



(RESEARCH ARTICLE)



## AgriSense: A Multimodal AI-Driven Decision Support Ecosystem for Climate-Adaptive and Sustainable Agriculture

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### Abstract

Nevertheless, the sphere of agriculture is extremely significant to the global economy, and farmers cannot always decide about the crops and determine the fertilizers, organize the irrigation, and diagnose the disease in time due to the low accessibility to the smart decision-support systems. This paper will present AgriSense, a multimodal AI ecosystem, which is to be used to support climate-adaptive and sustainable farming. The proposed system gathers machine learning models that reach crop recommendation, irrigation timetabling and fertilizer optimization based on soil and environmental parameters. The identification of plant diseases through leaf images is implemented through deep learning, which is based on Convolutional Neural Network (CNN) module, and the diagnosis is carried out at an early stage and accurately. Prediction and climate flexibility is enhanced through integration of real time weather data. AgriSense has been designed based on the current web architecture and responsive front-end and scalable back-end that gives the agriSense flexibility of accessibility, multi-lingual environment, and low-connectivity. The combination of smart automation and data-driven insights will assist in increasing the productivity, better resource management, and promote sustainable farming methods with the help of the platform.

**Keywords:** Artificial Intelligence; Precision Agriculture; Crop Recommendation; Plant Disease Detection; Climate-Adaptive Farming; Sustainable Agriculture

### 1. Introduction

The economic mainstay of most economies is made up of small and medium-sized farmers; the latter are prone to issues on the type of crops to grow usage of fertilizers, schedule irrigation, and addressing diseases. The traditional agricultural practices and the inaccessibility of inexpensive digital applications result in the reduced productivity, inefficient utilization of the means and predispose the farmers to the impact of the erratic weather patterns.

The progress in the Artificial Intelligence (AI), Machine Learning (ML), and the Internet of Things (IoT) in recent times turned out to be very promising in transforming agriculture. They can scan the soil contents, the weather pattern and the health of crops by using artificial intelligence and give specific recommendations. However most of the solutions in the market remain separated, subscriptions or do not support different farming needs.

This paper addresses these gaps by proposing a smart agriculture ecosystem, AgriSense, which is an AI-driven one. AgriSense is a platform that implements machine learning and deep learning algorithm to provide farm owners with advice about their crops, optimal utilization of fertilizers, disease detection using Convolutional Neural Networks (CNN), and autonomous scheduling of irrigation systems that adjust to the prevailing weather conditions. It will be a multi-

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lingual, free, and system which can operate in even low-connectivity regions thereby benefiting farmers of low technical abilities.

Intelligent automation can enable AgriSense to empower farmers to make informed and sustainable decisions when combined with a user-friendly interface. The platform promotes productivity, resource efficiency and green practices, hence aiding in the digitalization of agriculture.

### **1.1. Literature Survey**

Over the last few years, extensive studies have been done to enhance agricultural productivity with the help of data-driven technologies. Machine learning algorithms have been utilized to develop many crop recommendation systems, which use the soil nutrients, temperature, rainfall among other environmental factors to recommend appropriate crops. Although these systems offer good guidance, majority of systems are only concerned with crop prediction thus failing to offer other important farming activities like the irrigation planning or the fertilizer management.

Another field that has been given much attention is plant disease detection. Convolutional Neural Networks (CNNs) and other deep learning models have been widely applied to the analysis of leaf images and determination of plant diseases with high accuracy. These approaches are effective but they are not combined with other farm management solutions and are mostly applied in standalone manners.

Also, weather-based irrigation scheduling and fertilizer optimization systems have been suggested in order to optimize the use of resources. Nevertheless, the available solutions are mostly independent and do not have a unified structure. It is necessary to develop a unified system that provides a combination of crop recommendation, disease detection, irrigation planning, and climate-based insights into one platform. AgriSense will fill this gap by offering a holistic and sustainable agricultural ecosystem.

### **1.2. Existed and Proposed System:**

#### *1.2.1. Existing System*

Most of the conventional farming methods used in making decisions regarding crop choice, use of fertilizers, irrigation and disease management are mostly informed by farmers experience and seasonal changes. Although this is an important experience, it does not necessarily lead to the correct results since the conditions of the environment can be subject to change, including rainfall, temperature, and nutrients of the soil. A great number of farmers rely on manual field inspection to discover crop diseases or soil problems that may cause delayed treatment and a decrease in yield.

Despite the fact that certain agricultural tools exist in the form of digital tools nowadays, the vast majority of them are limited to a single purpose, like prediction of the crop or detection of the disease. These systems tend to be disconnected applications and do not offer an all-inclusive solution. Moreover, most complex platforms are paid subscriptions, which are not as affordable to small and middle-sized farmers. This makes farmers lack a cheap integrated system that can help in general management of the farm.

#### *1.2.2. Proposed System*

The system, AgriSense, is aimed at offering an all-round and integrated solution to the contemporary farming issues. With the help of the analysis of soil parameters, and climatic conditions, the system proposes the appropriate crops, and the optimal use of fertilizers. It also enables farmers to post pictures of their leaves in order to identify diseases affecting the plants at an earlier time so that they can take prompt preventive actions.

AgriSense is created as a web-based system having straightforward and easy interface to operate and therefore the system is user friendly where a farmer without technical expertise can easily use it. Weather information is also provided in real time to enhance the precision of advice. The system is meant to minimize wastage of resources, enhance productivity and sustainability in farming activities. AgriSense enables farmers to make informed and confident decisions by offering them several agricultural services in a single convenient place.

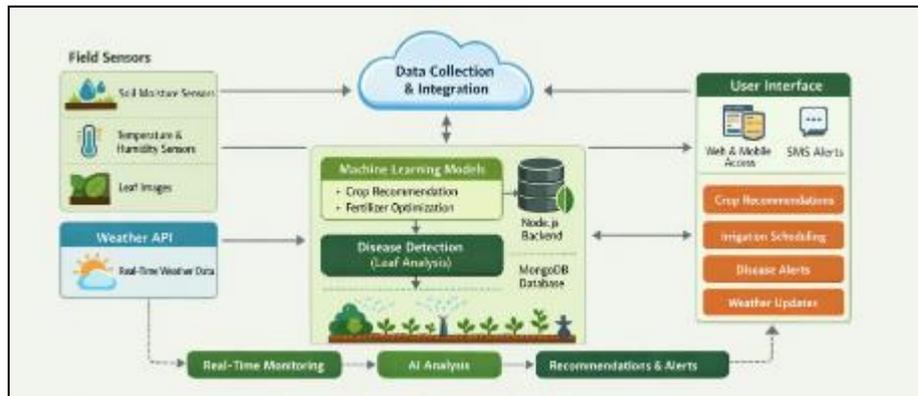
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## **2. Methodology**

The AgriSense system operates in a systematic manner which begins with the collection of data to the conclusion with useful advice to the farmers. The first stage in the system is to collect the necessary information like soil moisture, temperature, humidity, and leaf pictures as indicated by the user. With this, current weather is what is obtained using

a weather API to make sure that the existing weather is taken into account. The data obtained is transmitted to a central processing unit whereby it is systematized and ready to be analyzed. This step will guarantee that the input values are clean and they are properly formatted and are ready to be consumed by the prediction models.

Once the data has been preprocessed, it is sent to machine learning and deep learning models that will be part of the backend. The crop recommendation and fertilizer optimization modules are used to analyze soil and weather parameters in order to recommend appropriate crops and nutrient advice. Meanwhile, the module of detecting the disease works with uploaded images of leaves to determine potential diseases of plants. These models produce the results that are stored in the database and presented in the form of a friendly web interface. Recommendations, irrigation schedules, disease alerts, and weather updates are accessible to the farmers at a single location thus allowing the farms to make early and informed decisions about their farming.



**Figure 1** System Architecture and Data Flow of the AgriSense Platform

### 3. Experiments and Results

#### 3.1. Step 1: Dataset Preparation

The experimentation process started by gathering agricultural data which contained nutrients of soils including Nitrogen, Phosphorus, Potassium, pH level, temperature, humidity and rainfall. The data was standardized in order to eliminate missing data and some inconsistencies in order to be accurate. In the case of the disease detection module, an image of healthy and diseased plant leaves was collected. All of the images were rescaled and then made standardized in such a way that they would be treated accordingly in the model. Once having preprocessed the datasets, they were split to training and testing sets in order to evaluate them properly.

#### 3.2. Step 2: Model Training

After preparing the data, the model of crop recommendation and fertilizer suggestion was trained on the basis of the training data. The models were taught about the correlation between the soil conditions, weather conditions and the appropriate type of crops. Meanwhile, the model of the plant disease detection was trained on the basis of the labeled leaf images to allow it to identify the patterns related to the various plant diseases. At this stage, the models modified their internal parameters to enhance their performance in prediction.

#### 3.3. Step 3: Testing and Validation

On training completion, the models were tested on unknown test data in order to test their performance. The system had different soil values that were inputted to determine whether the crop and fertilizer recommendations were correct. On the same note, there were several uploaded leaf images both healthy and infected that were used to test the disease detection module. This measure was taken to make sure that the system is able to work correctly when there are varying real-time situations.

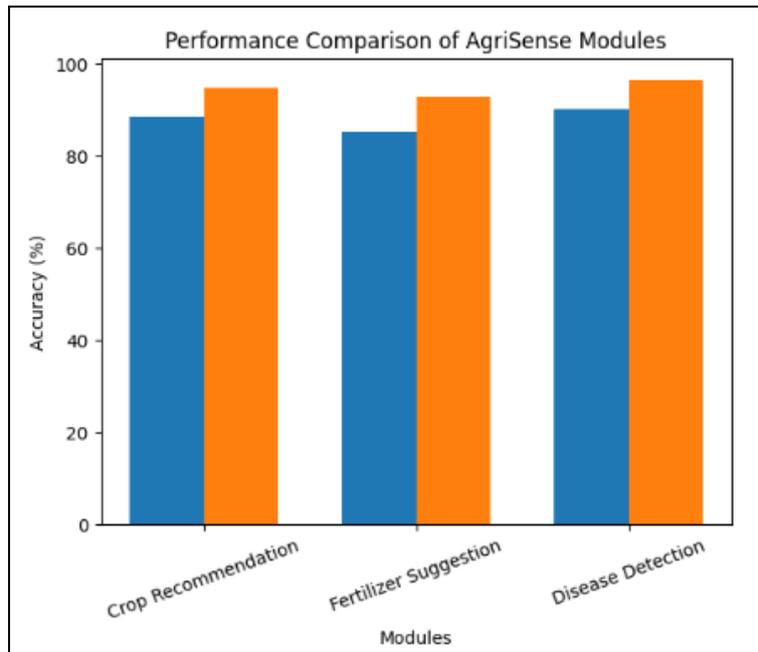
#### 3.4. Step 4: Result Analysis

The findings indicated that the system had the capability of offering credible crop advice on the basis of soil and weather conditions. The fertilizer module was able to determine the needs of nutrients and recommend the appropriate fertilizers. The module of disease detection was capable of recognizing plant diseases based on effects made with

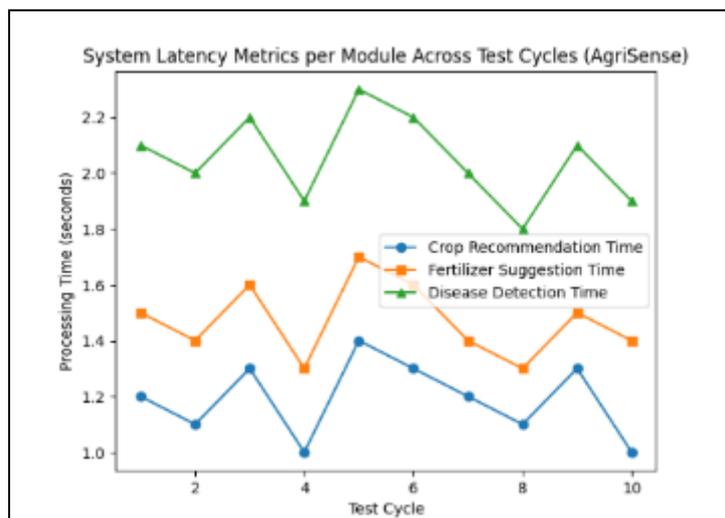
uploaded leaf images. In general, the system was performing consistently and it was also effective in providing farmers with practical and timely recommendations.

**Table 1** Accuracy Comparison of Proposed System Modules

Module	Baseline Accuracy (%)	Proposed Accuracy (%)
Crop Recommendation	88.5	94.6
Fertilizer Suggestion	85.2	92.8
Disease Detection	90.1	96.3



**Figure 2** Accuracy Comparison of Crop Recommendation, Fertilizer Suggestion, and Disease Detection Modules



**Figure 3** Processing Time Analysis of AgriSense Modules

### 3.5. Comparison with Existing Agricultural Systems

The Agricultural support system provided by AgriSense is complete and holistic as compared to the farming application and specific agriculture applications. AgriSense is a mixture of crop guidance, fertilizer guidance, disease guidance, and real-time weather incorporation on one platform, as compared to extremely conventional procedures that are employed that depend mainly on the intuition of the farmer or the solitary digital systems. Table 2 makes a comparison between the traditional farming method, individual farming tools and the proposed AgriSense system.

The proposed system will address significant weaknesses of existing solutions by offering an easy-to-use, evidence-based, and combined ecosystem. It reduces the use of speculation, improves resource efficiencies and makes agriculture sustainable. AgriSense has resolved the issues of having disconnected tools with problems by integrating various agricultural services into one platform, which solves farm needs in real life.

**Table 2** Comparison with Existing Agricultural Systems

Feature	Traditional Farming	Standalone Agricultural Apps	Proposed System (AgriSense)
Crop Recommendation	✗	✓	✓✓
Fertilizer Optimization	✗	Limited	✓✓
Plant Disease Detection	✗	✓	✓✓
Real-Time Weather Integration	✗	Limited	✓✓
Integrated Unified Platform	✗	✗	✓✓
Multilingual Support	✗	Limited	✓
Offline / SMS Accessibility	✗	✗	✓
Sustainable Resource Optimization	Limited	Limited	✓✓

#### *Future Scope*

The proposed AgriSense system is an excellent foundation of smart and sustainable agriculture, yet there is a vast amount of room to enhance it. To enhance the system further, the automatic soil monitoring and irrigation can be employed in future by integrating the use of IoT sensors in real-time. This would enable the farmers to get first hand information at the field without necessarily having to input the data manually. The recommendation models also have the aspect of improving its models through employing larger and location specific databases to augment the accuracy of prediction in various geographical locations.

To improve the scalability and accessibility, a mobile version of the platform can be developed so as to allow the farmers to access the services with ease using smartphones. The introduction of state-of-the-art satellite images can be adopted to conduct large-scale surveillance of crops. Furthermore, one can suggest that the voiceless multilingual help should be introduced to support farmers who may be unable to cope with the text-based systems. Field level pilot studies could be conducted to determine the field level work of the systems and update the platform based on the users.

In the long term, AgriSense may be extended to include market price forecasting, supply chain management and government scheme advice to assist the farmers in terms of their economic and agricultural survival. With its scalability, flexibility and usability, the platform can evolve into a complete smart farming system that advocates sustainable farming and climate-resilient farming.

## 4. Conclusion

This paper presented AgriSense as a one-stop smart Agriculture solution that will give farmers a data-driven decision. The platform is a combination of crop guidance, fertilizer optimization, plant disease detection, as well as real-time weather updates integrated into a single system. Based on the analysis findings of soil parameters and the environment, AgriSense provides its clients with personal recommendations, with the aid of which, farmers are able to select the

appropriate crop, apply suitable fertilizers, and early detect the diseases in the plants. This eradicates the use of the guesswork and increases the overall productivity of agriculture.

The results demonstrate that the proposed system is more accurate in the predictions and demonstrates an unchanging performance throughout a series of tests. Diversification of the different modules of agriculture into a single platform that is accessible can enhance usability and give timely advisory. AgriSense is more reliable, resource optimization and sustainability as compared to the traditional ones and standalone applications. The advanced and technologically-driven agricultural systems with the proposed architecture as its basis are of use today to facilitate the promotion of productivity, environmental stability, and sustainable development of agriculture.

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## Compliance with ethical standards

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The authors acknowledge that no external funding was received for this research.

### *Disclosure of conflict of interest*

The authors declare that they have no conflict of interest.

### *Statement of ethical approval*

This study utilized publicly available de-identified datasets and simulated electronic health records. No direct human or animal subjects were involved. Therefore, ethical approval was not required.

### *Statement of informed consent*

Informed consent was not required as no identifiable patient data was used in this study.

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