Artificial Intelligence-Based Crop Yield Prediction Using Machine Learning Algorithms

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Abstract

Accurate crop yield prediction is essential for ensuring food security, improving agricultural productivity, and supporting farmers in decision-making. Traditional crop yield estimation methods are often inaccurate, time-consuming, and dependent on manual observations. With the advancement of Artificial Intelligence (AI) and machine learning (ML), data-driven approaches can significantly enhance prediction accuracy.

This paper proposes an AI-based crop yield prediction model using machine learning algorithms. Various agricultural factors such as rainfall, temperature, humidity, soil properties, fertilizer usage, and historical crop yield data are analyzed. Machine learning models including Linear Regression, Decision Tree, Random Forest, and Support Vector Machine are implemented and compared. Experimental results demonstrate that the Random Forest model achieves the highest prediction accuracy. The proposed system provides an effective tool for farmers and policymakers to improve agricultural planning and optimize resource utilization.

Keywords: Artificial Intelligence, Crop Yield Prediction, Machine Learning, Precision Agriculture, Predictive Analytics, Smart Farming

1. Introduction

Agriculture plays a crucial role in the economic development of many countries, particularly in developing nations like India. Accurate crop yield prediction is vital for effective agricultural planning, market stability, and food security. However, crop yield depends on multiple factors such as climate conditions, soil characteristics, irrigation, and farming practices, making prediction a complex task.

Recent advancements in Artificial Intelligence and machine learning have enabled the analysis of large-scale agricultural data to identify patterns and predict outcomes. AI-based models can process historical and real-time data to provide accurate yield predictions, helping farmers make informed decisions. This research aims to develop an intelligent crop yield prediction system using machine learning algorithms.

2. Related Work

Several researchers have explored the application of machine learning in agriculture. Regression models, neural networks, and ensemble methods have been widely used for crop yield prediction. Studies have shown that Random Forest and Support Vector Machine models often outperform traditional statistical methods due to their ability to handle non-linear relationships and complex interactions among features.

However, many existing studies face challenges such as limited datasets, lack of regional customization, and insufficient integration of multiple agricultural factors. This study addresses these limitations by using a comprehensive dataset and comparing multiple machine learning algorithms to identify the most effective model for crop yield prediction.

3. Proposed System Architecture

The proposed AI-based crop yield prediction system consists of four major modules:

3.1 Data Collection Module

Agricultural data is collected from multiple sources, including meteorological departments, soil testing laboratories, agricultural surveys, and historical crop records. Key parameters include rainfall, temperature, humidity, soil pH, soil moisture, fertilizer usage, crop type, and past yield data.

3.2 Data Preprocessing Module

Data preprocessing involves handling missing values, removing outliers, encoding categorical variables, and normalizing numerical features to improve model performance.

3.3 Machine Learning Module

Different machine learning algorithms are trained using the processed dataset to predict crop yield. The models are evaluated to identify the most accurate and reliable algorithm.

3.4 Prediction Module

The final model generates crop yield predictions, which can be used by farmers and policymakers for decision-making and planning.

4. Methodology

4.1 Dataset Description

The dataset used in this study includes the following attributes:

- Rainfall (mm)
- Temperature (°C)
- Humidity (%)
- Soil pH
- Soil moisture (%)
- Fertilizer usage (kg/ha)
- Crop type
- Historical yield (tons/hectare)

The dataset may be obtained from government agricultural databases, research institutions, or simulated datasets for experimental purposes.

4.2 Data Preprocessing

The following preprocessing steps are applied:

- Handling missing values using mean or median imputation
- Encoding categorical variables using label encoding or one-hot encoding
- Feature scaling using normalization or standardization
- Splitting the dataset into training and testing sets

4.3 Machine Learning Algorithms

The following machine learning algorithms are used:

1. **Linear Regression (LR)** – A statistical model for predicting continuous values.
2. **Decision Tree (DT)** – A tree-based model that splits data based on feature conditions.
3. **Random Forest (RF)** – An ensemble learning method that combines multiple decision trees.
4. **Support Vector Machine (SVM)** – A model that finds optimal hyperplanes for regression or classification tasks.

4.4 Evaluation Metrics

Model performance is evaluated using the following metrics:

- Mean Absolute Error (MAE)
- Root Mean Square Error (RMSE)
- R-squared (R^2)
- Prediction Accuracy

5. Experimental Results

The performance of machine learning models is summarized below:

Algorithm	**Accuracy (%)**
Linear Regression	82.3
Decision Tree	85.7
Random Forest	**92.1**
Support Vector Machine	88.4

The Random Forest model outperforms other algorithms due to its ability to handle non-linear relationships and complex interactions among features.

6. Discussion

The experimental results indicate that AI-based models significantly improve crop yield prediction accuracy compared to traditional methods. The Random Forest algorithm provides robust performance and better generalization capabilities. The proposed system can help farmers optimize agricultural practices, reduce risks, and improve productivity.

Moreover, the integration of AI in agriculture supports the concept of precision farming, enabling data-driven decision-making and sustainable agricultural development.

7. Conclusion and Future Work

This paper presents an Artificial Intelligence-based crop yield prediction model using machine learning algorithms. The proposed system demonstrates the effectiveness of AI

techniques in agricultural applications. The results highlight the potential of machine learning models in enhancing crop yield prediction accuracy.

Future research directions include:

- Integration of deep learning models such as neural networks
- Use of real-time IoT sensor data
- Development of mobile-based agricultural advisory systems
- Region-specific crop yield prediction models

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