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A Comparative Analysis of AI-Based Smart Farming for Konkan Agriculture Challenges and Future Direction

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***Abstract*—Agriculture in the Konkan region faces challenges related to variable rainfall, soil conditions, crop productivity, and market uncertainties. This paper presents a comparative review of existing Artificial Intelligence (AI) and Machine Learning (ML) approaches for smart agriculture and evaluates a prototype Farmer Decision Support System designed for Konkan farming conditions. The proposed prototype integrates crop recommendation, Explainable AI (XAI), heuristic expected-yield estimation, and crop-variety recommendation. Four classification algorithms, namely Random Forest, Decision Tree, Support Vector Machine (SVM), and Logistic Regression, were evaluated using agricultural parameters including nitrogen, phosphorus, potassium, temperature, humidity, soil pH, and rainfall. Experimental results showed that Random Forest achieved the highest accuracy of 100%, with 100% precision, recall, and F1-score, followed by Decision Tree and SVM with 99.86% accuracy each, and Logistic Regression with 99.58% accuracy. SHAP-based explanations were incorporated to interpret crop recommendations. Historical yield analysis showed average yields of 1,579.82 kg/ha for Rice and 1,347.83 kg/ha for Ragi (Nachani), while the heuristic model estimated a Rice yield of 1,672.63 kg/ha under the evaluated conditions. The comparative analysis highlights limitations in existing approaches, including single-task functionality, infrastructure dependency, and limited regional adaptation. The findings demonstrate the feasibility of integrating AI-based agricultural decision-support modules while emphasizing the need for improved regional datasets, model validation, and field testing to support practical implementation in Konkan agriculture.**

***Index Terms*—Smart Agriculture, Artificial Intelligence, Machine Learning, Predictive Analytics, Crop Recommendation, Crop Yield Prediction, Konkan Agriculture**

I. INTRODUCTION

Agriculture in the Konkan region of Maharashtra is closely affected by seasonal rainfall, soil conditions, and local growing patterns. Farmers need to decide which crops to grow, how to cultivate them, what production to expect, and which varieties may be suitable, often under uncertain weather and changing agricultural conditions. Artificial Intelligence (AI) and Machine Learning (ML) can help analyze agricultural data and support these decisions. Previous studies have explored crop recommendation, yield prediction, plant disease detection, and environmental monitoring. Looking at these areas together can help show how useful they are for the Konkan region. This review examines existing AI-based agricultural methods, compares their approaches and limitations, and identifies possibilities for an integrated Farmer Decision Support System suited to Konkan agriculture.

II. REVIEW METHODOLOGY

This review explores how Artificial Intelligence (AI) and Machine Learning (ML) are being used in smart agriculture, especially for crop recommendation, crop-yield prediction, environmental monitoring, and explainable AI. Studies were selected because they relate to agricultural prediction or decision support. Each study was reviewed in terms of its application, techniques, main contributions, limitations, and relevance to farming conditions in the Konkan region. The findings were then compared to identify common limitations and gaps in existing research. These findings helped guide the development of the prototype decision-support approach.

III. LITERATURE REVIEW

A. Crop Recommendation Using Machine Learning (Scientific Reports, 2025)

Afzal et al. [1] studied how Machine Learning can support crop recommendation by using soil and other agricultural information. They compared models such as Random Forest, XGBoost, Multilayer Perceptron, Decision Tree, and Logistic Regression, and also explored an ensemble combining Random Forest and XGBoost. Their findings show that ML can help improve crop-selection decisions. However, the study is not specifically designed for Konkan farming and does not combine rainfall, crop-yield, and market-price information.

B. Plant Leaf Disease Detection Using Deep Learning (Scientific Reports, 2026)

Begum et al. [2] introduced a hybrid deep learning method for detecting plant leaf diseases using ResNet50, Principal Component Analysis (PCA), and Support Vector Machine (SVM). Their work uses image analysis to improve disease detection and shows how AI can support crop-health monitoring. However, disease detection is one specific agricultural task and does not provide combined decision support for rainfall, crop yield, and market conditions.

C. IoT and Edge Machine Learning in Agriculture (Scientific Reports, 2026)
Mekki et al. [3] examined Edge Machine Learning together with IoT-based environmental sensors for smart agriculture. Their study shows how environmental information can be collected and processed to support farm monitoring and decisions. However, these systems may need sensors, reliable connectivity, and other infrastructure, making them more complex to implement.

D. Secure Smart Farming Systems (Cluster Computing, 2026)
Patwal et al. [4] reviewed authentication methods for securing smart farming systems and discussed the security needs of agriculture systems that use connected technologies. Their work emphasizes the importance of protecting smart farming systems and data through proper authentication. However, the main focus is security, rather than combining agricultural predictions and decision support.

E. AI-Based Crop-Yield Prediction (Scientific Reports, 2025)
Dhanaraj et al. [5] studied lightweight AI models that can predict crop yield on smart agricultural devices. Their approach aims to make yield prediction more efficient in environments with limited computing resources. Although this can help with yield forecasting, the study mainly addresses yield prediction as a single task instead of offering a complete decision-support system.

F. Explainable AI for Crop Recommendation (Scientific Reports, 2025)
Shastri et al. [6] developed a crop recommendation method using supervised Machine Learning and Explainable Artificial Intelligence. Explainability helps users understand which factors influence a recommendation and may make AI-based agricultural systems easier to trust. However, the method is not specifically developed for the farming conditions of the Konkan region.

G. Mapping Recent Trends in Artificial Intelligence Research for Sustainable Agriculture
Pervez et al. [7] carried out a bibliometric and systematic review of 645 publications indexed in Scopus between 2010 and 2025 to examine recent trends in AI research for sustainable agriculture. They found that agricultural research using AI has grown considerably and identified key themes and emerging application areas. Their review shows the growing role of AI in sustainable, data-driven farming, while also highlighting the need for solutions that better reflect local needs. However, it reviews research trends broadly and does not present a farmer decision-support system specifically for Konkan agriculture.

H. ImMLPro Platform for Accessible Machine Learning and Statistical Analysis in Digital Agriculture and Beyond
Jeelani and Mansoor [8] introduced ImMLPro, a Shiny-based web platform that combines machine learning with statistical analysis to predict continuous values. It includes Random Forest, XGBoost, Support Vector Machines, and Neural Networks, along with model comparison, parameter tuning, visualizations, and result interpretation through an interactive interface. The

platform shows how accessible tools can help people without programming experience, as well as agricultural researchers, use predictive analytics. However, it is a general analysis platform rather than a decision-support system built specifically for Konkan farmers.

I. Interpretable Deep Learning Models for Independent Fertilizer and Crop Recommendation

Venkateswara and Padmanaban [9] developed an interpretable TabNet-based system for separate fertilizer and crop recommendations using agricultural data from Western Maharashtra. Their method combines iterative imputation, SMOTE for class balancing, TabNet classification, and SHAP-based explanations. Using five-fold cross-validation, they reported 96.21% accuracy for crop recommendation, showing the value of combining deep learning with explainable AI. However, their work mainly covers crop and fertilizer recommendations, rather than an integrated system that also considers yield, varieties, rainfall, and economic factors for Konkan farmers.

J. AI-Based Crop Health Monitoring and Predictive Analytics for Sustainable Crop Production

Mittal and Bhushan [10] reviewed how AI, remote sensing, and cloud computing can be used for sustainable crop production and crop-health monitoring. They discuss satellite and aerial images, smart sensors, cloud-based agricultural data systems, and AI prediction methods for tracking crop health and managing resources. They also describe challenges such as differences between data sources, false alarms, and difficulty interpreting models, and point to the need for robust AI systems that combine different types of information. However, their review covers crop-health monitoring and predictive analytics broadly and does not offer an integrated decision-support framework for the Konkan region.

IV. COMPARATIVE ANALYSIS

The studies reviewed show that Artificial Intelligence and Machine Learning can support several agricultural activities, including crop recommendation, crop-yield prediction, plant disease detection, environmental monitoring, security, and explainable decision-making. However, the studies vary in their goals, techniques, infrastructure needs, and suitability for different regions.

Afzal et al. [1] and Shastri et al. [6] focus mainly on crop recommendation, while Venkateswara and Padmanaban [9] add explainable deep learning for crop and fertilizer recommendations. Begum et al. [2] study plant disease detection using deep learning, whereas Mekki et al. [3] explore IoT and Edge Machine Learning for environmental monitoring. Dhanaraj et al. [5] examine crop-yield prediction with lightweight AI models, and Patwal et al. [4] focus on security and authentication in smart farming. Pervez et al. [7] and Mittal and Bhushan [10] review wider AI trends and predictive analytics in sustainable agriculture. Jeelani and Mansoor [8] present an accessible platform for machine learning and statistical analysis in digital agriculture.

Although these studies show that AI can be useful in agriculture, most focus on one task rather than offering farmers a combined decision-support system. Some approaches also rely on IoT devices, sensors, cloud infrastructure, or continuous connectivity. These requirements may make

implementation more difficult for small and marginal farmers. In addition, the studies give limited attention to the particular environmental and agricultural conditions of the Konkan region.

The comparison points to the need for a simple, integrated system designed for the Konkan region. Such a system could bring together crop recommendation, expected-yield estimation, crop-variety recommendation, environmental analysis, and economic information. This could make AI-based agricultural tools more practical and useful for farmers in the region.

Table I. Comparative Analysis of Reviewed Studies

Ref.	Application	Main Technique	Major Contribution	Major Limitation
[1]	Crop Recommendation	RF, XGBoost, MLP, DT, LR	Data-driven crop selection	Not Konkan-specific
[2]	Plant Disease Detection	ResNet50, PCA, SVM	Automated disease detection	Single-task focus
[3]	Environmental Monitoring	IoT + Edge ML	Environmental sensing and monitoring	Infrastructure dependency
[4]	Smart Farming Security	Authentication Framework	Security and privacy	Not focused on prediction
[5]	Crop-Yield Prediction	Lightweight AI	Efficient yield prediction	Individual task focus
[6]	Crop Recommendation	ML + XAI	Explainable crop recommendation	Not Konkan-specific
[7]	AI Trends in Agriculture	Bibliometric/Systematic Review	Identifies research trends	Does not provide a farmer system
[8]	Digital Agriculture Analytics	RF, XGBoost, SVM, NN	Accessible analytics platform	General-purpose platform
[9]	Crop/Fertilizer Recommendation	TabNet + SHAP	Interpretable recommendation	Limited agricultural scope
[10]	Crop Health and Predictive Analytics	AI + Remote Sensing + Cloud	Sustainable crop monitoring	Broad review, not region-specific

V. CHALLENGES AND RESEARCH GAP

Existing studies show that Machine Learning, Deep Learning, IoT, and predictive analytics can help improve agricultural decisions. However, some challenges still need to be addressed before these methods can be applied effectively to farming in the Konkan region.

One major challenge is the limited availability of agricultural systems designed specifically for the region. Many studies are based on general farming conditions and may not account for the Konkan region's local environment and crop-related needs.

Another issue is that current solutions are often separated by task. Most of the reviewed studies address only crop recommendation, plant disease detection, yield prediction, environmental monitoring, or security. As a result, they do not give farmers one platform for making related

decisions. Some systems also depend on IoT devices, sensors, and extra infrastructure. While these technologies can provide real-time environmental information, they may add complexity and require reliable connectivity.

Bringing data together and making it accessible are also important challenges. Agricultural information is often spread across different datasets and sources, which makes it difficult to combine environmental, production, variety, and economic details in one system.

VI. PROTOTYPE METHODOLOGY

A modular prototype of the proposed Farmer Decision Support System was developed using Python-based data processing, Machine Learning, Explainable AI, and rule-based analysis. It uses separate agricultural datasets for different decision-support tasks, processes each dataset for its intended purpose, and then presents the results to the farmer.

A. Data Preparation

Datasets related to crop conditions, historical crop yields, and crop varieties were collected and prepared for analysis. The data was checked for useful attributes, missing values, duplicate records, and consistency before being used for prediction.

B. Crop Recommendation

The Crop Recommendation module takes nitrogen (N), phosphorus (P), potassium (K), temperature, humidity, soil pH, and rainfall as inputs. Several classification algorithms, including Random Forest, Decision Tree, Support Vector Machine, and Logistic Regression, were trained and evaluated. The classifier with the best performance was selected to recommend a crop.

C. Explainable AI

SHAP (Shapley Additive explanations) was used with the selected Random Forest model to show how individual input features contribute to a crop prediction. This gives users an explanation for the recommendation instead of showing only the predicted crop.

D. Expected-Yield Estimation

The Expected Yield module uses a heuristic prediction method because the environmental dataset and historical-yield dataset do not contain directly matched observations. It compares the farmer's environmental conditions with the observed environmental profile of a crop using standardized similarity, then uses historical yield information to estimate expected yield.

E. Crop Variety Recommendation

The Crop Variety Recommendation module uses the available crop-variety dataset to identify varieties that may suit the recommended crop. It filters and ranks the available varieties using attributes such as duration, reported yield, growing conditions, and regional evidence.

VII. PROTOTYPE METHODOLOGY

A.Crop Recommendation

The Crop Recommendation module was built using an agricultural dataset containing nitrogen (N), phosphorus (P), potassium (K), temperature, humidity, soil pH, rainfall, and crop labels. After preprocessing, these input features were used to train and evaluate several classification algorithms: Random Forest, Decision Tree, Support Vector Machine (SVM), and Logistic Regression. The models were compared using standard classification measures, and the best-performing model was chosen for the final recommendation.

The selected model was connected to the farmer-input module so it could predict a suitable crop based on the conditions entered. SHAP-based Explainable AI was also applied to show how each input feature contributed to the crop prediction.

Table I. Performance comparison of classification models for crop recommendation

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)
SVM	99.86	99.87	99.86	99.86
Random Forest	100.00	100.00	100.00	100.00
Decision Tree	99.86	99.87	99.86	99.86
Logistic Regression	99.58	99.62	99.58	99.58

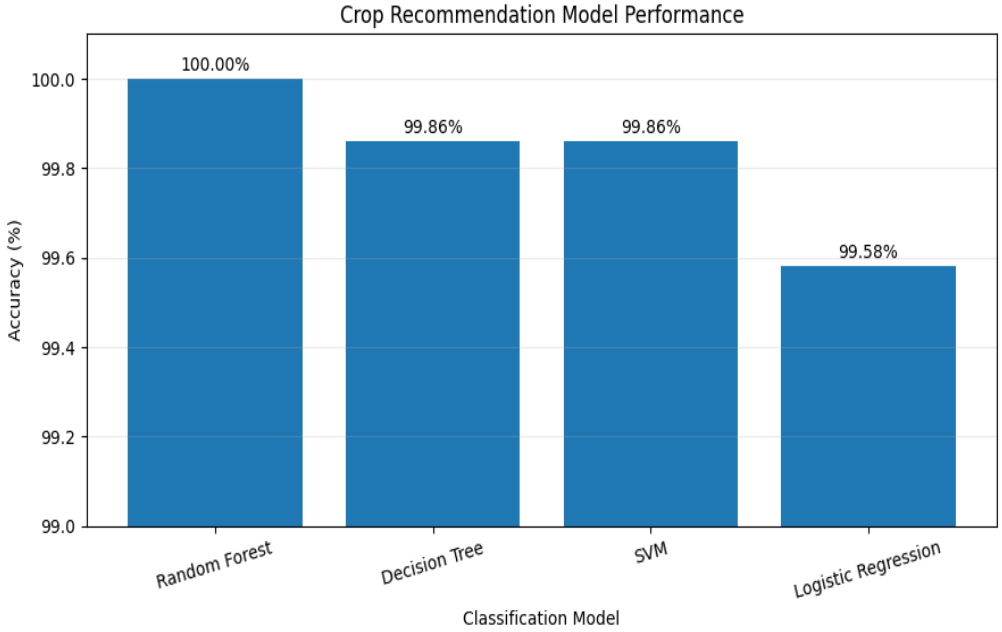


Fig. 1. Comparison of classification accuracy for crop recommendation models.

B. Expected-Yield Estimation

The Expected Yield module uses two agricultural datasets. The first contains environmental and crop information, including N, P, K, temperature, humidity, pH, and rainfall. The second contains

historical crop, year, production, area, and yield information. Because these datasets do not have environmental and yield observations matched directly to each other, they were not merged row by row for supervised regression.

Instead, the environmental dataset was used to describe the observed environmental profile for Rice, while the historical-yield dataset provided the historical yield distribution for Rice and Ragi (Nachani). In the heuristic approach, the conditions entered by the farmer are compared with the observed Rice environmental profile using standardized similarity. This similarity is then combined with historical yield statistics to estimate the expected yield.

The module also explains the estimated conditions by providing environmental suitability and confidence levels. This makes use of the available datasets without creating artificial records that appear to match environmental conditions with actual yields.

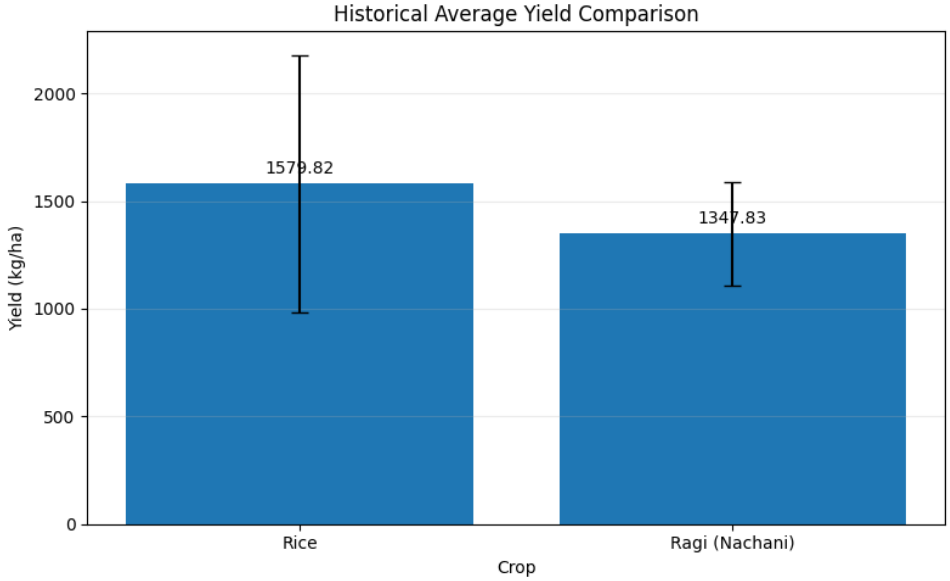


Fig. 2. Historical average yield comparison between Rice and Ragi (Nachani).

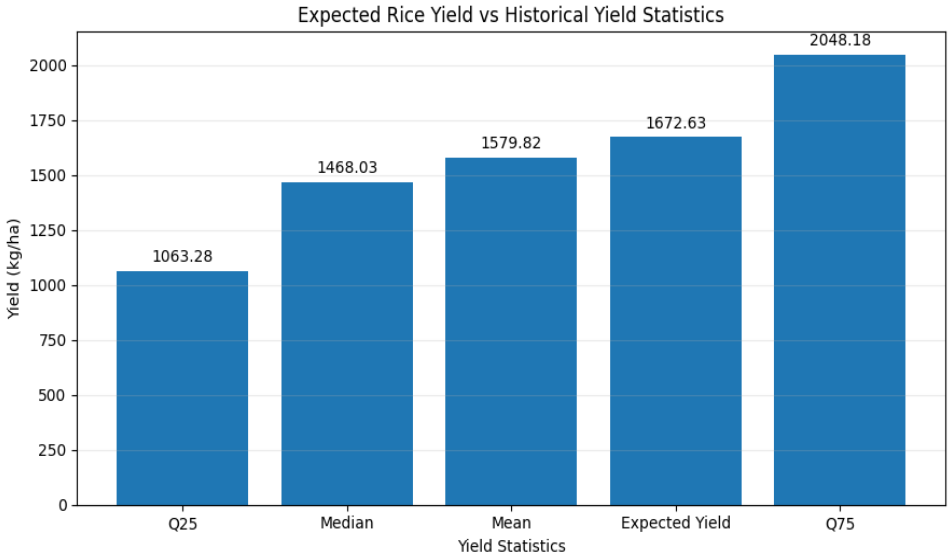


Fig. 3. Comparison of the estimated Rice yield with historical Rice yield statistics.

VIII. FUTURE DIRECTIONS

To improve AI-based smart farming systems, future work can develop predictive models that are more specific to the Konkan region by using rainfall patterns, soil characteristics, crop conditions, and historical agricultural data. The Expected Yield module could be improved by collecting environmental conditions matched with actual yield observations, allowing a supervised regression model to be trained. Rainfall prediction could also be strengthened with better weather datasets, improved features, and further model validation. A dependable Market/Mandi Price and Arrival module could be added using regularly updated market data to help farmers make cultivation and selling decisions.

The system could also be improved with explainable AI, multilingual and mobile-friendly interfaces, regularly updated datasets, and field testing with farmers and agricultural experts in Ratnagiri, Sindhudurg, and Palghar. Connecting it with reliable real-time weather and agricultural information sources may further improve its usefulness and ability to scale.

IX. CONCLUSION

Artificial Intelligence and Machine Learning can support agricultural decisions through crop recommendation, yield estimation, environmental analysis, variety selection, and economic assessment. The studies reviewed show the value of these technologies, but most existing methods deal with separate agricultural tasks instead of providing an integrated decision-support approach for the Konkan region.

This review highlights the need for a decision-support system that is designed for the region and its farmers, bringing different agricultural insights together in a clear and understandable way. Based on the research gap identified, a prototype was developed with Random Forest-based crop recommendation, SHAP-based Explainable AI, heuristic expected-yield estimation, crop-variety recommendation, and economic analysis.

The initial results show that the prototype is feasible, although the Rainfall Prediction module needs further improvement and the Market/Mandi module remains a future enhancement. Better regional datasets, testing in the field, and continued model improvement could make the system more reliable and support its practical use by Konkan farmers.

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