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AI-Based Smart Crop Recommendation System

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Abstract: *Modern agriculture is relying more and more on digital technology and intelligent decision-making systems. This paper presents a crop recommendation system using artificial intelligence (AI), which is designed to assist farmers in choosing the right crops based on soil and environmental factors. The proposed system employs machine learning methods for analyzing critical agricultural variables such as nitrogen, phosphorous, potassium, pH value, temperature, humidity, and rainfall.Several classification algorithms, models like Logistic Regression, Decision Tree, KNearest Neighbor (KNN), Support Vector Machine (SVM), Naive Bayes, Random Forest, and XGBoost were implemented and.*

Keywords: *Naive Bayes*

I. INTRODUCTION

The agricultural sector serves as a very important factor contributing to food security and the development of the economic condition of various nations. For developing nations, a significant number of people depend directly on agriculture for their income. However, the choice of crops is generally made on the basis of assumptions and not scientifically. Inaccurate selection of crops leads to low production, imbalanced nutrients, and wastage of natural resources. The development of the Artificial Intelligence (AI) and Machine Learning (ML) technology has provided a platform for modern farming. The use of intelligent systems has been found to be effective in the process of handling and predicting agricultural data in order to facilitate proper planning.

algorithms may analyze environmental aspects such as soil nutrients in order to select suitable crops.

Among all the considered models, the Random Forest model showed superior performance by achieving the accuracy of 98.2%. Moreover, a web application was also created using Flask to create an intuitive interface for farmers or agricultural practitioners. Depending on the inputs provided by the user, the crops are categorized into three classes: Recommended, Slightly Recommended, and Not Recommended.

Keywords: Artificial Intelligence, Machine Learning, Precision Agriculture, Crop Recommendation, Random Forest, Smart Farming

II. MATERIALS AND METHODS

2.1 Data Collection

The data set used in this research was gathered from open-source agricultural literature. It includes details on soil nutrient levels and environmental factors necessary for plant growth. The key inputs include:

1) Nitrogen (N)
2) Phosphorus (P)
3) Potassium (K)
4) Temperature
5) Humidity
6) Rainfall
7) Soil pH

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The data set has entries for various crops including cereals, vegetables, pulses, and fruits.

Crop recommendation systems can be considered one of the essential uses of AI in agriculture. The system relies on information like NPK values, soil pH, precipitation, temperature, and humidity levels to recommend the best crop. This technology makes farming more efficient and reduces the chances of crop failure.

The study centers around the implementation of an AI-based Smart Crop Recommendation System that utilizes several machine learning approaches. It highlights the comparison of various methods of classification to determine the best performing algorithm for predictions.

2.2 Data Preprocessing

Before feeding the data into the machine learning algorithm, the data set was preprocessed. Data cleansing included removing duplicates and missing values. Normalization of numeric values was done to improve the performance of the model. This is due to the effect that performance has on the algorithms being scaled. The dataset was then split into train and test data sets at an 80:20 proportion.

2.3 Machine Learning Models

A range of machine learning techniques were developed to determine which crops would be produced. Some of the models utilized include:

1. Logistic Regression
2. Decision Tree
3. K-Nearest Neighbors (KNN)
4. Support Vector Machine (SVM)
5. Naive Bayes
6. Random Forest
7. XGBoost

Models' performances were analyzed through classification accuracy and confusion matrices.

Model Accuracy Table

Model	Accuracy (%)
Logistic Regression	85.6
Decision Tree	91.5
KNN	94.3
SVM	93.4
Naive Bayes	80.1
Random Forest	98.2
XGBoost	97.5

However, the Random Forest method had the best accuracy and was chosen as the predictive model.

2.4 Tools and Technologies

These are the technologies used for the development:

Tool/Technology	Purpose
Python	Programming Language
Scikit-learn	Machine Learning Models
Pandas & NumPy	Data Processing
Flask	Web Framework
HTML/CSS/Bootstrap	Frontend Design

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Matplotlib & Seaborn	Data Visualization
Jupyter Notebook	Model Training
Render.com	Deployment Platform

2.5 Web Application Development

A web application was built using Flask for the deployment of the model. The farmers have the opportunity to provide details about soil conditions and environment using a simple input screen. From the entered information, the application provides predictions regarding appropriate crops such as:

1) Recommended Crops
2) Slightly Recommended Crops
3) Not Recommended Crops

The model trained was then stored using the Pickle (.pkl) format and embedded into the Flask backend framework.

III. RESULTS AND DISCUSSION

The crop recommendation system built was then tested on various machine learning models. The results proved that ensemble- based models worked better than regular classification models.

Of all the models used, Random Forest has the best accuracy at 98.2%. The reasons for the high accuracy include being able to create decision trees and minimize the risk of overfitting. The next model with high accuracy is XGBoost with 97.5%, followed by Naive Bayes that has the lowest accuracy.

It is clear that machine learning models are useful when it comes to analyzing agricultural data and providing highly accurate crop predictions. The created application will help farmers make the right planting decisions with the help of scientific evidence.

The application was able to recommend appropriate crops based on user inputs. The application interface was designed in such a way that

Many researchers have explored the application of Artificial Intelligence and Machine Learning in agriculture. Recent studies show that intelligent farming systems can significantly improve crop management and productivity.

IV. LITERATURE REVIEW

It is worth noting that numerous scientists have already researched using artificial intelligence and machine learning in agriculture. Recent research results prove that using intelligent agricultural systems can greatly enhance productivity.

Decision Trees, Random Forest, KNN, and SVM are examples of machine learning algorithms that are employed in predicting agricultural systems. Out of these algorithms, Random Forest is very dependable since it can process huge amounts of data with consistency.

Previous research has shown that AI systems can be used to make predictions on crop yield, soil fertility, and environmental suitability. The significance of incorporating climate and soil information in agricultural advice has been emphasized.

Even though some crop recommendation systems have been developed to date, they pay more attention to prediction accuracy rather than issues like adaptability, scalability, and user interface. Thus, more sophisticated models need to be considered to address those challenges effectively.

V. RESEARCH GAP

Though such AI-powered agriculture technologies are already available, there are certain drawbacks to current research.

1) Current systems do not use real-time environmental information.
2) Such systems offer general recommendations rather than personalized advice.
3) Lack of adaptability and feedback is common among many systems.

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4) Scalability problems hinder their usefulness in large-scale agriculture operations.
5) Adequate multilingual capability remains lacking
The presence of these drawbacks indicates the necessity of developing a more advanced agricultural prediction model.

VI. RESEARCH METHODOLOGY

System development was done using a scientific process approach.
Step 1: Data Collection
Agricultural data including soil nutrient content and environmental factors were obtained.
Step2: Data Cleaning and Preprocessing
Data cleaning, normalization, and preparation for machine learning models were performed.
Step 3: Feature Selection
Significant factors like N, P, K, pH, rainfall, humidity, and temperature were chosen.
Step 4: Model Training
Machine learning models were trained on the prepared agricultural data.
Step 5: Model Evaluation
Accuracy and classification measures were used to compare the performance of all models.
Step 6: Deployment
The most accurate machine learning model was implemented in the Flask web app.
Images:
The screen capture of the web interface is provided below, showing how both the inputs and the outputs look: This Flask Web Application is available via:
http://localhost:5000

VII. EXPERIMENTAL SETUP

The project was implemented using the computer system having a minimum of 8 GB RAM and a high-speed processor.
Software Requirements
1) Python 3.x
2) Jupyter Notebook
3) Flask
4) Scikit-learn
5) Pandas
6) NumPy
7) Matplotlib
The performance was evaluated using the train-test split methodology. The performance was assessed based on the prediction accuracy and efficiency of
classification.

VIII. ADVANTAGES

The proposed crop recommendation system offers several benefits:
1) Crop recommendations based on reliable data
2) Mitigates human efforts and reduces mistakes.
3) Saving time through automated crop predictions.
4) Facilitates precision agriculture.
5) Increases agricultural productivity.
6) User-friendly and scalable.
7) Scientifically advanced farming practices.

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IX. LIMITATIONS

Althoug Even though the system operates efficiently, certain limitations still exist: 30) The quality of prediction is reliant on the accuracy of the data set.

1) The internet must be accessible to access the website.
2) It cannot completely adjust to drastic changes in the environment.
3) The cost incurred during development and implementation is relatively high.
4) Sensor integration in real-time is not possible at present.

X. CONCLUSION AND FUTURE WORK

The development of an artificial intelligence- powered Smart Crop Recommendation System that predicts appropriate crops based on soil and environmental conditions was successful in this study. Various machine learning models were examined, and Random Forest showed the best prediction performance at 98.2%.

The incorporation of the machine learning algorithm into the Flask application renders the application practical and easy to use by farmers and agriculture experts alike. This proposed solution allows datadriven farming, thereby encouraging sustainable agricultural techniques.

In the future, the system could be improved upon by incorporating

1) Real-time weather APIs
2) IoT-based soil sensors
3) Satellite and GIS data
4) Support for mobile applications
4) Multilingual interfaces
6) Adaptive learning models

The above improvements will further enhance the performance of the system.

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