Application of Machine Learning to Enhance Crop Production

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Abstract - *Agriculture is the main source of earning for various farmers. Their earning largely depends on the crop yield and the amount paid for their crops. In India, the crop yield is not up to the expectation. This happens due to low soil fertility, not growing desired crops according to the need of the soil, exhaustive over use of fertilizer. This low crop yield adversely affects the famers living condition. The low crop yield is the major reason for the plight of the farmers. The present work focuses on recommendation of suitable crops to be sown in the particular field or soil and also endorsing the farmer in sprinkling desired amount of fertilizer in the soil for the particular crop so that the farmer can make significant profit. Our work focuses on recommending four to five crops which are suitable for growing in particular type of field or soil either corresponding to the N, P, K, pH values entered by the farmer or district wise suitable crops. This system uses different parameters such as pH, N, P, K values to predict the suitable crops. Our work also facilitates endorsing farmer in sprinkling the required amount of fertilizer in their field for the particular crop by using the N, P, K values. The proposed system will give suggestion to the farmer to meet up the required deficient nutrient and minerals in the soil. This paper also contains about the various algorithms and their accuracy for recommending crops. Our work uses the Naïve Bayes Algorithm for recommending the suitable crops to the farmers. We have used this algorithm as it is highly efficient, easy to implement and works for high dimensional data. This algorithm is highly accurate in high dimensional space and data. The accuracy along with algorithm is well represented in a table. Our present work aims to address the low crop yield problem and offering farmers choices to grow one or more crops out of four to five crops suitable for the particular soil i.e. companion cropping so that they could make high profit and also maintains soil fertility*.

***Key Words*: Naïve Bayes Algorithm, Crop Yield, High Dimensional data, Crop Companion**

1.INTRODUCTION

Food is a fuel that our body requires to carry day to day functions. Food directly relates to crop farming. Cultivations of crops encompasses many agricultural practices taken care by farmers. The economists failed to evolve a system fair to farmers. As farmers are not technically skilled, so they require a smart solution that can assist them in increasing the efficiency and profitability of cultivation. And those solutions can be produced by smart agriculture.

Smart agriculture, also known as precision agriculture, is an innovative approach to farming that integrates technology and data analytics to optimize crop yields, reduce waste, and minimize environmental impact. Precision agriculture (PA) is an agricultural management concept based on monitoring, measuring and responding to inter-field and intra-field variability of crops. PA is also sometimes referred to as precision agriculture, satellite agriculture, on-demand agriculture, and site-specific crop management (SSCM). Precision agriculture uses information technology (IT) to ensure that crops and soil receive exactly what they need for optimal health and productivity. It also ensures profitability, sustainability and environmental protection. It takes into account aspects such as soil type, terrain, weather, plant growth and yields in crop management.

Smart agriculture projects use a variety of cutting-edge technologies, including sensors, drones, and machine learning algorithms, to collect and analyze data about soil conditions, weather patterns, plant growth, and other key variables. These machines help to collect the data of various nutrient and mineral such as N, P, K , pH etc. along with their value of the agriculture land soil. By applying advanced analytics and automation, farmers can make more informed decisions about planting, fertilizing, watering, and harvesting crops, leading to increased efficiency and profitability. Overall, smart agriculture represents an exciting opportunity to transform the way we grow food and manage natural resources. By harnessing the power of technology and data, we can create a more sustainable, efficient, and equitable food system that benefits farmers, consumers, and the planet.

1.1 Benefits of Smart Agriculture

After the data is collected, predictive analytics software uses the collected data to provide guidance to farmers regarding crop rotation, optimal planting times, harvesting, and soil management. Agricultural control centers can integrate sensor data and imaging inputs with other data to enable farmers to identify fields that need treatment and determine the optimal amount of water, fertilizer and pesticides to apply.

This helps farmers avoid wasting resources and prevent runoff, ensuring the soil contains the right number of nutrients for optimal health while reducing costs and controlling the farm's environmental impact. There are other numerous benefits of precision agriculture such as-

i. Cost reduction- The ability to precisely reduce the amount of fertilizer, herbicide or seed in areas where it will not be economical to use is one of the key benefits of precision agriculture.
ii. Increased profitability- Increasing yields through the use of high-resolution agronomic principles while reducing costs increases overall profitability. Farmers Edge offers one of the lowest priced, high value packages in the industry through our unique application of technology.
iii. Increased sustainability- Ensuring that applied plant-based products actually reach the plant and do not impact the environment elsewhere not only delivers better results, but also promotes a safer environment and may even give you access to new markets for your crops in the future. Using our accurate services, we have been able to quantify that on average a Farmers Edge Variable Rate (VR) customer has reduced their carbon footprint by over 10% while increasing production!
iv. Better harvest- One of the most significant benefits of precision farming is the ability to understand the nutrient levels on the farm and the soil types on the farm. We know that fields and geographies are not created equal, and this can affect the amount of nitrogen mineralization, water holding capacity, and much more. By understanding these differences, we can make sure we don't overdo nitrogen, which can lead to lodging, or we can increase nutrients like potassium that help with stability in areas where it's low. To top it all off, we can do VR desiccation, which means we can have lower desiccant on hilltops or sandy areas and higher rates on low-lying areas to ensure your crop is easily harvested.
v. Increased land values- We know that accuracy is an excellent practice from an agronomic point of view, but it can also affect the value of land prices, as shown here.
vi. Higher resolution Understanding your farm- Farmers know their soil better than anyone else. Precision farming gives you the ability to understand why certain areas of your farm are not producing or producing better, giving you a basis for making decisions that continually improve the farm.
vii. Better understanding of yield in season- Using accurate imagery or accurate weather services can not only help you understand areas of your farm that are facing problems or need more attention, but with this combination of farm and field information, we can provide an accurate yield forecast for the season. , enabling better decision-making both from an agronomic point of view and for marketing or asset purchase purposes.

They are all interconnected, but they are only the beginning of the value that precision agriculture brings. As technology improves, the use of technology improves and we continue to improve products, experiences and outcomes for farmers from the High Level of Canada to the Deep South of Australia.

2. LITERATURE SURVEY

[1] Dr. S. Usha Kiruthika, Dr. S. Kanaga Suba Raja. "Design and Implementation of Fertiliser Recommendation System for Farmer". This paper aims to estimate nutrient dimension of soil and suggest appropriate fertilizer. Their methodologies comprise of four stages- (i) soil analysis (ii) data preprocessing (iii) Data Analysis (iv) Recommendation. They have collected the NPK ratio of the soil nutrient using NPK sensor.

The gathered data are processed using machine algorithm to identify the correct fertiliser required for that soil.

[2] Suresh, G., A. Senthil Kumar, S. Lekashri, and R. Manikandan. "Efficient Crop Yield Recommendation System Using Machine Learning for Digital Farming". This proposed system uses the data acquired by the location of the land and suggests the effective crops based on the soil fertility of that area. The system also provides the required quantity of fertilizers.

The work mainly used two datasets to produce the required output. One dataset is the sample dataset of location and its soil fertility parameters and the other one is for the crop data according to soil parameters. In order to suggest crops and fertilizer, the framework utilizes the calculations of support vector machine.

This proposed work utilizes supervised machine learning algorithm to suggest appropriate crops to maximize the yield. The system recommended particular crops based on nutrients (N, P, K and pH) values of the soil for the crops like rice, maize, black gram, carrot and radish.

[3] Aqeel-ur-Rehman, Abu Zafar Abbasi, Noman Islam and Zubair Ahmed Shaikh, "A Review of Wireless Sensors and Networks' Applications in Agriculture". This particular paper reviewed the applications of wireless sensors, WSN technology and its network application in various aspects of agriculture. Also, this paper presented the different systems available for this particular domain.

This paper presented the use case of different technologies in different aspects of agriculture such as irrigation, fertilization, pest control, horticulture and greenhouse. For the irrigation purpose, they reviewed the work of Damas et al. [4] in which they developed and tested remotely controlled, automatic irrigation system which utilizes WLAN network to connect all the regions and control them from a control system. And also, the work of Morais et al. [5] which implemented wireless data acquisition network to collect climate and soil moisture data for smart irrigation in Portugal. Similarly, for fertilization they reviewed different works in which GPS technology, sensors and Bluetooth technology was used to collect the data of soil and its nutrients to maximize crop yield.

[6] Dhruvi Gosai, Chintal Raval, Rikin Nayak, Hardik Jayswal, Axat Patel, "Crop Recommendation System using Machine Learning". The bad quality of crop is also due to the either excessive fertilizer or using not enough fertilizer. This proposed system of IoT and ML is using the soil sensors and collecting the information by observing the soil parameters. This lowers the probability of the degradation of the soil and helps maintain crop health.

By the use of Kaggle dataset based on different soil and climate parameter for different crops has been picked and pre-processed means removal of the noise and also identifying most suitable and relevant attribute from the dataset. Then by the help of the Decision Tree classifier methodology, the model was trained and by the help of SVM crops are classified as well as regression challenge. It is mainly used in classification challenge and using logistic regression for the model binary dependent variables. XG boost is used to maintain the accuracy.

[7] Qiming Zhou & Ali Ismaeel, "Integration of maximum crop response with machine learning regression model to timely estimate crop yield". This literature utilizes the satellite remote sensing data to predict crop yield. The collected data is then utilized by machine learning models to predict the yield.

In the study, they integrated the maximum Enhanced Vegetation Index (EVI) during the crop growing season with the Machine Learning Regression (MLR) models to estimate the crop yield for wheat and rice in Pakistan's Punjab province. They utilized the five-fold cross-validation model for predictive accuracy.

The proposed system was able to predict the crop yield 6-8 weeks before he harvests. The prediction then further can be utilized in the formulation of agricultural policies for social, environmental and economic progress.

[8] Suporn Pongnumkul, Pimwadee Chaovalit, and Navaporn Surasvadi, "Applications of Smartphone-Based Sensors in Agriculture: A Systematic Review of Research". This article systematically reviews smartphone application that are mentioned in various research literatures that utilizes built-in smartphone sensors for providing solutions to agricultural problems.

The study showcases that GPS and cameras are the most popular sensors utilized in the reviewed research papers. Other smartphone sensors such as accelerometer, gyroscope, light sensors and moisture sensors utilization is very complex and only comes with expensive devices which is not affordable for farmers.

The utilization of camera for disease detection and crop water needs estimation has been done using image processing of the leaves that can be captured through smartphone cameras.

[9] N. Bhavya, K. Govinda, "Targeted Yield Approach of Fertiliser Recommendation for Sustaining Soil and Crop Productivity." This research paper aims to focus on fertilizer recommendation to increase crop recommendation. This research uses STCR (Soil Test Crop Response) technique, which uses the test values of soil and targeted yield equation. STCR is one of the most scientific approaches to nitrogen application for crops among the different types of fertilizer recommendation.

3. PROPOSED SYSTEM

3.1 System Architecture

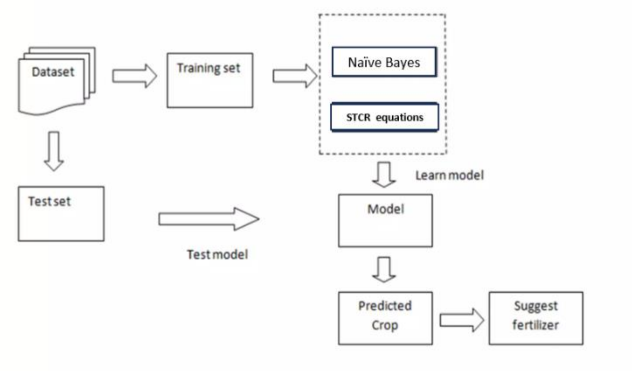

Fig.1: Backend module architecture

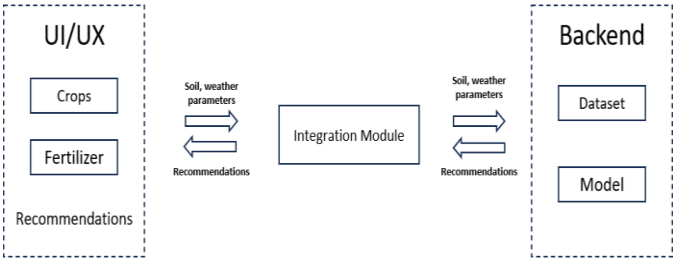

Fig.2: Frontend module architecture

3.2 Dataset Description

Proposed methodology for crop recommendations can be implemented on Agricultural Crop dataset available on Kaggle. It contains NPK parameters of soil, pH level of soil and weather conditions required for particular crop. For fertilizer recommendations, the dataset is prepared from STCR recommendation report of ICAR-IISS, Bhopal. It consists the coefficients of regression equations for respective crop and area.

	crop	state	district	a1	a2	a3	b1	b2	b3
0	rice	andhra pradesh	guntur	3.79	3.19	1.60	0.50	3.17	0.19
1	rice	andhra pradesh	karim nagar	3.78	1.96	2.96	0.44	2.13	0.36
2	rice	andhra pradesh	kurnool	3.35	2.52	1.24	0.33	4.53	0.12
3	rice	himachal pradesh	kangra	5.46	2.50	2.82	0.32	2.67	0.68
4	rice	himachal pradesh	shimla	5.46	2.50	2.82	0.32	2.67	0.68

Fig-1 STCR dataset sample

3.3 Backend Module

3.3.1 Crop Recommendation

a. Naïve Bayes Algorithm

Based on the Bayes theorem, the Naive Bayes algorithm is a straightforward probabilistic classifier. It operates under the naive assumption that the existence or absence of one feature implies the existence or absence of other features. Given a set of features, the algorithm calculates the probability of each class and outputs the class with the highest probability.

The following steps make up the Naive Bayes general methodology:

1. Cleaning, formatting, and dividing the dataset into training and testing sets are all part of data pre-processing.
2. Selecting the pertinent features from the dataset that will be used to train the model is known as feature extraction.
3. To train the model, determine the probabilities of each class given a set of features using the training set. The algorithm erroneously assumes that every feature is independent of every other feature.
4. Utilizing the testing set to gauge the model's effectiveness is known as testing the model. Given the features in the testing set, the algorithm calculates the probability of each class and outputs the class with the highest probability.
5. Utilizing performance metrics like recall, accuracy, precision, and F1 score, among others, to assess the model's performance.
6. Adjusting the model's parameters and/or choosing new features to enhance its performance is known as fine-tuning.

The Naive Bayes algorithm, in general, is a straight forward but efficient classification algorithm that can be applied to a variety of tasks, such as text classification, and spam filtering.

b. Decision Tree

Decision Tree is a supervised machine learning algorithm that can be used for classification and regression analysis. It works by recursively partitioning the data into smaller subsets based on the values of the input features and then making a prediction based on the subset's majority class or average output value. The benefits of decision trees include their ability to handle both categorical and continuous input features, their interpretability, and their handling of missing data. Non-linear relationships between input features and output variables can also be handled by decision trees.

c. SVM

SVM can be used for classification and regression analysis. The goal of classification is to predict the class of a given data point, whereas the goal of regression is to predict a continuous output variable. SVM finds the best hyperplane for categorising the data: The hyperplane is a decision boundary that divides data into different classes. SVM attempts to find the optimal hyperplane that maximises the margin between the hyperplane and the nearest data points of each class. This is known as the maximum margin hyperplane.

The accuracy of various algorithm used for recommending the crops are shown in the below table:

Table.1: Algorithm comparison table

Algorithms	Accuracy
Naïve Bayes'	96.13
Decision Tree	89.4
SVM	10.63
Logistic Regression	93.27
Random Forest	94.36

After testing with all the algorithm along with accuracy, we find that accuracy of Naïve Bayes Algorithm is highest. It helps to recommend the crops with high precision.

3.3.2 Fertilizer Recommendation

The proposed system estimates the soil nutrient content as provided by the user and recommends the suitable fertilizer content required for targeted yield by utilizing the particular STCR fertilizer recommendation equations for the provided field location.

The general STCR equations used for recommendations are:

$$FN = \left(\frac{NR}{CF} \times 100 \times T\right) - \left(\frac{CS}{CF} \times SN\right) \quad (1)$$

$$FP_2O_5 = \left(\frac{NR}{CF} \times 100 \times T\right) - \left(\frac{CS}{CF} \times SP_2O_5\right) \quad (2)$$

$$FK_2O = \left(\frac{NR}{CF} \times 100 \times T\right) - \left(\frac{CS}{CF} \times SK_2O\right) \quad (3)$$

Where, FN: fertilizer N (kg ha^{-1}); FP_2O_5: fertilizer P_2O_5 (kg ha^{-1}); FK_2O: fertilizer K_2O (kg ha^{-1}); SN: soil test value of available N (kg ha^{-1}); SP_2O_5: soil test value for available P_2O_5 (kg ha^{-1}); SK_2O: soil test value for available K_2O (kg ha^{-1}); NR: nutrient requirement; CF: contribution of nutrients from fertilizer; CS: contribution of nutrient from soil. [9]

The ratios $\frac{NR}{CF}$ and $\frac{CS}{CF}$ varies according to vivid crops, soil type and locations. So, we've substituted them variables a_i and b_i respectively for above three equations as:

$$FN = (a_1 \times T) - (b_1 \times SN) \quad (i)$$

$$FP_2O_5 = (a_2 \times T) - (b_2 \times SP_2O_5) \quad (ii)$$

$$FK_2O = (a_3 \times T) - (b_3 \times SK_2O) \quad (iii)$$

The user inputs the crop he wants with soil nutrients content and the location of field. Now, with the details of location and crop, variables 'a' and 'b' are fetched from the dataset prepared and fertilizers are calculated and recommended.

3.4 Frontend Module

a. React JS

React is a JavaScript library for building user interfaces. React is used to build single-page applications. React allows us to create reusable UI components. React is a JavaScript library for web native user interfaces. The frontend and UI of this project is implemented using it with a third-party library 'react-router-dom' for routing purpose.

b. Tailwind CSS

Tailwind is a CSS framework that provides us with single purpose utility class which are opinionated for the most part, and which help us design our web pages from right inside our markup or .js/.jsx/.ts/.tsx files. It is a utility-first CSS framework that is used to build designs in markup.

c. Flask

Flask is a micro web framework written in Python. It is classified as a microframework because it does not require particular tools or libraries. It has no database abstraction layer, form validation, or any other components where pre- existing third-party libraries provide common functions. However, Flask supports extensions that can add application features as if they were implemented in Flask itself. Extensions exist for object-relational mappers, form validation, upload handling, various open authentication technologies and several common framework related tools.

4. RESULTS

Crop recommendation uses the Naïve Bayes model to predict most suitable crops for the field by analyzing the NPK, pH values and weather conditions of the area as entered by the user.

Fig-2: Crop recommendations

The fertilizer recommendation module utilizes STCR fertilizer recommendation equations for fertilizer recommendations for the crop and area details entered by the user.

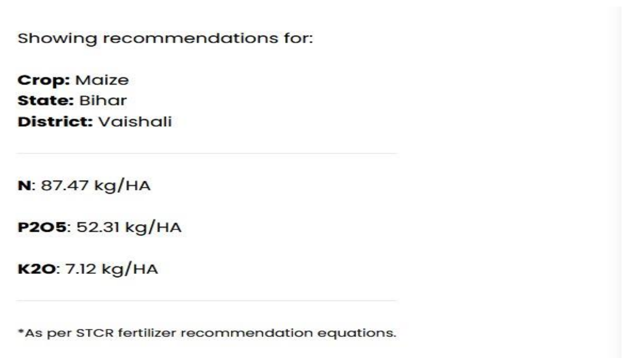

Fig -3: Fertilizer recommendations

5. CONCLUSIONS

We proposed a crop recommendation system in this report using machine learning and artificial intelligence techniques. The system is intended to assist farmers in making informed crop and fertiliser management decisions, which can improve crop yield while reducing environmental impact. Our results showed that the proposed system predicted crops with high accuracy and precision, used companion farming techniques, and of fertiliser. The system outperformed other approaches and demonstrated the potential for crop improvement, companion farming techniques, and fertiliser reduction. Our research also aims to recommend suggestion and solution for the required deficiency of fertiliser. Our research helps to advance precision agriculture and sustainable crop management practises. Farmers can use the system to optimise crop and fertiliser management, reduce environmental impact, and increase profitability

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