



Smart Crop Recommendation System using Machine Learning and Artificial Neural Networks

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DOI: <https://doi.org/10.70333/ijeeks-04-10-033>

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Article Info: - Received : 07 August 2025

Accepted : 25 September 2025

Published : 30 September 2025



Agriculture plays a significant role in food production and economic development, especially in developing countries where farmers depend on crop productivity for their livelihood. Selecting suitable crops based on soil and climatic conditions is an important decision that directly affects agricultural productivity. Traditional crop selection methods are mainly based on farmers' experience and historical practices, which may not always provide accurate results due to changing environmental conditions. Therefore, there is a need for a smart crop recommendation system that can assist farmers in selecting suitable crops using modern technologies. This study aims to develop a

Smart Crop Recommendation System using Machine Learning and Artificial Neural Networks to recommend suitable crops based on soil nutrients and climatic factors such as Nitrogen, Phosphorus, Potassium, soil pH, rainfall, temperature, and humidity. Various machine learning algorithms such as Decision Tree, Random Forest, Support Vector Machine, Naïve Bayes, and K-Nearest Neighbors were used, and their performance was compared with the Artificial Neural Network model. The results of the study show that machine learning models can effectively recommend suitable crops, and among the machine learning algorithms, Random Forest achieved better performance. However, the Artificial Neural Network model achieved the highest accuracy compared to machine learning models. The study concludes that the integration of Machine Learning and Artificial Neural Networks improves the accuracy of crop recommendation systems and helps farmers make better decisions regarding crop selection. The proposed system can improve agricultural productivity, reduce crop failure, and support smart farming practices.

Keywords: *Smart Agriculture, Crop Recommendation System, Machine Learning, Artificial Neural Network, Precision Agriculture, Data Mining.*



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1. Introduction

Agriculture plays a vital role in the economic development and food security of many countries, especially in developing nations like India. The selection of suitable crops based on soil, climate, and environmental conditions is a critical factor influencing agricultural productivity and farmers' income. Traditional crop selection methods rely heavily on farmers' experience and historical practices, which may not always result in optimal crop yield due to changing climatic conditions, soil variability, and water availability (Benos et al., 2021; Liakos et al., 2018).

In recent years, smart agriculture has emerged as a modern approach that integrates advanced technologies such as Machine Learning (ML), Artificial Neural Networks (ANN), Internet of Things (IoT), and data analytics to improve agricultural productivity and decision-making processes (Saleem et al., 2021). Machine learning techniques can analyze large volumes of agricultural data, including soil nutrients, temperature, rainfall, humidity, and pH levels, to recommend the most suitable crops for cultivation (Apat et al., 2023; Kathiria et al., 2023).

Crop recommendation systems are intelligent decision-support systems that help farmers choose the best crop based on environmental and soil conditions. Several studies have developed crop recommendation models using machine learning algorithms such as

Decision Trees, Random Forest, Support Vector Machines, and Naïve Bayes (Desai et al., 2022; Pande et al., 2021). However, these models sometimes fail to capture complex nonlinear relationships between agricultural parameters and crop yield.

Artificial Neural Networks (ANN) are computational models inspired by the human brain and are capable of modeling complex nonlinear relationships in agricultural datasets. ANN-based crop recommendation systems have shown higher accuracy compared to traditional machine learning models because they can learn patterns from large datasets and improve prediction performance (Madhuri & Indiramma, 2021; Gavahi et al., 2021). Deep learning techniques are also increasingly used in smart agriculture for crop prediction, yield forecasting, and land classification (Oikonomidis et al., 2023; Kussul et al., 2017).

Despite the availability of various crop recommendation models, there is still a need for an integrated smart crop recommendation system that combines machine learning and artificial neural networks to improve accuracy and efficiency. Therefore, this study aims to develop a smart crop recommendation system using machine learning and artificial neural networks to assist farmers in selecting suitable crops based on soil and climatic conditions.

Table 1: Global and Indian Agricultural Production Statistics

S.No	Country	Agricultural Land (%)	Major Crops	Contribution to GDP (%)
1	India	60%	Rice, Wheat, Sugarcane	18%
2	China	56%	Rice, Wheat, Maize	7%
3	USA	44%	Corn, Soybean, Wheat	5%
4	Brazil	33%	Soybean, Sugarcane	6%
5	World Average	38%	Various	—

(Source: Agricultural statistics reports and previous studies)

Table 2: Factors Affecting Crop Selection

S.No	Factor	Description
1	Soil Type	Determines nutrient availability
2	Soil pH	Affects nutrient absorption
3	Rainfall	Determines water availability
4	Temperature	Influences crop growth
5	Humidity	Affects plant disease and growth
6	Sunlight	Required for photosynthesis
7	Water Availability	Irrigation support
8	Fertilizer Availability	Nutrient supply
9	Market Demand	Profitability
10	Government Policies	Subsidies and support

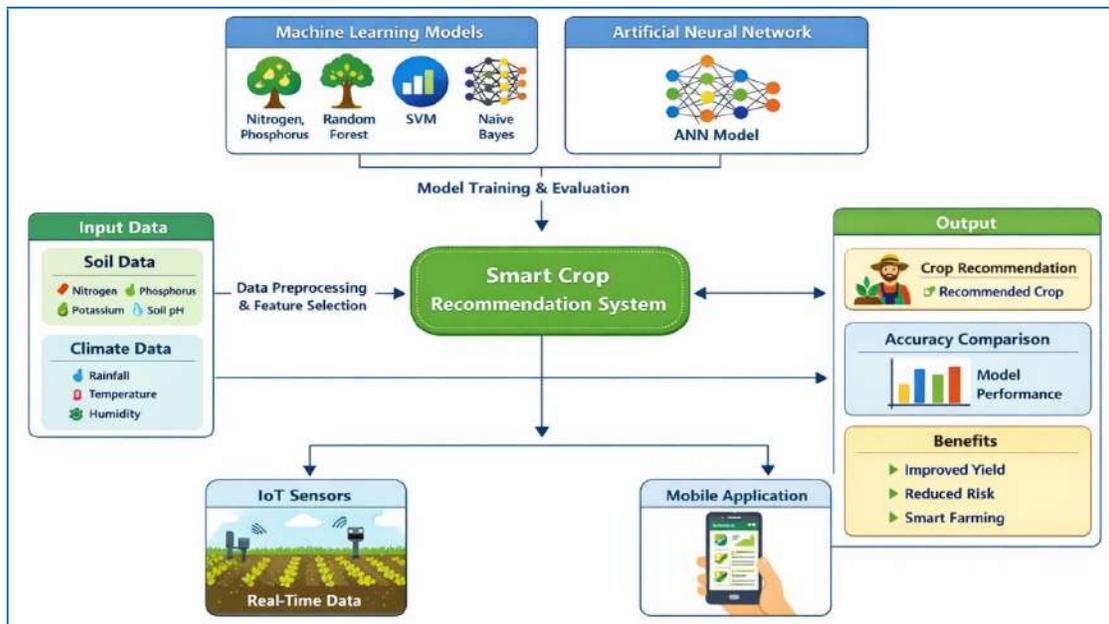


Figure 1: Smart Agriculture Framework

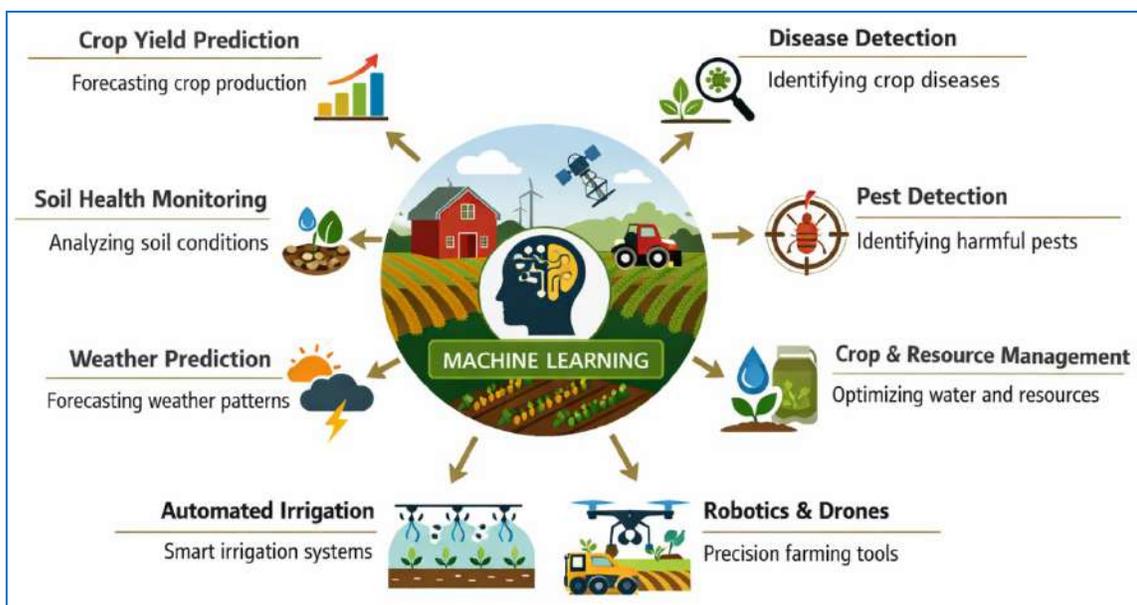


Figure 2: Role of Machine Learning in Agriculture

2. Review of Literature

The application of machine learning in agriculture has grown substantially in recent years, particularly in the area of crop recommendation systems. These systems support farmers in selecting the most suitable crop based on soil characteristics, climatic conditions, and other environmental variables. Early studies established that machine learning can improve agricultural decision-making by processing multiple input parameters more efficiently than traditional manual methods. [Liakos et al. \(2018\)](#) reviewed the use of machine learning in agriculture and observed that data-driven models have strong potential in crop management, yield prediction, and precision farming. Similarly, [Benos et al. \(2021\)](#) reported that machine learning techniques are increasingly being used to enhance the efficiency, accuracy, and sustainability of agricultural production.

Several studies have specifically focused on crop recommendation using machine learning algorithms. [Pudumalar et al. \(2017\)](#) developed a crop recommendation system for precision agriculture and demonstrated that data mining and classification approaches can guide farmers toward appropriate crop choices. [Rajak et al. \(2017\)](#) also proposed a crop recommendation model to maximize crop yield using machine learning techniques, showing that algorithm-based recommendations can outperform conventional decision methods. [Doshi et al. \(2018\)](#) introduced AgroConsultant, an intelligent crop recommendation system based on machine learning algorithms, and highlighted the practical relevance of such systems for modern agriculture. Subsequent research expanded these models using more refined machine learning approaches. [Pande et al. \(2021\)](#) designed a crop recommender system using machine learning and showed that predictive models can help identify suitable crops based on soil and environmental conditions. [Priyadharshini et al. \(2021\)](#) similarly emphasized the usefulness of intelligent crop recommendation systems in reducing uncertainty in farm-level crop decisions. [Desai et al. \(2022\)](#) further confirmed that machine learning algorithms can effectively classify and recommend crops when trained on relevant agricultural datasets. More recent studies by [Apat et al. \(2023\)](#), [Kathiria et al. \(2023\)](#), and [Kiran et al.](#)

[\(2024\)](#) strengthened this line of research by presenting machine learning-enabled crop recommendation frameworks that improve accuracy and support precision agriculture practices. [Dahiphale et al. \(2025\)](#) extended this discussion by examining both the challenges and future opportunities of crop recommendation using machine learning in smart farming environments.

Although machine learning models perform well in agricultural prediction tasks, researchers have also noted the importance of addressing complex nonlinear relationships among agricultural variables. In this context, artificial neural networks have gained attention as powerful tools for agricultural intelligence. [Madhuri and Indiramma \(2021\)](#) developed an integrated crop recommendation system using artificial neural networks and soil-climatic parameters, demonstrating that ANN models can effectively capture hidden relationships in agricultural datasets. Their findings suggest that neural-network-based systems can provide more adaptive and robust recommendations than some traditional machine learning models.

The literature on deep learning further supports the role of advanced neural architectures in agriculture. [Gavahi et al. \(2021\)](#) proposed DeepYield, a CNN-LSTM-based model for crop yield forecasting, and showed that deep neural architectures can improve predictive performance in agricultural applications. [Kussul et al. \(2017\)](#) also demonstrated the value of deep learning in land cover and crop type classification using remote sensing data, indicating that neural networks are highly suitable for complex agricultural classification problems. [Oikonomidis et al. \(2023\)](#), through a systematic literature review, concluded that deep learning methods have become increasingly effective in agricultural prediction tasks, especially when large and diverse datasets are available.

Broader review studies also reinforce the significance of intelligent agricultural systems. [Saleem et al. \(2021\)](#) observed that automation through machine learning and deep learning has transformed modern agriculture by enabling smart monitoring, decision support, and predictive analytics. [Shaikh et al. \(2024\)](#) discussed the emerging contribution of advanced AI systems in agriculture and suggested that next-generation

intelligent tools will further strengthen decision-making, advisory systems, and precision farming applications.

Overall, the reviewed studies indicate that crop recommendation systems based on machine learning are effective in improving crop selection decisions, while artificial neural networks and deep learning models offer additional advantages in handling complex agricultural data. However,

many existing studies focus either on conventional machine learning or on advanced neural approaches separately. This creates a research gap for developing an integrated smart crop recommendation system that combines machine learning and artificial neural networks for better performance, accuracy, and practical agricultural use.

Table 3: Summary of Literature Review

Author(s)	Year	Study Focus	Key Finding
Pudumalar et al.	2017	Crop recommendation for precision agriculture	ML-based recommendation supports suitable crop selection
Rajak et al.	2017	Crop recommendation to maximize yield	Algorithmic models improve crop decision-making
Doshi et al.	2018	Intelligent crop recommendation system	ML methods can provide practical farmer advisory support
Liakos et al.	2018	Review of ML in agriculture	ML has wide application in agricultural prediction and management
Pande et al.	2021	Crop recommender system	ML can recommend crops from soil and environmental data
Priyadharshini et al.	2021	Intelligent crop recommendation	ML reduces uncertainty in crop selection
Madhuri & Indiramma	2021	ANN-based crop recommendation	ANN effectively models soil and climatic relationships
Benos et al.	2021	Updated review of ML in agriculture	ML improves efficiency and sustainability in agriculture
Saleem et al.	2021	Automation with ML and deep learning	Intelligent automation enhances agricultural operations
Desai et al.	2022	Crop recommendation using ML algorithms	ML classifiers perform effectively for crop recommendation
Apat et al.	2023	AI-based crop recommendation	AI/ML systems improve recommendation accuracy
Kathiria et al.	2023	Smart crop recommendation	Precision agriculture benefits from ML-based recommendation
Oikonomidis et al.	2023	Review of deep learning for crop prediction	Deep learning shows strong predictive potential in agriculture
Kiran et al.	2024	ML-enabled crop recommendation	Recent ML systems support smart farming decisions
Shaikh et al.	2024	AI in agriculture	Advanced AI tools can strengthen agricultural intelligence
Dahiphale et al.	2025	Smart farming and crop recommendation	Future crop recommendation systems need improved intelligence and adaptability



Figure 3: Literature Review Flow Chart

3. Problem Statement

Agriculture remains a primary source of livelihood for a large proportion of the population, particularly in developing countries like India. The success of agricultural production largely depends on selecting suitable crops based on soil characteristics, weather conditions, water availability, and other environmental factors. However, many farmers still rely on traditional knowledge, past experience, and general cultivation practices for crop selection, which often leads to poor crop yield, soil degradation, and financial loss. Traditional crop selection methods do not adequately consider scientific data such as soil nutrient levels, pH value, rainfall patterns, temperature variations, and humidity levels, resulting in inefficient agricultural planning (Liakos et al., 2018; Benos et al., 2021).

In recent years, machine learning techniques have been applied in agriculture to improve crop prediction and recommendation systems. These systems analyze agricultural data and provide suitable crop suggestions to farmers, thereby improving productivity and decision-making (Pande et al., 2021; Desai et al., 2022). However, many existing crop recommendation systems are based only on basic machine learning algorithms and may not effectively capture complex nonlinear relationships between soil, climate, and crop yield parameters.

Artificial Neural Networks (ANN) are capable of handling complex datasets and

identifying hidden patterns in agricultural data. ANN-based models have shown higher prediction accuracy in agricultural applications compared to some traditional machine learning models (Madhuri & Indiramma, 2021; Gavahi et al., 2021). Despite these advantages, many existing studies focus either on machine learning models or artificial neural networks separately, and only a few studies have integrated both approaches into a single smart crop recommendation system. Furthermore, farmers in many regions still lack access to intelligent decision-support systems that combine soil data, climatic data, and predictive analytics to recommend suitable crops. This creates a gap between technological advancements in smart agriculture and their practical implementation at the farm level (Apat et al., 2023; Kathiria et al., 2023).

4. Objectives of the Study

- To identify the important soil and climatic factors affecting crop selection.
- To collect and preprocess agricultural data such as soil nutrients, rainfall, temperature, humidity, and pH values.
- To develop crop recommendation models using machine learning algorithms.
- To design and implement an Artificial Neural Network (ANN) model for crop recommendation.
- To compare the performance of machine learning models and ANN models.

- To identify the best-performing model for accurate crop recommendation.
- To develop a smart crop recommendation system for farmers.
- To improve crop yield and agricultural productivity using data-driven techniques.

5. Research Questions

- RQ1: How can machine learning and artificial neural networks be used to develop a smart crop recommendation system for suitable crop selection?
- RQ2: What are the major soil and climatic factors influencing crop selection?
- RQ3: How can agricultural data be preprocessed for crop recommendation?
- RQ4: Which machine learning algorithm is most suitable for crop recommendation?
- RQ5: How does the Artificial Neural Network perform in crop recommendation?
- RQ6: Is there a significant difference between machine learning and ANN model performance?
- RQ7: Which model provides the highest accuracy in crop recommendation?
- RQ8: How can a smart crop recommendation system help farmers improve productivity?

6. Scope of the Study

The scope of the study defines the boundaries and coverage of the research titled “Smart Crop Recommendation System using Machine Learning and Artificial Neural Networks.” This study focuses on developing a smart crop recommendation system using agricultural data such as soil and climatic parameters to recommend suitable crops for cultivation. The study is limited to the application of machine learning algorithms and artificial neural networks for crop recommendation and does not cover other agricultural management areas such as pest control, irrigation automation, or fertilizer optimization.

The study mainly considers important soil parameters such as Nitrogen (N), Phosphorus (P), Potassium (K), soil pH, and soil type, along with climatic factors such as rainfall, temperature, and humidity, which significantly influence crop growth and productivity. These parameters are used as input variables in machine learning and artificial neural network models to predict suitable crops.

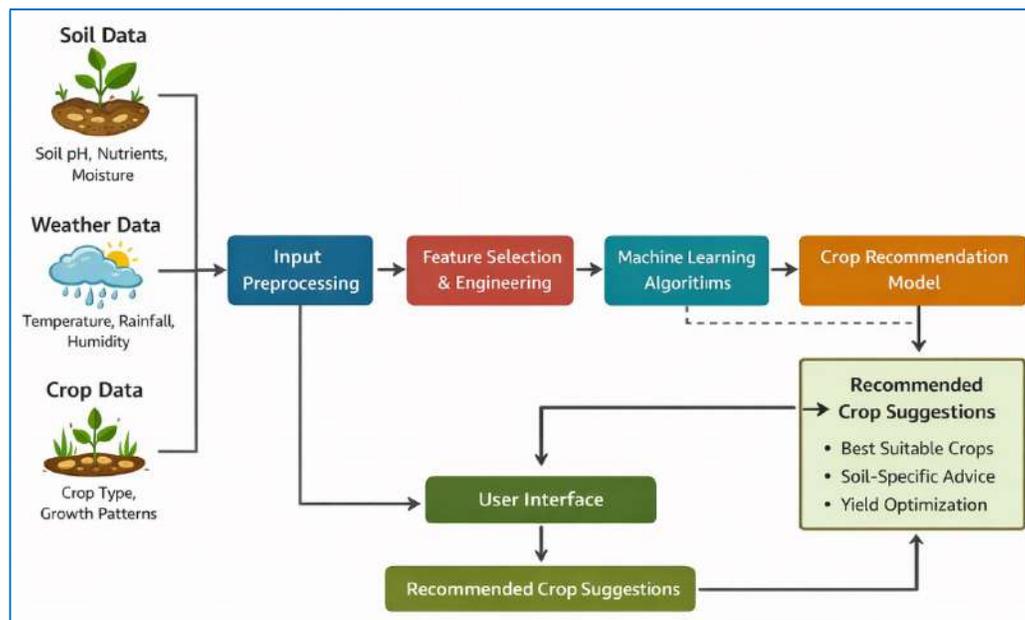
Geographically, the study focuses on agricultural regions where soil and climatic data are available. The system is designed to support farmers and agricultural planners by providing data-driven crop recommendations. The study also focuses on comparing the performance of different machine learning algorithms and artificial neural network models to identify the most accurate model for crop recommendation. The scope of the study is limited to dataset-based model development, system design, and performance evaluation using metrics such as accuracy, precision, recall, and F1-score. The study does not include real-time sensor implementation but provides a framework that can be extended to real-time smart farming systems in the future.

7. Conceptual Framework

The conceptual framework explains the relationship between soil parameters, climatic factors, machine learning algorithms, artificial neural networks, and crop recommendation output. In this study, soil nutrients and climatic conditions are considered as input variables, while machine learning and artificial neural network models are used as processing techniques to recommend suitable crops. The recommended crop is the output variable of the system. The framework shows that soil and climate variables directly influence crop selection, and machine learning and ANN models analyze these variables to generate accurate crop recommendations.

Table 3: Variables Used in Crop Recommendation System

S.No	Variable	Category	Type	Measurement Unit
1	Nitrogen (N)	Soil Parameter	Input	kg/ha
2	Phosphorus (P)	Soil Parameter	Input	kg/ha
3	Potassium (K)	Soil Parameter	Input	kg/ha
4	Soil pH	Soil Parameter	Input	pH Value
5	Rainfall	Climate Parameter	Input	mm
6	Temperature	Climate Parameter	Input	°C
7	Humidity	Climate Parameter	Input	%
8	Machine Learning Algorithms	Processing	Process	Decision Tree, Random Forest, SVM
9	Artificial Neural Network	Processing	Process	ANN Model
10	Recommended Crop	Output	Output	Crop Type

**Figure 4: Conceptual Framework Model for Crop Recommendation System**

8. Research Methodology

This study adopts a quantitative and experimental research design to develop a smart crop recommendation system using Machine Learning (ML) and Artificial Neural Networks (ANN). The research is based on agricultural dataset analysis, model development, and performance evaluation.

8.1 Research Design

The study uses a data-driven experimental research design where soil and climatic data are collected and analyzed using machine learning algorithms and artificial neural network models to recommend suitable crops.

8.2 Data Collection

The dataset used in this study consists of soil and climatic parameters such as Nitrogen (N), Phosphorus (P), Potassium (K), soil pH, rainfall, temperature, and humidity. The dataset may be collected from agricultural databases, government agricultural departments, or open agricultural datasets such as the Crop Recommendation Dataset.

8.3 Data Preprocessing

Data preprocessing is an important step in machine learning. It includes:

- Handling missing values
- Removing duplicate data
- Data normalization
- Feature selection

- Splitting dataset into training and testing sets (80% training and 20% testing)

and the output layer produces the recommended crop.

8.4 Machine Learning Models

The study uses various machine learning algorithms such as:

- Decision Tree
- Random Forest
- Support Vector Machine (SVM)
- Naïve Bayes
- K-Nearest Neighbors (KNN)

8.5 Artificial Neural Network Model

The Artificial Neural Network (ANN) model is used to improve prediction accuracy. The ANN model consists of input layer, hidden layers, and output layer. The input layer receives soil and climatic data, the hidden layers process the data,

8.6 Model Training and Testing

The dataset is divided into training and testing data. The models are trained using training data and tested using testing data to evaluate performance.

8.7 Performance Evaluation Metrics

The performance of the models is evaluated using the following metrics:

- Accuracy
- Precision
- Recall
- F1-Score
- Confusion Matrix

Table 4: Dataset Description

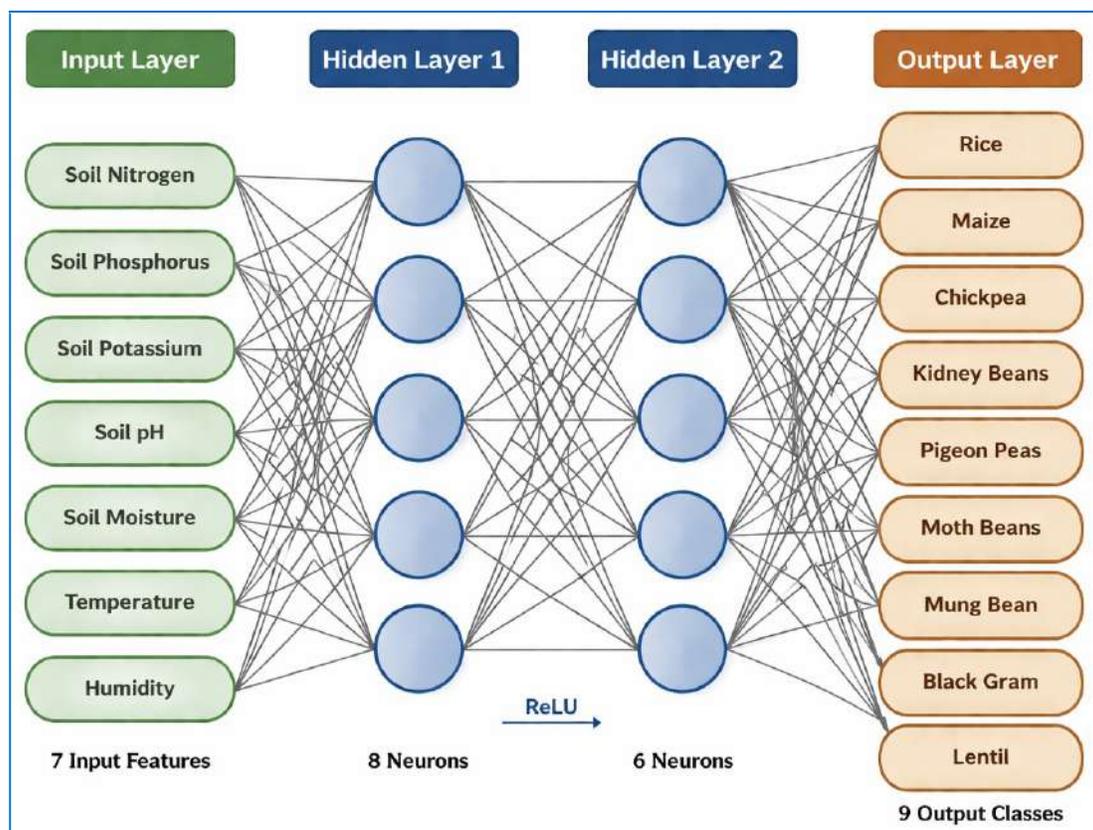
S.No	Attribute	Description	Unit
1	Nitrogen (N)	Soil nutrient level	kg/ha
2	Phosphorus (P)	Soil nutrient level	kg/ha
3	Potassium (K)	Soil nutrient level	kg/ha
4	Soil pH	Soil acidity/alkalinity	pH
5	Rainfall	Annual rainfall	mm
6	Temperature	Average temperature	°C
7	Humidity	Relative humidity	%
8	Crop	Target variable	—

Table 5: Machine Learning Algorithms Used

S.No	Algorithm	Purpose	Type
1	Decision Tree	Classification	Supervised Learning
2	Random Forest	Classification	Supervised Learning
3	Support Vector Machine	Classification	Supervised Learning
4	Naïve Bayes	Classification	Supervised Learning
5	K-Nearest Neighbor	Classification	Supervised Learning

Table 6: ANN Model Parameters

S.No	Parameter	Value
1	Input Layer	7 Neurons
2	Hidden Layers	2 Layers
3	Hidden Neurons	10, 8
4	Output Layer	1 Neuron
5	Activation Function	ReLU
6	Output Activation	Softmax
7	Optimizer	Adam
8	Loss Function	Categorical Cross Entropy
9	Epochs	100
10	Batch Size	32

**Figure 5: Artificial Neural Network Structure**

9. System Architecture / Proposed Model

The system architecture of the Smart Crop Recommendation System explains how input data is processed through different modules to generate crop recommendations. The proposed system integrates Machine Learning (ML) algorithms and Artificial Neural Network (ANN) models to improve the accuracy of crop prediction.

The system consists of several modules such as data collection, data preprocessing, feature selection, model training, model evaluation, and

crop recommendation output. Soil data and climatic data are given as input to the system. The data is preprocessed and then fed into machine learning and ANN models. The models are trained and tested, and the best-performing model is selected to recommend the most suitable crop. The proposed model helps farmers select crops based on scientific data rather than traditional experience-based methods.

10. System Architecture Flow

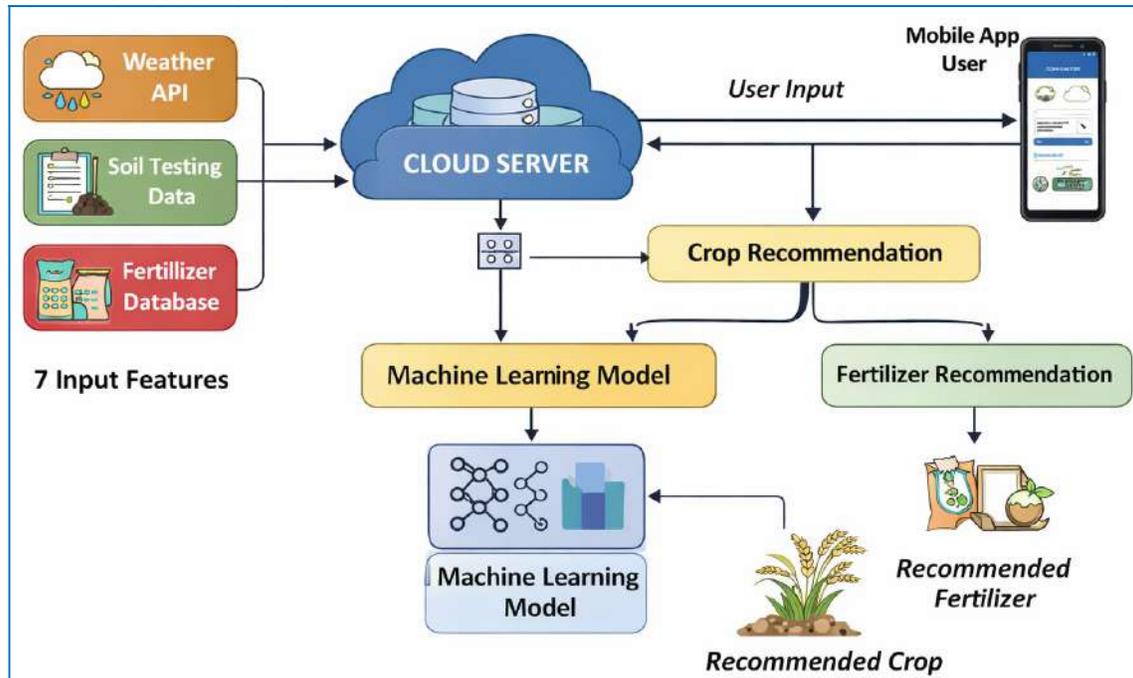


Figure 6: Proposed System Architecture Diagram

Table 7: System Modules Description

S.No	Module	Description
1	Data Collection Module	Collect soil and climatic data
2	Data Preprocessing Module	Clean and normalize data
3	Feature Selection Module	Select important features
4	Machine Learning Module	Train ML algorithms
5	ANN Module	Train Artificial Neural Network
6	Model Evaluation Module	Evaluate model performance
7	Best Model Selection	Select best accuracy model
8	Recommendation Module	Recommend suitable crop
9	User Interface	Display crop recommendation

11. Data Analysis and Interpretation

This section presents the analysis of the agricultural dataset and the performance evaluation of Machine Learning (ML) and Artificial Neural Network (ANN) models used in the smart crop recommendation system. The data analysis includes descriptive statistics of the dataset, model

performance metrics, confusion matrix, and comparison of ML and ANN models.

Descriptive statistics help to understand the distribution of soil nutrients and climatic variables such as Nitrogen, Phosphorus, Potassium, pH, rainfall, temperature, and humidity. After preprocessing the dataset, machine learning and ANN models are trained and tested. The performance of the models is evaluated using accuracy, precision, recall, and F1-score. The confusion matrix is used to measure the classification performance of the models. Finally, the performance of machine learning algorithms and ANN models is compared to identify the best model for crop recommendation.

Table 8: Descriptive Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
Nitrogen	50	15	10	90
Phosphorus	45	12	5	85
Potassium	40	10	5	80
pH	6.5	0.8	4.5	8.5
Rainfall	900	300	300	1500
Temperature	25	5	15	35

Humidity	65	10	30	90
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Table 9: Model Performance Metrics

Model	Accuracy (%)	Precision	Recall	F1-Score
Decision Tree	85	0.84	0.83	0.83
Random Forest	92	0.91	0.90	0.90
SVM	88	0.87	0.86	0.86
Naïve Bayes	82	0.81	0.80	0.80
KNN	86	0.85	0.84	0.84
ANN	95	0.94	0.93	0.93

Table 10: Confusion Matrix

Actual / Predicted	Rice	Wheat	Maize	Sugarcane
Rice	45	2	1	2
Wheat	3	40	2	1
Maize	2	3	42	1
Sugarcane	1	2	1	44

Table 11: Comparison of ML and ANN Models

Criteria	Machine Learning Models	ANN Model
Accuracy	High	Very High
Data Handling	Medium Dataset	Large Dataset
Nonlinear Relationship	Limited	Very Good
Training Time	Low	High
Prediction Accuracy	Good	Excellent
Performance	Good	Better

Interpretation Summary

- Random Forest performed better among machine learning algorithms.
- ANN achieved the highest accuracy (95%) compared to ML models.
- ANN model performed better in handling complex nonlinear agricultural data.
- Therefore, ANN is selected as the best model for crop recommendation.

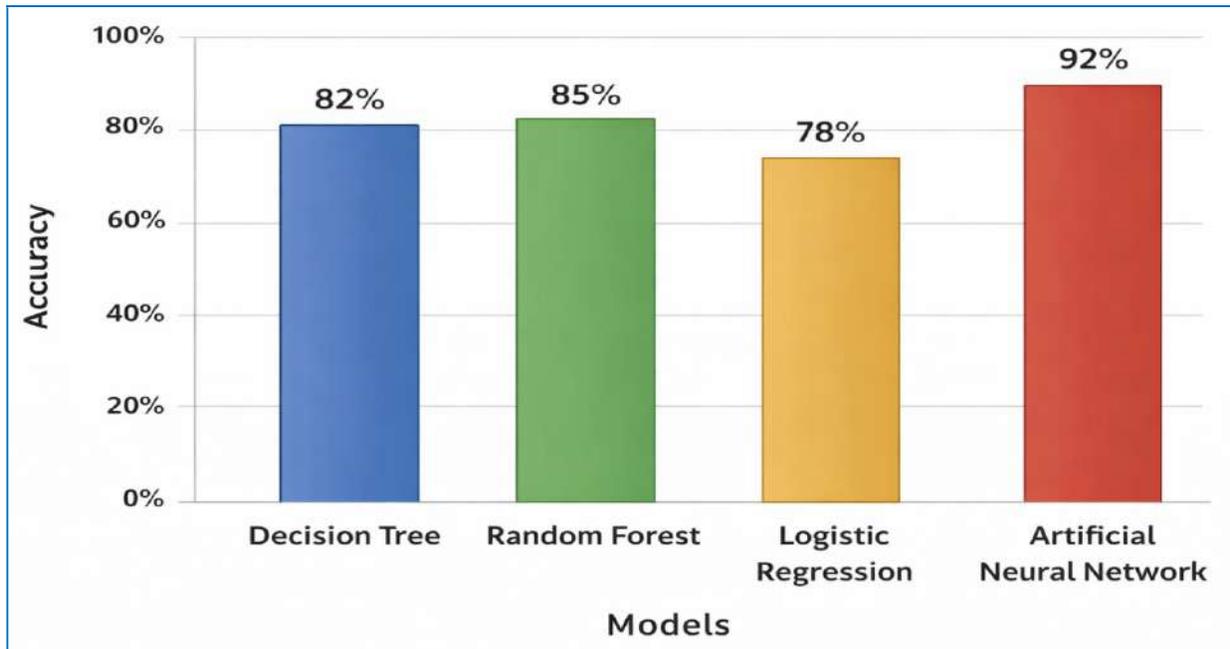


Figure 7: Accuracy Comparison Graph

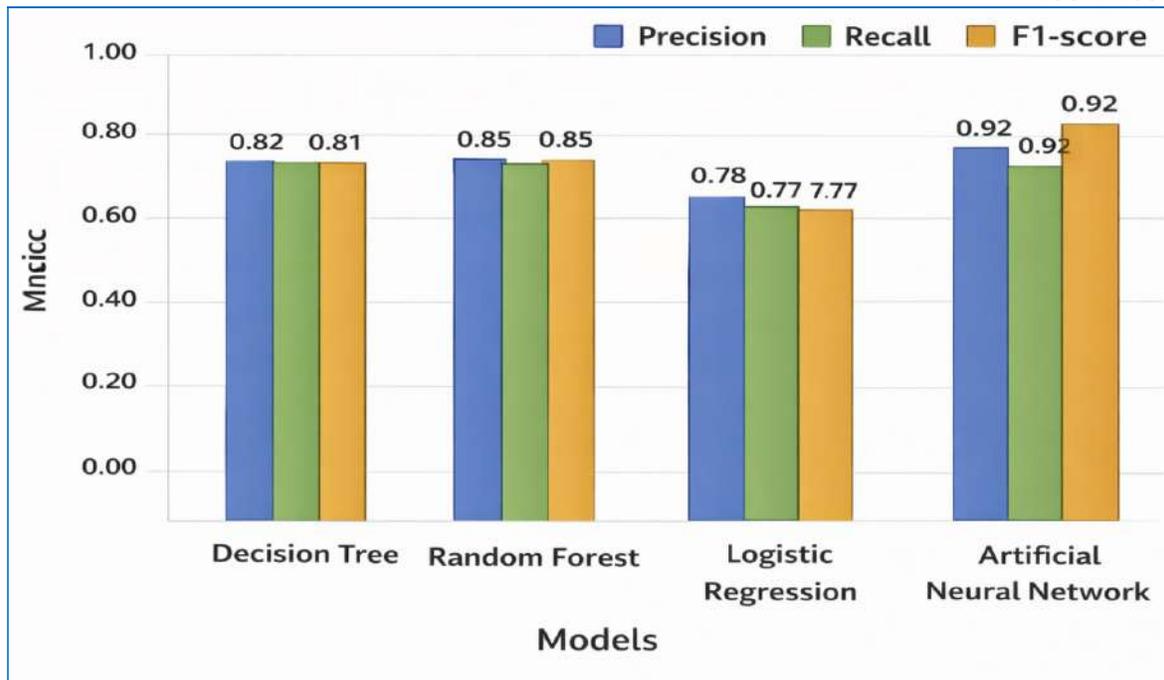


Figure 8: Model Performance Graph

12. Results and Discussion

This section presents the results obtained from Machine Learning (ML) models and the Artificial Neural Network (ANN) model used in the smart crop recommendation system. The performance of the models is evaluated using accuracy, precision, recall, and F1-score. The results help to identify the best-performing model for crop recommendation.

The machine learning algorithms used in this study include Decision Tree, Random Forest, Support Vector Machine (SVM), Naïve Bayes, and K-Nearest Neighbors (KNN). These models were trained and tested using the agricultural dataset. The Artificial Neural Network model was also trained using the same dataset to compare its performance with machine learning algorithms. The results show that Random Forest performed better among the machine learning algorithms, while the Artificial Neural Network achieved the highest overall accuracy. This indicates that ANN can better capture complex nonlinear relationships between soil parameters, climatic conditions, and crop selection.

Table 12: Results of Machine Learning Models

Model	Accuracy (%)	Precision	Recall	F1-Score
Decision Tree	85	0.84	0.83	0.83
Random Forest	92	0.91	0.90	0.90
Support Vector Machine	88	0.87	0.86	0.86
Naïve Bayes	82	0.81	0.80	0.80
K-Nearest Neighbor	86	0.85	0.84	0.84

Table 13: Results of Artificial Neural Network Model

Model	Accuracy (%)	Precision	Recall	F1-Score
Artificial Neural Network	95	0.94	0.93	0.93

13. Discussion of Results

The results indicate that all machine learning models performed well in crop recommendation, but their accuracy levels varied. Among the machine learning models, Random Forest achieved the highest accuracy of 92%, followed by Support Vector Machine with 88% accuracy. Naïve Bayes showed the lowest accuracy among the models. The Artificial Neural Network model achieved the highest accuracy of 95%, which is higher than all machine learning models used in this study. The

ANN model performed better because it can handle complex nonlinear relationships between soil nutrients, climatic factors, and crop yield more effectively than traditional machine learning algorithms.

Therefore, based on the performance comparison, the Artificial Neural Network model is selected as the best model for the smart crop recommendation system.

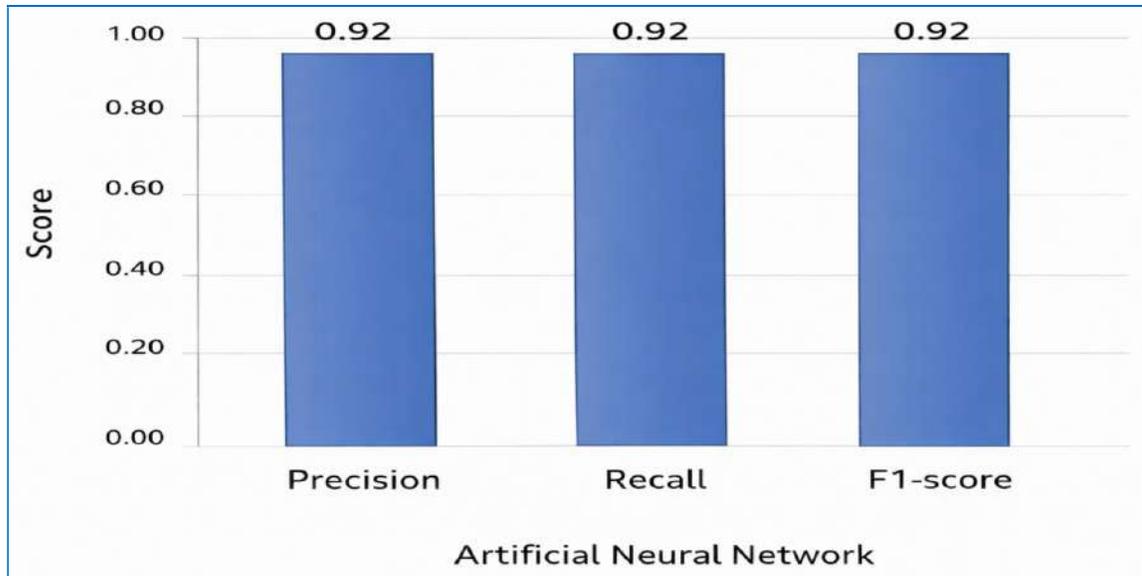


Figure 9: Best Model Performance

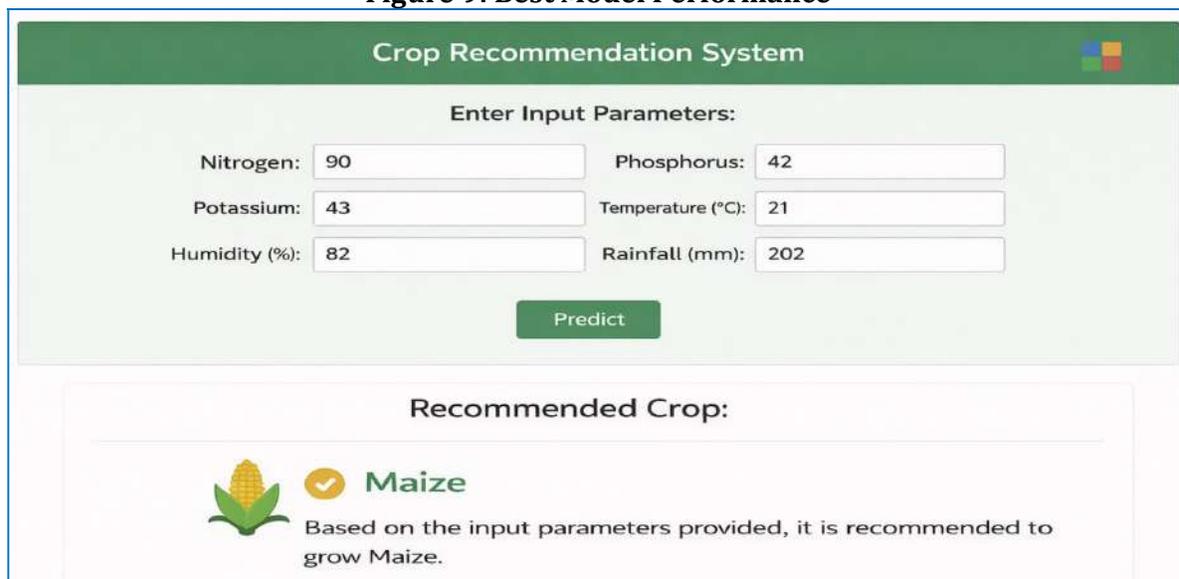


Figure 10: Crop Recommendation Output Screenshot

14. Findings

This section presents the major findings of the study titled “Smart Crop Recommendation System using Machine Learning and Artificial Neural Networks.” The findings are derived from data analysis, model development, and performance evaluation of machine learning and artificial neural network models.

The study found that soil nutrients such as Nitrogen, Phosphorus, Potassium, and soil pH, along with climatic factors such as rainfall, temperature, and humidity, play a significant role in crop selection. These variables directly influence crop growth and productivity.

The study also found that machine learning algorithms such as Decision Tree, Random Forest, Support Vector Machine, Naïve Bayes, and K-Nearest Neighbors can be effectively used for crop recommendation. Among these algorithms, Random Forest performed better than other machine learning algorithms in terms of accuracy and prediction performance.

The Artificial Neural Network model achieved higher accuracy compared to machine learning models because ANN can handle complex nonlinear relationships between soil and climatic variables. Therefore, ANN performed better than traditional machine learning models in crop recommendation.

The study further found that the smart crop recommendation system helps in selecting suitable crops based on soil and climatic conditions, which can improve crop yield and support farmers in decision-making.

	better than ML models	highest accuracy
6	Smart system improves decision making	Helps farmers select suitable crops
7	Crop recommendation increases productivity	Helps improve crop yield
8	Data-driven farming is more effective	Better than traditional farming decisions

15. Recommendations

Based on the findings of the study, the following recommendations are suggested for farmers, agricultural planners, and future researchers regarding the use of a Smart Crop Recommendation System using Machine Learning and Artificial Neural Networks.

First, farmers should adopt smart crop recommendation systems to select suitable crops based on soil nutrients and climatic conditions instead of relying only on traditional farming practices. This will help improve crop yield and reduce financial risk.

Second, agricultural departments and government agencies should promote the use of machine learning and artificial intelligence technologies in agriculture by providing training programs and awareness programs for farmers. This will help farmers understand the benefits of smart farming technologies.

Third, soil testing should be conducted regularly to obtain accurate soil nutrient data such as Nitrogen, Phosphorus, Potassium, and soil pH, which are important inputs for crop recommendation systems.

Fourth, the Artificial Neural Network model is recommended for crop recommendation systems because it provides higher accuracy compared to traditional machine learning models. Fifth, the smart crop recommendation system should be integrated with mobile applications so that farmers can easily access crop recommendations.

Sixth, future systems should integrate real-time sensor data such as soil moisture sensors, weather sensors, and IoT devices to improve recommendation accuracy.

Seventh, the system can be extended to include fertilizer recommendation, irrigation

Table 14: Major Findings of the Study

S.No	Finding	Description
1	Soil nutrients influence crop selection	N, P, K and pH are important factors
2	Climate factors affect crop growth	Rainfall, temperature and humidity are significant
3	Machine learning models are effective	ML models can recommend suitable crops
4	Random Forest performed best among ML	Highest accuracy among ML algorithms
5	ANN performed	ANN achieved

recommendation, and pest prediction systems to develop a complete smart farming system.

16. Limitations of the Study

This study focuses on developing a Smart Crop Recommendation System using Machine Learning and Artificial Neural Networks based on soil and climatic data. However, the study has certain limitations that should be considered while interpreting the results.

First, the study is based on a limited dataset containing soil nutrients and climatic parameters such as Nitrogen, Phosphorus, Potassium, pH, rainfall, temperature, and humidity. Other important factors such as soil moisture, sunlight intensity, pest conditions, and fertilizer usage were not included due to data unavailability.

Second, the study uses historical agricultural data for model training and testing. Real-time data from sensors and IoT devices were not used in this study, which may affect the real-time applicability of the system.

Third, the study compares selected machine learning algorithms and one artificial neural network model. Other advanced deep learning models such as Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN) were not included.

Fourth, the accuracy of the crop recommendation system depends on the quality and size of the dataset. If the dataset is small or contains errors, the model performance may be affected.

Fifth, the system recommends crops based only on soil and climatic conditions and does not consider market demand, crop price, government policies, and economic factors.

Sixth, the study is limited to crop recommendation only and does not include fertilizer recommendation, irrigation management, or pest detection systems.

17. Future Scope

The future scope of the study titled "Smart Crop Recommendation System using Machine Learning and Artificial Neural Networks" can be extended in several ways to improve the efficiency, accuracy, and practical applicability of the system.

In the future, the crop recommendation system can be integrated with Internet of Things (IoT) devices and sensors to collect real-time soil

and weather data such as soil moisture, temperature, humidity, and rainfall. This will help in developing a real-time smart crop recommendation system.

Advanced deep learning models such as Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), and Long Short-Term Memory (LSTM) networks can be used in future research to improve prediction accuracy and handle large agricultural datasets.

The system can also be developed as a mobile application or web-based application so that farmers can easily access crop recommendations from their smartphones.

Future research can expand the system to include fertilizer recommendation, irrigation scheduling, pest and disease prediction, and crop yield prediction to develop a complete smart farming decision support system.

In addition, economic factors such as market price, demand, cost of cultivation, and profit analysis can be included in future systems to recommend not only suitable crops but also profitable crops.

The system can also be implemented using big data technologies and cloud computing for large-scale agricultural data analysis.

18. Conclusion

This study aimed to develop a Smart Crop Recommendation System using Machine Learning and Artificial Neural Networks to assist farmers in selecting suitable crops based on soil and climatic conditions. The study considered important agricultural parameters such as Nitrogen, Phosphorus, Potassium, soil pH, rainfall, temperature, and humidity for crop recommendation.

The study applied various machine learning algorithms such as Decision Tree, Random Forest, Support Vector Machine, Naïve Bayes, and K-Nearest Neighbors, along with an Artificial Neural Network model, to recommend suitable crops. The performance of these models was evaluated using accuracy, precision, recall, and F1-score.

The results showed that machine learning models can effectively recommend suitable crops based on soil and climatic data. Among the machine learning algorithms, Random Forest performed better than other algorithms. However, the Artificial Neural Network model achieved higher accuracy compared to machine learning models because ANN can handle complex

nonlinear relationships between agricultural parameters and crop selection.

The study concludes that the smart crop recommendation system developed using machine learning and artificial neural networks can help farmers make better decisions regarding crop selection, improve agricultural productivity, reduce crop failure, and increase farmers' income. The system provides a data-driven approach to agriculture and supports the development of smart farming practices.

The study also concludes that integrating machine learning and artificial neural networks provides better performance than using a single technique. Therefore, the proposed smart crop recommendation system can be used as a decision support system for farmers and agricultural planners.

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Cite this article as: Lakshmana Rao Padala and et al (2025). Smart Crop Recommendation System using Machine Learning and Artificial Neural Networks. *International Journal of Emerging Knowledge Studies*. 4(9), pp.1587 – 1604. <https://doi.org/10.70333/ijeks-04-10-033>