

Early Crop Loss Prediction and Safe Pesticide Recommendation System

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ABSTRACT: Unpredictable environmental conditions, pests, and crop diseases continue to threaten agricultural productivity, often leading to significant yield losses. To address this issue, this project presents a machine learning-based web application designed for early crop loss prediction and safe pesticide recommendation. The system utilizes historical crop data, weather parameters such as temperature, humidity, and rainfall, soil health indicators, and pest or disease information to train models using XGBoost and Scikit-Learn. By analyzing these factors, it predicts the likelihood of crop failure, enabling farmers to take timely preventive measures. Additionally, the integrated recommendation engine suggests effective and environmentally safe pesticides by evaluating their efficiency, human safety, environmental impact, and cost. Built with a Python Flask backend and an interactive frontend dashboard, the platform allows users to input real-time data, visualize risks, and access actionable insights. Overall, the system supports proactive decision-making, enhances crop yield, and promotes sustainable agricultural practices. Furthermore, it reduces economic losses for farmers by improving resource management and timely intervention. It also contributes to precision agriculture by leveraging data-driven insights for smarter and more efficient farming.

KEYWORDS: Early Crop Loss Prediction, Machine Learning, XGBoost, Precision Agriculture, and Safe Pesticide Recommendation. Flask Web Application, Crop Disease Detection, Environmental Sustainability, Smart Farming, and Decision Support System

I. INTRODUCTION

Agriculture is an important part of the food security and economic stability of the world but is constantly challenged by unpredictable weather patterns, pest attacks and crop diseases that in most cases cause massive losses in production. Conventional farming techniques, which rely much on experience and response measures, are not adequate to control such dynamic problems. As machine learning and data driven technologies progress, agriculture can be made a more specific and smart system.

This project includes a web application to predict early crop loss and recommend safe pesticides using machine

learning. With the help of historical crop data, weather parameters; temperature, humidity, and rainfall, indicators of soil health, and pests or disease information, the system uses models such as XGBoost and Scikit-Learn to forecast the chances of crop failure. It also incorporates a recommendation engine which proposes effective and environmentally safe pesticides depending on the aspects of their efficiency, human safety, environmental impact and cost. The platform, created on a Python Flask back-end with an interactive frontend dashboard, allows users to enter real-time data, visualize risks, and get actionable insights. On the whole, the system facilitates proactive decision-making, enhances agricultural productivity, and encourages sustainable agricultural practices. Furthermore, the proposed system helps farmers make informed decisions by providing timely alerts and preventive measures to reduce potential losses. It enhances resource utilization by minimizing excessive pesticide usage and promoting eco-friendly alternatives. The integration of real-time data processing ensures that recommendations remain relevant and adaptive to changing field conditions. In addition, the system can be extended to support large-scale agricultural monitoring

II. RELATED WORK

Various studies have helped to build smart agricultural systems based on machine learning and data-driven solutions. Crop yield prediction using algorithms like Random Forest, Support Vector Machines (SVM), and Gradient Boosting involving the use of environmental variables such as temperature, rainfall and soil nutrients as critical inputs has been a topic of many studies. These models have demonstrated greater accuracy over the conventional statistical techniques particularly when it comes to nonlinear relationships in agricultural data.

Deep learning technologies, especially the Convolutional Neural Networks (CNNs) are widely used by researchers in the field of crop disease detection of leaf diseases in leaf images. Such systems are very precise and allow early-detection, however, they tend to be restricted to image analysis and fail to incorporate environmental or predictive risk factors.

Other studies have offered the IoT-based smart farming systems that can gather real-time data on the soil moisture, temperature, and humidity using sensors. Such systems contribute to the continuous monitoring of the crop state and aid in decision-making based on the data. They are however more on monitoring as opposed to predictive analysis and recommendation.

Rule-based and decision-support techniques have also been used to develop pesticide recommendation systems where pesticides are recommended based on the type of crop and the diseases detected. Some of the progressive methods use multi-criteria decision-making to determine pesticides in terms of effectiveness, cost, and environmental safety. In spite of this, the majority of these systems are independent of each other and are not integrated with predictive crop loss systems.

III. METHODOLOGY

The proposed Early Crop Loss Prediction and Safe Pesticide Recommendation System is intended to be a multi-step procedure which will combine data gathering, data preprocessing, machine learning modelling, and the creation of recommendations in a single web-based application.

A variety of data are first gathered including historical crop yield data, meteorological data (temperature, humidity and rainfall), soil health parameters (pH and nutrient levels), and pest or disease presence data. Such a wide dataset guarantees that the model will be able to capture both environmental and biological conditions that can affect the health of crops.

During the preprocessing phase, the data that is collected is cleaned and converted to eliminate inconsistencies, missing values, and normalize features to improve the performance of the model. The techniques used to select features and engineer features are employed to determine the most relevant features which have a significant influence on predicting crop losses.

The machine learning models (primarily XGBoost and others in Scikit-Learn) are then trained on the processed data. These models are trained to learn patterns and correlation of input features and crop loss results. The dataset will be

segmented into training and test sets to test how the models perform with measures of accuracy, precision, recall, and F1-score. The most successful model is chosen to be implemented. After being trained, the model is incorporated into a Flask-based Python web app. The system is able to predict the likelihood of crop loss and the users can use an interactive dashboard to input real-time field data. The recommendation module is triggered, based on the prediction results and the risks that are identified.

The pesticide recommendation system is a rule-based and ranking procedure, with pesticides being considered in terms of effectiveness, human safety, environmental impact, and cost. It then proposes the most appropriate and environmentally friendly solutions that depend on the state of the crop and the level of risk. Lastly, the system displays the findings in an easy-to-use interface, such as risk visualization, alerts, and actionable advice. This end to end methodology helps farmers make wise decisions, minimize possible losses, and have sustainable agriculture practices.

IV. IMPLEMENTATION DETAILS

The Early Crop Loss Prediction and Safe Pesticide Recommendation System is implemented with the help of a modular and scalable architecture, which combines machine learning models and a web-based interface. The system is coded in Python as the main programming language because it has a wide range of data analysis and machine learning libraries. The data is gathered on agricultural sources with characteristics of temperature, humidity, rainfall, nutrients in the soil, the type of crop and indicators of pests or diseases. Preprocessing of data is conducted through the help of such libraries as Pandas and NumPy, with missing values replaced, categorical variables coded, and feature scaling performed. The feature engineering methods are applied in order to increase the performance of the model by selecting the most relevant attributes.

In case of the prediction module, Scikit-Learn and XGBoost are used to implement machine learning models. Several models are trained and tested and the best model chosen is the XGBoost, as it is more accurate and efficient as compared to other models. To assess the model, metrics like accuracy, precision, recall, and f1-score are used and cross-validation is carried out to make it robust. The application backend is built with the Flask framework and it receives user requests, processes input data and communicates with the trained machine learning model. RESTful APIs are designed to bind the frontend interface and the logic on the server. The frontend is created with the help of HTML, CSS, and JavaScript, with visualization libraries like Chart.js or Plotly to present the result of predictions and risk analysis in an interactive form.

Pesticide recommendation module is implemented through a scoring system and rule based. Pesticide database is kept and every pesticide is rated in terms of its effectiveness, safety, environmental impact, and cost. Depending on the projected risk level and condition of the crop, the system prioritizes and advises on the most appropriate pesticides. Lastly, the system is overall tested on performance, usability and accuracy. The app may be implemented on the local servers or cloud servers, which provides users with real-time access. This deployment guarantees an effective, dependable, and easy-to-use solution to aid smart and sustainable agricultural decision-making.

V. EXPERIMENTAL RESULTS

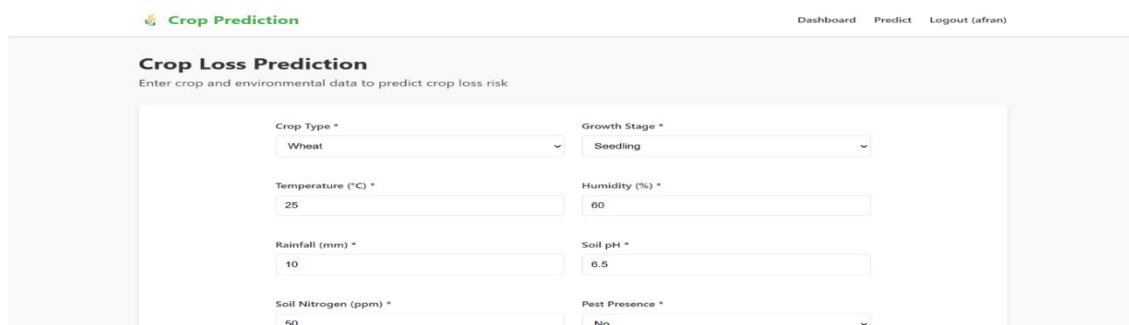


Fig 1

This figure shows the input form of the Crop Loss Prediction System, where users enter crop and environmental data such as temperature, humidity, rainfall, soil conditions, and pest presence. The interface is designed to be simple and user-friendly, ensuring accurate data entry for reliable prediction results.

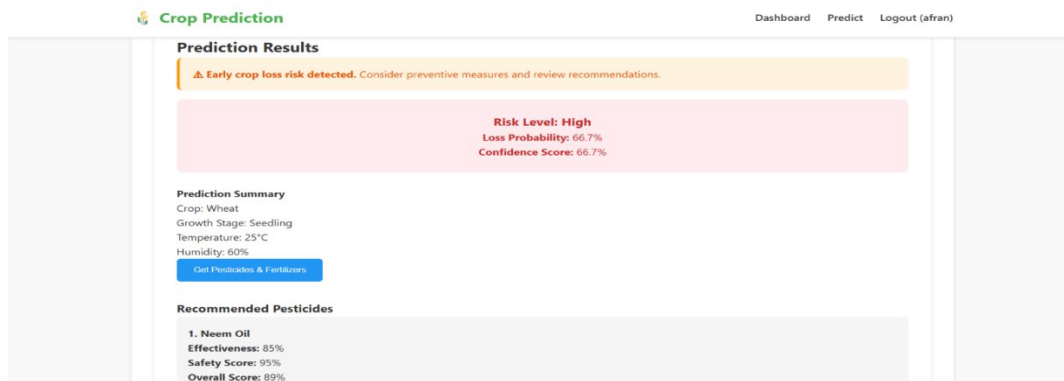


Fig 2

This figure displays the prediction output, indicating a high crop loss risk with probability and confidence score, along with a summary of the input conditions. It also provides recommended pesticides to help users take preventive measures and reduce potential crop loss.

VI. CONCLUSION

In conclusion, the proposed system presents an effective and practical solution to key challenges in modern agriculture. By leveraging machine learning techniques such as XGBoost and Scikit-Learn, the system analyzes important factors including weather conditions, soil health, and pest or disease presence to predict potential crop loss. This enables farmers to take timely preventive actions and minimize damage.

Furthermore, the system provides safe and effective pesticide recommendations by considering factors such as cost, human safety, and environmental impact. This ensures not only better crop protection but also promotes sustainable farming practices. The implementation as a Flask-based web application makes the system easy to use and accessible, allowing users to input data and visualize results efficiently. Even users with minimal technical knowledge can benefit from its features. Overall, the system serves as a valuable decision support tool that enhances productivity, reduces losses, and supports eco-friendly agriculture. With further improvements and real-time data integration, it has strong potential for wider adoption in the future.

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