Intelligent Approach for Transforming Crop Recommendations with Machine Learning Excellence

Pritam Das*[1], Sumit Das[2]
[1,2]*JIS College of Engineering*
[1]*pritamdas.0510@gmail.com*, [2]*sumit.das@jiscollege.ac.in*

Abstract

A significant portion of India's population relies on agriculture as their primary livelihood, emphasizing the pivotal role crop production plays in the nation's economy. However, suboptimal crop yields often stem from either excessive or inadequate fertilizer usage. This article examines the efficacy of crop recommendation using seven distinct machine learning algorithms, leveraging diverse features such as soil composition and climate data to accurately forecast suitable crops for specific regions. With a dataset encompassing 2200 cases and eight parameters including temperature, humidity, rainfall, nitrogen (N), phosphorus (P), and potassium (K), eleven crops are analyzed: chickpea, kidney beans, pigeon peas, moth beans, mung beans, lentil, cotton, jute, coffee, pomegranate, apple, orange, papaya, and coconut. Notably, the Random Forest classifier emerged as the most effective among the models assessed, yielding an impressive accuracy of 99.31%. Through exhaustive evaluation of historical data and diverse model configurations, this study presents a novel approach to crop recommendation, poised to revolutionize agricultural practices. By enhancing crop yields, sustainability, and overall profitability, this system holds promise for farmers of all scales, promising to reshape the landscape of agricultural decision-making and yield optimization in India and beyond.

Keywords: *Crop recommendation, Machine Learning (ML), Decision Tree (DT), Naïve Bayes (NB), Random Forest (RF).*

1. Introduction

An important sector of the Indian economy and human life is agriculture. It is one of the fundamental jobs which is vital for human life. It likewise contributes a huge part to our day-to-day life Farmers typically commit suicide as a result of decreased productivity because they are unable to repay bank loans they have taken out for their operations. As a result of the ongoing climate change, which is bad for crops and pushing farmers into debt and suicide, we have observed that the current climate is changing. When different mathematical or statistical techniques are applied to data, these risks can be reduced. With the use of these techniques, we can advise farmers on the best crop to plant on their agricultural land, enabling them to receive the most yields possible.Precision agriculture focuses on determining these factors in a site-specific approach to identify concerns. While not every precision agriculture result is accurate, it is important to have precise and accurate recommendations in agriculture because mistakes can result in significant material and financial loss. Numerous studies are being conducted in an effort to develop a more precise and effective model for crop prediction.

Machine Learning focuses on algorithms like supervised, unsupervised, and Reinforcement learning and each of them has their advantages and limitations. The algorithm for supervised learning builds a mathematical model from a set of data that includes the inputs and the intended outputs. An unsupervised learning-the method develops a mathematical model from a set of data that contains only inputs and no desired output labels. Algorithms for semi-supervised learning extend mathematical models from insufficientUse Programming language used for model development, data preprocessing

The purpose of this paper is to suggest the best crop based on input parameters such as soil pH, humidity, temperature, rainfall, phosphorus (P), potassium (K), and nitrogen (N). This paper predicts the accuracy of the future production of eleven different crops such as rice, chickpea, kidney beans, pigeon peas, moth beans, lentil, pomegranate, banana, mango, grapes, watermelon, muskmelon, apple, orange, papaya, coconut, cotton, jute, and coffee crops using various supervised machine learning approaches in of India and recommends the most suitable crop. The dataset contains various parameters like Nitrogen (N), Phosphorous (P), Potassium (K), PH value of soil, Humidity, Temperature, and Rainfall. This proposed system applied different kinds of Machine Learning algorithms like Decision Trees, Naïve Bayes (NB), Support Vector Machine (SVM).

2. Literature Review

The paper explores the feasibility of a smart agriculture model that integrates IoT sensors, mobile applications, and cloud-based big data analytics. The model aims to improve agricultural practices by providing real-time data and insights to farmers. The authors discuss potential limitations, such as cost, compatibility with existing equipment, and digital literacy gaps. They also discuss the effectiveness of IoT sensors, mobile application functionality, and cloud-based big data analytics. The paper suggests case studies or pilot projects to test the model's effectiveness in real-world farming scenarios [1]. The study aims to explore the use of data mining in analyzing soil data to recommend optimal fertilizer application for improved crop yield. Traditional fertilizer recommendations often rely on generic guidelines without considering specific soil conditions. The research aims to identify the most effective data mining techniques, integrate them with existing agricultural practices, and explore the challenges and limitations of using data mining for fertilizer recommendations. It also explores the use of real-time sensor data and weather information to create dynamic fertilizer recommendations. The study also aims to develop user-friendly interfaces for farmers to easily access and utilize data mining-based fertilizer recommendations [2].

This research aims to examine the effectiveness of supervised machine learning techniques in predicting crop yield in agriculture. It will analyze existing research, identify successful applications, and discuss limitations. The study will also consider the specific dataset used for training the models, which may limit generalizability to other locations or crop types. The research will also explore the use of deep learning techniques, combining machine learning with other data sources, and developing models for specific regional contexts and crop varieties [3].This research investigates the effectiveness of machine learning (ML) algorithms in predicting crop yield. It aims to identify the most successful ML approaches and understand how they leverage various agricultural data sources. However, limitations exist such as data availability and quality, and the interpretability of complex ML models. The research will explore various ML algorithms, including regression, decision trees, and artificial neural networks, and investigate the impact of different data sources and feature engineering techniques on model performance. The goal is to develop interpretable models that can inform decision-making in agricultural practices [4]. The research aims to explore the use of machine learning techniques for analyzing weather data and recommending optimal crop selection for farmers, potentially improving agricultural productivity and decision-making under varying weather conditions. The study will focus on specific geographical locations or limited crop sets, and the accuracy of weather forecasts and machine learning algorithms could influence the effectiveness of these recommendations. The research will evaluate different algorithms, integrate historical crop yield data with weather forecasts, and develop a user-friendly interface for farmers [5].

This study evaluates the effectiveness of different data mining techniques in predicting crop yield, comparing their strengths and weaknesses. It aims to identify the most suitable method for accurate yield estimation, considering factors like data availability and quality. The study may focus on specific crops or regions, and explores the integration of data mining techniques with other approaches like crop modeling or remote sensing for enhanced prediction [6]. The research aims to predict crop yields in Tamilnadu, India, using K-means clustering and a modified K-Nearest Neighbor (KNN) approach. The study assesses the accuracy of this method for major crops in the region. However, the modified KNN may be specific to this study and may not consider all factors affecting yield. The study also explores the comparison of this approach to traditional methods, the most beneficial KNN modifications, and the impact of additional data sources like soil quality and pest infestation on prediction accuracy [7]. Develop a recommender system that utilizes weather forecasts to suggest optimal practices for improving crop production. The system's effectiveness depends on the accuracy of weather forecasts and the comprehensiveness of recommendations. How can weather forecasts be integrated into a recommender system for crop production? What kind of recommendations can be provided to improve crop yield based on weather data? How can the recommender system be adapted to different crops and regions? Explore combining weather data with other agricultural data (e.g., soil type, historical yield) to create more specific recommendations [8]. This research aims to investigate the effectiveness of machine learning algorithms in predicting crop yield and recommending suitable fertilizers for optimal growth. Existing studies might focus on specific crops or regions. This research might need more data for broader applicability. Can machine learning algorithms accurately predict crop yield based on historical data and environmental factors? What machine learning algorithms are most effective for crop yield prediction and fertilizer recommendation? The research will explore different machine learning algorithms and compare their performance in predicting crop yield and recommending fertilizers. It will also consider incorporating real-time sensor data for improved accuracy [9].

The research aims to create a machine learning-based crop recommendation system for the Ramtek region, considering soil conditions, climate patterns, and historical yield data. The system's accuracy may be limited and may not be applicable to other areas. The study will analyze historical agricultural data from the Ramtek region and develop a machine learning model for crop recommendation, evaluating its performance and potential impact on crop yield [10]. The research aims to create a precision agriculture crop recommendation system using machine learning to analyze farm-specific data like soil health and weather patterns. The system will require user-friendly interfaces for farmer adoption and will investigate machine learning algorithms for analyzing farm-specific data and generating personalized crop recommendations. The study will also consider user interface design and data management strategies for practical implementation [11]. The research aims to create a system that recommends crops to farmers based on factors like soil conditions, weather patterns, and historical yield data using machine learning regression techniques. The accuracy of these recommendations may depend on the quality and completeness of training data. The research also explores the effectiveness of different machine learning regression models in predicting crop yields and the integration of additional data sources like satellite imagery or sensor data [12].

The research aims to develop a machine learning system for predicting crop yields and detecting diseases using image recognition or sensor data. The accuracy of disease detection may depend on the quality and resolution of the image data. The study also explores the use of deep learning techniques for improved disease detection and yield prediction, and the development of a system that recommends disease treatment strategies based on identified illnesses [13]. The research aims to create a crop recommendation system that optimizes crop yield using machine learning techniques. The system will focus on a specific region or limited crops, but may not consider factors beyond crop selection, such as farming practices. The study explores the use of machine learning models, incorporating additional data points to improve yield prediction accuracy, and integrating data on farming practices, soil health, and market prices. The system will suggest adjustments to farming practices to further optimize yield based on the chosen crop [14]. Agro Consultant is a crop recommendation system using machine learning algorithms to suggest suitable crops based on environmental factors like soil properties, rainfall, and temperature. Traditional methods may not consider all relevant factors, and existing models may be opaque. The goal is to evaluate different machine learning algorithms for crop recommendation and develop techniques to explain the model's reasoning to farmers, improving user trust and accuracy [15].

This title suggests the research focuses on improving the accuracy of crop type detection, which could be a sub-task for a crop recommendation system. Current machine learning methods for crop-type detection might have limitations in accuracy. How can existing machine learning methods be improved for crop-type detection? Can a hybrid approach combining different techniques enhance accuracy? Investigate hybrid machine learning methods for crop-type detection. Evaluate the effectiveness of the proposed approach compared to traditional methods [16]. To implement machine learning algorithms for crop recommendation within a precision agriculture framework. Precision agriculture uses technology to optimize agricultural practices based on specific field conditions. The literature review might discuss limitations of existing crop recommendation systems, or limitations in integrating machine learning with precision agriculture practices. How can machine learning algorithms be effectively implemented for crop recommendations in a precision agriculture setting? Research to be Explored: Develop and evaluate a crop recommendation system that considers data from various precision agriculture technologies [17].

To analyze existing crop recommendation systems and identify the factors considered for crop selection, the methodologies used, and the potential benefits for farmers. This survey might focus on specific types of recommendation systems (e.g., machine learning-based) or a particular geographic region. What are the different types of crop recommendation systems available? What factors do these systems consider when recommending crops (e.g., soil characteristics, climate, and market demand)? How effective are these systems in improving crop yield and farmer income? The review could explore the integration of new technologies like remote sensing data or economic factors into recommendation systems [18]. To evaluate the effectiveness of collaborative filtering techniques in developing crop recommendation systems for the agriculture sector. The study might be limited to a specific dataset or collaboration platform. Can collaborative filtering approaches recommend suitable crops based on the experiences of other farmers in similar conditions? How does the accuracy of recommendations change with the size and diversity of the user base? How can these systems be adapted to address the privacy concerns of farmers? The review could explore hybrid recommendation systems that combine collaborative filtering with other techniques [19]. To assess the potential of ensemble learning methods for improving the accuracy and effectiveness of crop recommendation systems. The study might focus on a particular ensemble technique or a limited set of crops. Can ensemble learning techniques achieve higher accuracy in crop recommendations compared to single machine learning algorithms? How do different ensemble configurations (e.g., weighting schemes) impact the performance of the system? The review could explore the application of ensemble techniques to other agricultural tasks like disease prediction or fertilizer recommendation [20].

3. Methodology

Developing a complete machine learning-based system for agricultural crop suggestion is the main goal of this effort. Three datasets, the disease detection dataset, the crop recommendation dataset, were obtained in order to achieve this.

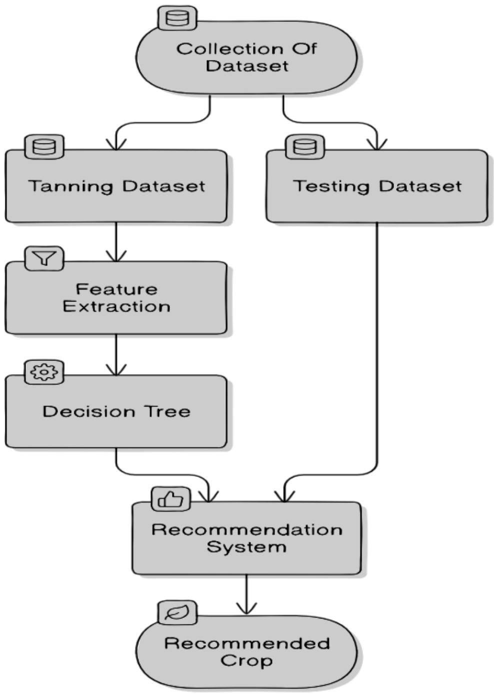

Fig.1 Block Diagram of Overall Methodology of Proposed System

As shown in Figure 1, we have outlined a process in our framework that is divided into multiple steps.In the first stage, datasets are collected. Then, relevant features are extracted from this data. Next, diverse machine learning algorithms are employed to analyze the data. This analysis leads to the development of a recommendation system, which ultimately suggests the most suitable crop for a particular situation.

Crop Recommendation dataset that we acquired from Kaggle[21], dataset has 2200 cases with 8 columns containing various parameters like temperature, humidity, rainfall, nitrogen (N), phosphorus (P), and potassium (K). The eleven crops that are discussed are the following: chickpea, kidney beans, pigeon peas, moth beans, mung beans, and lentil; also, cotton, jute, coffee, pomegranate, apple, orange, papaya, and coconut.

3.1. Decision Tree:

Using greedy technique, decision tree classifiers are employed. A tree is used to represent the attributes and class labels in this supervised learning approach. The major goal of employing decision trees is to create a training prototype that, by learning decision rules inferred from prior data (training data), allows us to predict the class or value of target variables. Decision nodes and leaves are the two different types that make up a decision tree. The outcomes, or the ultimate results, are the leaves. Every node in the tree is a test case for a particular property, and every edge that descends from that node represents a potential response to the test case. This process is recursive in nature and is repeated for every sub-tree rooted at the new nodes The accuracy of the Decision Tree Crop dataset is shown in Figure 2.

```
In [70]:
from sklearn.tree import DecisionTreeClassifier
ds = DecisionTreeClassifier()
ds.fit(X_train,y_train)
ypred = ds.predict(X_test)
accuracy_score(y_test,ypred)
Out[70]: 0.9863636363636363
```

Fig.2 Accuracy of Decision Tree

3.2. Naive Bayes:

An algorithm for calculating orders in binary and multi-class arrangements is called Naive Bayes. The Naive Bayes approach is incredibly simple when binary or categorical input esteems are provided. A Naive Bayes classifier acknowledges that the existence of one element in a class does not necessarily imply the presence of another. The Naive Bayes classifier is based on the Bayes theory, and it is a useful approach when the dimensionality of the data sources is high. Naive Bayes has a variety of uses, such as real-time prediction, predicting the likelihood of many classes of the target attribute, spam filtering, and recommendation system development when combined with collaborative filtering. The first step is to calculate the class probability, or probability for each attribute in the dataset. Given each class value, the conditional probability provides the conditional probability of each information value. Figure 3 represents the accuracy of Naive Bayes Crop dataset.

```
In [69]:
from sklearn.naive_bayes import GaussianNB
nb = GaussianNB()
nb.fit(X_train,y_train)
ypred = nb.predict(X_test)
accuracy_score(y_test,ypred)
Out[69]: 0.9850818181818182
```

Fig.3 Accuracy of Naive Bayes

3.3. Random Forest:

ML algorithms include Random Forest. During training, a large number of decision trees are created, and the output is split into two categories: number of classes, or classification, and prediction of class, or regression. The relationship between prediction accuracy and tree count is linear. Rainfall, perception, temperature, and production are among the variables included in the dataset. The training process makes advantage of these dataset variables. The remaining dataset serves as an experimental foundation. Three parameters make up the random forest algorithm: m try indicates the number of variables that must be taken into account at a node split; n tree indicates the n number of trees that must grow. Node size: At the terminal nodes, it indicates how many observations we should make. The accuracy of the Random Forest Crop dataset is shown in Figure 4.

```
In [28]:
from sklearn.ensemble import RandomForestClassifier
rfc = RandomForestClassifier()
rfc.fit(X_train,y_train)
ypred = rfc.predict(X_test)
accuracy_score(y_test,ypred)
Out[28]: 0.9931818181818182
```

Fig.4 Accuracy of Random Forest

4. Result and Discussion

With the aim of revolutionizing agricultural operations, our work uses machine learning techniques to enhance crop forecast. Our three essential datasets—a custom-built Crop Recommendation dataset that we acquired from Kaggle [21] have been gathered in order to do this. Since they provide the necessary data for evaluating and improving our machine learning models, these datasets serve as the cornerstone of our work.

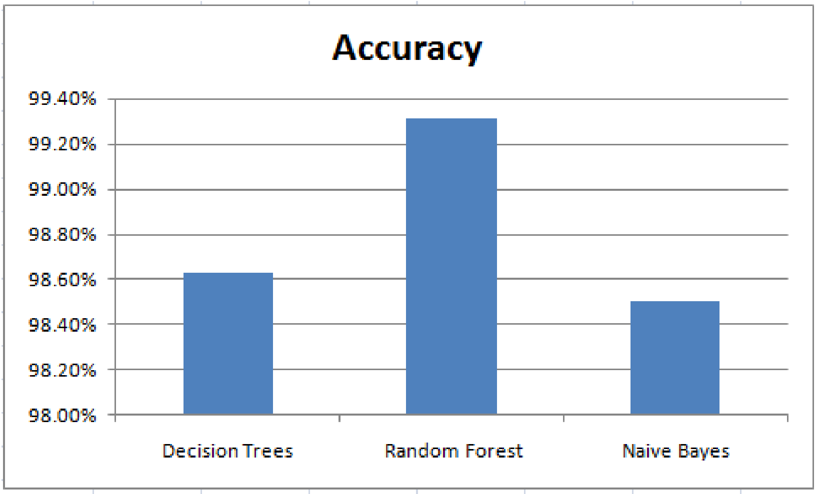

Fig.5 Accuracy Comparison among Decision Trees, Naive Bayes, and Random Forest

```
In [76]:
N = 40
P = 22
k = 33
temperature = 22.0
humidity = 40
ph = 52
rainfall = 100

predict = recommendation(N,P,k,temperature,humidity,ph,rainfall)


crop_dict = {1: "Rice", 2: "Maize", 3: "Jute", 4: "Cotton", 5: "Coconut", 6: "Papaya", 7: "Orange",
                 8: "Apple", 9: "Muskmelon", 10: "Watermelon", 11: "Grapes", 12: "Mango", 13: "Banana",
                 14: "Pomegranate", 15: "Lentil", 16: "Blackgram", 17: "Mungbean", 18: "Mothbeans",
                 19: "Pigeonpeas", 20: "Kidneybeans", 21: "Chickpea", 22: "Coffee"}

if predict[0] in crop_dict:
    crop = crop_dict[predict[0]]
    print("{} is a best crop to be cultivated ".format(crop))
else:
    print("Sorry are not able to recommend a proper crop for this environment")

Papaya is a best crop to be cultivated
```

Fig 6: Crop recommendation

Table 1: Accuracy Comparison

Algorithm	**Proposed work**	article **1[22]**	article **2 [23]**	article **3 [24]**
Decision Tree	**98.63%**	**87.4%**		
Naïve Bayes	**98.50%**		**92.1%**	
Random Forest	**99.31%**			**93.7%**

Significant improvements in accuracy were observed across all three algorithms compared to the findings reported in the relevant literature papers. An accuracy of 98.63% was achieved by the Decision Tree, surpassing the 87.4% reported in article 1, while Naive Bayes achieved 98.50%, an improvement over the 92.1% reported in article

2. Notably, the Random Forest algorithm attained the highest accuracy at 99.31%, exceeding the 93.7% reported in article 3. These findings suggest that the project's data and implementation may favor these algorithms. Information regarding the machine learning research with an agricultural focus can be disseminated through the website, aiming to showcase how technology, particularly machine learning, can be applied to address agricultural challenges such as disease detection, crop forecasting, and fertilizer recommendations. The webpage is intended to provide insights into the study's techniques, objectives, and potential outcomes for stakeholders including farmers, researchers, policymakers, and technology enthusiasts. Innovation and collaboration in the agricultural technology sector are sought to be fostered by sharing knowledge on emerging technologies and the research and development process. It is believed that technology possesses the potential to revolutionize agriculture and enhance the livelihoods of millions of farmers globally. Through the utilization of machine learning and data-driven insights, farmers can be equipped with relevant information to support decision-making and improve agricultural operations. The initiative aims to bridge the gap between conventional farming practices and state-of-the-art technologies in order to enhance agricultural productivity, sustainability, and resilience.

5. Conclusion

The research has successfully demonstrated the effectiveness of machine learning algorithms, particularly Random Forest, in recommending suitable crops based on various environmental factors. The intelligent crop recommendation system holds great promise for Indian farmers, offering a practical solution to optimize crop selection and enhance agricultural productivity. By leveraging advanced technologies, such as machine learning, farmers can make informed decisions leading to improved yields and national profitability.

Moving forward, there are several avenues for further development and enhancement of the crop recommendation system. Expanding the dataset to include a broader range of attributes will refine the accuracy and scope of recommendations. Additionally, efforts should focus on developing a model capable of accurately diagnosing crop diseases and predicting their presence. Integration of real-time weather data will enhance the system's responsiveness to changing environmental conditions, while incorporating market prices and profitability analysis will empower farmers to make economically viable decisions. Furthermore, ongoing refinement through user feedback and data collection will ensure the continual improvement and optimization of the recommendation system, ultimately advancing agricultural practices and sustainability in India.

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