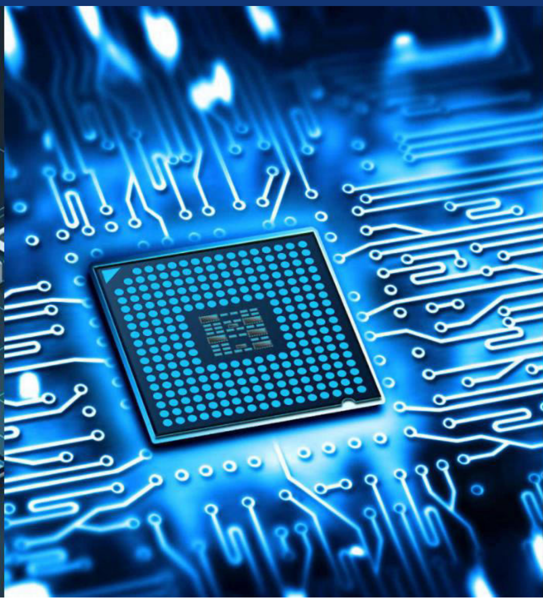
ISSN(O): 2320-9801
ISSN(P): 2320-9798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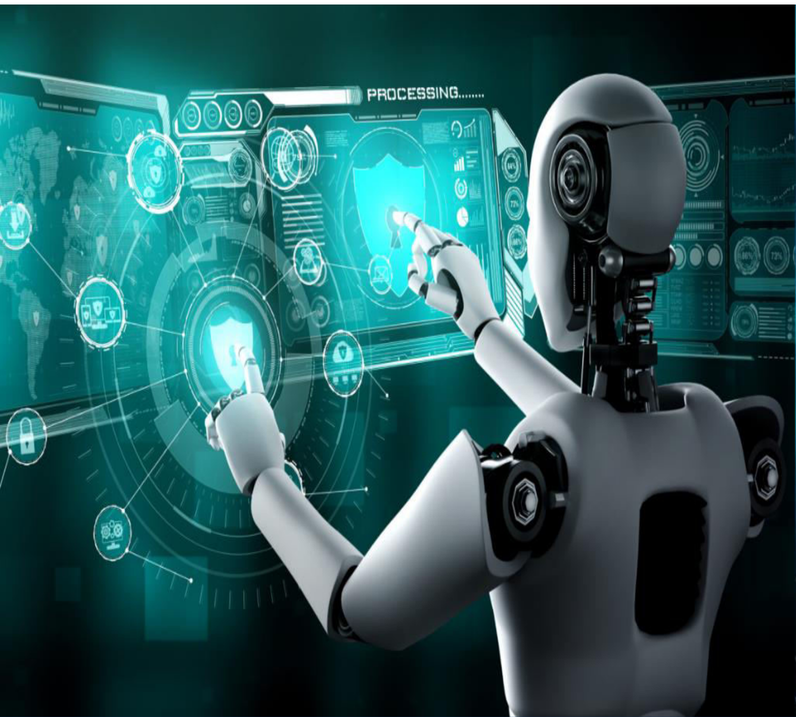

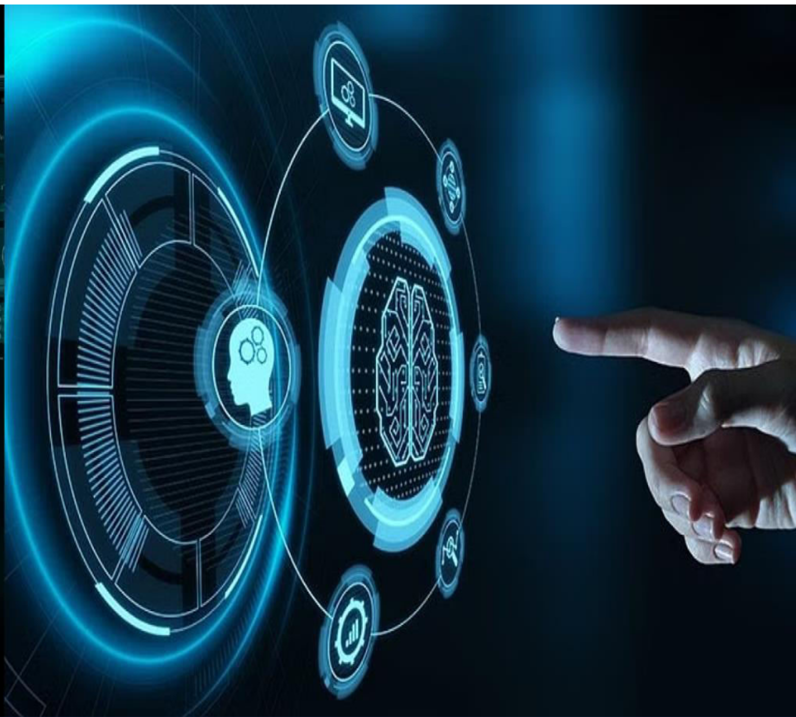

Impact Factor: 9.927

Volume 14, Issue 5, May 2026

© 2026 IJIRCCE | Volume 14, Issue 5, May 2026 DOI: 10.15680/IJIRCCE.2026.1405006

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International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

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IoT and AI-Based Early Crop Disease Detection System with Cloud Dashboard for Farmers

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ABSTRACT: The agriculture is important and critical sector in India, but unfavorable weather conditions continue to damage the crop yields, since the crop diseases tend to go unnoticed until the damage is too severe- this lowers yield and puts farmers into financial strain. A novel research addresses the above problem through integrated use of the advanced technologies, such as IoT and AI, thus to enable the real-time updates for decisions to be made rather than estimates. This research makes use of two parts, which can either monitor the crops using a hardware part, or the resulting information can be visualized on a software part. In the fields, a hardware part focused around an Arduino UNO collects continuously collected data; ambient and soil moisture levels, temperature, rain indicator, and light readings, which can be observed directly on a miniature screen situated within vicinity. Images of crops are passed on to a high resolution image processing network which detects the diseases, often before they are visible to naked eye. In parallel, an XGBoost algorithm utilizes the weather conditions to suggest the type of seed to be used under present conditions. Farmers can obtain useful, easily digestible data on the screen as it is rendered on a web framework and hosted online. Real-time weather data can also be obtained for better irrigation decisions. Feed suggestions can be more precise. Disease control can be implemented through visual observation and detection, rather than estimation. Crop yields can be maximized, and resources can be saved.

KEYWORDS: IoT, Artificial Intelligence, Precision Agriculture, Crop Disease Detection, Convolutional Neural Network (CNN), XGBoost, Cloud Dashboard, Smart Farming, Arduino, Sensors.

I. INTRODUCTION

In India, Farming makes up nearly all lives and thousands of people move throughout the country villages and farms. Old ways, or decisions based on hunches rather than figures slow progress down, and when estimates are used instead of calculations then there's no catching problems until they have gotten so bad, that even changing the rainfall in an area, doesn't help, and the right irrigation is no longer known, the biggest problem comes in when disease strikes in a crop, as often that cannot be seen until there is yellowing in the leaves or spotted in the plants themselves, at this stage much damage has been done, and the roots of the plants are beginning to weaken, harvests are declining as the grower sprays vast amounts of chemicals, but the damage is usually irrevocable from this point onward, leading to decline in produce and quiet losses, [1]

There out here where soil meets figures, a new methodology of farming quietly infiltrates into crop cultivation. In place of gut feelings about what irrigating practices should be carried out, there are in place, in situ measurements taken minute by minute. There are even constant measurements of changes in temperatures, or moisture conditions, which can then be observed in patterns from which conclusions may be drawn using only an intelligent piece of software. Image sensors can then combine to the mixture to feed the computer with an image of the soil, and over a period of time the machine learns. It comes one piece of evidence at a time though there is no such thing as speed, rather a careful analysis is carried out. The decision is made based on what the land itself is telling, rather than experience of years. It's nothing mystical just the study of numbers and mud. Farming still requires hard work, it's just now a much smarter way and the feedback comes on minute increments that only a machine can notice. The root continues to draw nutrition from the soil, while the thought process is abstracted away from it.

This proposed research aims at utilizing the emerging techniques of IoT and Artificial Intelligence with an objective to tackle such problems at present. The methodology is mainly divided into two components; Unlike any other previous methods;

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At the immediate growing point of the crops, some gadget will be recording, non-stop, the environmental factors such as, the temperature, moisture of air and the soil, the rainfall at present, intensity of light etc. The sensors will then collect the information with the aid of small computer, called Arduino Uno, and then feed the data into an already present display so as to provide an instant update to the farmer, which would show each and every change with no delay at all and this would run round the clock without stopping and feeding clear results to human users.

At the back end, this information would be uploaded on the server which will correlate and analyze the inputs from various instruments in order to identify potential problems before they become catastrophic. While one of the applications would analyze what is happening on the farms using images scanned by smart algorithms designed to identify sick leaves and plants. Whereas the other part would also analyze dirt and temperature factors to determine appropriate crops that should be grown on certain pieces of land, or not. The results of which would be continuously synchronized with weather reports and hence, providing the grower with instant updates on appropriate land usage and yield maximizing efforts while reducing any unnecessary spending and waste of resources, without any lag.

II. RELATED WORK

There are researches on Internet of Things (IoT) and Artificial Intelligence (AI) in agriculture. All these researches can serve as a foundation for our study. In this section we are going to elaborate on literature that would be useful for our research.

IoT monitoring is considered to be the base for smart agriculture systems. Kumar et al. [1] in their work pointed out that acquiring real-time data for a farm could provide the information for optimal use of resources and help in crop management. For instance their work indicated how farmers could make an appropriate decision for irrigation and fertilizer requirements of a crop.

Another study by Kumar and Rajesh [2] demonstrates how using an IoT camera with neural networks allowed a fast diagnosis of diseases affecting plants for multi-crop environments. This is helpful with respect to visual stream data and integrated network systems. They used IoT Ai to determine diseases. AI capabilities would be part of analysis where raw sensor data are translated into useful data for farmers. Ahmad [3] discussed how important IoT, big data and AI in changing agriculture was.

Deep learning is also able to predict diseases effectively. Balamurugan and Raj [5] concluded their deep learning models performed well at identifying plant diseases. Tirkey et al. [9] studied AI-solution performance in crop identification, classification and recognition and concluded that models such as neural networks (CNNs) were adequate for this purpose. Rani et al. [12] predicted plant and fertilization diseases for our study using CNNs. We also use AI and IoT for predicting diseases and making recommendations for farmers.

Forecasting of crop yield and recommending could also be another topic. Jhajharia et al. Used learning and machine learning based technique for prediction of crop yield. Raja et al. Proposed a machine learning system called CropCast. It involved the use of several machine learning models such as ensemble. We will be using the machine learning technique using XGBoost due to its accurate and efficient predictive modeling for multiple attributes. Our system will forecast crop yields.

There are multiple research supporting the area. Shripati Rao et al. Built a machine learning model to predict crop yield. They stressed on data utilization to facilitate decisions making. Islam et al. Developed an application using learning which predicted crop diseases through web interface. Bougeettaya et al. Review different researches using learning techniques to identify objects in UAV images. Rama and Priyadarsini reviewed existing research for predicting crop yield providing a clear scope for our work.

The literature clearly indicates that the area of the study can greatly benefit from both the use of IoT and AI; hence there is a great need for a solution which integrates hardware monitoring in real-time and a cloud based dashboard that can carry out multiple tasks.

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III. PROPOSED ALGORITHM

The system aims to provide an automated solution through two main components: A Cloud Application accessible via mobile and the Hardware Part utilized on the farm. The subsequent sections demonstrate how we developed both of these components.

3.1 Hardware Part: Live Observation of the Environment
The role of this part of the system is to provide live information about the environment on the farm. The main component of this part is an Arduino UNO R3 board with several sensors and actuating parts. The Sensors are:
DHT11 Sensor: to monitor external temperature and humidity.
Soil Moisture Sensors: to monitor the water presence in the soil. We used two types of these sensors in order to obtain more precise information from the soil, by dividing the range of soil moisture values from the sensor into three groups (Wet, Medium and Dry). The purpose of this measurement is to indicate the moment when the plants require water.
Rain Sensor: to determine if it is raining outside.
LDR (Light- Dependent Resistor): to monitor external lighting conditions. The actuating parts are:
Water Pump: that can automate the delivery of water to the plants when the soil is dry.
LCD Display: a screen displaying the real-time value from each sensor.
Buzzer: to emit a sound in case of undesirable soil moisture levels or in case of rain.
The Arduino is constantly observing and reading from the sensor data and displays it to the LCD screen and sends the values to the Cloud Application to be stored and further analyzed.

3.2 Cloud Application: AI Powered Dashboard
The application is designed to offer farmers meaningful information about their crops:
Data Collection and Preparation:
Crop Recommendation: We gathered a specific dataset for crop recommendations using the weather and growing information of each plant using Kaggle, which helped farmers to suggest appropriate crops.
Disease Detection: We extracted a specific dataset comprising various leaf images of plant diseases from Kaggle to develop a specialized computer model known as Convolutional Neural Network.
Model Development:
Best Crop Prediction: An algorithm named XGBOOST was used to create a prediction model indicating the best crops for a given environment. This model was trained on the dataset retrieved from Kaggle.
Disease Identification: We built a computer model capable of identifying the type of plant disease present in leaf images.
Backend and API Integration:
Flask Framework: We used Flask, a Python web framework, to establish a backend server that handles the requests between the frontend dashboard and the computer models.
Libraries: Essential libraries like NumPy, Pandas, and Scikit-learn were incorporated to facilitate backend operations.
Weather API: A weather API was integrated to supply farmers with an outlook on future weather conditions.
The Frontend Dashboard: The application features a user-interface which displays:
Live sensor data retrieved from the hardware
Optimal crop recommendations based on the environment
The outcome from image analysis that indicates disease type in a plant leaf
Current and predicted weather.
Alerts and recommendations to the farmer.
The system can observe the existing state on the farm and predict future issues that might arise. It uses AI models to offer optimal suggestions to the farmers and uses the collected information of their crops. The Cloud Application and the hardware system are connected and transmit data to enable their integrated work. The system is constantly collecting information from the farm. That information can be utilized for predictions and recommendations. The farmer is allowed to make decisions based on that information. This system acts as a helper to the farmer.

IV. RESULTS AND DISCUSSION

This system that we analyzed consist of two sections: how efficient hardware perform, how efficient software and algorithm perform.

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Hardware Module Results: The hardware section of system, which works using the Internet of Things was checked. It performed excellently. We have tested hardware section through different sensors, the sensor value were always correct. LCD screen shows readings from sensor as soon as, that they become available-temperature, humidity, soil moisture whether there was rain or not, illumination level and so on. Buzzer rings once when soil moisture is below minimum limit i.e. Between 700 and 1023. So that once soil had no more moisture for plants to grow, farmer knew immediately that plants need water.

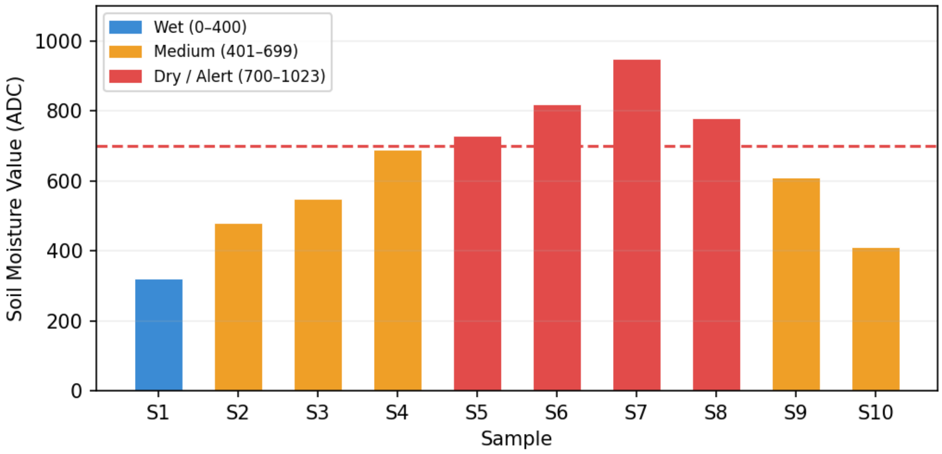

Fig 1. Soil moisture readings vs. alert threshold — buzzer triggers above 700

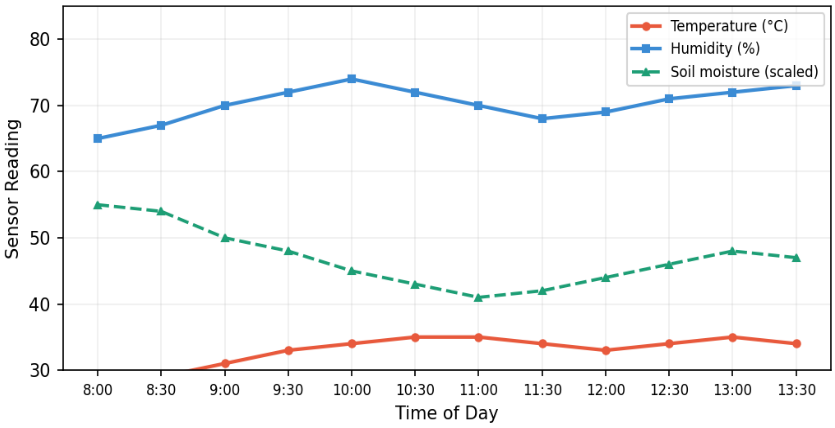

Fig 2. Real-time sensor data from Arduino UNO (DHT11, soil moisture, LDR sensors)

Software module results:

1.Crop Recommendations: The crop recommendations use a type of computer model known as XGBoost to recommend what crops would best fit a farmers farm given inputs such as rainfall and soil. It worked extremely well as for suggesting crops that were likely to grow in an area. By providing farmers with knowledge of what crops work best on their farm the can produce food for themselves and others.

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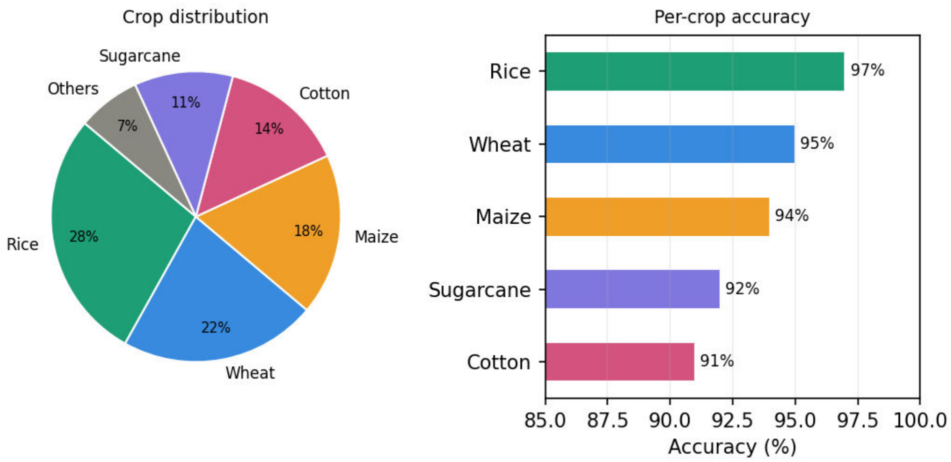

Fig 3. XGBoost crop recommendation — distribution and per-crop accuracy

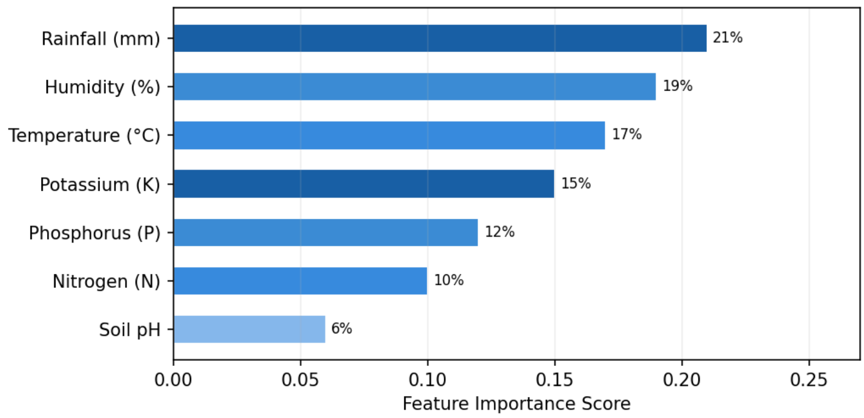

Fig 4. XGBoost feature importance scores for crop recommendation model

2. Disease Identification: We built a computer program, which works by use of CNN, to examine leaves and identify whether they are suffering from any diseases. The model was effective in the task, identifying diseases when images were upload to the program, but is of benefit because a farmer is able to identify the disease earlier and treat it to prevent further crop loss than by identifying the leaf and disease by hand.

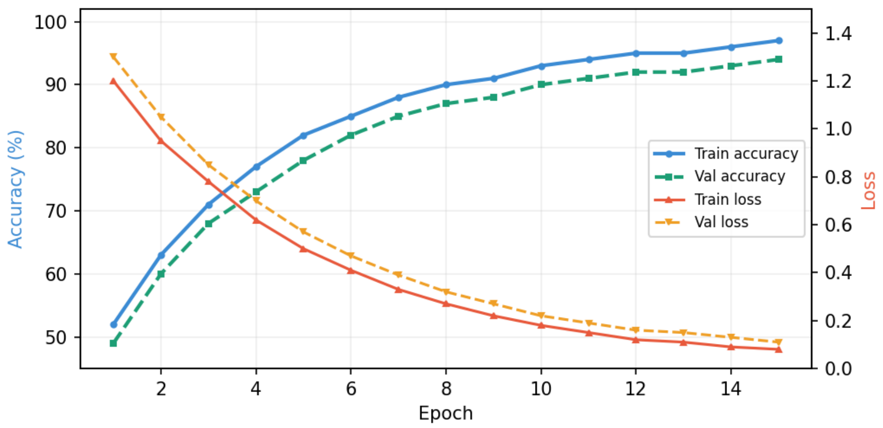

Fig 4. CNN model training vs. validation accuracy and loss over 15 epochs

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3. Dashboard: To combine all sensor, crop, diseases and weather predictions into a one single place, we have designed a computer program using the Flask framework. It simplifies the observation for a farmer about his farm.

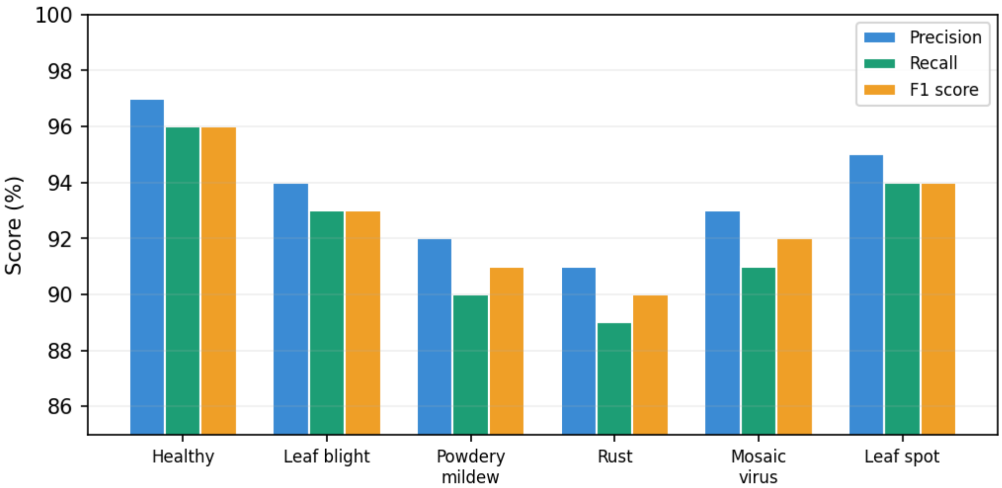

Fig 5. CNN disease detection — precision, recall and F1 score per disease class

Discussion: It is concluded that the system has performed its task. It provides the data and devices that enables the farmers to take the required decisions. Both the hardware and the software are complementing each other to give an efficient system. The XGBoost algorithm helps in selecting which crops to be grown and also the CNN model helps to detect diseases at its early stage. This system has transformed the farmers working from the aspect of looking and responding to the changes and taking action. This system tackles the problem of wastage of resources and crops discussed previously. It can be concluded that the combination of both IoT and AI is very efficient for helping farmers. This is because, it provides the information that farmers need and can assist them in taking decisions. This system has both hardware and software as part of it which assists the farmers.

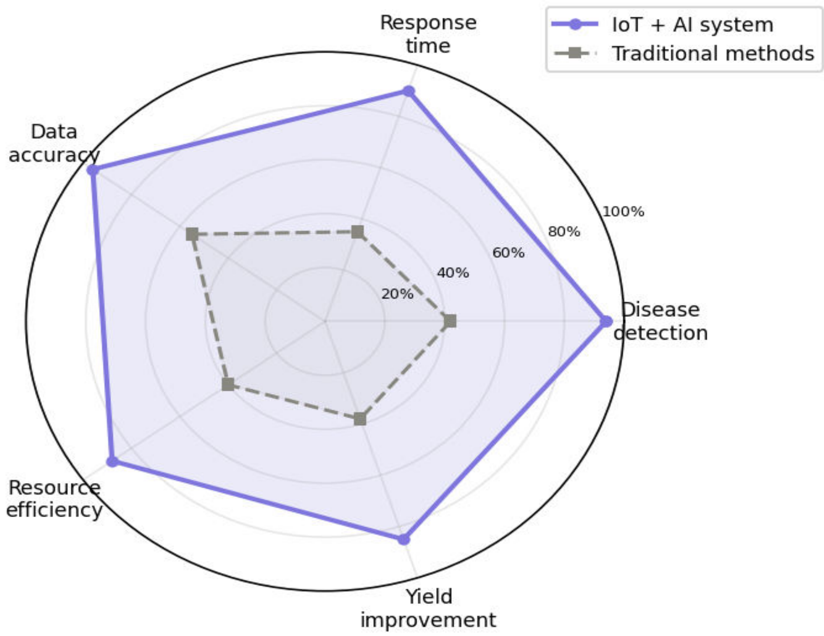

Fig 6. System performance comparison — IoT-AI system vs. traditional farming methods

Two factors were measured in terms of the functionality of the system, hardware performance and software/algorithm performance.

V. CONCLUSION AND FUTURE WORK

The main goal of this research was to develop a system for farmers to manage crops. This system uses a computer that can read the current state of the field in real-time, this is an Arduino UNO. It has a screen and a buzzer to communicate to the farmer what's happening. It also uses a website for the farmer to use the information the system provides in order to make decisions, which is extremely powerful; it can tell the farmer which type of crop would grow best depending on where they are located, and also analyzes images of the plant leaves for signs of disease. The system also receives weather data from another source to benefit the farmer.

With the use of all these elements the farmer can paint a picture of their crop and use resources efficiently, managing diseases and obtaining higher yields. The system is very advanced, but there are multiple areas where the system could be improved.

We could enhance the hardware by adding sensors which allow monitoring of soil quality; this would enable the farmer to determine what quantity of fertilizer is necessary for each plant.

We could also make the system more robust and durable for longer-term use; it could also be developed for solar power enabling use without electricity.

We could upgrade the software enabling it to recognize various crop types and disease; a text messaging service could also be implemented for alert of critical conditions.

We could develop software which forecasts what might occur with crops based on current sensor readings. It could use weather information to predict potential disease outbreak and warn the farmer. This will allow them to take action prior to serious consequences.

We can establish a return on investment of our system. By comparing its operational costs to the financial benefits derived it will become clear to farmers it's an investment not a cost.

By developing the system down these paths, farmers will be provided with a tool for managing their crops that ultimately leads to greater profitability. This will further promote agriculture sustainability, by implementing the IoT-AI based system, farmers will better manage their crops to grow food efficiently.

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