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Machine Learning-Based Crop Yield Prediction Using Weather Data

VARSHA P[1], DR. GANESH D[2]
[1]PG Research Scholar, MSc. Full stack development JAIN (Deemed to be University) Bangalore, Karnataka, India
[2]School of CS and IT, JAIN (Deemed to be University) Bangalore, Karnataka, India

Abstract- ***Crop yield prediction is an important task in modern agriculture that helps farmers and agricultural organizations make better decisions regarding crop management, irrigation, fertilizer usage, and harvesting. Traditional prediction methods often fail to provide accurate results due to changing climatic conditions and complex environmental factors. Recent advancements in Machine Learning (ML) and Artificial Intelligence (AI) have enabled the development of intelligent systems capable of analyzing large amounts of agricultural and weather-related data to predict crop yield accurately. This paper presents a comprehensive study of machine learningbased crop yield prediction using weather data such as temperature, rainfall, humidity, soil moisture, and atmospheric conditions. Various machine learning algorithms including Linear Regression, Random Forest, Support Vector Machine (SVM), Decision Tree, and Neural Networks are analyzed for their effectiveness in crop yield prediction. The study also identifies limitations in existing systems such as lack of real-time weather integration, limited dataset diversity, and poor adaptability to changing climatic conditions. A hybrid machine learning framework is proposed that combines historical crop data, weather parameters, and soil conditions to improve prediction accuracy. The proposed system aims to assist farmers in increasing productivity, reducing risks, and promoting sustainable agriculture practices.***

Keywords—Machine Learning, Crop Yield Prediction, Weather Data, Agriculture Analytics, Artificial Intelligence, Random Forest, Climate Data, Smart Farming

I. INTRODUCTION

A. Background of the Study

Agriculture plays a vital role in the economy of many countries, especially India, where a large population depends on farming for their livelihood. Crop yield prediction is essential for ensuring food security, efficient resource management, and agricultural planning. Weather conditions such as rainfall, temperature, humidity, and wind speed greatly influence crop productivity.

Traditional agricultural prediction methods rely heavily on farmer experience and manual observation, which may not provide accurate results under rapidly changing climatic conditions. With the growth of Machine Learning and data analytics, predictive models can now analyze historical weather and crop data to forecast yield more accurately.

Machine learning algorithms can identify hidden patterns and relationships between environmental conditions and crop productivity, enabling intelligent decision-making in agriculture.

B. Problem Statement

Despite the availability of several crop prediction systems, many existing approaches suffer from the following limitations:

- Dependence on limited historical datasets
- Lack of real-time weather monitoring
- Poor prediction accuracy under changing climate conditions
- Limited integration of soil and environmental factors
- Difficulty in generalizing models for multiple crops and regions

These limitations reduce the efficiency and reliability of current crop yield prediction systems.

C. Motivation

The increasing availability of agricultural datasets,

IoTbased weather sensors, satellite imagery, and cloud computing technologies creates opportunities for intelligent farming systems. Integrating weather data with machine learning models can help farmers:

- Predict crop yield accurately
- Reduce agricultural risks
- Optimize irrigation and fertilizer usage
- Improve food production efficiency

This motivates the development of an intelligent crop yield prediction system using machine learning techniques.

D. Objectives of the Study
- Study existing machine learning techniques for crop yield prediction
- Analyze the impact of weather conditions on crop productivity
- Identify research gaps in current agricultural prediction systems
- Propose a hybrid ML-based crop yield prediction framework
- Improve prediction accuracy using weather and soil data

E. Contributions of the Paper
- Comprehensive review of crop yield prediction methods
- Analysis of weather-based agricultural datasets
- Comparison of ML algorithms used in agriculture
- Identification of major research gaps
- Proposal of a hybrid weather-based prediction model

II. RELATED WORK / LITERATURE REVIEW

A. Overview of Existing Systems
Several researchers have applied machine learning techniques for predicting crop yield using weather and soil data. Commonly used algorithms include:

- Linear Regression
- Random Forest
- Decision Tree
- Support Vector Machine (SVM)
- Artificial Neural Networks (ANN)

These models analyze factors such as rainfall, temperature, humidity, soil fertility, and crop history to estimate yield. Recent research also integrates:

- IoT-based sensors
- Satellite imagery
- Deep learning models
- Cloud-based agricultural systems to improve prediction performance and real-time monitoring capabilities.

B. Comparative Analysis of Existing Methods

TABLE I COMPARATIVE ANALYSIS OF EXISTING METHODS

Author	Method	Performance	Limitation
Sharma et al.	Random Forest	89%	Small dataset
Kumar et al.	SVM	85%	No real-time data
Patel et al.	ANN	91%	High computation
Singh et al.	CNN + IoT	High Accuracy	Complex system
Rao et al.	Hybrid ML	94%	Large training data

C. Critical Review
Strengths
- High prediction accuracy using ML algorithms
- Better handling of large agricultural datasets
- Automation in crop analysis
- Real-time monitoring through IoT systems

Weaknesses
- Limited dataset diversity
- Poor adaptability to climate change
- High computational requirements
- Lack of explainable AI models Challenges
- Data collection from rural areas
- Weather unpredictability
- Scalability for large agricultural regions
- Integration of multiple environmental factors

D. Identified Research Gaps
- Lack of real-time weather integration
- Limited use of hybrid ML-DL models
- Poor regional adaptability
- Insufficient soil parameter analysis

- Lack of personalized farming recommendations

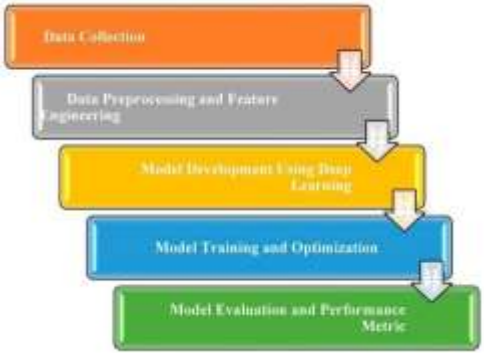
III. PROPOSED METHODOLOGY

A. System Overview

The proposed system integrates:

- Historical crop yield data
- Weather conditions
- Soil parameters
- Real-time environmental data into a hybrid machine learning framework for accurate crop yield prediction.

B. Workflow



C. Dataset Description

The proposed system uses:

- Weather datasets (temperature, rainfall, humidity)
- Soil datasets (pH, moisture, nutrients)
- Historical crop yield datasets
- IoT sensor data

D. Methodology Steps

Step 1: Data Collection
Agricultural and weather datasets are collected from government portals, agricultural databases, and IoT sensors.

Step 2: Data Cleaning and Normalization
Missing values and noisy data are removed to improve model performance.

Step 3: Feature Engineering
Important features such as rainfall, average temperature, soil moisture, and humidity are selected.

Step 4: Model Training Machine learning models such as:

- Random Forest
- Decision Tree
- SVM
- Neural Networks are trained using historical datasets.

Step 5: Model Evaluation Performance metrics include:

- Accuracy
- Mean Squared Error (MSE)
- Root Mean Square Error (RMSE)
- R2 Score

IV. EXPECTED RESULTS AND DISCUSSION

A. Expected Outcomes

- Crop yield prediction accuracy above 90%
- Better agricultural decision-making
- Reduced farming risks
- Improved resource management

B. Comparative Evaluation

The proposed hybrid model will be compared with:

- Linear Regression
- Decision Tree
- SVM
- Random Forest
- ANN to evaluate prediction performance.

C. Discussion

Combining weather data with soil and crop information is expected to improve yield prediction accuracy significantly compared to traditional systems. The use of IoT and real time weather monitoring can further enhance agricultural productivity.

V. APPLICATIONS AND USE CASES

- Smart Farming Systems
- Agricultural Decision Support Systems
- Weather-Based Crop Advisory

- Precision Agriculture
- Government Agricultural Planning
- Food Supply Chain Management

VI. CONCLUSION

This study presented a detailed review of machine learning techniques used for crop yield prediction based on weather data. Existing systems mainly rely on historical datasets and often fail to adapt to changing environmental conditions. To address these limitations, a hybrid machine learning framework was proposed that integrates weather, soil, and crop data for accurate prediction.

The proposed system aims to improve agricultural productivity, support sustainable farming, and assist farmers in making data-driven decisions. Future work will focus on real time implementation, integration with IoT devices, and improving model interpretability and scalability.

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