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Crop Recommendation System using Machine Learning and Environment Parameters

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ABSTRACT: Agriculture is a vital sector of India's economy, yet traditional practices often disregard soil quality and environmental conditions, resulting in low productivity. To address this, a Crop Recommendation System (CRS) is developed using Internet of Things (IoT) data and machine learning. The system processes soil nutrients, pH, temperature, rainfall, and humidity to recommend suitable crops. Feature selection is achieved through Improved Distribution-based Chicken Swarm Optimization (IDCSO), while a Weight-based Long Short-Term Memory (WLSTM) model enhances prediction accuracy. Additional models, including Kernel Ridge, Lasso, Elastic Net, Random Forest, and Naïve Bayes, are applied for yield forecasting, with Random Forest and Naïve Bayes showing the best performance. The CRS also offers a simple interface for farmers, enabling personalized recommendations. This approach promotes precision farming, boosts productivity, and encourages sustainable agricultural practices.

I. INTRODUCTION

Agriculture has long been the backbone of India's economy, culture, and livelihood, with more than half of the population engaged directly or indirectly in farming activities. India has one of the largest cultivable lands globally, yet the sector contributes only about one-fifth of the national income. This imbalance highlights the gap between the extensive human effort invested in farming and the actual economic returns. Traditional farming practices, largely dependent on family knowledge, soil fertility, and weather conditions, struggle to meet the growing demands of food security in the face of climate change, irregular rainfall, soil degradation, and excessive use of fertilizers and pesticides. These challenges often result in inconsistent yields, misuse of resources, and environmental damage.

Modern agricultural practices demand a shift towards data-driven solutions that improve productivity while ensuring sustainability. Emerging technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and Machine Learning (ML) have shown great potential in transforming agriculture. IoT devices enable real-time monitoring of essential factors such as soil nutrients, pH, temperature, moisture, and rainfall, while ML algorithms analyze this data to provide actionable insights. Crop Recommendation Systems (CRS) represent one of the most impactful applications of these technologies, offering farmers precise suggestions on which crops to cultivate based on local soil and climate conditions. Such systems not only enhance yield but also reduce input costs and promote eco-friendly practices.

However, existing CRS models face limitations, including reliance on outdated datasets, high computational needs, and inadequate adaptation to India's diverse agro-climatic zones. To overcome these issues, this research proposes a hybrid model that integrates Improved Distribution-based Chicken Swarm Optimization (IDCSO) for feature selection and a Weight-based Long Short-Term Memory (WLSTM) network for prediction. The IDCSO method ensures that only the most relevant soil and climatic parameters are considered, improving both speed and accuracy, while WLSTM captures temporal variations in crop and weather patterns for more reliable forecasting.

The proposed system processes critical inputs such as nitrogen, phosphorus, potassium, pH, rainfall, temperature, and humidity to recommend region-specific crops. By combining IoT-enabled data collection with advanced ML models, the system provides farmers with timely and accurate advice, reduces resource wastage, and helps mitigate risks posed by climate change. Ultimately, this approach aims to bridge the gap between conventional farming and precision agriculture, ensuring food security, economic stability, and long-term sustainability for Indian agriculture

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II. LITERATURE SURVEY

The use of computers in farming has become increasingly prevalent, especially for advising on crop selection and forecasting harvest sizes.

Khosla et al. (2020) [7] researched predicting the quantity of key Kharif crops in Visakhapatnam, Andhra Pradesh, using a combined MANNs-SVR (Modular Artificial Neural Networks – Support Vector Regression) model. Their approach initially used MANNs to estimate monsoon rainfall and then used that rainfall data to forecast crop growth. This combined approach predicted Kharif crop growth better than standard machine learning approaches. This highlights how important rainfall is for forecasting crop quantities and how combining different models can improve predictions.

Jaison et al. (2017) [8] developed a complex system using several machine learning algorithms, including Deep Belief Networks (DBNs) for feature learning, Decision Trees (DTs) and K-means clustering optimized with Particle Swarm Optimization (PSO) for training, and Naïve Bayes (NB) clustering with PSO for testing. This system achieved 98.35% accuracy with minimal errors. It offers a robust method to assist farmers in selecting optimal crops to maximize yield. They used Python in Anaconda Spyder for its creation, demonstrating ML models' applicability in actual farming contexts.

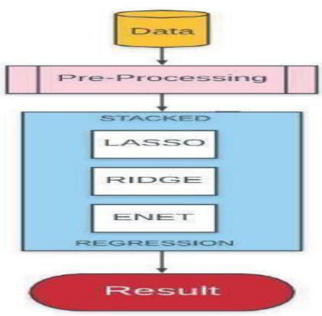
Abbaszadeh et al. (2022) [9] employed Bayesian Model Averaging (BMA) alongside groups of Copula functions to combine the outputs from various deep neural networks, including 3D Convolutional Neural Networks (3DCNNs) and Convolutional Long Short-Term Memory (ConvLSTM) networks, to forecast soybean production across several U.S. states. Their model predicted crop quantity more effectively and was more dependable than using individual models. This emphasizes the usefulness of combining models and assessing uncertainty when forecasting crop quantities in farming.

Abbaszadeh et al. (2022) [9] used a method to mix different deep learning models using math and stats, along with some functions, to put together what the models found. The different models were types of neural networks that work with three-dimensional data and can remember things over time. They did this to guess how much soybean would be grown in a few states in the U.S. Their system made better guesses about how much soybean would grow than using just one model. This showed that putting models together and checking how sure you are can really help when predicting things about farming.

Pant et al. (2021) [10] looked at how to use computer-based learning to guess how much of four important crops would grow in India: wheat, potatoes, rice, and maize. They said that when you can predict how much crops will grow in certain areas, you can use things like fertilizer in a better way. This helps make farms more efficient and keeps them going for longer.

Hafez et al. (2015) [11] came up with a new way of doing things called Chicken Swarm Optimization (CSO), which is based on how chickens act in groups. This way of doing things picks out the best parts to make categorizing things better and easier. Their way worked better than other common ways of doing things, like Genetic Algorithms (GAs) and Particle Swarm Optimization (PSO), when tested on different sets of information. This shows it could be helpful for picking out important things in farming data.

III. METHODOLOGY



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Our crop suggestion plan begins by collecting lots of information. The information includes key farming details like soil health (pH, nitrogen, potassium, etc.), weather details (temperature, rainfall, humidity), crop production amounts, and trends by place or time of year. This diverse set of facts aids in determining the influence of crops. Once we have the information, we clean it up and prepare for review. This involves correcting any incorrect or missing information, maintaining uniformity, modifying crop types to allow the computer to read it, and selecting the most crucial information to improve the model.

The main focus of our approach is on a combined regression model. The model incorporates three successful regression methods: LASSO, Ridge, and Elastic Net (ENET). The use of LASSO regression allows for the selection of optimal features by minimizing or eliminating the influence of secondary features. By utilizing big coefficients in ridge regression, it is possible to reduce problems with highly related variables and enhance the overall model. Elastic Net leverages the strengths of LASSO and Ridge, maintaining a balance between feature selection and reliability. When the models are merged, their individual forecasts are utilized through another model to produce more precise and consistent overall forecasting.

The concluding section of our approach demonstrates the conclusion. This could involve providing guidance on the optimal crop to cultivate based on current soil and weather conditions, forecasting the growth rate of each crop, or listing several crops in order of their potential success. This structured approach enables individuals to make more informed farming decisions by providing them with data-driven information to select the most suitable crops.

3.1 Dataset

The data utilized for suggesting crops is sourced from Kaggle (https://www.kaggle.com/siddharthss/crop-recommendation-dataset/). It contains significant data that influences the amount of crop produced and the level of rainfall in various regions. These details consist of:

- Soil nutrients: Nitrogen (N), Phosphorus (P), Potassium (K)
- Environmental factors: Temperature, Humidity, pH, Precipitation
- Crop label indicating the type of crop grown

Combined, these specifics form the foundation for guiding and forecasting crops.

3.2 Data Pre-processing

Getting data ready is really key for making sure what you put in is good and that things match up well. Here&039;s what steps we took:

Handling Missing Values: When some pieces of info were not there, they were shown with a \&039;.\&039;. We turned these into really big negative numbers instead. This lets the system spot different values without messing up key information.

Label Generation: The info we had didn&039;t have simple labels, so we made them using how much crop was made (in tonnes) and the space used to grow it (in hectares). If the space used was bigger than zero, we called it \&039;1\&039;, meaning there was a crop. If it wasn&039;t, we called it \&039;0\&039;.

Scaling: We used tough scaling on the numbers to deal with things being uneven and cut down the effects of weird values by using the range between quartiles.

Normalization and Transformation: We straightened out features that were uneven by using quantile changes to be sure the features were spread out more equally.

3.3 Integrating Sensors Based on IoT

To gather information in real-time and give better advice, IoT sensors were utilized in the area to determine:

- How wet the soil is
- How acidic or basic the soil is
- How hot or cold it is
- How much water is in the air

This up-to-date environmental information is sent to online storage, where it is organized and readied. To detect sicknesses in crops, images captured by phone cameras are employed. These images are looked at using ways to process images to spot diseases and advise the correct plant food.

3.4 Feature Selection using IDCSO

The Improved Discrete Chicken Swarm Optimization (IDCSO) method is used to choose the best features for guessing what crops will grow. Feature selection aims to make the information easier to understand, remove features that say the same thing or don't matter, and improve how well we sort things.

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IDCSO acts like how chicken groups act together, with leader chickens, female chickens, and baby chickens. It uses how they act and move around to look at the different features in a good way. This way of doing things, based on nature, helps find the best group of features faster, which helps predict crop amounts more correctly.

3.5 Model Development: WLSTM with Stacked Regression

The system for suggesting crops uses a Weighted Long Short-Term Memory (WLSTM) network to figure out how weather data changes over time. A stacked regression approach is employed to arrive at the final guess.?...

Stacked Regression Workflow:
Train and Holdout are the two training information sources.
Basic models are taught using the Train section of the information.
The main model is based on the base models of the Holdout group's assumptions (meta-features).".
In this study, the primary model is a Lasso Regressor and learns these meta-features to make the final predictions.
This method merges various models to minimize errors in guessing. A decrease in the RMSE to less than 1 was observed when stacking models. The results were similar but different.

3.6. Data Analysis and Visualization.

EDA was utilized to examine the data closely and identify how the features were grouped and interconnected. Common things and trends were identified using bar charts, scatter plots, box plotted data, and other pictures. This helped in the selection of features and the creation of the model.

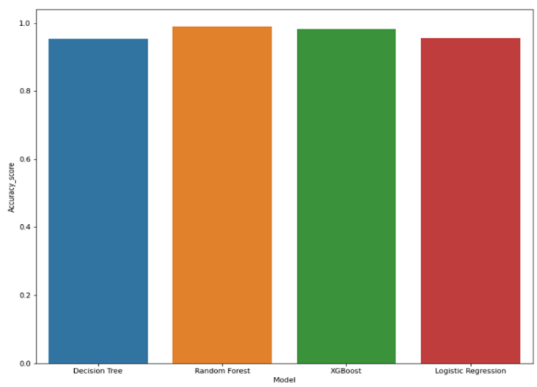
3.7 System Integration and User Feedback

The system has an easy screen where farmers can put in information about their land and weather and get crop suggestions made just for them. Farmers can use a phone app to tell their results and change the system's suggestions, which helps the model change to different field conditions.

IV. RESULT AND ANALYSIS

The project that suggests crops used computer learning and information to provide farmers with correct and helpful suggestions. After making the information clear and seeing it visually, four sorting ways were used: Decision Tree, Random Forest, Logistic Regression, and XGBoost. These ways used the following dataset features: Nitrogen (N), Phosphorus (P), Potassium (K), temperature, humidity, rainfall, and pH.

After checking each model, the Random Forest sorter worked the best, with a correctness of 98.9%. This happened because it puts together many models and is not as likely to react too much to small information changes. The XGBoost math steps were the next best, with 98.2% correctness, showing it can deal with hard patterns and links between features. Logistic Regression did fine as a simple comparison with 95.6% correctness. The Decision Tree had the lowest correctness at 95.3%, likely because it is easily changed by small differences in the information.



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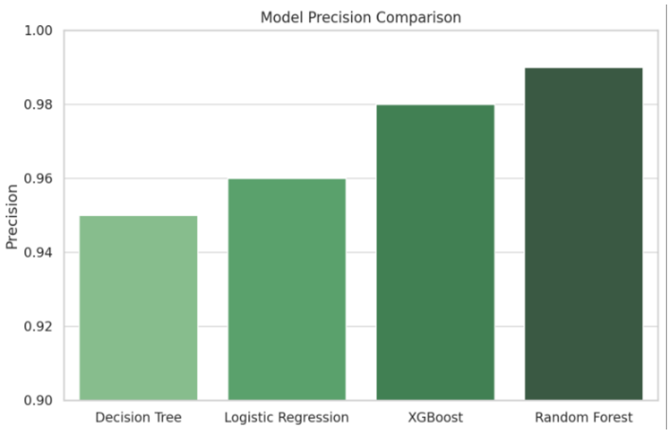

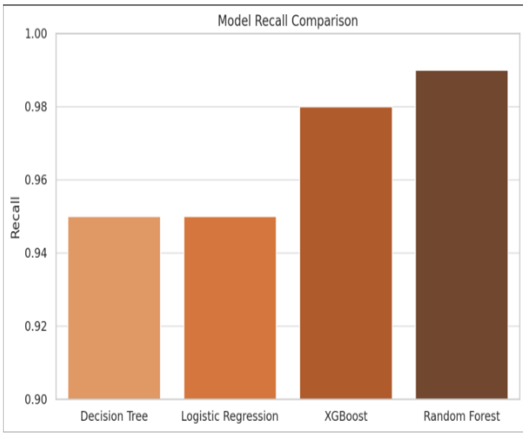

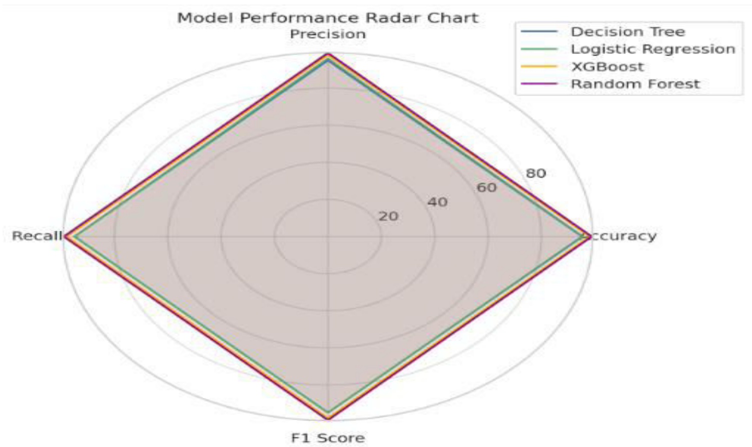

V. CONCLUSION

This research emphasizes the growing role of intelligent systems in agriculture, particularly in crop recommendation and yield prediction. By integrating IoT-based sensing with advanced machine learning techniques, farmers can make data-driven decisions rather than relying solely on traditional practices. Such systems improve efficiency, reduce resource wastage, and promote sustainability by aligning crop choices with soil and climate conditions. The reviewed studies demonstrate that hybrid models and optimization methods significantly enhance prediction accuracy.

Furthermore, the adoption of algorithms like WLSTM, Random Forest, and Naïve Bayes ensures reliable and adaptable solutions across diverse regions. Real-time monitoring through IoT devices strengthens the data pipeline, enabling models to provide timely recommendations. However, challenges remain regarding data quality, scalability, and adaptability to India's varied agro-climatic zones. Addressing these limitations will be crucial for developing universally applicable systems that can empower farmers at scale.

In summary, the future of farming lies in combining traditional knowledge with modern computational intelligence. A robust crop recommendation system not only improves productivity but also secures food supply and strengthens rural livelihoods. With continuous advancements in AI, IoT, and optimization algorithms, agriculture can move towards greater resilience and sustainability. This work lays the foundation for bridging the gap between conventional farming and precision agriculture.

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