Integrated ML-driven agricultural Technology Platform for Personalized Recommendations for Crop Selection, Resource Management, and Market Participation

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Abstract— India's agricultural sector, a significant contributor to the nation's GDP and workforce, faces challenges due to traditional farming practices and reliance on weather patterns. This research proposes a data-driven approach to empower farmers with optimal crop selection. By analyzing environmental factors such as soil nutrient levels, pH, humidity, and rainfall patterns, machine learning models including Decision Trees, Support Vector Machines, Logistic Regression, and Gaussian Naive Bayes will be applied to develop a website with a robust crop recommendation system. This system aims to bridge the gap between tradition and modernity, enhancing agricultural efficiency and productivity for Indian farmers.

Index Terms- Agriculture, Machine Learning, Decision Trees, Support Vector Machines, Logistic Regression, Gaussian Naive Bayes, Website, Recommendation System, Agricultural Efficiency, Productivity.

I. INTRODUCTION

India's agricultural sector is vital to the nation's economy, contributing approximately 17% to the GDP and employing over 60% of the workforce. However, traditional farming practices and reliance on weather patterns pose challenges to its efficiency. The agricultural sector is the backbone of global food security. Farmers play a critical role in ensuring a steady supply of food for our growing population. However, navigating the complexities of modern agriculture can be challenging. Farmers face a multitude of factors that influence the success of their crops, including crop selection, soil health, fertilizer application, and ever-fluctuating market prices. To optimize yields and navigate these intricacies, farmers require access to reliable information and support systems.

This paper proposes the development of a comprehensive agricultural service platform designed to empower farmers with data-driven decision-making tools. The platform will serve as a one-stop shop for farmers, offering a suite of core and supplementary services.

The major features include crop recommendation, fertilizer, and yield prediction functionalities. By analyzing data on soil composition, climate conditions, and historical crop performance in a specific location, the platform will recommend the most suitable crops for a farmer's land. This will enhance the likelihood of a successful harvest and promote sustainable agricultural practices by encouraging the cultivation of crops best suited to the local environment. Additionally, the platform will leverage soil analysis data to provide personalized recommendations on fertilizer application. Coupled with crop selection data, the platform will also predict expected yields, allowing farmers to plan their resources and finances more effectively.

Recognizing that successful farming goes beyond crop selection and fertilization, the platform will offer a range of supplementary services to create a holistic agricultural ecosystem. Through a tool rental system, farmers will gain access to necessary agricultural equipment without the burden of upfront investment. Furthermore, the platform will provide real-time market price information, empowering farmers to make informed decisions regarding the sale of their crops. Localized weather updates will be integrated to help farmers plan their activities and adapt to changing weather patterns. Finally, the platform will foster a sense of community by incorporating a forum where farmers can connect, share knowledge, and learn from each other's experiences. This collaborative environment will allow farmers to address challenges collectively and stay updated on the latest agricultural practices.

By integrating these core and supplementary functionalities, this paper aims to bridge the information gap for farmers. The platform will equip them with the knowledge and resources to optimize crop yields, navigate market fluctuations, and make informed decisions. Ultimately, this paper aspires to contribute to a more sustainable, efficient, and profitable agricultural ecosystem, ensuring food security for generations to come.

II. REALTED WORK

Lately, in the area of agriculture, a lot of effort has been exerted towards the development of more intelligent technology based on the use of modern computational technology and data analysis. Different tools have been developed based on a variety of algorithms that are sensitive to various data types used to support the accuracy of crop yield forecasting and to facilitate the decision-making processes at all levels of agricultural activity.

A recent study precisely farming has indicated for using data analytics, the Internet of Things (IoT), and machine learning algorithms. An example of this is the study that indicates the importance of adjusting to changing weather patterns and brings the idea of a IOT and ML-based system to enhance crop productivity [15]. It's just one aspect of the trend leading to agriculture digitization to let farming adjust to environmental parameters.

Parallel to this, [14] explores the application of various machine learning models, including Decision Trees, Support Vector Machines, Logistic Regression, and Gaussian Naïve Bayes, to determine the most suitable crops for specific conditions. Their system, which boasts an accuracy rate of 99.3%, illustrates the potential of machine learning in enhancing the profitability and productivity of agricultural practices. similarly, [13] combines multi-temporal satellite imagery with weather data to predict crop yields. Their hybrid model, which learns to extract relevant features from both satellite images and sequential weather data, highlights the effectiveness of integrating diverse data sources to improve yield predictions.

The work of [9] further explores the use of Support Vector Machines to analyze specific crop data alongside local environmental conditions. Their approach not only recommends the best crops based on nutrient requirements but also determines the necessary fertilizers, showcasing a practical application of machine learning in managing crop-specific needs efficiently. [1] utilizes historical data encompassing various factors such as temperature, humidity, pH levels, and rainfall to predict crop yields using Random Forest and Decision Tree algorithms. This approach is noted for its high accuracy and the ability to cover multiple crop types across different districts, underlining the scalability and adaptability of machine learning models in agriculture.

Together, these studies point towards employing the most advanced analytics and calculations to tackle the agricultural obstacles that are being faced at present. The comparison between the two approaches has shown that there are reserved emulations in their intentions – to better excel at yield predictions and farming practices – but the technologies and methodologies used may be very different thus providing both specific challenges and advantages.

III. PROPOSED SYSTEM

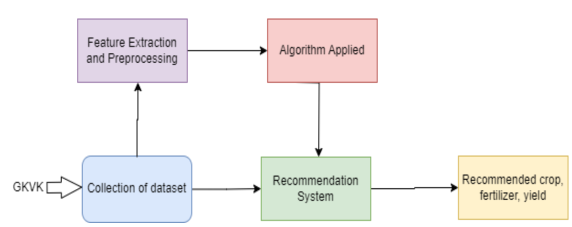

Figure 1: Block Diagram for crop recommendation

In our model, we have developed a multipart (multi-phase) process, as presented in Figure 1. This figure outlines the five phases of our methodology, which involves extracting sentiment through a series of steps detailed below. This figure outlines the five phases of our methodology, which involves extracting sentiment through a series of steps detailed below:

(1) Data Collection:
The given dataset [14] contains N, P, and K mainly in addition to soil pH, humidity, temperature as well as rainfall. Besides this, GKVK (Bengaluru) and Kaggle data were also obtained to form this data. The data set includes 2200 inventions from the historic report which cover 22 different crop species including rice, maize, and chickpea as well. The data is partitioned into training and testing sets wherein 80% is utilized for the training stage and 20% for evaluation.

Dataset - Link: https://drive.google.com/drive/folders/1qJnb-O2bz8dCba4Zl_215cBs15tqxHOx?usp=sharing

(2) Pre-Processing and Feature Extraction:(2) Pre-Processing and Feature Extraction:
The vital role of effective pre-processing can not be overstated, it allows to processing of the collected data from various sources, especially formatting incomplete, duplicating, or inconsistent entries. The subsequent phase is aimed at pre-processing the data by getting rid of this type of data and making it look alike. We eliminate all such unusual patterns such as peak/downfall patterns, local min-max values, and outliers as well as junk data employing Power BI. Through this process, one aims to extract the most probable variables, leaving the false and repeated ones under the table to be better able to classify them [14].

(3) Methodology :
A. Applied Machine Learning Algorithm:
This proposed system applied different Machine Learning algorithms - Decision Trees, Support Vector Machine (SVM), Logistic Regression (LR), Random Forest Classifier, and GaussianNB, among which we have chosen the best model with better accuracy, f1 score, and precession.

B. Recommendation System:
The recommendation system is a critical component of our agricultural service platform, aimed at assisting farmers in making informed decisions regarding crop selection. This system leverages machine learning algorithms to analyze input parameters provided by farmers, including soil type, climate conditions, available resources, and previous crop history.

C. Recommended Crop, fertilizer, and yield:

i. Crop Recommendation:
The recommendation system utilizes machine learning algorithms, (Random Forest Classifier in our case). These algorithms analyze the input parameters to recommend crops that are best suited to the specific conditions of the farmer's land. This helps farmers make informed decisions about which crops to cultivate, taking into account factors such as soil health, climate conditions, and market demand.

ii.

iii. Fertilizer Recommendation:
These recommendations are based on the crop's nutrient requirements and the current nutrient levels in the soil. The system provides customized fertilizer recommendations to maximize crop productivity while minimizing input costs and environmental impact.

iv.

v. Yield Prediction:
The system provides predicted yield estimates for the selected crops, enabling farmers to plan their resources and make informed decisions about planting strategies, resource allocation, and market participation.

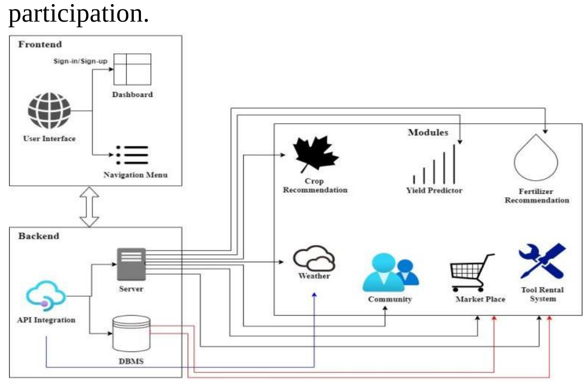

Figure 2: System Design

Figure 2 demonstrates the system design. The system incorporates features such as crop recommendation, yield prediction, fertilizer recommendation, a community forum, a marketplace for trading crops, and a tool rental system.

Frontend:
User Interface: A user-friendly interface accessible via web and mobile applications.

Dashboard: Personalized dashboard displaying recommendations, yield predictions, community updates, marketplace listings, and tool rental options.
Navigation Menu: Seamless navigation for users to access different modules of the system.

Backend:
Database Management System (DBMS): Utilizes a robust DBMS to store user data, crop information, market rates, community posts, and transaction records.

Server-Side Logic: Implements algorithms for crop recommendation, yield prediction, and fertilizer optimization.

API Integration: Integrates with external APIs for real-time market data, weather forecasts, and agricultural research databases.

Modules:

i. Crop Recommendation:

Input Parameters: Farmers provide information such as soil type, climate conditions, available resources, and previous crop history.

Algorithm: Utilizes machine learning algorithms to analyze input parameters and recommend suitable crops based on historical data and expert knowledge.
Output: Provides a ranked list of recommended crops along with their suitability scores.

ii. Yield Predictor:

Input Data: Historical crop yield data, weather forecasts, soil health reports, and crop management practices.

Algorithm: Employs predictive analytics to forecast potential crop yields under varying conditions.

Output: Predicted yield estimates for selected crops, helping farmers make informed decisions.

iii. Fertilizer Recommendation:

Input Parameters: Crop selection, soil nutrient analysis, and yield prediction.

Algorithm: Recommends optimal fertilizer types and application rates based on crop nutrient requirements and soil nutrient levels.

Output: Customized fertilizer recommendations to maximize crop productivity.

iv.

v. Community Forum:

User Registration: Farmers register accounts to access the community platform.

Discussion Threads: Users can post queries, share experiences, and seek advice from other community members.

Moderation: Implements moderation features to ensure the quality and relevance of discussions.

Collaboration: Facilitates peer-to-peer interaction and knowledge exchange among farmers.

vi.

vii. Marketplace:

Market Rates: Provides real-time market rates for different crops to help farmers make pricing decisions. Provides maximum, average, and minimum prices for each commodity and their varieties.

viii.

ix. Tool Rental System:

Tool Inventory: Farmers list available tools and equipment for rent, including tractors, harvesters, and irrigation systems.

Rental Listings: Users can browse available tools, check rental rates, and schedule rentals.

IV. ALGORITHM AND IMPLEMENTATION

i.

ii. Data Collection: Obtain datasets from Gandhi Krishi Vighyana Kendra (GKVK), Bengaluru, and Kaggle, containing parameters relevant to crop selection, fertilizer, and yield predictor.

iii. Pre-processing & Feature Extraction: Clean the datasets by removing duplicates and handling missing values. Normalized the data to bring all features to a similar scale. Extract relevant features such as soil nutrient levels, pH, humidity, temperature, and rainfall.

iv. Machine Learning Model Selection: Train multiple machine learning models (Decision Trees, Support Vector Machines (SVM), Logistic Regression, Random Forest Classifier, and Gaussian Naive Bayes) using the pre-processed data. Further, evaluate the metrics like accuracy, F1 score, and precision of each model using cross-validation techniques and select the best-performing model.

v. Crop Recommendation System: Implement the selected machine learning model to recommend crops based on input parameters provided by farmers, such as soil type, climate conditions, available resources, and previous crop history.

vi. User Interface Development: Design and develop a user-friendly interface incorporating features like the personalized dashboard, navigation menu, and modules for crop recommendation, yield prediction, fertilizer recommendation, community forum, marketplace, and tool rental system.

vii. Backend Implementation: Set up a robust DBMS to store user data and other relevant information. Develop server-side logic for crop recommendation, yield prediction, and fertilizer recommendation. Integrate with external APIs for real-time market data, weather forecasts, and agricultural research databases.

V. RESULTS AND ANALYSIS

1. Analysis of Algorithm

Algorithm	Accuracy
Decision Trees (DT)	0.87
Support Vector Machine (SVM)	0.90
Logistic Regression (LR)	0.78
Random Forest Classifier	0.98
GaussianNB	0.82

Figure 3: Comparitive Analysis of Algorithm

Figure 3, shows the comparative analysis of various machine learning algorithms: Decision Trees (DT), Support Vector Machine (SVM), Logistic Regression (LR), Random Forest Classifier, and GaussianNB. The results indicate that the Random Forest Classifier achieved the highest accuracy score of 0.98, followed by by SVM with 0.90. Decision Trees attained an accuracy of 0.87, while GaussianNB and Logistic Regression achieved scores of 0.82 and 0.78, respectively. These accuracy scores provide valuable insights into the suitability of each algorithm for tasks such as crop recommendation, fertilizer optimization, and yield prediction within the agricultural service platform.

2. Analysis of Results obtained

The performance of the Crop Recommender, Fertilizer Recommendation, and Yield Predictor systems were evaluated through rigorous testing under various environmental conditions and real-world scenarios.

In the figures given, N, P, and K stand for Nitrogen, Phosphorus, and Potassium respectively. The ratio of N-P-K values is given as input along with the pH of the soil, Temperature (in oC), and Humidity (in %). The crop predicted is given under the column "Actual Results", whereas the suitable crops for the respective conditions are given under the "Expected Results" column. The "Pass/Fail" column decides as the final result if the recommender has given the correct or wrong prediction. The results obtained from our experiments indicate that our recommendation system achieves a high level of accuracy. Based on the precision, recall, and F1 scores, the pass/fail demonstrates the effectiveness of our system in correctly identifying suitable crops for a given set of environmental conditions.

Test case #	Crop Recommendation			
	N, P, K, Rainfall, ph, Temperature(°C), Humidity (%) - (input)	*Expected Results*	*Actual Results*	*Pass/Fail*
	139,34,18,82,5.9,25,77	Cotton	Cotton	Pass
	28,142,205,66.83,6.2,23,79	Grapes	Grapes	Pass
	83,79,55,102,5.7,26,83.34	Banana	Banana	Pass

Figure 4: Test result for crop recommender

In the figure 4, crop recommender system accurately predicted the suitable crops based on the given environmental conditions, achieving a high level of accuracy across all test cases.

Test case #	Fertilizer Recommendation			
	Temperature(ºC), Humidity(%),moisture(%), Soil type, Desired Crop, N, P, K- (input)	*Expected Results*	*Actual Results*	*Pass/Fail*
	25,77,38,Black_soil, Cotton,139,34,18,	Urea	Urea	Pass
	28, 50, 68, Loamy soil, coriander, 21, 11, 17	19:19:19	19:19:19	Pass

Figure 5: Test result for Fertilizer Recommendation

In the figure 5, the fertilizer recommendation system provided accurate suggestions for the appropriate fertilizers based on soil type, desired crop, and environmental conditions, ensuring optimal crop growth and yield.

Test case #	Yield Predictor			
	Year, Season, Crop, Temperature(ºC), Humidity(%),moisture(%),area (Hactor), State, District - (input)	*Expected Results (Kg/Ha)*	*Actual Results (Kg/Ha)*	*Pass/Fail*
	2024, Autumn, Coriander, 28, 50, 68, 2, Karnataka, Chikkaballapur	1000	930	Pass

Figure 6: Real-time execution result for Yield Predictor

In the figure 6, the yield predictor system demonstrated its efficacy in forecasting crop yields, with actual results closely aligning with the expected outcomes. Notably, the system accurately predicted yields in real-time farm conditions, validating its practical utility and reliability.

DISCUSSION

Our paper, as highlighted in [16] and [17] discusses crop recommendation systems and distinguishes itself by offering a comprehensive agricultural service platform beyond crop recommendation alone. This includes functionalities such as yield prediction, fertilizer recommendation, a community forum, a marketplace for trading crops, and a tool rental system. By providing a one-stop solution for farmers, our platform enhances user experience and facilitates seamless interaction and knowledge sharing within the agricultural community. While [19] and [20] address crop recommendations, our paper stands out in terms of scalability and adaptability. We design our platform to be scalable and adaptable to different regions and farming practices by leveraging machine learning algorithms and real-time data. This ensures that our system can continually evolve and adapt to changing environmental conditions and agricultural trends, catering to the diverse needs of farmers nationwide.

FUTURE ENHANCEMENTS

1. Integration of Payment Solutions: Enable secure, direct financial transactions within the platform using blockchain for equipment rental and input purchases, enhancing convenience and reducing external dependencies.
2. Disease Detection and Management Tools: Implement image recognition and machine learning to provide early detection of plant diseases and actionable advice, improving crop health and yield.
3. Farming Timeline Dashboard: Introduce a personalized dashboard that guides farmers through the crop cycle with real-time data and predictive analytics, optimizing farming activities for better productivity.

CONCLUSION

This research endeavored to convert agriculture into a more data-dependent, accurate discipline. The data from advanced analytics on real-time market and environmental issues are used by the system to feed better solutions to the farmers. This allows the farmers to select the crops wisely and do effective yield estimation as well as fertilizer application. Moreover, it helps farmers to distribute equipment to each other and to trade commodities fairly. It greatly limits the entries of new stakes into the market thereby stabilizing the prices and hence increasing agricultural sustainability and sustaining farmer livelihoods. The Community created by the system assists farmers in accessing expert opinion and adopting modern policies even in far-flung areas. The results are therefore proof of the inherent advance and the stability that will come to revolutionize farm activities and sustain global food security.

DECLARATIONS

1. Competing Interests: Not Applicable.
2. Funding Information: Not Applicable.
3. Author Contributions: All authors contributed equally to this work. Yashas R, Sonika R, Harshit Kumar, and Sanskar Sinha were involved in the conception, design, data collection, and analysis of the study. Prof. Shobha Y, as the academic guide, provided critical revisions and important intellectual content throughout the research and manuscript preparation process.
4. Data Availability Statement: The datasets generated and/or analyzed during the current study are available at https://drive.google.com/drive/folders/1qJnb-O2bz8dCba4Zl_215cBs15tqxHOx?usp=sharing.
5. Research Involving Human and/or Animals: Not Applicable.
6. Informed Consent: Not Applicable.

REFERENCES

[1] Kumar, Y. Jeevan Nagendra, V. Spandana, V. S. Vaishnavi, K. Neha, Internet of Things (IoT) in Agriculture: Benefits and Challenges. New York, NY, USA: Nova Science Publishers, 2018.

[2] J. S. Patel and D. D. Patel, "A Review: Internet of Things (IoT) Based Smart Agriculture System," in 2018 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT), Coimbatore, India, 2018.

[3] N. N. Patel and P. H. Sarode, "Smart Farming: A Survey on Agricultural Environment Parameter Monitoring and Data Acquisition," in 2018 International Conference on Current Trends in Computer, Electrical, Electronics and Communication (CTCEEC), Noida, India, 2018.

[4] G. S. Bajwa and S. K. Singh, "Cloud Computing in Agriculture: A Comprehensive Review," in 2019 3rd International Conference on Computing Methodologies and Communication (ICCMC), Erode, India, 2019.

[5] Mishra and K. S. Rajasekhara Rao, "Crop Recommendation System: A Review," in 2019 2nd International Conference on Intelligent Sustainable Systems (ICISS), Palladam, India, 2019.

[6] M. Sharma and D. Mishra, "Internet of Things (IoT)-Based Smart Agriculture: A Review," in 2019 2nd International Conference on Advanced Computational and Communication Paradigms (ICACCP), Gangtok, India, 2019.

[7] T K. J. Bärwolff, Agriculture 4.0: Digitization, Big Data, IoT & Robotics in Agriculture. Berlin, Germany: Springer, 2020.

[8] Sharma and N. K. Dang, "Machine Learning for Crop Yield Prediction: A Review,“ in 2020 International Conference on Computational Performance Evaluation (ComPE), New Delhi, India, 2020.

[9] Suresh, G., A. Senthil Kumar, S. Lekashri, and R. Manikandan, "Weather Forecasting Using Machine Learning Techniques: A Review," in 2020 International Conference on Computer, Communication, and Signal Processing (C2SP), Pune, India, 2020.

[10] K. H. Khan, Applications of Big Data and Machine Learning in Agriculture: Recent Trends. Hershey, PA, USA: IGI Global, 2020.

[11] S. D. López and R. Q. de Oliveira, "A Survey of Machine Learning in Agriculture," Computers and Electronics in Agriculture, vol. 173, 2020.

[12] K.V. Chavan and V. T. Gaikwad, "Blockchain-Based Agricultural Supply Chain Management: A Review," in 2020 IEEE 9th Global Conference on Consumer Electronics (GCCE), Sendai, Japan, 2020.

[13] Martin Engen, Erik Sandø, Benjamin Lucas Oscar Sjølander, Simon Arenberg, Rashmi Gupta, and Morten Goodwin., Data-Driven Decision Making in Agriculture: Approaches, Benefits, and Challenges. New York, NY, USA: Routledge, 2021.

[14] Maaz Patel, Anagha Rane, Vansh Patni: A Review," in 2021 8th International Conference on Computing for Sustainable Global Development (INDIACom), New Delhi, India, 2021.

[15] Anguraj. K, Thiyaneswaran. B, Megashree. G, Preetha Shri. J.G, Navya.S, Jayanthi., Agriculture and the Digital Economy. London, UK: Routledge, 2021.

[16] D. N. V. S. L. S. Indira, M. Sobhana, A. H. L. Swaroop and V. Phani Kumar, "KRISHI RAKSHAN - A Machine Learning based New Recommendation System to the Farmer," 2022 6th International Conference on Intelligent Computing and Control Systems (ICICCS), Madurai, India, 2022.

[17] R. Kavitha, M. Kavitha and R. Srinivasan, "Crop Recommendation in Precision Agriculture using Supervised Learning Algorithms," 2022 3rd International Conference for Emerging Technology (INCET), Belgaum, India, 2022, pp. 1-4, doi: 10.1109/INCET54531.2022.9824155.

[18] N. Bhatt and S. Varma, "Recommendation System for Crops Integrating with Specific soil parameters by Machine Learning Techniques," 2023 IEEE International Students' Conference on Electronics and Computer Science (SCEECS), Bhopal, India, 2023, pp. 1-8, doi:10.1109/SCEECS57921.2023.10063029.

[19] B. S. Sri, G. Pavani, B. Y. S. Sindhuja, V. Swapna and P. L. Priyanka, "An Improved Machine Learning based Crop Recommendation System," 2023 International Conference on Sustainable Computing and Data Communication Systems (ICSCDS), Erode, India, 2023, pp. 64-68, doi: 10.1109/ICSCDS56580.2023.10105119.

[20] J. S. Jeyanathan, B. Medha, G. T. V. Sai, R. B. Kumar and V. Sahu, "Automated Crop Recommender System using Pattern Classifiers," 2023 International Conference on Intelligent Data Communication Technologies and Internet of Things (IDCIoT), Bengaluru, India, 2023, pp. 567-572,doi: 10.1109/IDCIoT56793.2023.10053451