

SmartAgroWeb: A Multi-Module AI-Driven Agriculture Platform

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Abstract : Agriculture is a essential driver of economic development and food security, but farmers are still confronted with many obstacles such as unpredictable climate, the wrong crop choice, plant diseases, and the inability to access information about price, government scheme or market in real-time.

The purpose of this paper is to introduce and present SmartAgroWeb: An intelligent web-based agricultural support system, built using AI, ML and real-time APIs into one cohesive solution.

The proposed solution is established using a multi-layer architecture which includes the presentation, application, service/API, and data layers. The system provides numerous features such as crop recommendation based on soil parameters, plant disease detection using image processing, weather forecasting in real-time, monitoring of market prices, government scheme recommendations, and consultation from experts. The system also incorporates an AI-based chatbot which provides instant advisory support based on a hybrid of rule-based logic and large language models.

The system is developed on a client-server architecture using modern web technologies such as React.js for the frontend, Spring Boot for backend processing, and MongoDB for data storage. It also relies on third party APIs to provide real-time data,

thus helping to improve the accuracy and reliability of its recommendations.

The aim of this project is to integrate multiple services into a single user-friendly platform.

INDEX TERMS: Smart Agriculture, Crop Recommendation, Plant Disease Detection, Machine Learning, Artificial Intelligence, Decision Support System, AI Chatbot, Sustainable Farming

1.INTRODUCTION

Agriculture is one of the most important economic sectors in developing nations and is critical to providing food security and creating jobs. In India alone, many citizens rely upon agricultural work to provide for themselves and their families. Yet, despite its importance, agriculture in many developing nations continues to struggle due to multiple challenges, including climate change; ineffective use of resources; poor access to real-time information; and a slow uptake of technological advancements. These issues undermine not only crop output but also the income received by farmers and the overall sustainability of agricultural practices.

The main challenge of agriculture today is increasing variability in weather patterns that makes planning for planting/irrigating/harvesting crops nearly impossible. Farmers also often choose crops based on intuition and experience rather than utilizing available data to make

informed selections; therefore many farmers miss out on higher yield potential by failing to identify suitable crops. The inability to quickly dress injured crops still contributes to substantial yield losses. Furthermore, due to a farmer's lack of real-time knowledge regarding the current prices for their products or about the various government assistance programs available to them, they miss out on potentially lucrative sales opportunities, ultimately resulting in lower levels of income.

Currently, rapid technology developments in the areas of Artificial Intelligence ("AI"), Machine Learning ("ML"), and Web-Based Systems provide a tremendous opportunity for transforming traditional, non-technologically enabled forms of agribusiness into "smart" agriculture with data-derived decisions to improve yield through better crop selection.

2. LITERATURE REVIEW:

In recent years, agriculture has seen major improvements through the use of Artificial Intelligence (AI), Machine Learning (ML), and digital technologies aimed at boosting productivity and sustainability. Several studies have looked into intelligent systems that help farmers make decisions.

Recent research found on platforms like ScienceDirect, Springer, and PMC highlights the creation of smart agricultural systems that combine weather forecasting, crop recommendations, and disease detection to improve farming efficiency [1][2][3]. These systems show the importance of data-driven agriculture; however, most are built to tackle specific agricultural issues rather than provide a complete solution.

Big data methods have also been widely used in agriculture. Tseng et al. proposed a data-driven crop selection system that uses environmental and soil factors to suggest suitable crops [5]. While the system increases accuracy in crop prediction, it mainly concentrates on crop selection and does not include other critical services like disease detection or market analysis.

Climate change has emerged as a key factor affecting agricultural productivity. Shevchenko et al. studied land suitability using machine learning models under changing climate conditions [6]. Their study gives valuable insights into climate impact; however, it lacks real-time decision support and interactive advisory features for farmers.

The adoption of modern technologies in agriculture continues to face hurdles. Kasemi et al. discussed the gap between technology advancements and their actual use, pointing out issues like lack of awareness, high costs, and system complexity [7]. These challenges limit the practicality of modern agricultural systems for small-scale farmers.

In crop disease detection, Bhargava et al. developed a deep learning-based method using leaf image analysis, achieving high accuracy in identifying plant diseases [8]. Although effective, these systems are usually standalone and do not connect with other necessary agricultural services for farmers. Market transparency has also been looked at in recent studies. Madrewar et al. explored the use of IoT technologies to provide real-time market price information, allowing farmers to make better selling choices [9]. However, these systems

mainly focus on market data and do not tie it in with advisory or predictive features.

Additionally, web-based agricultural platforms have been created to enhance accessibility and information delivery [4]. While these systems improve user access, they often miss intelligent features like AI-based recommendations, expert consultation, and integrated services.

From these studies, it is clear that although there has been significant progress in using AI, ML, and IoT in agriculture, most current systems focus on single functionalities such as crop recommendations, disease detection, or market analysis. There is a strong need for a unified and integrated platform that combines multiple agricultural services into one system to provide complete support for farmers.

3. PROPOSED SYSTEM:

3.1. System description:

The proposed system is SmartAgroWeb, a web-based agricultural decision support system designed to improve the efficiency of agriculture through the use of data to make better decisions. SmartAgroWeb was created using advanced technologies like Artificial Intelligence (AI), Machine Learning (ML) and real-time APIs to provide reliable, scalable and user-friendly agricultural services.

The SmartAgroWeb system is different from traditional systems which use multiple single tools or require the farmer to provide technical knowledge on how to use each tool because it's a single, web-based application that can be accessed using any standard web browser; therefore no complicated installations are required. In addition, SmartAgroWeb uses a modular and service-oriented approach, meaning that each function is separately and independently developed but they work together through a back-end server.

SmartAgroWeb is designed to solve many of the major problems in agriculture today, including: unpredictability of weather, selecting the wrong crop to plant, delayed diagnosis of pest diseases, lack of access to current market information, and lack of access to professional advisors. By offering all the agricultural services on one site, SmartAgroWeb allows farmers to have better and more timely information, which will enable them to be more productive and sustainable.

3.2. Functional Modules:

1) Crop Recommendation Module

The Crop Recommendation Module uses supervised machine learning to provide recommendations for which crops are best suited to be planted in specific fields based on the physical and chemical characteristics of the soil, including: pH level of the soil, moisture level of the soil and nitrogen, phosphorus and potassium (NPK) composition of the soil. In this module, will be used as inputs for the database that is used to train the machine learning model to provide the crop recommendations.

2) Module to Detect Diseases

Plants are grown in agricultural environments or through cropping systems can suffer from diseases and experience environmental stresses that slow down their growth or destroy them. The process of obtaining information regarding the health of these plants is performed through image processing techniques and Deep Learning applications using leaf images taken by the user. Upon carrying out this process, image processing activities of the uploaded image such as resizing, normalizing, removing/reducing any background noise, etc., as well as passing the processed image to a trained classification model (typically a Convolutional Neural Network), the system can take the visual symptoms of a leaf and predict the possible diseases affecting that leaf with a confidence score. The module also provides other relevant actionable recommendations such as ways to prevent future occurrences and how to treat the various diseases.

3) Module Intended to Predict Weather Conditions

The weather value representing actual and predicted weather conditions are obtained from external weather API integration with our Price Finder Application. Each of the components of these weather conditions can have an effect on the agricultural processes associated with crops being produced by farmers such as irrigation timings, sowing and harvesting of crops. Thus, the Weather Forecasting Module contains an easy-to-understand graphical representation of the weather data. The Weather Forecasting Module also promotes the use of real-time weather data, which allows farmers to make accurate and reliable decisions using the most current weather data.

4) Module to Determine Market Pricing

The Market Price module will use agricultural market prices determined by APIs for the collection and analysis of real-time commodity prices. Based upon this information, the farmers will be able to view price trends across various different markets which will better help them to determine the best time and place to sell their crops. In addition, by using the Market Pricing module, farmers will improve their profit margin while also decreasing their reliance on middle parties (i.e., individuals or agencies between the grower and consumer) and eliminating price uncertainty.

5) AI Chatbot & Advisory Module

The AI Advisory Module is developed using a hybrid design, incorporating rule-based systems and LLM APIs for successful implementation. The AI Advisory Module serves as an intelligent virtual assistant that understands users' requests for advice and assistance through natural language communication and provides contextually relevant answers. The AI Chatbot encompasses information regarding crop management, pest management, disease prevention, and general agriculture practices in a simplified and usable format, resulting in bridging the gap in agriculture education for farmers.

3.3. System Workflow

The system operates under a traditional client/server structure. The first step to requesting information or assistance begins with the user utilizing the web interface to input soil parameters, crop pictures, or descriptive request queries. Once this information has been sent to the backend server, the routing mechanism is used to route through the different modules.

The next step in this workflow is determining whether the inputs are meant for predictive features, such as crop suggestions or disease detection, and using machine learning and/or image analysis pipelines to process these inputs. The backend also processes the real-time weather and market data queries by retrieving the requested information from outside data sources using external API calls. Once all of the processed data has been formatted, it is sent back to the frontend interface and presented to the user visually.

In summary, this workflow results in effective handling of data, creation of real-time results, and integration of multiple services into one platform.

4. SYSTEM ARCHITECTURE

The SmartAgroWeb System, with its multi-layered and modular architecture, provides scalable, flexible, and efficient data processing solutions. Utilizing a service-oriented architecture allows for clear functional separation between the various system components, enabling independent development of different functional areas, simplified maintenance, and facilitated incorporation of new features.

The whole of the SmartAgroWeb System's architecture consists of four primary layers—the Frontend Layer, the Backend Layer, the AI/ML Processing Layer, and the Database Layer. Each of these four layers represents a core component of the SmartAgroWeb System. Additionally, the SmartAgroWeb System provides integration of numerous other external services via APIs to provide additional sources of real-time data and improve decision-making. Each layer has its own responsibilities for performing specific tasks, with communication between layers via defined interfaces, promoting the free flow of data across the SmartAgroWeb System.

1.Front End:

The front end provides the user with a platform through which to interact with the system. The front end has three main interfaces:

- Farmer interface - provides a way for the farmer to enter his crop information, soil parameters, and questions, as well as access weather information and market prices.
- Expert interface - provides a way for the agricultural expert to see the farmer's question, provide the farmer with his response, and track his answer through the reporting functions of the system.

- Admin interface - provides a way for the administrator to monitor the system, verify users, assign queries to users, and analyze data.

The front end layers are responsible for collecting input from the end user, while also providing the end user with a method of interpreting the output generated by the system.

2.Back End:

The back end layer is built on top of node.js and written in TypeScript. The back end is considered the "central processing unit" of the system. The back end serves as the primary means of communication between the front end, artificial intelligence (AI) and machine learning (ML) services, and database.

The back end provides many functionalities, including:

- REST API handling, authentication
- Query management and routing
- Communication between farmer and expert
- Processing of recommendations
- Handling of requests for disease detection
- Processing of weather and market data
- Report generation

The back end serves as a single point of entry for all requests to all components of the system.

3. AI/ML Levels

The AI/ML Levels provide intelligent information analysis and predictive analytics by integrating AI-based APIs with machine learning models to deliver advanced agriculture-based insights.

Key functionality that this level provides includes:

- Soil analysis - to provide crop recommendations
- Medical image classification - to detect diseases
- Market price forecasting
- Query classification and response generation
- Government Scheme Recommendation engine
- AI-based chatbot (Large Language Model) to provide personal advice

The AI/ML levels will increase the system's ability to provide accurate recommendations through the use of data to drive them.

4. Integrated External Services

Through the integration of multiple external services through APIs, this system can provide real-time data as well as enhanced functionality. For instance, the following services/locations will provide the required details:

- Weather API - to provide climate data
- Market prices API - to provide real-time price of crops

- Government scheme portal - to provide information related to policy
- Notification services - to provide alerts
- Voiceto-text API - to help users enter queries

These services will provide up-to-date and relevant information for the system.

5. Database Layer

The database layer of the Agribusiness system is built using MongoDB and holds all data that is in use by the system. The data is held in five categories:

- Farmer/expert records
- Record of crop/soil data
- Record of each query and response
- Advisory history
- Weather and query cache data
- Government scheme information

The database layer ensures that data is consistent, retrieved quickly, and can be scaled (addition of more data).

6. System Workflow

The Agribusiness system uses a structured workflow for both input through the frontend and output processed through the backend. Upon receiving user input through the frontend, the backend routes the request either to the AI/ML layer and/or to an external API based on how the user made the request. The retrieved output is then pulled from the database or generated dynamically at the time of the request and delivered back to the frontend for display.

By configuring the Agribusiness system with a layered architecture is allows for efficient data flow through the system, which is modular in development and provides for the highest level of performance.

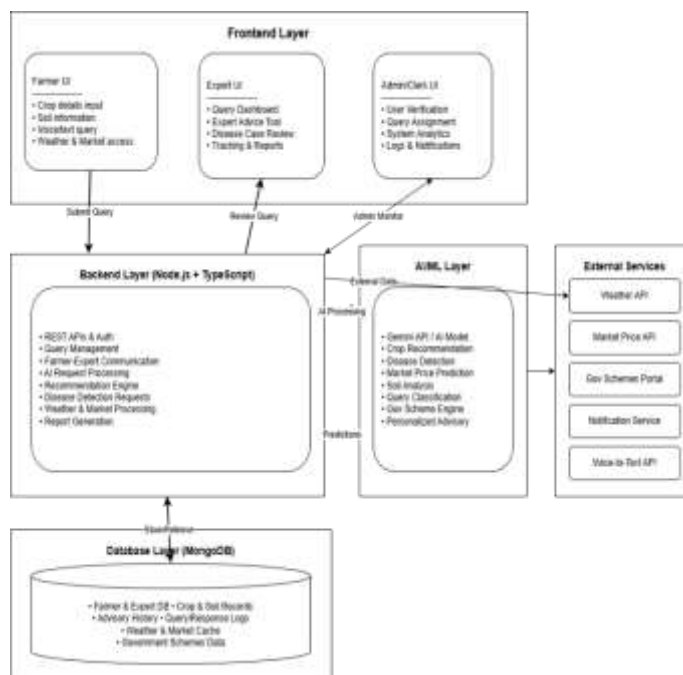


Fig 4.1 System Architecture

4.1 DFD Diagram:

4.1.1 Level 0 DFD:

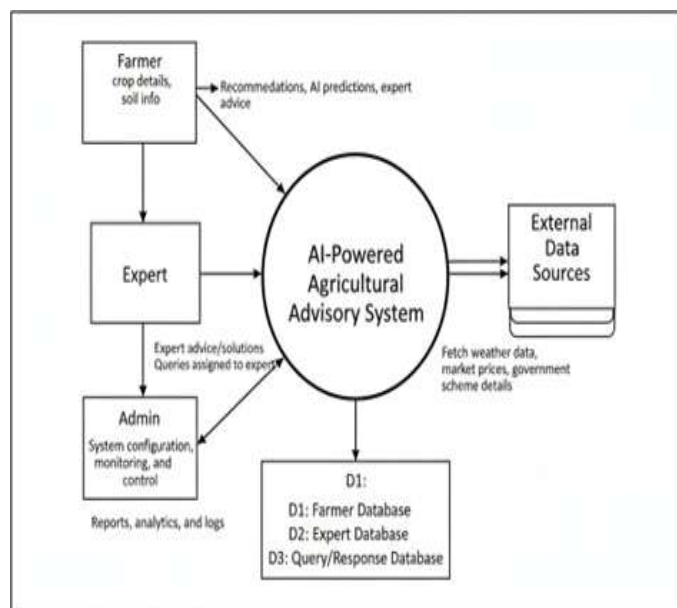


Fig 4.2 Level 0 Data Flow Diagram

The Level 0 DFD illustrates the general interactions between the User and the SmartAgroWeb system. Farmers provide information (e.g., soil data, images of their crops, and questions) to the system, which processes that information and produces outputs (e.g., recommendations, predictions of problems, and advice).

4.1.2 Level 1 DFD:

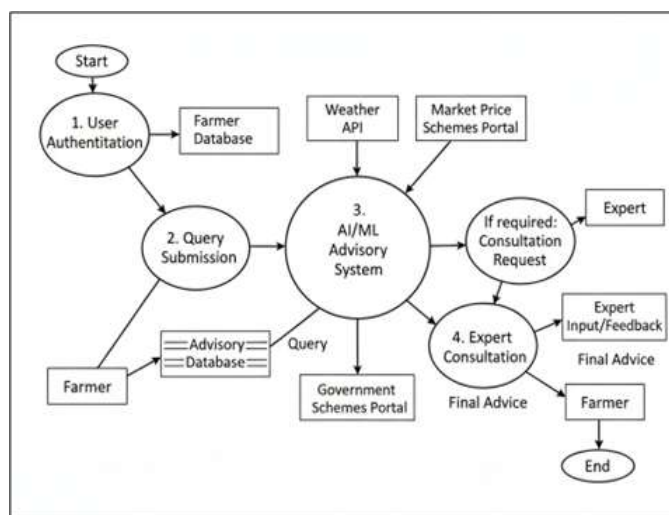


Fig 4.3 Level 1 Data Flow Diagram

The Level 1 Data Flow Diagram visualizes how the system works from inside out, illustrating major modules including crop recommendation, disease detection, weather forecasting, market analysis and AI advisory. This diagram demonstrates how information flows between these modules and to the central processing system.

4.1.3 Level 2 DFD:

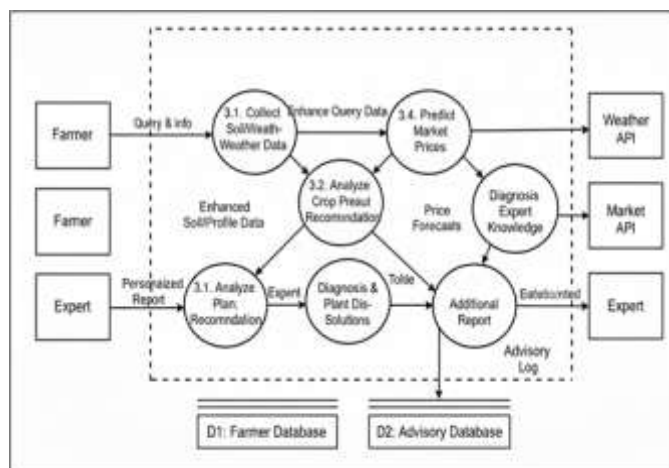


Fig 4.4 Level 2 Data Flow Diagram

A Level 2 Data Flow Diagram shows details of a specific module like disease detection or crop recommendation, as well as how data is processed from start to finish. That is, it shows how an input is processed, including steps like input preprocessing, analyzing data using a model, and producing an output.

5. METHODOLOGY

The planned system is developed as a one-stop digital platform that provides different types of agricultural support services to farmers through a single application. The main objective of the system is to reduce the difficulty farmers face in accessing important information from multiple sources. To

achieve this, the project follows a modular approach where each feature is designed as an independent module, and all modules are connected through a centralized backend.

The system works on a client-server architecture. Farmers interact with the platform using a simple and easy-to-use web interface. Through this interface, users can enter soil details, upload crop images, check market prices, explore government schemes, and interact with the chatbot. Once the input is provided, the request is sent to the backend server for processing.

The crop recommendation module is designed to suggest suitable crops based on soil conditions. Parameters such as pH value, moisture level, and nutrient content are taken as input. Based on these values, the system predicts the crops that are most suitable for cultivation in the given conditions.

The crop disease detection module helps farmers identify diseases in crops by analyzing the images uploaded by them. The uploaded image is processed by the model, which examines visible symptoms and predicts the possible disease. Along with the disease name, the system also provides precautionary and treatment-related suggestions.

The market price checking module is integrated with agricultural APIs to fetch real-time crop prices from the market. This helps farmers compare prices and make better decisions regarding when and where to sell their produce.

The government scheme recommendation module is included to help farmers easily find schemes for which they are eligible. The system checks details such as crop type, location, and land size, and then recommends the most relevant government schemes.

To provide expert guidance, a human consultant module is also included in the system. Consultant data is collected from agricultural competitions and trusted sources, and the details are stored in the database for farmer access.

The chatbot acts as the primary communication interface of the system. It uses a combination of rule-based logic and LLM API support to understand farmer queries and generate responses in simple language. The main focus of this module is to present technical information in a way that is easy for farmers to understand.

6. IMPEMENATION

The proposed system is implemented as a web-based application by integrating machine learning models, APIs, database support, and AI-based conversational features.

The frontend is developed with a user-friendly design so that farmers can easily access all the services available in the platform. The dashboard includes options for crop prediction, disease checking, market prices, scheme recommendations, consultant support, and chatbot interaction.

The backend is responsible for handling all user requests and connecting different modules of the system. Whenever a farmer submits data, the backend processes the request and forwards it to the required module.

A centralized database is used to store farmer details, consultant information, government scheme data, crop records, and chatbot history. This helps in maintaining data consistency and improving response speed.

For crop recommendation and disease identification, the respective models are integrated with the backend server. The

backend receives the input, processes it, and returns the output in a readable format.

For crop image analysis, preprocessing steps such as resizing and normalization are applied before passing the image to the prediction model. This improves the overall performance and accuracy of the system.

The market price feature is implemented using external APIs that provide updated crop price data. Similarly, government scheme data is also fetched and managed through APIs and stored data sources.

The chatbot module is implemented using a hybrid approach. Common queries are handled through predefined rules, while more detailed and conversational responses are generated using the LLM API. This combination helps improve both speed and response quality.

The human consultant feature is connected with the database, allowing farmers to access consultant details whenever expert guidance is required.

The complete system is tested using different agricultural use cases to ensure smooth performance, proper response generation, and accurate results.

7. RESULTS AND DISCUSSION

SmartAgroWeb's system has been evaluated to support intelligent agriculture to farmers. It contains various modules such as crops' recommendations, detection of diseases, forecasting of the weather, analysis of market prices, and Artificial Intelligent based advice.

The modules were evaluated by testing the performance of each individual module, analyzing the performance based on the functions provided, response time, and usability.

The Crop Suggestions module was evaluated by considering the parameters of the soil samples including pH (acidic or basic), moisture and nutrient levels. The system provided a list of appropriate crops based on the given soil condition, showing that the system would provide correct and relevant examples of what farmers could consider planting based on the conditions of their soil. Using machine learning to predict the farmers' decisions would improve their ability to grow crops environmentally suitable for the soil in which they are planted.

The Disease Detection module was assessed thoroughly using several sets of images uploaded of plant leaves infected with common disease. The performance of the system was rated positively for accurately identifying the type of disease affecting the plant using visual symptoms. To achieve a high level of accuracy, different techniques were implemented to improve the input images through preprocessing, including resizing and normalization techniques. The Disease Detection module provided preventive actions and treatment recommendations for diseased plants, which will greatly increase its usefulness in the real world.

The Weather Forecasting module does utilise an external web service (API) to obtain real-time weather data. Temperatures, humidity and precipitation data are some examples of relevant data provided to farmers. The Weather Forecasting Module appeared to function as expected, indicating a low latency rate which will enhance the ability for farmers to be able to plan agricultural activities.

8. FUTURE WORK

Improving accessibility and intelligence of the SmartAgroWeb system, through the development of a mobile application specifically geared toward usability for farmers in rural settings, enhancement of disease detection through implementation of improvements associated with advancements in deep learning models, as well as the ability to leverage more extensive data sets. The current system lacks support for several languages which limits use of the application among many farming communities. Models for predictive market analysis could be implemented using drone/satellite technologies to enhance precision agriculture, with all improvements of this system making it better suited for use in real-world environments, while increasing its utility to farmers/other stakeholders at an even greater pace than was previously possible.

9. CONCLUSION

In this article, we described SmartAgroWeb, which is a smart agricultural decision support system (DSS) for web-based agriculture to solve common farmer problems about choosing crops, detecting crop disease, forecasting weather events (uncertainty), and monitoring market prices. Agricultural decision-making is made easy by SmartAgroWeb through the integration of Artificial Intelligence (AI), Machine Learning (ML), and real-time application programming interface (API) services.

SmartAgroWeb includes many functional modules to support the various functions of the agricultural decision-support system. Some examples of functionality include crop recommendations based on soil conditions, image analysis for disease detection, weather forecasting, market price monitoring, and an AI-powered virtual advisor (chatbot).

The modular/layered architecture of SmartAgroWeb provides an optimal environment for the operation of the modules/functions of the system by allowing seamless interaction between the components of the system and giving the system the scalability and flexibility necessary.

The results of SmartAgroWeb show that it provides accurate, timely, and relevant insight to help farmers be more productive and reduce reliance on traditional farming methods. The system is also designed to provide easy access via a user-friendly interface for farmers with little technical knowledge.

In summary, SmartAgroWeb can be viewed as a bridge between traditional farming methods and modern technology, promoting sustainable and intelligent agriculture. SmartAgroWeb has undergone successful testing in a laboratory environment and shows great potential for implementation in a real-world setting with the potential to improve the lives of farmers and the efficiency of the agricultural sector.

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