytics. The proposed framework integrates multiple agricultural services into a unified platform that supports farmers throughout the complete agricultural lifecycle—from crop planning and cultivation to harvesting and market trading. The framework combines machine learning-based crop recommendation, real-time weather intelligence, market price retrieval, cost-profit estimation, and crop hygiene assessment within a single web-based ecosystem, thereby reducing dependence on fragmented information sources and improving decision-making efficiency.

The crop recommendation module employs the Random Forest machine learning algorithm to analyze soil characteristics and environmental parameters, enabling farmers to identify the most suitable crops for cultivation. Weather intelligence is obtained through external APIs, providing real-time atmospheric information that assists in agricultural planning and risk management. The market intelligence module retrieves current commodity prices from government-supported databases, enabling farmers to make informed marketing decisions. In addition, the cost-profit prediction module estimates cultivation expenses, expected revenue, and profitability, while the crop hygiene assessment module supports preventive crop health management through systematic evaluation and recommendations.

Unlike many existing smart agriculture systems that require expensive IoT infrastructure and specialized hardware, AgroSphere adopts a lightweight and scalable architecture based on publicly available datasets and cloud-based APIs. The system is implemented using a FastAPI backend with a responsive web interface, making it accessible, affordable, and suitable for deployment in diverse agricultural environments. This design enables broader adoption, particularly among small and medium-scale farmers who may have limited access to advanced technological resources.

The proposed framework contributes to the advancement of precision agriculture by integrating agronomic, environmental, and economic intelligence into a single decision-support platform. By providing farmers with accurate recommendations and real-time insights, AgroSphere aims to improve agricultural productivity, optimize resource utilization, reduce operational risks, and enhance overall farm profitability. Furthermore, the modular architecture provides a strong foundation for future enhancements, including IoT-based field monitoring, computer vision for crop disease detection, multilingual advisory services, and advanced predictive analytics, thereby supporting the long-term vision of sustainable and intelligent agriculture.

2. LITERATURE SURVEY

Extensive research has been conducted to apply computational intelligence to individual segments of agriculture.

- **Crop Recommendation:** Numerous studies have utilized algorithms like Support Vector Machines (SVM), K-Nearest Neighbors (KNN), and Naive Bayes to predict crop suitability. Research indicates that Ensemble methods, particularly Random Forest, outperform singular classifiers due to their ability to handle non-linear relationships and prevent overfitting in multi-class agricultural datasets.

- **IoT and Weather Integration:** Early smart farming frameworks relied heavily on localized IoT sensor networks. While accurate, the high capital expenditure for hardware installation makes it unviable for small-scale farmers. Recent literature validates the use of cloud-based weather APIs (e.g., OpenWeather) as a cost-effective, highly reliable alternative for regional macro-climate tracking.

- **Market Analytics:** Agricultural economics research highlights that price volatility can be mitigated by giving farmers direct access to centralized government databases, such as AGMARKNET in India. Integrating these endpoints directly into farmer-facing apps eliminates information asymmetry.

While the existing literature addresses these modules in isolation, there is a distinct research gap regarding a unified framework that connects soil characteristics directly to market trading data. AgroSphere fills this gap.

3. PROBLEM STATEMENT

Agriculture remains one of the most important sectors supporting global food production and economic development. However, modern farming is increasingly challenged by unpredictable climatic conditions, declining soil fertility, inefficient resource utilization, fluctuating market prices, and limited access to timely agricultural information. These challenges significantly affect crop productivity and farmers' income, particularly for small and medium-scale farmers who often rely on traditional knowledge and experience-based decision-making.

Conventional farming practices generally lack scientific analysis of soil characteristics, environmental conditions, and market trends. As a result, farmers frequently select unsuitable crops, leading to reduced yields, increased cultivation costs, and financial losses. Moreover, the absence of integrated decision-support systems forces farmers to depend on multiple independent

platforms for weather forecasts, crop recommendations, market prices, and financial planning. This fragmented approach complicates decision-making and limits the effective adoption of digital agriculture technologies.

Another major challenge is the lack of real-time monitoring and predictive analytics. Without timely weather information and market intelligence, farmers are unable to plan irrigation, fertilizer application, harvesting schedules, or marketing strategies effectively. In addition, limited access to crop health assessment tools delays the identification of potential diseases and cultivation issues, further impacting agricultural productivity.

Although several smart agriculture solutions have been proposed, most address only individual aspects of farming rather than providing a comprehensive end-to-end solution. There is a clear need for an integrated, intelligent, and user-friendly platform that combines agronomic, environmental, and economic information to support farmers throughout the complete agricultural lifecycle.

To address these challenges, this research proposes AgroSphere: A Terra-to-Trade Intelligent Decision Support Framework for Precision Agriculture Using Machine Learning and Real-Time Analytics. The proposed framework integrates machine learning-based crop recommendation, real-time weather intelligence, market price retrieval, cost-profit prediction, and crop hygiene assessment into a unified web-based platform. By providing data-driven insights and actionable recommendations, AgroSphere aims to improve agricultural productivity, optimize resource utilization, reduce financial risks, and promote sustainable farming practices.

4. OBJECTIVES

The primary objective of this research is to develop AgroSphere, a Terra-to-Trade Intelligent Decision Support Framework that leverages Machine

Learning and Real-Time Analytics to assist farmers in making informed decisions throughout the agricultural lifecycle. The framework aims to improve agricultural productivity, optimize resource utilization, and enhance farm profitability through an integrated digital platform. The specific objectives of the proposed work are as follows:

To develop an intelligent crop recommendation system using the Random Forest machine learning algorithm based on soil characteristics and environmental conditions.

To provide real-time weather intelligence by integrating external weather APIs, enabling farmers to make timely decisions related to irrigation, fertilizer application, and harvesting.

To integrate live agricultural market information that allows farmers to monitor commodity prices and make informed marketing decisions.

To develop a cost-profit prediction module that estimates cultivation expenses, expected revenue, and profitability for effective financial planning.

To implement a crop hygiene assessment module that evaluates crop health and provides preventive recommendations for maintaining healthy crop growth.

To integrate multiple agricultural services into a unified platform, thereby reducing the dependence on fragmented applications and improving decision-making efficiency.

To promote sustainable and data-driven farming practices by combining agronomic, environmental, and economic intelligence within a single decision-support framework.

To develop a scalable and user-friendly web-based application using FastAPI and modern web technologies that is accessible to farmers with varying levels of technological expertise.

Through these objectives, AgroSphere aims to bridge the gap between traditional farming practices and intelligent digital agriculture, providing farmers with an affordable, efficient, and comprehensive solution for precision farming and sustainable agricultural development.

5. EXISTING SYSTEM

The existing agricultural ecosystem primarily relies on traditional farming practices and fragmented digital solutions for decision-making. Farmers often depend on personal experience, local agricultural experts, and conventional cultivation methods when selecting crops, managing resources, and planning farming activities. Although digital technologies have been introduced in agriculture, most existing systems focus on individual functionalities such as crop recommendation, weather forecasting, disease detection, or market price monitoring, rather than providing a unified decision-support platform.

Several agricultural applications offer weather updates and crop advisory services, while government portals provide market price information and soil health records. However, these systems operate independently and require farmers to access multiple platforms to gather relevant information. This fragmented approach increases complexity and often results in inconsistent or delayed decision-making.

Most existing systems generate static recommendations based on limited datasets without considering real-time environmental conditions or changing market dynamics. In addition, many solutions lack financial planning features such as cultivation cost estimation and profit analysis, making it difficult for farmers to evaluate the economic feasibility of their farming decisions. Furthermore, the absence of integrated crop health assessment and personalized recommendations reduces the overall effectiveness of these platforms.

As agriculture becomes increasingly data-driven, there is a growing need for an intelligent and comprehensive framework that integrates agronomic, environmental, and economic information into a single platform. Addressing these limitations is essential for improving productivity, reducing risks, and supporting sustainable farming practices.

6. PROPOSED SYSTEM

To overcome the limitations of conventional agricultural practices and fragmented digital solutions, this research proposes AgroSphere: A Terra-to-Trade Intelligent Decision Support Framework for Precision Agriculture Using Machine Learning and Real-Time Analytics. The framework is designed as an integrated web-based platform that assists farmers throughout the complete agricultural lifecycle, from crop planning and cultivation to harvesting and market trading.

The proposed system combines Artificial Intelligence (AI), Machine Learning (ML), real-time weather intelligence, market analytics, financial forecasting, and crop hygiene assessment within a single platform. By integrating these services, AgroSphere enables farmers to make informed, data-driven decisions while reducing dependence on multiple independent applications.

The framework employs a Random Forest machine learning model to recommend suitable crops based on soil characteristics and environmental conditions. Real-time weather information is obtained through external weather APIs, enabling farmers to plan irrigation, fertilizer application, and harvesting activities effectively. The Market Intelligence Module retrieves live commodity prices from government-supported agricultural databases, helping farmers identify favorable selling opportunities.

In addition, the Cost-Profit Prediction Module estimates cultivation expenses, expected revenue, and profitability, allowing farmers to evaluate the financial viability of their farming practices. The Crop Hygiene Assessment Module assists in monitoring crop health through a structured questionnaire and provides preventive recommendations to reduce disease-related losses.

The proposed framework follows a modular architecture in which each component performs a specific agricultural function while interacting seamlessly with the others through a FastAPI-based backend. This design improves scalability, simplifies maintenance, and supports future integration with advanced technologies such as IoT

sensors, computer vision, satellite imagery, and multilingual advisory systems.

By integrating agronomic, environmental, and economic intelligence into a unified ecosystem, AGROSPHERE transforms traditional farming into a smart, efficient, and sustainable decision-support system. The framework aims to improve crop productivity, optimize resource utilization, enhance farmer profitability, and promote environmentally responsible agricultural practices.

7. SYSTEM ARCHITECTURE (BLOCK DIAGRAM)

The proposed AgroSphere framework follows a modular architecture that integrates machine learning, real-time APIs, and decision-support modules into a unified smart agriculture platform. The architecture is designed to provide end-to-end assistance to farmers by connecting data acquisition, intelligent processing, and recommendation services within a single workflow.

The system begins with the User Interface, where farmers provide essential agricultural inputs such as soil type, geographical location, crop details, cultivation area, and other relevant parameters. The responsive web application serves as the interaction layer, allowing users to access all services through a simple and intuitive interface.

The user inputs are transmitted to the FastAPI Backend, which acts as the central processing unit of the framework. The backend validates incoming data, coordinates communication between different modules, invokes the machine learning model, and manages requests to external services. This centralized architecture ensures efficient data processing and seamless integration of all components.

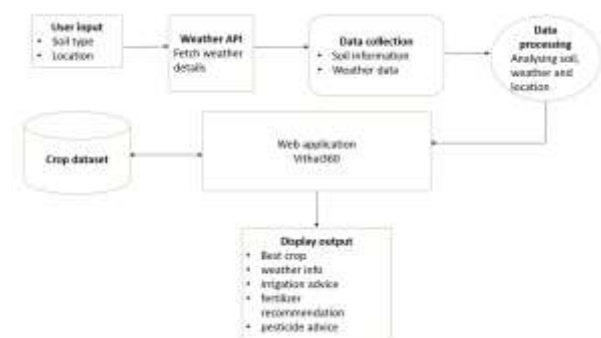
The Machine Learning Module employs a trained Random Forest algorithm to analyze soil and environmental parameters and recommend the most suitable crop for cultivation. Simultaneously, the backend retrieves real-time weather information through the OpenWeather API and current commodity prices from AGMARKNET or

other government-supported agricultural databases. These external data sources enrich the decision-making process by incorporating dynamic environmental and market conditions.

The framework also includes a Cost-Profit Prediction Module, which estimates cultivation expenses, expected revenue, and projected profitability based on user inputs and market information. In addition, the Crop Hygiene Assessment Module evaluates crop health using a structured questionnaire and generates preventive recommendations to support healthy cultivation practices.

Finally, all outputs generated by the various modules—including crop recommendations, weather forecasts, market prices, financial analysis, and crop hygiene reports—are consolidated and displayed through the web interface. This integrated architecture enables farmers to make informed decisions at every stage of cultivation, improving productivity, optimizing resource utilization, and enhancing overall farm profitability.

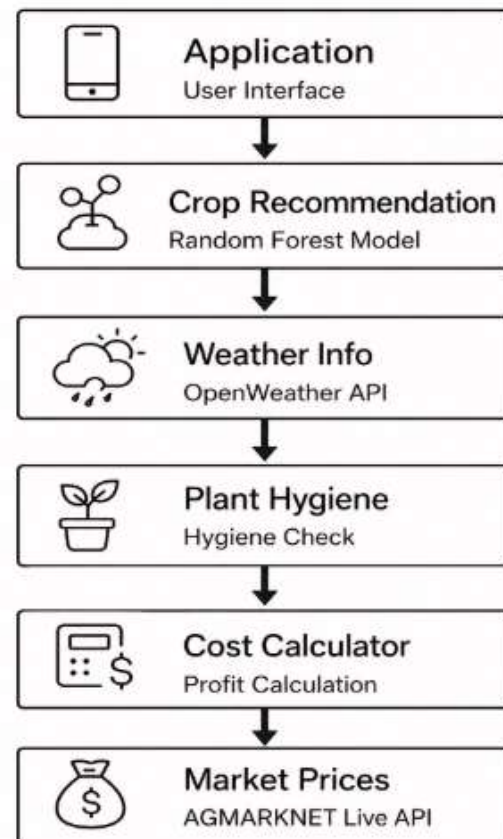
The modular design of AgroSphere ensures scalability, maintainability, and flexibility, allowing future integration of advanced technologies such as IoT-based sensing, satellite imagery, deep learning models, and multilingual advisory services without significant modifications to the existing framework.



8. DATA FLOW DIAGRAM (DFD)

The Data Flow Diagram (DFD) illustrates the movement of data through the AgroSphere framework, from user input to the generation of

intelligent recommendations and outputs. It represents how different system modules interact with one another and with external data sources to support data-driven agricultural decision-making. The process begins when the farmer accesses the AgroSphere web application and provides essential agricultural information such as soil type, geographical location, crop details, cultivation area, and cost-related inputs. These inputs are validated by the FastAPI backend before being forwarded to the respective processing modules. For crop recommendation, the system combines user-provided soil parameters with environmental data obtained from the Weather API. The collected information is preprocessed and supplied to the Random Forest machine learning model, which analyzes the input features and predicts the most suitable crop for cultivation. The generated recommendation is then returned to the user along with additional advisory information, including irrigation suggestions, fertilizer recommendations, pesticide guidance, and weather conditions. Simultaneously, the Market Intelligence Module communicates with the AGMARKNET API to retrieve real-time agricultural commodity prices. The Cost-Profit Prediction Module uses cultivation expenses, estimated yield, and current market prices to calculate the expected revenue and projected profit. The Crop Hygiene Assessment Module collects responses from a structured questionnaire, evaluates crop health conditions, and generates preventive recommendations based on the user's responses. Finally, all processed information from the individual modules is consolidated and displayed through the web interface. The integrated data flow ensures that farmers receive comprehensive recommendations from a single platform rather than relying on multiple independent systems. This streamlined workflow improves decision-making, reduces operational complexity, and supports efficient resource utilization throughout the agricultural lifecycle.



9. METHODOLOGY

The proposed AgroSphere framework follows a systematic methodology to provide intelligent agricultural decision support by integrating machine learning techniques, real-time data acquisition, and web-based technologies. The methodology is designed to assist farmers throughout the complete agricultural lifecycle, beginning with crop planning and extending to market analysis and profitability estimation. The workflow begins with the collection of user inputs, including soil characteristics, geographical location, crop information, cultivation area, and cost-related details. In parallel, the system retrieves real-time environmental information such as temperature, humidity, and weather conditions using the OpenWeather API. These datasets are validated and preprocessed before being utilized by the machine learning model and other analytical modules.

The Crop Recommendation Module employs the Random Forest algorithm to analyze soil properties and environmental parameters to identify the most suitable crop for cultivation. The selected algorithm is capable of handling multiple agricultural variables and producing reliable recommendations by learning complex relationships within the training dataset.

The Weather Intelligence Module continuously gathers real-time climatic information to support agricultural planning. Weather forecasts assist farmers in scheduling irrigation, fertilizer application, pesticide spraying, and harvesting activities, thereby reducing risks associated with adverse environmental conditions.

The Market Intelligence Module retrieves current commodity prices from government-supported agricultural databases such as AGMARKNET. The retrieved market information enables farmers to monitor pricing trends and make informed decisions regarding the timing of crop sales.

The Cost-Profit Prediction Module estimates cultivation expenses by considering inputs such as land area, seed cost, irrigation cost, fertilizer cost, and labour charges. Using estimated crop yield and current market prices, the system calculates expected revenue and projected profit, allowing farmers to evaluate the economic feasibility of cultivation before investment.

The Crop Hygiene Assessment Module evaluates crop health through a structured questionnaire. Based on user responses regarding crop condition and cultivation practices, the system identifies potential issues and provides preventive recommendations to improve crop health and productivity.

Finally, the outputs generated by all modules are integrated and displayed through the web application. Farmers receive comprehensive recommendations including suitable crop selection, weather updates, irrigation advice, fertilizer suggestions, market prices, cost analysis, profit estimation, and crop hygiene reports. This integrated methodology enables efficient, data-driven, and sustainable agricultural decision-

making while minimizing operational complexity and improving farm productivity.

10. MODULE 1 – EXPLORE FARMING

Objective

The Explore Farming module is designed to provide farmers with an interactive platform to access essential agricultural information and initiate the decision-support process. It acts as the gateway to the AgroSphere framework by collecting preliminary user inputs and directing them to the appropriate intelligent modules.

Input

The module accepts basic user information, including:

Soil type

Geographical location

Crop preferences (if any)

User-selected agricultural service

Process

After receiving the user inputs, the system validates the information and forwards it to the FastAPI backend. The backend retrieves real-time weather information through external APIs and prepares the collected data for further processing. Depending on the user's selection, the system redirects the request to the Crop Recommendation, Crop Hygiene, Cost Calculator, or Real-Time Crop Price Retrieval module.

The Explore Farming module serves as the central navigation component of the framework, ensuring smooth communication between users and the intelligent decision-support services.

Output

The module provides:

Access to all agricultural services

Basic farming information

Weather overview

Navigation to intelligent recommendation modules

User-friendly dashboard for agricultural decision support

Advantages

Simple and intuitive user interface.

Centralized access to all agricultural services.

Reduces navigation complexity.
Provides quick access to real-time farming information.
Improves user experience through an integrated dashboard.

11. MODULE 2 – CROP RECOMMENDATION

Objective

The Crop Recommendation Module is the core component of the AgroSphere framework. Its primary objective is to recommend the most suitable crop for cultivation based on soil characteristics, environmental conditions, and geographical location. The module utilizes the Random Forest machine learning algorithm to generate accurate and reliable recommendations, enabling farmers to make informed cultivation decisions while improving productivity and resource utilization.

Input

The module accepts the following user inputs:

Soil type

Geographical location

Soil parameters (such as pH, Nitrogen, Phosphorus, and Potassium values, where available)

Environmental conditions

User preferences (optional)

In addition to user inputs, the system retrieves real-time weather information—including temperature, humidity, and rainfall—from the OpenWeather API.

Process

The crop recommendation process begins with the collection of soil information and geographical location from the user. The backend communicates with the Weather API to obtain current climatic conditions for the specified location. The collected soil and weather data are validated and preprocessed before being supplied to the trained Random Forest machine learning model.

The Random Forest algorithm analyzes the relationship between soil properties, climatic conditions, and historical agricultural data to determine the crop that is most suitable for

cultivation. The model evaluates multiple decision trees and generates the final recommendation based on majority voting, ensuring robust and reliable predictions.

After identifying the suitable crop, the system generates additional farming recommendations, including irrigation guidance, fertilizer suggestions, pesticide recommendations, and weather information. These recommendations assist farmers in planning cultivation activities more effectively.

Output

The module provides the following outputs:

Recommended crop for cultivation

Current weather conditions

Irrigation recommendations

Fertilizer recommendations

Pesticide recommendations

Supporting farming guidance for informed decision-making

Advantages

Provides scientific crop recommendations based on data analysis.

Improves crop productivity by considering soil and climatic conditions.

Reduces the risk of inappropriate crop selection.

Integrates real-time weather information with machine learning predictions.

Assists farmers in optimizing the use of water, fertilizers, and other agricultural resources.

Supports sustainable and data-driven farming practices.

12. MODULE 3 – CROP HYGIENE

Objective

The Crop Hygiene Module is designed to assist farmers in monitoring and maintaining crop health through a systematic assessment process. The primary objective of this module is to identify potential crop health issues at an early stage and provide preventive recommendations that help reduce crop damage, improve productivity, and promote sustainable farming practices.

Input

The module requires the following inputs:

Crop name

User responses to hygiene-related questions

Observations regarding crop condition (leaf color, pest presence, disease symptoms, irrigation practices, etc.)

Process

The crop hygiene assessment begins when the user selects the crop and initiates the hygiene evaluation. The system presents a structured questionnaire containing a series of Yes/No questions related to crop health, farming practices, irrigation, pest infestation, nutrient deficiency, and disease symptoms.

The user responses are collected and analyzed using predefined evaluation rules. Based on the number of positive and negative responses, the system calculates a hygiene score that reflects the overall health condition of the crop. The score is then categorized into different health levels such as Low, Moderate, or High.

After the evaluation, the system generates personalized recommendations to help farmers improve crop health. These recommendations may include better irrigation practices, balanced fertilizer application, pest management techniques, disease prevention measures, and general crop maintenance guidelines.

Output

The Crop Hygiene Module provides the following outputs:

Crop hygiene score

Crop health classification (Low, Moderate, or High)

Preventive recommendations

Suggested agricultural best practices

Crop health assessment report

Advantages

Enables early identification of crop health issues.

Assists farmers in adopting preventive measures before severe damage occurs.

Encourages good agricultural and hygiene practices.

Reduces crop losses caused by diseases and poor cultivation methods.

Improves crop quality and overall agricultural productivity.

Provides simple and user-friendly crop health assessment without requiring specialized equipment.

13. MODULE 4 – COST CALCULATOR

Objective

The Cost Calculator Module is designed to assist farmers in estimating the total cost of cultivation, expected revenue, and projected profit before crop production. The primary objective of this module is to support financial planning by enabling farmers to evaluate the economic feasibility of cultivation based on crop type, land area, and cultivation expenses.

Input

The module accepts the following user inputs:

Crop name

Land area

Seed cost

Fertilizer cost

Irrigation cost

Labour cost

Other cultivation expenses

Process

The Cost Calculator Module begins by collecting cultivation-related information from the user. The system computes the total cultivation cost by summing all input expenses, including seed, fertilizer, irrigation, labour, and additional operational costs.

The estimated crop yield is then determined using predefined agricultural data and cultivation parameters. Based on the expected yield and the current market price obtained from the Market Intelligence Module, the system calculates the estimated revenue. Finally, the projected profit is determined by subtracting the total cultivation cost from the estimated revenue.

To improve user understanding, the calculated financial information is presented using graphical visualizations such as bar charts and pie charts, allowing farmers to easily compare expenses, revenue, and profit.

Output

The module provides the following outputs:

Total cultivation cost

Estimated crop yield

Expected revenue

Projected profit

Financial analysis using graphical representations

Advantages

Supports effective financial planning before cultivation.

Enables farmers to estimate profitability prior to investment.

Helps optimize agricultural expenditure.

Improves budgeting and resource allocation.

Assists farmers in selecting economically viable cultivation strategies.

Provides easy-to-understand graphical analysis for better financial decision-making.

14. MODULE 5 – REAL-TIME CROP PRICE RETRIEVAL

Objective

The Real-Time Crop Price Retrieval Module is designed to provide farmers with up-to-date market prices of agricultural commodities. The primary objective of this module is to reduce information asymmetry by enabling farmers to access current market rates, compare prices, and make informed decisions regarding the sale of their agricultural produce.

Input

The module accepts the following input:

Crop name

Process

The process begins when the user enters the name of the crop for which market information is required. The FastAPI backend sends a request to the AGMARKNET API, which provides real-time agricultural commodity prices from various regulated markets.

The received data are processed, validated, and formatted into a structured output. The system extracts relevant information such as the crop name, market name, price per quintal, and the source of the data. The processed information is

then displayed through the web interface in a simple and user-friendly format.

By providing real-time market information, the module enables farmers to compare commodity prices across markets and identify suitable selling opportunities, thereby improving their bargaining power and overall profitability.

Output

The module provides the following outputs:

Crop name

Market name

Current market price per quintal

Source of the market data

Real-time pricing information

Advantages

Provides real-time access to agricultural commodity prices.

Assists farmers in selecting the most profitable market for selling their produce.

Reduces dependence on intermediaries for price information.

Improves transparency in agricultural marketing.

Supports better financial planning and marketing decisions.

Enhances farmer profitability through timely market intelligence.

15. RESULTS AND DISCUSSION

The AgroSphere framework was successfully designed and implemented as a web-based intelligent decision support system for precision agriculture. The system integrates machine learning, real-time weather information, market intelligence, financial analysis, and crop hygiene assessment into a unified platform that assists farmers throughout the agricultural lifecycle. The Crop Recommendation Module successfully analyzes soil characteristics and environmental parameters using the Random Forest algorithm to recommend suitable crops for cultivation. The integration of real-time weather information further enhances the reliability of recommendations by considering current climatic conditions.

The Weather Intelligence Module retrieves and displays real-time atmospheric information, enabling farmers to plan irrigation schedules, fertilizer application, and harvesting activities more effectively. The Market Intelligence Module successfully fetches current commodity prices from agricultural market databases, allowing farmers to monitor market trends and make informed selling decisions.

The Cost Calculator Module accurately estimates cultivation expenses, expected revenue, and projected profit based on user-provided inputs. The graphical visualization of financial information through charts improves the readability of cost analysis and supports better financial planning. The Crop Hygiene Assessment Module provides an interactive mechanism for evaluating crop health through a structured questionnaire. Based on user responses, the system generates hygiene scores and preventive recommendations that assist farmers in maintaining healthy crop conditions. The developed framework demonstrates that integrating multiple agricultural services into a single platform significantly simplifies agricultural decision-making. Farmers no longer need to rely on separate applications for crop recommendation, weather monitoring, market analysis, financial estimation, and crop health assessment. The unified architecture improves usability, reduces operational complexity, and promotes data-driven farming practices.

16. CONCLUSION

This paper presented AgroSphere: A Terra-to-Trade Intelligent Decision Support Framework for Precision Agriculture Using Machine Learning and Real-Time Analytics, an integrated web-based platform developed to support farmers throughout the agricultural lifecycle. The proposed framework addresses key challenges in modern agriculture, including inappropriate crop selection, weather uncertainty, fluctuating market prices, inefficient financial planning, and limited access to crop health assessment.

The framework successfully integrates five major modules: Crop Recommendation, Weather Intelligence, Market Intelligence, Cost-Profit Prediction, and Crop Hygiene Assessment. By leveraging the Random Forest machine learning algorithm, real-time weather services, and agricultural market data, AgroSphere provides farmers with accurate recommendations and actionable insights for effective decision-making.

The implementation of a FastAPI-based backend and a responsive web interface ensures scalability, accessibility, and ease of use. The integrated architecture eliminates the need for multiple independent agricultural applications by consolidating essential farming services into a single platform. This enables farmers to optimize resource utilization, improve productivity, reduce cultivation risks, and make economically informed decisions.

Overall, AgroSphere demonstrates the potential of combining machine learning, real-time analytics, and modern web technologies to support sustainable precision agriculture. The proposed framework contributes toward the digital transformation of agriculture by providing an intelligent, affordable, and scalable decision-support system that can benefit farmers, agricultural organizations, and policymakers alike.

17. FUTURE SCOPE

Although AgroSphere provides a comprehensive intelligent decision-support framework for precision agriculture, there is significant potential for further enhancement and expansion. Future developments can improve the system's accuracy, scalability, and practical applicability by integrating emerging technologies and advanced analytical techniques.

One of the major future enhancements is the integration of Internet of Things (IoT) sensors for real-time field monitoring. Sensors capable of measuring soil moisture, temperature, humidity, pH, and nutrient levels can provide continuous environmental data, enabling more accurate crop

recommendations and automated irrigation management.

The framework can also be extended by incorporating Computer Vision and Deep Learning techniques for automatic crop disease detection. By analyzing images captured using smartphones or drones, convolutional neural network (CNN) models can identify diseases, pest infestations, and nutrient deficiencies at an early stage, allowing farmers to take timely corrective actions.

Another promising enhancement is the integration of satellite imagery and remote sensing technologies for monitoring crop growth, vegetation health, and land-use patterns over large agricultural areas. These technologies can improve yield prediction and provide valuable insights for precision farming.

Developing a dedicated mobile application would further improve accessibility by allowing farmers to access crop recommendations, weather updates, market prices, and financial analysis directly from their smartphones. Offline functionality and multilingual support would make the application more suitable for rural farming communities.

Future versions of AgroSphere can also incorporate an AI-powered multilingual chatbot capable of providing real-time agricultural guidance, answering farmers' queries, and offering personalized cultivation recommendations in regional languages.

The integration of government agricultural schemes, subsidy information, crop insurance services, and financial assistance programs can further enhance the usefulness of the platform by connecting farmers with relevant support services and improving awareness of available benefits.

In addition, advanced machine learning and predictive analytics techniques can be employed to improve crop yield estimation, market price forecasting, and climate-risk assessment. These enhancements would enable more accurate long-term agricultural planning and better resource management.

Overall, these future improvements will transform AgroSphere into a more intelligent, scalable, and comprehensive smart agriculture ecosystem capable of supporting sustainable farming practices and improving the socio-economic well-being of farmers.

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