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Crop Advisor: Intelligent Crop Recommendation System

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***Abstract:** Agriculture has long been a cornerstone of the Indian economy, crucial in sustaining livelihoods and contributing to national growth. By 2024, the sector will contribute approximately 18-20% of India's GDP and employ nearly half of the population. It also ensures food security for over 1.4 billion people. However, crop yields per hectare continue to lag international standards, which has been a significant factor contributing to the rising suicide rates among farmers. This paper proposes a machine learning-based Crop Regulating System to assist farmers. The system takes inputs such as historical and current yield data, weather conditions, soil quality and fertiliser usage from farmers and predicts weather impact, rainfall, and disease effect to predict crop yield before sowing. Also, the system takes inputs such as current market data, sowed land, market import/export data, historical retail data, and consumer data for market demand analysis. Machine learning algorithms analyze this data to predict the market demand and the yield for a chosen crop. After that machine learning algorithms like Regression Forest (RF) and Support Vector Machine (SVM) were used to provide Decision support to Farmers. Regression models like Support Vector Machines (SVM) and Random Forests (RF), Multiple Linear Regression (MLR) and classification models like K-Nearest Neighbors (KNN) are utilized for Crop Yield Prediction. Time series models such as AutoRegressive Integrated Moving Average (ARIMA), and Genetics Algorithms (GAs) are used for Market Demand Analysis.*

***Keywords:** Crop Yield Prediction, Market Demand Analysis, Machine Learning, Random Forest, Support Vector Machine (SVM), Multiple Linear Regression (MLR), K-Nearest Neighbors (KNN), AutoRegressive Integrated Moving Average, Time Series Models, Genetics Algorithms (GAs), Classification Models.*

I. INTRODUCTION

Agriculture has long been a cornerstone of the Indian economy, accounting for around 18-20% of the country's Gross Domestic Product (GDP) and serving as a primary source of employment for nearly half of the population. India has a rich and long-standing agricultural history. In recent times, the country has secured the position of being the second-largest producer of agricultural products globally [13]. This vital sector supports the livelihoods of millions of farmers while ensuring food security for India's vast population of over 1.4 billion people. However, despite its importance, Indian agriculture faces significant challenges, such as rising temperatures, changing precipitation patterns, and extreme weather events, as well as the variability of weather conditions and the complexity of factors influencing crop growth, which pose significant obstacles also crop yield prediction, market demand analysis which is essential for effective decision-making [12].

The accurate prediction of market demand is a complex task influenced by numerous factors, including market data, sowed land under the same crop, import/export strategies, retail data, consumer data, climatic conditions, soil quality, and agricultural practices [14]. Predicting crop yield is a crucial challenge in the agricultural industry [15]. Farmers aim to estimate crop yields to determine if they align with their expectations, often relying on their prior experiences with specific crops [16]. Crop yields are influenced by factors such as weather conditions, pest infestations, and the planning of harvesting activities [17]. Having precise data on crop history plays a vital role in making informed decisions for agricultural risk management [18]. Farmers often encounter difficulties in determining which crops to plant, the optimal planting times [19], and the appropriate use of fertilizers due to the unpredictability of weather patterns and fluctuating market prices [20]. As noted by Dash et al. [3], the inability to accurately predict rainfall can have dire consequences on crop yields and, consequently, farmer livelihoods. This uncertainty is compounded by the lack of a reliable crop prediction system, leaving farmers vulnerable to economic losses and contributing to the rising suicide rates among agricultural communities in India, which have ranged from 1.4 to 1.8% per 100,000 people over the past decade.

Recent advancements in machine learning (ML) have shown promise in addressing these critical issues. Research has demonstrated that ML algorithms can effectively model complex relationships in agricultural data, leading to more accurate crop yield predictions. For instance, Elavarasan and Vincent proposed a deep reinforcement learning model for sustainable agricultural applications [1], highlighting its potential for improving crop yield forecasting. Additionally, Singh et al. explored the application of machine learning for high-throughput stress phenotyping in plants [2], underscoring the ability of ML to assist in managing various agricultural stressors effectively.

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This research aims to develop a comprehensive market demand analysis model that utilizes market data, sowed land data, import/export market stats, retail data and consumer data. After that this system aims to analyze a crop yield prediction model that utilizes historical data, including previous crop yields, environmental conditions, and weather impacts, to provide actionable insights for farmers before sowing the crop. By leveraging past and present data, this system will empower farmers to make informed decisions regarding crop selection and management practices. The model will analyze factors such as rainfall, temperature, and soil type to predict the yield of specific crops, thereby maximizing productivity and profitability.

In summary, this paper addresses the urgent need for a reliable market demand analysis and crop yield prediction system that can help Indian farmers navigate the challenges they face [8]. By harnessing machine learning techniques, we aim to create a user-friendly platform that not only predicts crop yields but also assists in determining the optimal times for fertilizer application and selecting the most suitable crops for cultivation. The outcomes of this research will significantly contribute to improving agricultural sustainability and enhancing food security in India.

II. RELATED WORK

Improving agriculture increasingly relies on integrating technology and innovative tools to make farming more efficient and manageable [4]. One approach involves using machine learning (ML) to forecast the most suitable crops to cultivate. This paper explores various ML methods, such as K-Nearest Neighbors (KNN), Support Vector Machine (SVM), Multiple Linear Regression (MLR) and Random Forest detailing how each contributes to more informed farming decisions and deep learning (DL) methods, such as AutoRegressive Integrated Moving Average (ARIMA), Genetics Algorithms (GAs). However, a major challenge lies in adapting these technologies to process real-time data from markets and farms effectively [5].

An early project created a website to study how weather affects crop production in certain districts of Maharashtra [10]. The districts were chosen based on the types of crops grown there. The topmost district with the largest crop areas was selected for the study. The crop chosen for the study is Tomato, as these are commonly grown in the area. The project looked at crop yields over 3 years. The model developed to predict the yields was fairly accurate, with accuracy ranging from 90% to 98%, and an average accuracy of 93%.

Significant efforts and numerous machine learning (ML) algorithms have been applied within the agriculture sector to address pressing challenges. One of the primary objectives in agriculture is to boost farm productivity while delivering produce to consumers at optimal prices and quality. However, statistics reveal that around half of farm produce goes to waste and fails to reach the consumer. The proposed model aims to address this issue by implementing methods to minimize post-harvest losses, ensuring more efficient distribution and reducing wastage in the supply chain [11].

Firstly, for market demand analysis, we utilize the AutoRegressive Integrated Moving Average (ARIMA) algorithm. ARIMA is highly effective for analyzing and forecasting trends based on historical and time-dependent data. It processes real-time inputs such as current market trends, sowed land under a crop, import/export statistics, retail data, and consumer data to predict future market demand accurately. Additionally, it incorporates seasonal variations, helping identify recurring patterns in demand across different times of the year. With an accuracy of 93%, ARIMA provides valuable insights to assist farmers in aligning their crop production with future market needs.

To further enhance market demand analysis, we explored other algorithms like Genetics Algorithms (GAs), and Long Short-Term Memory (LSTM). These algorithms effectively analyze complex relationships and classify market dynamics based on high-dimensional data [9]. While all these methods offer accuracy above 90%, ARIMA stands out due to its ability to model temporal patterns and integrate seasonal effects, making it the most suitable choice for market demand forecasting in agriculture.

Secondly, we use the Regression Forest (RF) algorithm for crop yield prediction before sowing the Crop. The prediction model takes input data, including cropland area (in acres), season, soil quality, fertilizer usage, crop rotation, variable plant variety, intercropping, last year's yield, and the yield from the year before last. Additionally, rainfall, weather impact, and disease effects are predicted using APIs and integrated into the model for more accurate predictions.

After processing this input data, the Regression Forest model achieves an outstanding accuracy of 99%. We also explored other algorithms like K-Nearest Neighbors (KNN), Artificial Neural Networks (ANN), Multiple Linear Regression (MLR), and Support Vector Machines (SVM). While all these algorithms provided accuracy above 95%, Regression Forest outperformed them, making it the best choice for crop yield prediction.

Then, to minimize wastage, we use the Regression Forest (RF) algorithm to help farmers decide whether to sow a crop. This algorithm analyzes factors like market demand and predicted crop yield to ensure the decision aligns with market needs. It effectively handles complex relationships between various factors like Market demand and predicted crop yield while identifying and prioritizing the most critical ones influencing yield and profitability. If the expected yield meets demand, it recommends sowing; otherwise, it advises against it, avoiding overproduction. With an accuracy of 98%, Regression Forest is a highly effective tool for guiding farmers in making informed decisions.

Example:

In our market demand analysis system, we employ the AutoRegressive Integrated Moving Average (ARIMA) algorithm, which is effective for time-series forecasting. ARIMA consists of three components: the Autoregressive (AR) term, which captures dependencies on past market demand values; the Differencing (I) term, ensuring stationarity by removing trends or seasonal effects; and the Moving Average (MA) term, which accounts for past error terms. It also includes external factors such as market trends, sowed land area, import/export data, retail, and consumer data, represented as coefficients to improve predictions.

The general formula for market demand prediction using ARIMA is:

1. Market Demand=β0+i=1∑pβi·Market Demandt−i +j=1∑qθj·ϵt−j+k=1∑mαk·Xk+ϵt

This model forecasts market demand with 93% accuracy, aligning crop production with anticipated demand.

For crop yield prediction, the Regression Forest (RF) algorithm is used, analyzing factors like cropland area, season, soil quality, fertilizer usage, crop rotation, variable plant variety, intercropping, last year's yield, and year-before-last yield. Additionally, predicted values for rainfall, weather impact, and disease effects are used. The general formula for crop yield prediction is:

1. Crop Yield= F (Cropland, Season, Soil Quality, Fertilizer Usage, Crop Rotation, Variable Plant Variety, Intercrop, Last Year Yield, Year Before Last Yield, Predicted Rainfall, Predicted Weather Impact, Predicted Disease Effect)

The RF model predicts crop yields with 99% accuracy. The Decision Support System (DSS) integrates market demand and predicted crop yield. The system recommends sowing a crop only if the predicted yield meets or exceeds market demand, preventing overproduction. The decision rule is:

1. If Predicted Yield ≥ Market Demand, recommend sowing ("Sow").
2. If Predicted Yield < Market Demand, advise against sowing ("Do not Sow").

Combining ARIMA for market demand analysis and Regression Forest for crop yield prediction offers a data-driven, efficient approach to crop recommendation, enhancing sustainability and profitability for farmers.

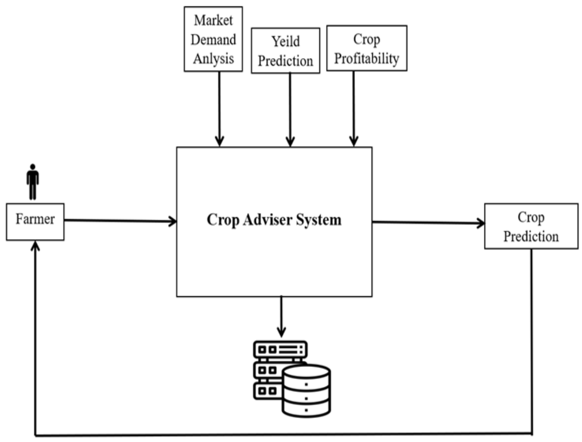
This integrated system ensures crops are aligned with market needs, optimizing production, and minimizing waste.

III. MODEL AND METHODOLOGIES

Despite numerous recent solutions, there are still ongoing challenges in designing a user-friendly application for crop recommendation [6]. This proposal aims to address these limitations by developing an intuitive application that factors in essential parameters, such as rainfall, weather impact, soil quality, fertilizer usage, disease effect, crop rotation, Variable plant variety, Intercrop, Previous two-year yield and other critical cultivation factors like market data, sowed land data, import/export stats, retail data and consumer data. The primary goal is to identify the market demand and then crop yield before sowing the crop in different seasons. This system intends to assist farmers in making informed crop choices, thereby maximizing yield potential, reducing yield surplus production, and shortages and ultimately helping reduce the hardships that have impacted farmer livelihoods.

The proposed model forecasts market demand and crop yields specific to one crop and the Maharashtra region. By integrating agriculture with machine learning, this model aims to enhance agricultural practices by regulating yields and optimizing resource use. Historical data plays a critical role in predicting current outcomes, gathered from credible sources like farmers, agricultural universities, data.gov.in, kaggle.com, and indianwaterportal.com [7].

The data required for market demand analysis includes current market data, sowed land data, import/export stats, retail data, and consumer data and the crop yield prediction dataset includes attributes such as rainfall, weather impact, soil quality, fertilizer usage, disease effect, crop rotation, plant variety, intercropping, and crop yields from the previous two years. Additionally, soil type data with state and district specifics is obtained from other sources and merged with the primary dataset. Temperature and average rainfall details are also added to create a comprehensive dataset for the region. The data is cleaned and pre-processed, with missing values replaced by mean values. Categorical data is converted into labels, and one-hot encoding is applied to handle categorical variables before feeding them into the model.



[Fig.1: System Architecture]

Figure 1 shows the system architecture for a proposed crop recommendation system, designed as a mobile application with three primary modules: Market demand analysis Module, Crop yield prediction and Decision Support Module.

A. Input Data

a. Market Demand Analysis

i. Current market data
ii. Sowed land data
iii. Import/Export data
iv. Retail data
v. Consumer data

b. Crop Yield Prediction

i. Season
ii. Disease Effect
iii. Rainfall
iv. Crop Rotation
v. Weather Impact
vi. Variable Plant Variety
vii. Soil Quality
viii. Intercrop
ix. Fertilizer Usage
x. Last Year's Crop Yield

c. Decision Support

i. Market demand
ii. Predicted Crop Yield

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B. Mobile Application: The model operates as a mobile app, where farmers must first register through a registration process. Once registered, they gain access to the app's features.

Overall, the system is designed to support farmers by making data-driven predictions and recommendations, thus helping them analyze market demand regulate crop yield according to it and manage resources more effectively.

The Graphical User Interface (GUI) for the proposed model is developed using the Ionic Framework, along with JavaScript, AngularJS, and ReactJS. This setup enables the system to be built and deployed across multiple platforms, including iOS, Android, desktop, and the web, as a Progressive Web App all managed with a single code base.

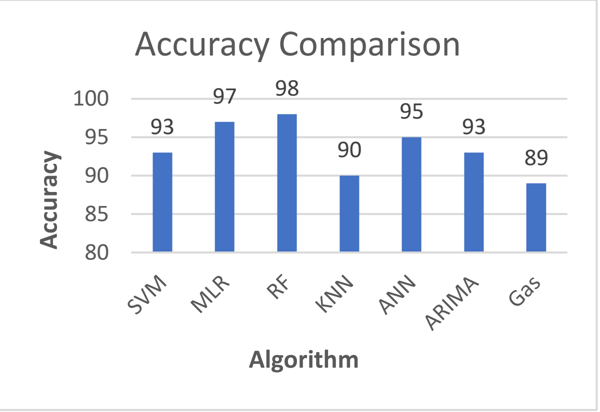
The necessary datasets and resources for the system are hosted on Firebase. A machine learning approach is applied for analyzing market demand and predicting crop yields, allowing the system to identify patterns and relationships within the data. The model is trained on historical data to leverage past trends for generating predictions. Various standard machine learning algorithms are tested for accuracy, with Random Forest regression and ARIMA showing the highest performance. This algorithm constructs multiple decision trees and combines them to generate stable and accurate predictions.

IV. RESULTS AND DISCUSSION

This section presents the outcomes derived from the application of selected algorithms to data from the Maharashtra region. The parameters utilized for the algorithms include factors such as market data such as sowed land data, retail data, import/export stats, consumer data and farmer-collected data like rainfall, weather impact, soil quality, fertilizer application, disease effects, crop rotation, plant variety variations, intercrops, and the yield from the past two years. The accuracy of market demand analysis and crop yield predictions generated by these algorithms are evaluated and compared. Among the algorithms tested, the Random Forest algorithm achieved the highest accuracy of 99% and the ARIMA algorithm achieved 93%. The following machine learning models were employed to predict crop yield: ANN, SVM, Multivariate Linear Regression, Random Forest, and KNN and ARIMA and Genetics Algorithms (GAs) for market demand analysis. Table 1 presents a summary of the accuracy comparisons across the different algorithms, while Figure 2 offers a graphical representation of these results.

Table 1: Accuracy VS Algorithm

Algorithm	Accuracy (%)
Support Vector Machine (SVM)	93
Multivariate Linear Regression (MLR)	97
Random Forest (RF)	98
K-Nearest Neighbor (KNN)	90
ANN	95
ARIMA	93
Genetics Algorithms (GAs)	89



[Fig.2: Accuracy VS Algorithm]

V. CONCLUSION

This study introduces an integrated machine learning-based system for crop yield prediction and market demand analysis aimed at supporting farmers in making data-driven decisions. Agriculture plays a crucial role in the economy, and accurate forecasting is vital for ensuring food security and optimizing production. The proposed system utilizes various inputs, including cropland area, season, soil quality, fertilizer usage, crop rotation, and historical yield data, along with real-time predictions of rainfall, weather impact, and disease effects, to offer reliable crop yield predictions.

For market demand analysis, the system uses data such as current market trends, sowed land under a crop, import/export statistics, retail data, and consumer data. The AutoRegressive Integrated Moving Average (ARIMA) model processes these data points to predict future market demand with 93% accuracy. This data-driven approach enables farmers to adjust their crop production to meet market needs effectively.

Among the algorithms tested, including K-Nearest Neighbors (KNN), Artificial Neural Networks (ANN), Multiple Linear Regression (MLR), and Support Vector Machines (SVM), the Regression Forest (RF) algorithm achieved the highest accuracy of 99% for crop yield prediction.

The decision support system, powered by the Regression Forest (RF) model for crop yield prediction and the ARIMA model for market demand analysis, recommends whether a farmer should sow a particular crop based on the predicted yield and forecasted market demand. By analyzing market demand and predicted yield, the system advises against sowing if the predicted yield exceeds market demand, preventing overproduction and ensuring profitability.

This integrated approach represents a significant step toward addressing key agricultural challenges such as fluctuating market demand and unpredictable environmental conditions. Future advancements may focus on incorporating additional external data sources, improving real-time prediction models, and extending the system to mobile platforms for broader accessibility. Ultimately, this system has the potential to significantly improve agricultural productivity and stability, providing valuable support to farmers in meeting both market needs and sustainability goals.

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DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

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- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
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