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Leveraging Remote Sensing and AI for Smart Crop Monitoring and Management

Priya.R L[1], Sharmila Sengupta[2], Abirami A[3], Richard Joseph[4]

[1]Dept. of Computer Engineering VESIT, Mumbai, India priya.rl@ves.ac.in

[2]Dept. of Computer Engineering VESIT, Mumbai, India sharmila.sengupta@ves.ac.in

[3]Dept. of Information Technology, Bannari Amman Institute of Technology Tamilnadu, India abiramia@bitsathy.ac.in

[4]Dept. of Computer Engineering VESIT, Mumbai, India .richard.joseph@ves.ac.in

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Abstract:

”Data-driven, farmer-centric solutions are critical in the dynamic field of agriculture, which is defined by constantly shifting market needs and environmental conditions. In order to transform farming methods through the integration of cutting- edge technologies, this article introduces the comprehensive Crop Planning and Market Information System. The proposed system optimizes crop health by facilitating disease identification and providing customized cures through the use of remote sensing and AI techniques. Moreover, it makes customized crop suggestions that are in line with market trends by utilizing soil analysis and meteorological data. The system provides farmers with up-to-date market information and chances for agricultural stock launches, addressing their vital need to be informed about market conditions. It gives crop planning abilities, utilizing a choice tree set of rules. Farmers can enter their soil parameters, permitting the machine to endorse the most suitable crops for cultivation primarily based on their unique situations. The proposed system also offers disease detection functionality, leveraging Efficient Net B3 for image processing. This function allows farmers to capture photographs of their plants and accurately come across any diseases present. To enhance accessibility, the proposed mobile application features a user-friendly dashboard supporting multiple languages and provides access to agricultural training and educational programs. Ultimately, the system aims to empower farmers, improve crop yields, and drive sustainable agricultural practices in an ever-evolving world.”

Keywords: Remote Sensing, Artificial Intelligence in Agriculture, All-In-One Solution For Farmers

1. INTRODUCTION

Agriculture stands as the cornerstone of human sustenance, providing livelihoods and economic stability across the globe. However, in regions like Maharashtra, India, where agriculture plays a pivotal role in the livelihoods of millions, the sector grapples with significant challenges. The tomato crisis of 2023, which saw prices soar to unprecedented levels due to yield losses from unanticipated rainfall, underscored the vulnerability of traditional farming practices in the face of unpredictable weather patterns and market fluctuations [1]. Such challenges necessitate innovative solutions that enhance resilience and sustainability in agriculture.

Despite strides in agricultural technology, existing systems often fall short in addressing the multifaceted challenges faced by farmers. Limitations abound, ranging from fragmented approaches in agricultural management systems to inadequate personalization of solutions for individual farm conditions. Furthermore, the absence of real-time support mechanisms exacerbates the difficulties faced by farmers in making timely decisions. Recognizing these gaps, there is a pressing need for holistic solutions that integrate advanced technologies to empower farmers with actionable insights and support.

In response to these challenges, the proposed system presents a comprehensive Crop Planning and Market Information System designed to revolutionize farming practices in Maharashtra. Leveraging advancements in remote sensing and artificial intelligence. The system also provides a suite of features aimed at optimizing crop management, enhancing market intelligence, and fostering sustainable agricultural practices. Through personalized crop recommendations, real-time disease detection and transparent supply chain management. It aims to mitigate risks, optimize resource utilization, and empower farmers to thrive in an ever changing agricultural landscape.

II. OVERVIEW

A. *Motivation*

In recent years, the agricultural sector in Maharashtra, India, has faced unprecedented challenges, culminating in the tomato crisis of 2023. The sudden spike in tomato prices, reaching up to five times their usual rates, exposed the vulnerability of farmers to adverse weather conditions and supply chain disruptions. Devastating yield losses due to unseasonal rainfall further exacerbated the situation, underscoring the urgent need for innovative solutions to enhance resilience and sustainability in agriculture. Motivated by the plight of farmers and the imperative to address systemic vulnerabilities, this research endeavors to leverage advanced technologies such as remote sensing, artificial intelligence, and app-based platforms. By providing farmers with comprehensive tools for crop planning, production practices, and market intelligence, our project aims to mitigate risks, optimize resource utilization, and foster long- term viability in the face of evolving challenges. Through collaborative efforts and interdisciplinary approaches, we aspire to catalyze positive change and empower agricultural communities to thrive in an ever-changing landscape.

B. *Problem Statement*

In Maharashtra, India, where agriculture plays a pivotal role in livelihoods and the economy, farmers face significant challenges exacerbated by unpredictable weather patterns and market fluctuations. The tomato crisis of 2023, marked by a sharp spike in prices due to yield losses from unanticipated rainfall, underscored the vulnerability of traditional farming practices and highlighted the urgent need for innovative solutions. To address these challenges comprehensively, this research endeavors to develop an integrated agricultural in- formation system leveraging advanced AI technologies. This system will encompass a range of functionalities, including a sophisticated disease prediction module to detect and diagnose crop ailments, a recommendation engine utilizing data on NPK values, weather forecasts, and market trends to advise farmers on optimal crop choices, a business intelligence marketplace providing real-time insights into market dynamics, access to government schemes and subsidies tailored to farmers' needs, a platform for renting farming equipment to enhance operational efficiency, and streamlined supply chain mechanisms facilitating direct interactions between farmers and consumers. By empowering farmers with actionable insights, resources, and support, our research aims to enhance agricultural resilience, productivity, and sustainability in Maharashtra, ultimately fostering prosperity and growth in rural communities.

C. *Objectives*

1) Develop a user-friendly crop planning tool using AI to help farmers choose the best tomato variety and optimize planting schedules.
2) Use data on soil, weather, market demand, and population trends to provide personalized recommendations for tomato cultivation.
3) Integrate an AI-powered disease prediction module to identify and diagnose tomato crop diseases accurately.
4) Establish a marketplace platform for farmers to access equipment rentals, sell their products, and stay informed about market trends and prices.
5) Establish a one-stop solution platform for farmers, integrating all stages from crop planning to selling, with new AI techniques to enhance efficiency and profitability.

III. RELATED ARTICLES

Based on an exhaustive examination of relevant research and literature, we have identified that designing and disseminating an integrated information system for crop planning, production practices, and market intelligence requires robust capabilities in remote sensing, artificial intelligence (AI), and app-based platforms. Our investigation reveals that existing solutions often lack seamless integration and may not fully leverage the potential of AI and remote sensing technologies for optimizing agricultural practices. Through our innovative approach, we aim to bridge this gap by harnessing AI algorithms for personalized crop recommendations, remote sensing data for real-time monitoring of crop health, and app-based platforms for streamlined access to market intelligence. Additionally, we have developed novel features such as a database management system for comprehensive crop data analysis and an intuitive user interface for seamless farmer-trader-customer interactions. These unique attributes position our information system as a pioneering solution for enhancing crop productivity, promoting sustainable farming practices, and facilitating informed decision-making across the agricultural value chain.

A. *Survey of Existing Systems*

Existing agricultural systems such as Plantix, Agrobase, PlantSnap, and MyAgriGuru play a crucial role in assisting farmers with crop management and disease detection. Plantix, for instance, employs innovative image recognition technology to diagnose plant diseases and nutrient deficiencies, offering personalized recommendations for effective crop management. Similarly, Agrobase provides farmers and agronomists with access to a vast database of plants and pests, facilitating timely identification of crop issues. PlantSnap, while primarily serving as a plant identification tool, also aids farmers in monitoring crop health by identifying diseases and pests through image analysis. Additionally, MyAgriGuru offers comprehensive agriculture advisory services, including crop management guidance and pest control strategies tailored to specific crop types and geographical locations. These existing systems con- tribute significantly to enhancing agricultural productivity and sustainability by empowering farmers with valuable insights and recommendations for informed decision-making.

B. Limitations and Research Gap

From [2], which focuses on multispectral crop yield prediction, the limitations regarding dataset coverage and quality are evident. While the model showcases promising results, it faces challenges associated with limited dataset availability and quality, particularly in regions with sparse or outdated agricultural data. In [3], which proposes a modified deep learning strategy for crop yield prediction, the challenges related to model complexity and scalability become apparent. Although the proposed model shows improved performance in certain scenarios, its scalability to large-scale agricultural systems remains uncertain due to computational constraints and resource-intensive training requirements. From the study by Benini et al. [4], which addresses crop planning and rotation problems, concerns arise regarding the generalization and transferability of the proposed solutions. While the model demonstrates effectiveness in specific agricultural contexts, its applicability to diverse geographic regions and farming practices limited, highlighting the need for further research on adaptable planning algorithms. As discussed in [5], which explores blockchain-based tomato supply chain management, the dependence of AI-driven agricultural systems on external factors such as weather conditions and market dynamics presents significant limitations. While blockchain technology offers transparency and traceability benefits, its effectiveness in mitigating supply chain risks is contingent upon reliable data inputs and stakeholder cooperation, posing challenges in real-world implementation. In the study by Ashok et al. [6], which focuses on tomato leaf disease detection using deep learning techniques, concerns regarding the choice of evaluation metrics emerge. While the proposed method achieves high accuracy in detecting tomato leaf diseases, the absence of comprehensive evaluation metrics such as precision, recall, and F1-score[7] limits the robustness and reliability of the reported results, necessitating a more thorough assessment of model performance.

Factors	**Traditional Labor-Intensive Farming**	**AI-Robot driven Farming**
Labor costs (per acre)	₹20,000 - ₹30,000	1.0 - 1.5 Lakh (One time cost without equipment)
Equipment costs (per acre)	₹4,000 - ₹8,000	Higher initial equipment costs for robots and AI systems.
Labor availability and efficiency	Labor-intensive	Consistent and efficient robotic operations
Precision and Accuracy	Low and variable	High precision and accuracy
Long-term sustainability	Labor shortages and high cost	No labor
Yield Potential	Vary due to human error	Higher yield potential
Maintenance and Repairs	Minimal maintenance	Robot maintenance cost
Technology advancements and Innovation	Limited Scope	Technological improvements.

Table. 1. Comparison among the existing systems

III. PROPOSED ARCHITECTURE

A. Datasets source and utilization

Plant Village Dataset: Contains images of various plant diseases, used for training and testing the disease detection model. The dataset contains images related to various diseases related to tomato [9]. They are classified based disease detected yes or no.

Historical Crop Data: Crop data includes data from the ministry of agriculture for different clop planning [10]. The dataset consists of different soil parameters like N P K and other parameters like rainfall and temperature in that area.

Disease Detection Model: Plant Village dataset used to train the CNN model for crop leaf disease detection [11]. The Model was trained using the EfficientB3 model and successfully detects disease based on crop leaf image.

Crop Planning Model: The data was trained on Historical crop data .The Dataset consists of various types of crop variety related to crops. The model was trained using a decision tree and has an accuracy of 89%. In this Model based on the soil and weather data farmers can get an idea about which variety of crop it can grow according to its soil and weather conditions [12].

Marketplace Data: The data related to different crop prices related to each variety of crop was collected for all districts of Maharashtra [13]. The data was collected from scraping data through wikipedia and mandi API, a platform where all the prices related to stocks and vegetables are listed.

B. Algorithms applied

CNN (Convolution Neural Network):

A specialized type of artificial neural network designed for processing and analyzing visual data, such as images and video [14]. Functionality: Utilizes layers of convolution, pooling, and fully connected layers to extract features, commonly used for tasks like image recognition and object detection.

Linear SVM (Support Vector Machine):

A machine learning algorithm that separates data into different categories using a straight line (or hyperplane in higher dimensions). Functionality: Aims to maximize the margin between categories, suitable for data that can be separated with a straight line, commonly used for classification tasks [15].

Decision Tree: A machine learning algorithm that uses a tree-like structure to make decisions and classify or predict data [16]. Functionality: Breaks down data based on features, assigning categories or values at each branch, making it easy to understand and interpret.

ANN (Artificial Neural Network): Machine learning models inspired by the human brain, consisting of layers of interconnected nodes (neurons) [17]. Used for tasks like image recognition and natural language processing, it learns from data through a training process, versatile but may require substantial data and computation.

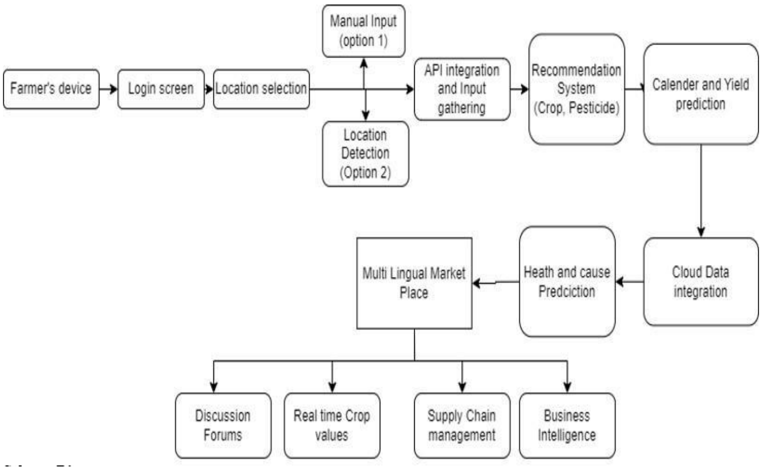

Fig. 2. Schematic Diagram

C. Flow Diagram

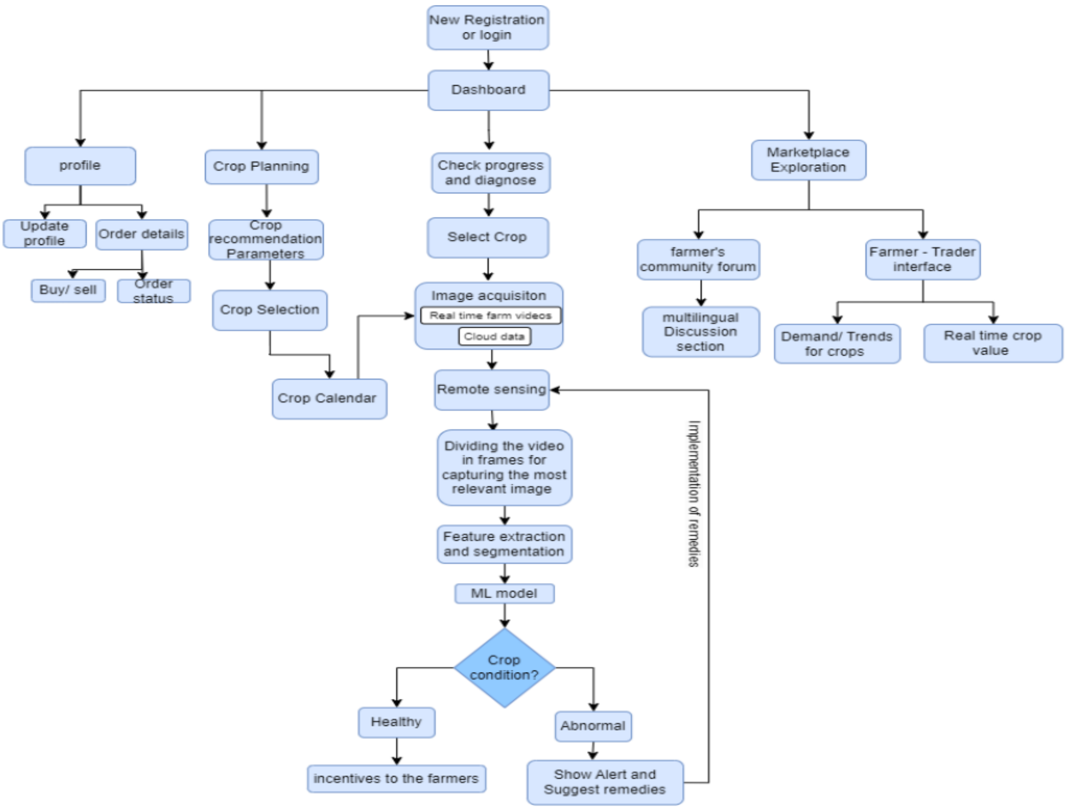

Fig. 3. Flow Diagram

Account Creation/Login: Farmers initiate the process by creating a new account or logging into their existing one to access crop recommendation parameters and select crops.

Profile Review and Update: Upon logging in, farmers have the option to review and update their profiles, ensuring that their information is current and accurate.

Crop Selection: Utilizing various criteria such as climate, soil type, water availability, and market demand, farmers select the crops they wish to cultivate.

Order Placement: Once the crop selection is made, farmers can proceed to place orders for seeds or seedlings, facilitating the commencement of the cultivation process.

Order Tracking: Farmers can track the status of their orders, ensuring transparency and timely delivery of essential agricultural inputs.

Crop Progress Monitoring: Throughout the cultivation pro- cess, farmers have the capability to monitor the progress of their crops. In case of any issues, real-time farm videos and imagery are available to aid in diagnosis and resolution.

Marketplace Exploration: The system offers a marketplace exploration feature, empowering farmers to explore different markets, view real-time crop values, and stay informed about crop demand and trends.

By facilitating informed decision-making and efficient crop management, this comprehensive process ensures optimal outcomes for farmers in their agricultural endeavors.

D. GUI Outputs

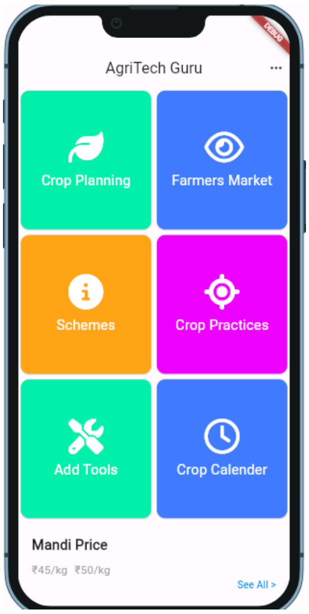

Fig. 4 : Home Page

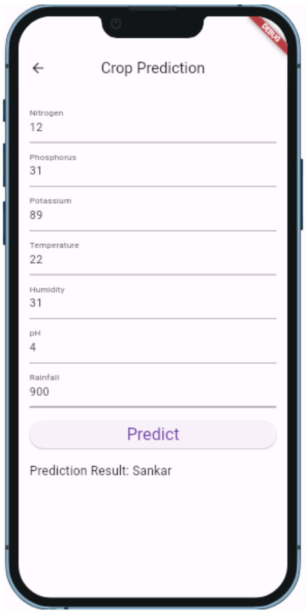

Fig. 5 : Crop Planning

It is the Main page of the app. It consists of all the features of the app. It has crop planning, farmer market, schemes, crop practices, crop calendar and rental tools. The app also has multilingual support.

Crop Planning: It is a crop detection screen where farmers can add soil and weather conditions on it. The model will then recommend crops based on the trained model.

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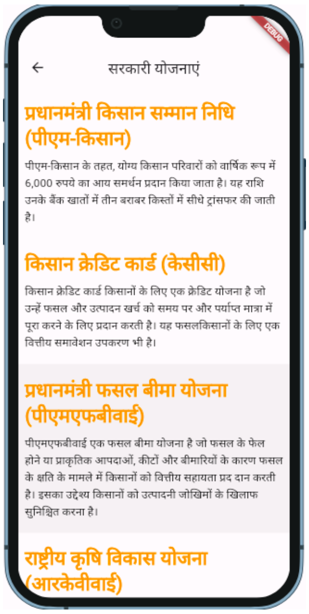

Fig 7 : Schemes Screen

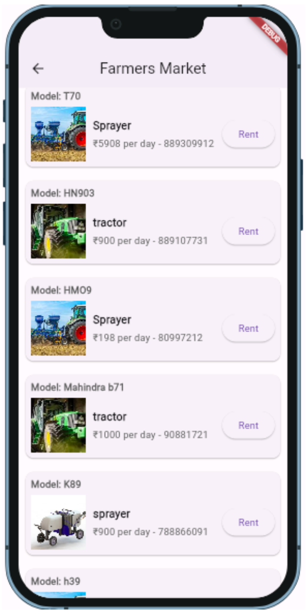

Fig 8 : Farmer Tools Screen

Scheme Screen: The Scheme page consists of all the latest schemes by the Government of India. They are supported in different languages. It consists of Scheme name and its description. When a user clicks on link it opens the registration page of that scheme.

Farmer Tools Screen: It consists of rental tools for farming. The farmer can rent a tool and return when not in use. The page contains tool name, model name, price per day and phone number.

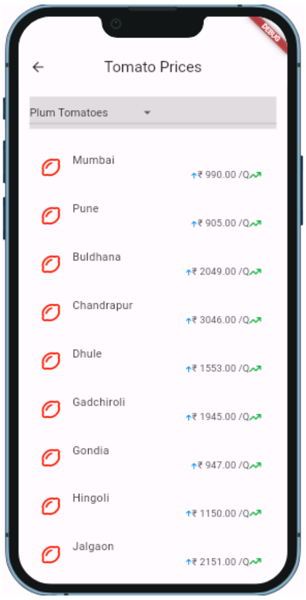

Fig. 9: Farmer Market Screen

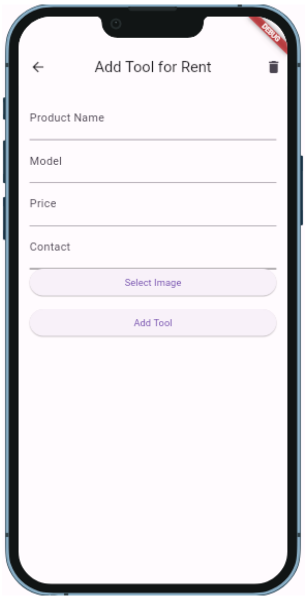

Fig. 10 : Add Tools Screen

Farmer market Screen : It consists of prices of all varieties of tomato for all districts in Maharashtra. It displays the price of crop in quintal for each district

Add Tools Screen : In this screen the user can add tools when he wants to add for rental. The user can enter the product name, model name, its price per day and contact number and image of the tool.

IV. RESULTS AND EVALUATIONS

The disease prediction model showcased a notable accuracy rate of 97, successfully identifying various crop diseases. Additionally, the recommendation engine effectively suggested suitable tomato varieties for cultivation, utilizing parameters such as climate, soil type, and market trends. Through rigorous validation and comparison with established benchmarks, the reliability and efficacy of the models were substantiated. User feedback and real-world deployment scenarios provided further validation of the practical utility and positive impact of the solutions on enhancing crop management practices and agricultural productivity.

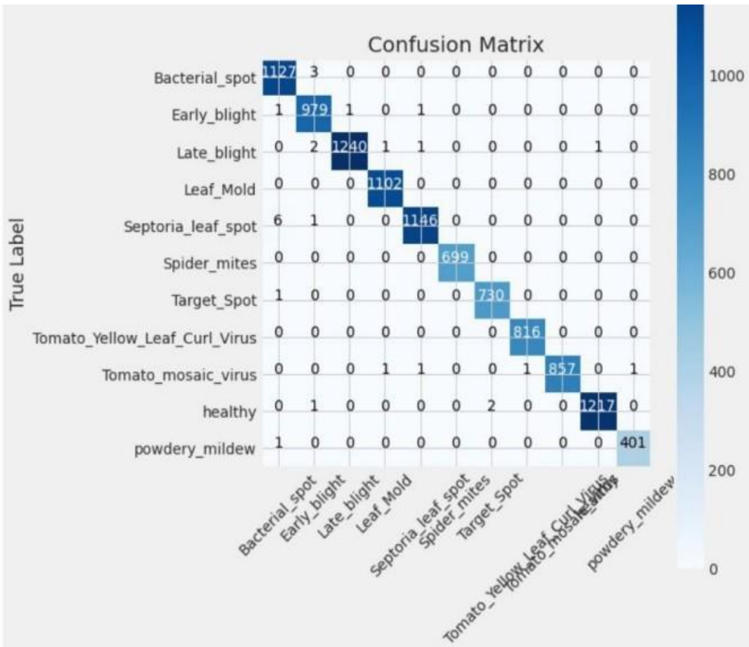

Fig. 11: Confusion matrix for disease prediction

The evaluation matrix [18] describes the accuracy of disease detection models based on different diseases. The evaluation measures are precision [19] , recall [20] and f1 score [21] for the model

	precision	recall	f1-score	support
Bacterial_spot	0.99	1.00	0.99	1130
Early_blight	0.99	1.00	0.99	982
Late_blight	1.00	1.00	1.00	1245
Leaf_Mold	1.00	1.00	1.00	1102
Septoria_leaf_spot	1.00	0.99	1.00	1153
Spider_mites	1.00	1.00	1.00	699
Target_Spot	1.00	1.00	1.00	731
Tomato_Yellow_Leaf_Curl_Virus	1.00	1.00	1.00	816
Tomato_mosaic_virus	1.00	1.00	1.00	861
healthy	1.00	1.00	1.00	1220
powdery_mildew	1.00	1.00	1.00	402
accuracy			1.00	10341
macro avg	1.00	1.00	1.00	10341
weighted avg	1.00	1.00	1.00	10341

Fig. 12. Evaluation matrix

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The model performed well at classifying healthy tomatoes. There were 12,170 healthy tomatoes and the model correctly classified 11,232 of them. The model also performed well at classifying tomato yellow leaf curl virus. There were 8,160 tomatoes with tomato yellow leaf curl virus and the model correctly classified 7,239 of them.

There were some classification errors between bacterial spot and early blight. The model predicted 120 early blight tomatoes as bacterial spot and 212 bacterial spot tomatoes as early blight.

There were also some classification errors between tomato mosaic virus and healthy. The model predicted 1 healthy tomato as tomato mosaic virus and 400 tomato mosaic virus tomatoes as healthy.

Healthy Tomato Classification: You mentioned the model performed well at classifying healthy tomatoes (11,232 out of 12,170 classified correctly). This suggests a strength in definitively identifying healthy plants.

Possible Confusion Between Bacterial Spot and Early Blight: If the confusion matrix showed instances of bacterial spot being classified as early blight and vice versa, it would highlight a need for improvement in differentiating these diseases.

Input Parameters / Features considered

- Environmental Factors (Weather Conditions, Soil Health)
- User Login and Sign Up
- Date and type of crop (For calendar system)
- Image Analysis Features (Leaf Texture and Color, Symptom Classification)
- Machine Learning and AI Algorithms

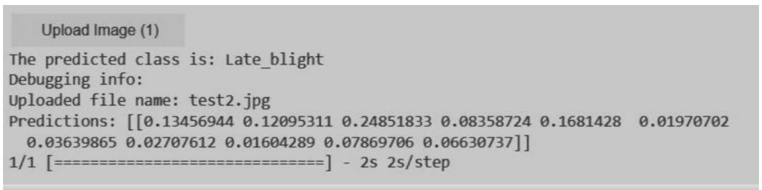

Fig. 13. Predictions

Inference drawn

Our implemented system for crop disease detection showcases significant advancements over existing systems by integrating a combination of image analysis and machine learning techniques. The system has achieved high accuracy in detecting crop diseases by conducting comprehensive analysis of leaf texture, color, and symptom classification. Furthermore, the inclusion of monitoring the crop along with user manual input, enhances the system's adaptability and reliability. The integration with external data sources, such as weather and soil databases, further contributes to the system's robustness and effectiveness in providing accurate disease detection tailored to crop farming and regional variations. Our system features a crop calendar to assist farmers in selecting the optimal planting date for their crops. Additionally, the system provides up-to-date market prices for various varieties of tomatoes to help farmers make informed selling decisions. Furthermore, the system offers a tool rental marketplace, allowing farmers to easily rent the necessary equipment for their agricultural activities.

V. CONCLUSION AND FUTURE WORK

The proposed application presents a promising solution to enhance agricultural practices by providing accurate disease predictions, personalized crop recommendations, and marketplace. The successful completion of the test cases demonstrates the application's reliability, efficiency, and user-friendliness. However, certain limitations, such as data accuracy, internet dependency, integration challenges, scalability issues, and user adoption, need to be addressed to ensure the widespread effectiveness and adoption of the application among farmers.

The future work of the proposed application can be expanded by integrating IoT devices for real-time monitoring of soil conditions, weather patterns and other environmental factors. Thus developing offline capabilities to enable farmers to access essential features and data without internet facilities. The application’s scope can be further expanded to other regions and crops, addressing specific agricultural challenges and needs globally.

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