A Machine Learning Based Model For Predicting The Crop To Harvest

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Abstract— **Agribusiness is an important component of the Indian economy, but it is facing challenges due to a variety of factors such as soil erosion, climate change, and inefficient resource use. Farmers can overcome these obstacles by leveraging cutting-edge technologies like machine learning (ML) and the Internet of Things (IoT). This paper proposes a system that employs machine learning to predict which plant to harvest based on variables such as NPK soil nutrients, pressure, temperature, wind speed, area, production, yield, crop year, season names and soil type. Data is collected from the state of Maharashtra, and the system uses this information to recommend crops for specific soil types and environmental conditions. Farmers can use the system to make informed decisions about resource allocation and planting techniques by receiving accurate crop growth data. Several algorithms are used in this case, including Decision Tree, Random Forest, KNN, naive bayes, and XG Boost techniques. The accuracy, precision, recall, and AUC score of the classifier will be used to evaluate its performance. Based on the above-mentioned criteria XG Boost is better performing with an accuracy score of 70% and AUC of 0.95. Also, a website will be created where users may enter their information and choose the optimal crop for harvesting.**

Keywords:- Machine Learning, Internet of Things, Decision Tree, Random Forest, KNN, Navies Bayes, XG Boost.

I. INTRODUCTION

More than half of the population of India works in agriculture, which also makes up a considerable portion of the GDP of the country, making it a crucial sector for the Indian economy. However, the industry has a few difficulties, including poor productivity, limited infrastructure, knowledge and resource gaps, and climate change. The Internet of Things (IoT) and machine learning [8] have emerged as potent technologies that have the potential to revolutionize India's agricultural industry by giving farmers access to real-time data and insights that will enable them to make better decisions and increase crop yields. In this study, we will investigate how machine learning and IoT are used in Indian agriculture and examine their advantages and drawbacks. Statistics on agriculture in India.

India is one of the world's top producers of agricultural goods, and the sector accounts for over 17% of its GDP. Despite this, the industry has several difficulties, including low production, restricted access to capital and markets, and climate change. The average production of the main crops in India is substantially lower than the average yield worldwide, according to the Ministry of Agriculture and Farmers Welfare. For instance, India produces 2.7 tons of rice per hectare of land on average, compared to 4.3 tons worldwide.

Over 60% of the people in the agricultural nation of India relies on agriculture as their main source of income despite the effects of the Covid-19 outbreak, the Economic Survey of India 2021 predicts that the agriculture sector would increase at a pace of 3.4% in 2020–21.

By enabling farmers to recognise nutrient deficits and modify their fertiliser applications appropriately, precision agriculture can also aid in addressing the problem of deteriorating soil fertility. Additionally, it can aid farmers in more efficient pest and disease detection and management, lowering the need for hazardous pesticides and enhancing agriculture's environmental sustainability. Precision agriculture has great promise, and the Indian government has started a number of measures to encourage its use.

By giving farmers access to real-time information on soil moisture, weather patterns, and crop health, machine learning and the internet of things have the potential to completely change the Indian agriculture industry. Utilizing this information will improve crop productivity and boost profitability. Sensors can track soil moisture levels, for instance, and provide farmers real-time information on whether to water their crops. Following this data analysis, machine learning algorithms can offer ideas on how to optimize irrigation schedules to increase agricultural yields. Utilizing technology in farming, precision agriculture maximizes [8] crop yield while minimizing waste. To track crop health, soil moisture, and weather patterns, sensors, and machine learning algorithms are used. The application of fertilizer and pesticides is then optimized using this data, which also helps to save water and increase crop yields. For smallholder farmers in India who frequently lack access to the most recent farming technologies and encounter substantial difficulties in producing high crop yields, precision agriculture might be very helpful. Farmers may enhance their livelihoods, boost output, and save expenses by utilizing precision agricultural technology.

II. LITERATURE SURVEY

Plenty research had gone to find the problem in Indian agriculture and many more research are going along with the time to predict the solution for the issue.

The technique for determining which crop is most suited for harvesting is suggested in the study [1]. They utilized many algorithms, including Decision tree, Random Forest, KNN, and neural network, on the Indian Agricultural and Climate Data set in order to obtain the highest level of accuracy.

Using data acquired from the Madurai area, the Crop Suggestions System for Precision Agriculture [2] was created to assist farmers in planting the proper seed according to soil conditions. The main goal is to find a solution for the classifier selection issue in ensemble learning and to have the greatest accuracy possible.

The authors of [3] have suggested a model that uses data from the Government of India's repository website, data.govt.in. The dataset primarily includes the 4 crops, totalling 9000 samples, of which 6750 are utilized for training and the remaining 2250 for testing. Following pre-processing, ensemble-based learners such as Random Forest, Navies Bayes, and Linear SVM are utilized, and the majority voting technique is used to get the greatest accuracy.

By utilizing multiple machine learning algorithms, this research primarily focuses [4] on estimating the crop's production. Logistic Regression, Naive Bayes, and Random Forest are the classifier models employed in this instance, with Random Forest offering the highest level of accuracy. By considering variables like temperature, rainfall, area, etc., the forecast provided by machine learning algorithms will assist farmers in choosing which crop to cultivate to induce the greatest yield.

Sandhya Tara and Sonal Agrawal, the authors of this research [5] present a framework that uses machine learning and deep learning techniques to suggest the best crop based on soil and climate parameters. Area, Relative Humidity, PH, Temperature, and Rainfall are the predictive variables in the dataset. once the dataset has been pre-processed. The information is then divided into a training set and a test set. The response is then depicted graphically for each of the parameters, including fertilizer use, pesticide use, area, UV exposure, and water, using the above-mentioned algorithms, and the yield is forecasted using the data for these parameters. Thus, with little loss and a high yield, the results can assist farmers in growing suitable crops.

The authors of [6] proposed a model that uses previous farmland data as the data set. It consists of various attributes such as county name, state, humidity, temperature, NDVI, wind speed, and yield. The model is trained to identify the soil requirements necessary for yield prediction. Algorithms applied to the dataset are random forest, decision tree, and polynomial regression. Among all three algorithms, Random Forest provides better yield prediction compared to other algorithms.

In the paper [7], the factors used by the proposed system include soil pH, temperature, humidity, rainfall, nitrogen, potassium, and phosphorus. Various crops are also included in the dataset. after utilizing the dataset to train and test the model. A variety of algorithms, including Decision Tree, Random Forest, XGBOOST, Naive Bayes, and LR, are used to forecast a specific crop under specific environmental conditions and parameter values that aid in growing the best crop. Thus, evaluating the accuracy of algorithms and selecting the greatest accuracy will assist farmers in selecting the appropriate seed and aid in boosting agricultural yield.

Authors of [8] implemented precision farming, where a variety of internet of things (IOT) sensors and devices are used to collect data on environmental conditions for farming, the amount of fertilizer to be used, the amount of water needed, and the levels of soil nutrients. Through wired or wireless connectivity, the data gathered by the numerous IOT sensors at the end node is then saved in the cloud or on remote servers. Afterward, relevant meanings and interpretations are inferred from the data using a variety of data analytic techniques, which are then applied to the data to make precise and correct decisions. Then, several algorithms are used to select crops, and the data analysed can be used to understand agricultural conditions and whether they are favourable as well as forecast crop yields with the highest yield.

In [9] The right crop is advised using the proposed approach based on details like soil PH, temperature, humidity, rainfall, nitrogen, potassium, and phosphorus. The historical data with the above-mentioned parameters are included in the dataset. To eliminate outliers and missing values, the gathered data is pre-processed. The model is subsequently tested and trained. The method utilizes a variety of machine learning classifiers, including Deep Sequential Model, KNN, XGB, Decision Tree, and Random Forest, to select a crop accurately and effectively for site-specific factors. Farmers will be assisted in growing appropriate crops with the highest yield thanks to this research report.

This suggested approach in [10] produced a crop recommendation system for smart farming. This study report analysed several machine learning methods, including CHAID, KNN, K-means, decision trees, neural networks, naive bayes, C4.5, LAD, IBK, and SVM algorithms. The complex computations in this study were performed using the Hadoop framework, which improved the system's precision.

[11] The study examines the value of climatic and meteorological elements in influencing agricultural choices and proposes a district-by-district forecasting model for the Tamil Nadu state. To raise the quality of incoming data, the paper suggests employing pre-processing and clustering techniques. Furthermore, it recommends employing artificial neural networks (ANN) to predict agricultural productivity and daily precipitation using meteorological data. In order to improve the system's success rate, the study article suggests a hybrid recommender system that makes use of Case-Based Reasoning (CBR). The effectiveness of the proposed hybrid technique is evaluated against conventional collaborative filtering.

III. PROPOSED WORK

3.1 Data Description

The dataset was collected from website of Smart AI Technologies. Which consists 18 years of crop data (i.e,1997–2014) for 35 various districts of Maharashtra State, Crop data includes Season Names,CropNames,Area,Temperature,Wind_Speed ,Pressure,Humidity,Soil_Type,NPK_Nutrients, Production, Yield. a small snippet of data was shown below [fig 1.] where, Area is measured in hectares, Crop production is measured in tonnes per hectare and Crop Yield is measured in crop production weight (in kg) per area of land harvested or area of land planted (in hectares). This dataset is previously performed for Crop yield Prediction, But We are Performing for a Crop Recommendation using Machine Learning.

1		state_nam	district_na	crop_year	season_na	crop_nam	area	temperatu	wind_spe	pressure	humidity	soil_type	N	P	K	productio	Yield
2	125191	Maharash	AHMEDNA	1997	Autumn	Maize	1	20.77089	2.06826	1014.864	21.94715	loamy	56.07	0	0	1113	1113
3	125192	Maharash	AHMEDNA	1997	Kharif	Arhar/Tur	17600	20.16043	1.97648	1015.194	20.64324	sandy	9	9	0	6300	0.357955
4	125193	Maharash	AHMEDNA	1997	Kharif	Bajra	274100	21.9983	2.000524	1014.185	21.42231	clay	0	0	0	152800	0.557461
5	125194	Maharash	AHMEDNA	1997	Kharif	Gram	40800	21.77638	2.01975	1015.053	21.81057	chalky	38.25	38.25	38.25	18600	0.455882
6	125195	Maharash	AHMEDNA	1997	Kharif	Jowar	900	20.07573	1.974351	1015.17	21.93021	clay	0	23.184	0	1100	1.222222
7	125196	Maharash	AHMEDNA	1997	Kharif	Maize	4400	21.64235	2.075066	1015.702	21.5714	sandy	5.64	14.664	14.664	4700	1.068182
8	125197	Maharash	AHMEDNA	1997	Kharif	Moong(Gr	10200	21.19966	2.079552	1013.866	20.83372	peaty	41.7	111.2	55.6	900	0.088235
9	125198	Maharash	AHMEDNA	1997	Kharif	Pulses tota	451	21.36685	2.078574	1013.051	20.08436	silty	7.476	7.476	0	130	0.288248
10	125199	Maharash	AHMEDNA	1997	Kharif	Ragi	2600	21.87754	2.054199	1014.983	21.64336	silty	2.1	5.25	2.1	2100	0.807692

Fig 1. Small snippet of data.

3.2 Data Pre-Processing

Before Performing a model building for any data, It’s an Essential Step to perform a Data Pre Processing step, Where raw data is cleaned and transformed to provide a quality data for further Analysis,In this csv dataset we had a total 17 Attributes Column values on which 12 attributes are Numerical Column values and rest 5 are Categorical Column attributes, by following this 17 Attribute Columns, the dataset contains 12,628 records of crop data.

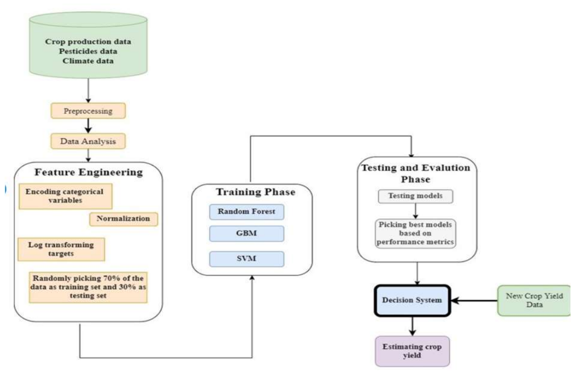

Fig 2. Workflow diagram

3.3 EDA

EDA plays a Crucial role in Model Building, which is one of the major task in data science life cycle. After doing Analysis for this csv dataset, we found out couple of major Aspects which makes sense and shape to a dataset, to build the models efficiently and effectively.

As mentioned before, this dataset had been used to predict the crop yield, where we noticed a **High Spike,** which was shown in below [Fig 3]. Yield Values, In Initial 3-4 years, later the yield was Stabilized. So, we were Considering the data from the year 2000, By this we can get rid off high Variance and low bias which may cause of Overfitting of data which leads to wrong predictions of the model.

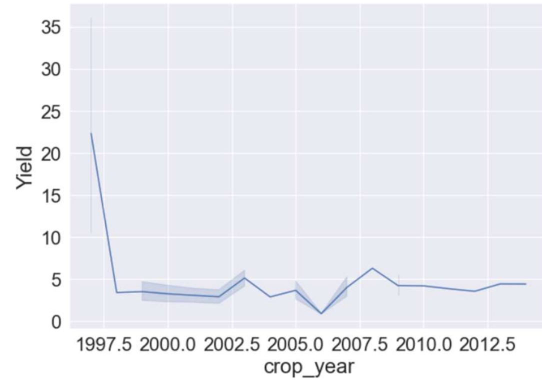

Fig 3. Yield distribution across the years

Secondly, as we were doing a Crop Recommendation model, we know that crop names are the label/Target Column. where we noticed the high **Data Imbalance** among the crop names. Again, this may cause to the high bias towards crops which having higher number of crops. So that We were choose a best 8 crops where crops having less imbalance between them same was shown in the below [fig 4].by this, we can make our model to predict Effectively.

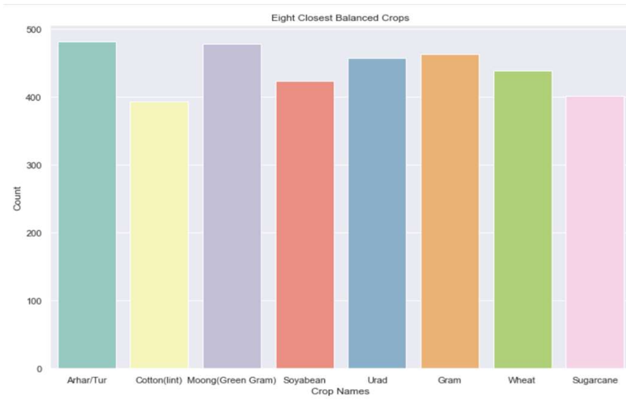

Fig 4. distribution of crops

3.4 Feature Engineering

Sometimes, it is very difficult to make conclusions and draw methods from the raw data where Feature Engineering comes into the picture and makes easier to draw methods. In this data also we had Categorical Columns to draw Conclusions from this Categorical Values. We had been used Feature Engineering Techniques such as One-hot Encoding, Label Encoding. So that machine can understand the data properly and provide useful insights to draw conclusions.

3.5 Algorithms

3.5.1 Decision Tree:

This algorithm can be used in a crop recommendation machine learning project to provide farmers with valuable insights and recommendations. To make informed predictions about the best crop choice, the algorithm can learn from historical data such as previous crop yields and agricultural practices. Decision tree [7] models can also take multiple decision paths into account, allowing for complex decision-making based on a variety of factors. The interpretability of decision trees makes them especially useful in explaining the reasoning behind crop recommendations, which can help farmers make decisions. Furthermore, decision tree models can be easily updated with new data, allowing for continuous crop recommendation system refinement and improvement. Overall, the decision tree algorithm can be a useful tool in crop recommendation projects by providing data-driven insights to optimize agricultural practices and increase crop yields.

3.5.2 Random Forest:

Because it can handle complex datasets and produce precise predictions, the Random Forest algorithm can be very helpful in a project recommending crops. Random Forest can identify a variety of patterns and connections between various factors, including soil characteristics, climatic conditions, and crop attributes, by using a number of decision trees. With the help of this ensemble method, recommendations can be generated that are strong and trustworthy despite noise and overfitting. Additionally, Random Forest [1] provides feature importance rankings that can be used to pinpoint the crop selection variables that have the greatest influence. Additionally, Random Forest is effective at processing large amounts of data in parallel, allowing for real-time recommendations. Overall, Random Forest can improve crop recommendations' precision and interpretability, helping farmers make wise decisions and maximizing their crop selection tactics.

3.5.3 Navies Bayes:

Because of its ease of use, effectiveness, and capacity for both categorical and discrete data, the Naive Bayes algorithm can be helpful in a crop recommendation project. The conditional probability that a crop will be suitable for a given set of features, such as soil type, weather conditions, and crop attributes, is determined by the probabilistic classifier Naive Bayes [3]. Given that it only needs a small amount of training data to produce predictions, it is especially well suited for projects with little available data. Naive Bayes is quick and effective for real-time recommendations because it has low computational requirements. Additionally, Naive Bayes offers results that are easy to interpret, enabling farmers to comprehend the rationale behind the suggestions. Overall, Naive Bayes can be a useful tool in crop recommendation projects because it provides precise and comprehensible predictions for the best crop choice.

3.5.4 XGBoost:

Due to its ability to handle complex and non-linear data relationships, XGBoost, an advanced gradient boosting algorithm, can be extremely useful in a crop recommendation project. XGBoost [7] is well-known for its high accuracy and predictive power, which makes it ideal for making precise crop recommendations based on a variety of factors such as soil quality, weather conditions, historical crop data, and more. It can handle large datasets efficiently and automatically handle missing data, making it suitable for real-world agricultural scenarios. XGBoost also provides feature importance rankings, which help farmers understand which features influence crop recommendations. XGBoost also supports parallel processing, making it suitable for large-scale crop recommendation applications. Overall, XGBoost has the potential to be a powerful tool for crop recommendation projects, providing accurate predictions as well as valuable insights for optimal crop selection.

3.5.5 KNN:

K-nearest neighbours (KNN) algorithm can be useful in a crop recommendation project due to its simplicity and ability to handle both numerical and categorical data. KNN [9] is a lazy learner, which means it does not need to be trained and can be used to make real-time recommendations. Based on the similarity of neighbouring data points, KNN can make crop recommendations based on historical data on crop performance, soil quality, weather conditions, and other relevant factors. It can also adapt to changing environmental conditions, making it ideal for fast-paced agricultural settings. KNN is interpretable, allowing farmers to comprehend the reasoning behind the recommendations. It is simple to implement and has a low computational overhead, making it appropriate for resource-constrained environments. KNN, on the other hand, may necessitate the careful tuning of hyperparameters such as the number of neighbours (K) and the distance metric. Overall, KNN has the potential to be a useful and interpretable method for crop recommendation projects, providing real-time recommendations based on data point local similarity.

3.6 Metrics

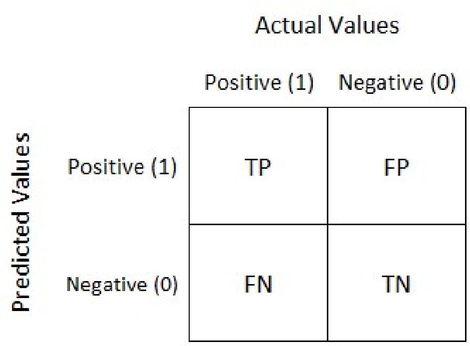

Fig 5. Confusion matrix

AUC (Area Under the ROC Curve [Fig 6]), precision, recall, accuracy score and recall are often used measures to assess the effectiveness of a machine learning model, including a crop recommendation model. These measures may be used to evaluate how effectively the model can forecast the suitable crops to grow in a certain area.

Accuracy Score [Equation 1] is defined as the total number of correct predictions out of the total predictions made from the testing data. Given below is the formula of accuracy score formula in terms of confusion matrix [Fig 5].

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

Equation 1: Accuracy

Precision [Equation 2] is defined as the ratio of true positives, or the number of crops that were accurately forecast, to all the anticipated crops. A high accuracy rating means the model can correctly determine the best crops to produce in a certain area.

$$\text{Precision} = \frac{True\ Positive}{True\ Positive + False\ Positive} = \frac{True\ Positive}{Total\ Predicted\ Positive}$$

Equation 2: Precision

Recall [Equation 3] quantifies the ratio of actual crops that should have been advised to the overall number of true positives. A high recall score means that the model can accurately identify a significant fraction of the crops that should be grown in a specific area.

$$Recall = \frac{True\ Positive(TP)}{True\ Positive(TP) + False\ Negative(FN)}$$

Equation 3: Recall

AUC indicates how well the model performs overall at differentiating between the right crops and the wrong ones. A high AUC value demonstrates that the model can confidently and reliably forecast the suitable crops.

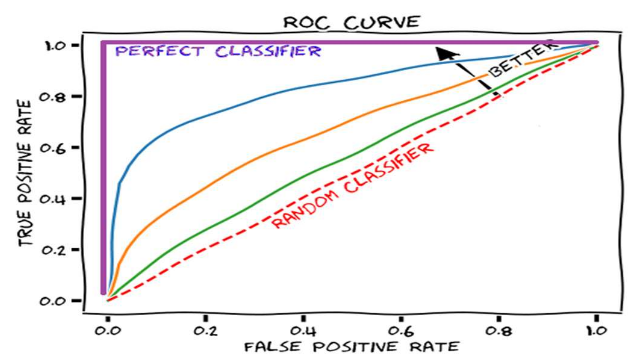

Fig 6. ROC curve

The accuracy, recall, and AUC scores of a successful crop recommendation model should be high. While minimizing the number of false positives (crops that are projected to be acceptable but are not suited for that site), the model should be able to correctly identify the right crops to grow in a certain place. The model should also be highly confident in its ability to discriminate between the proper crops and the incorrect ones. It is crucial to assess a crop recommendation model's performance using these measures on a sample dataset before recommending it. If the model does well on the assessment dataset, it may be a feasible alternative for advising suitable crops in a specific area.

IV RESULTS AND DISCUSSIONS

The above-mentioned metrics, such as accuracy score, precision, recall, and area under the curve, help determine which model to use. These metrics are frequently used to assess the effectiveness of machine learning algorithms. In the table mentioned below, XG Boost is the best-performing algorithm, with an accuracy of 70%, precision of 0.71, recall of 0.70, and AUC of 0.95. These results show that XG Boost can accurately predict the outcomes of the task at hand, making it a dependable choice for the project. Furthermore, the model's high AUC value of 0.95 indicates that it has excellent discriminatory power in distinguishing between positive and negative outcomes. Overall, XG Boost outperforms other algorithms, making it a promising candidate for further use in the project.

An attempt was made to improve accuracy by selecting more important features from the XG Boost classifier and training the model with a smaller feature set than the previous model. The resulting metrics, however, did not show a significant difference in performance as shown in [Table 2]. After careful consideration, it was decided to build the webpage for this project using the initial model, which had been trained with the entire feature set. This decision was made because the initial model, despite having more features, performed similarly to the reduced feature set model, and thus provides a more comprehensive and reliable prediction for the task at hand as seen from [Table 1].

	feature_names	importance
0	Yield	1492.0
1	area	1405.0
2	wind_speed	1129.0
3	temperature	1099.0
4	humidity	1070.0
5	pressure	1066.0
6	production	927.0
7	crop_year	875.0
8	N	654.0
9	P	581.0
10	season_names	247.0
11	K	207.0
12	district_names_OSMANABAD	79.0
13	soil_type_clay	77.0
14	district_names_CHANDRAPUR	74.0
15	district_names_AMRAVATI	67.0
16	district_names_GONDIA	66.0
17	district_names_BHANDARA	63.0
18	district_names_GADCHIROLI	58.0
19	soil_type_peaty	58.0
20	district_names_JALGAON	57.0
21	soil_type_silt	57.0
22	district_names_NASHIK	54.0
23	district_names_AHMEDNAGAR	51.0
24	district_names_WASHIM	50.0
25	soil_type_chalky	50.0
26	district_names_KOLHAPUR	50.0
27	soil_type_sandy	49.0
28	district_names_LATUR	48.0
29	soil_type_loamy	48.0
30	district_names_NANDURBAR	46.0
31	district_names_NAGPUR	45.0
32	district_names_BEED	45.0
33	soil_type_silty	44.0
34	district_names_YAVATMAL	43.0
35	district_names_SANGLI	40.0
36	district_names_SATARA	40.0
37	district_names_AURANGABAD	38.0
38	district_names_DHULE	32.0
39	district_names_RAIGAD	32.0
40	district_names_PARBHANI	31.0
41	district_names_SOLAPUR	30.0
42	district_names_BULDHANA	29.0
43	district_names_PUNE	29.0
44	district_names_RATNAGIRI	29.0
45	district_names_JALNA	26.0
46	district_names_WARDHA	25.0
47	district_names_HINGOLI	24.0
48	district_names_THANE	23.0
49	district_names_AKOLA	23.0
50	district_names_NANDED	22.0
51	district_names_SINDHUDURG	5.0

Fig 7. feature importance from XGBoost classifier

Table 1: Model performance table before feature reduction.

Algorithm	Accuracy	Precision	Recall	AUC
Decision Tree	0.62	0.63	0.62	0.81
Random Forest	0.66	0.67	0.66	0.93
XG Boost	0.70	0.71	0.70	0.95
KNN	0.47	0.49	0.47	0.84
Naïve Bayes	0.33	0.40	0.33	0.71

Table 2: Model performance table after feature reduction

Algorithm	Accuracy	Precision	Recall	AUC
Decision Tree	0.60	0.61	0.60	0.78
Random Forest	0.61	0.63	0.61	0.92
XG Boost	0.67	0.68	0.67	0.94
KNN	0.47	0.49	0.47	0.84
Naïve Bayes	0.33	0.40	0.33	0.71

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V FUTURE WORK

Our future work in this project involves improving the model accuracy by Analysing the in-depth correlations and patterns by performing EDA and Feature Engineering Techniques, and also addressing data inconsistencies, which may help to enhance the model's ability to capture patterns and make accurate crop recommendations. We will also focus on removing any inconsistencies or errors in the data to ensure the model's reliability. Additionally, we plan to develop a user-friendly webpage that farmers can easily access to input their data and receive crop recommendations based on the trained model. This webpage will be designed with usability in mind, making it accessible and convenient for farmers to use in their day-to-day operations. Our goal is to provide a practical and effective tool for farmers to make informed decisions about crop selection, ultimately leading to improved agricultural practices and increased crop yields.

VI CONCLUSION

Finally, our crop recommendation project has demonstrated the effectiveness of using machine learning algorithms to provide crop selection recommendations to farmers. We discovered that the XGBoost algorithm performs better with an accuracy of 70% and an AUC of 0.95 after implementing and evaluating various algorithms such as Decision Trees, Random Forest, Naive Bayes, XGBoost, and KNN. Although the results are encouraging, there is still room for improvement. Additionally, domain-specific knowledge and expert opinions can be used to fine-tune the model for specific regions or crop types. Furthermore, creating a user-friendly webpage for crop recommendations that farmers can easily access and use would be a valuable addition to the project. This website could be a useful tool for farmers to make informed crop selection decisions, thereby improving agricultural practices and crop yields. To summarize, our crop recommendation project has laid the groundwork for the use of machine learning in agriculture and has the potential to have a significant impact on the farming community. The findings and future work outlined above serve as a road map for additional research and development in this field, with the goal of providing farmers with reliable and effective crop recommendation solutions.

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