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Smart Farming Using Machine Learning: A Concise Review

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Abstract: Agriculture is the primary source of food for the global population. It provides essential nutrients and sustenance for billions of people worldwide. Without agriculture, there would be no reliable food supply, leading to hunger and malnutrition. Agriculture plays a significant role in the economy, source of Raw Materials, Biodiversity and Ecosystem Services etc. This paper explores the Real-World uses of Machine Learning (ML) in sustainable agriculture to confront the difficulties of a growing global population and climate change. With traditional methods suffering from reduced effectiveness due to changing climate patterns and rising food demands, ML offers a data-centric approach to revolutionize crop management. The study investigates ML algorithms such as neural networks, support vector machines, decision trees, and ensemble models to analyze key factors like soil quality, climate conditions, and past crop performance. The aim is to optimize crop selection for specific regions, resulting in higher yields and reduced environmental impact.

Keywords*:* Smart Farming, Crop Yield Prediction, Soil Fertility Assessment, Machine Learning, AI Applications, IoT Applications

I. INTRODUCTION

Smart farming, widely recognized as precision agriculture, refers to Leveraging modern technologies like the Internet of Things (IoT) and Artificial Intelligence (AI), Machine Learning (ML), drones, sensors, and big data analytics to optimize farming practices. It involves the collection and analysis of real-time data from farms to make informed decisions that improve crop yields, reduce resource usage, and enhance sustainability.

Smart farming seeks to improve the efficiency and productivity of agricultural practices while minimizing environmental impact. With rising global population and the impact of climate change on conventional farming, smart farming introduces advanced solutions to address these challenges.

In smart farming we use Machine Learning (ML) algorithms, particularly for crop selection and cultivation, to tackle the challenges of a growing global population and climate change. Traditional methods are becoming less effective due to shifting climate patterns and increasing demand for food. The various ML algorithms including neural networks, decision trees, and ensemble models, to analyse factors like soil quality, climate conditions, and historical crop performance. The objective is to optimize crop selection for specific regions, improving yields and minimizing environmental impact.

Various related work has been studied to understand the significance of existing research work being already carried out towards Smart Farming. P. Suresh et al. introduces the Support Tree Algae Algorithm (STAA), a machine learning-based solution for smart irrigation that accurately predicts soil moisture. By integrating the SVM Support Vector Machine and DT Decision Tree classifiers with Artificial Algae Optimization, STAA overcomes the limitations of traditional methods like Random Forest (RF), Fuzzy Logic, and K-Nearest Neighbor (KNN). It achieves exceptional results, including 99.5% accuracy, 98.4% precision, 97.5% specificity, and 99.2% sensitivity, improving irrigation management while minimizing water usage and contamination risks [1]. Mohammadaldossary et al. proposes an IoT-enabled hybrid model for smart agriculture, integrating Machine Learning (ML) and Artificial Intelligence (AI) for efficient decision-making and anomaly detection. Using dry bean and soil type datasets, models like MobileNetV2, VGG16, InceptionV3, and SVM were applied for classification. MobileNetV2 achieved 97% accuracy, SVM 93%, and a hybrid random forest model and the neural network model 92%.

The analysis demonstrates the model's effectiveness in optimizing resource use and enhancing agricultural productivity [2]. Basavaraju N M et al. has proposed The Smart Agriculture Yield and Fertilizer Optimization System (SAYFOS) is a modern approach designed to address challenges in traditional farming, such as inefficient fertilizer use and inaccurate crop yield predictions. By integrating IoT technologies, data analytics, and machine learning, SAYFOS ensures continuous monitoring of crop health and soil conditions. It optimizes fertilizer application and predicts crop yields with high accuracy, improving productivity by 0.25%, reducing water usage by 0.33%, and enhancing fertilizer efficiency by 0.25%. SAYFOS helps minimize environmental pollution and empowers farmers to make better decisions, promoting more sustainable and productive agricultural practices [3].

M. Rezwanul Mahmood et al. has developed the integration of modern communication technologies, intelligent sensors, and machine learning (ML) in the agricultural industry to create smart agricultural systems. With the growing need for large-scale, independent agricultural production to secure the food supply for an expanding population, efficient data processing from multiple sources is crucial. The use of ML in agricultural operations is being investigated to optimize data management and system performance.

The article emphasizes the role of the Internet of Things (IoT) and Artificial Intelligence of Things (AIoT) in transforming agriculture by automating and streamlining operations through sensors that collect data on various environmental factors like temperature, moisture, and soil quality. It also highlights the importance of understanding local weather, soil conditions, and crop monitoring to improve farming practices. Recent research (2019–2023) on ML and AI applications in agriculture is reviewed, providing guidelines and insights for enhancing smart farming systems. This article acts as a guide for future advancements in AIoT-based agricultural health solutions [4].

Vandana W M et al. has proposed the project "Soil Fertility Assessment and Crop Recommendation for Sustainable Farming using Machine Learning and Deep Learning" combines agriculture and data science to address modern farming challenges. By utilizing a diverse dataset containing soil properties, historical rainfall, and temperature records, the project applies advanced machine learning algorithms to predict soil fertility and recommend suitable crops based on regional conditions. This approach aims to optimize resource use, increase crop yields, and reduce environmental impact by adjusting planting schedules and nutrient management. The system promotes sustainability by encouraging responsible land use, vital for adapting to changing climates and ensuring food security. The dataset, consisting of 2200 instances and 8 features, was used to train various machine and deep learning models. After hyper-tuning, the Naive Bayes model achieved 99.5% accuracy, while the CNN model showed a lower accuracy of 87.1%. These findings contribute to the development of improved recommendation systems, enhancing farming practices for greater sustainability and productivity [5].

Sargam Yadav et al. explores the adoption of smart farming, an innovative approach that uses disruptive technologies (DTs) and information and communication technologies (ICTs) to enhance agricultural efficiency, reduce costs, and minimize resource wastage. One of the main barriers to the widespread adoption of smart farming is the lack of knowledge and concerns about its drawbacks. To understand user sentiment towards these technologies, sentiment analysis was performed on YouTube comments related to smart farming. The study utilized three text representation methods count vectorizer, TF – IDF i.e. term frequency-inverse document frequency (TF-IDF), and fastText embeddings and applied various machine learning algorithms as classifiers. The findings revealed that TF-IDF using unigrams achieved the best macro-F1 score of 0.6616 with a Support Vector Machine with Radial Basis Function (SVM-R) classifier. The analysis also included visualizations using Shapley Additive Explanations (SHAP) to provide insights into the model's predictions [6].

Sathies kumar Senthil et al. has investigates the application of Machine Learning (ML) in sustainable agriculture to tackle the challenges of a growing population and climate change. It demonstrates how ML algorithms, including neural networks, decision trees, and ensemble models, can enhance crop selection by evaluating aspects like soil quality, climate conditions, and historical crop data.

The paper also explores the use of real-time data through IoT sensors and satellite imagery to support precision agriculture, improving decision-making in areas like crop watering, fertilization, and pest management. Overall, it highlights ML's potential to optimize crop yields, minimize resource waste, and foster environmentally sustainable agricultural practices [7].

Nita Jaybhaye et al. have presented the "Farming Guru" app, designed to assist farmers in making informed decisions for more efficient farming. With India's population expected to grow rapidly by 2025 while agricultural land increases by only 4%, the app helps mitigate crop losses caused by changing seasons, market conditions, and atmospheric factors.

The app covers five key areas: crop analysis, accurate weather forecasting, a machine learning-based approach to humidity, cultivation zones, atmospheric conditions, and pressure, as well as predicting suitable markets for crops. By providing weather insights before cultivation, the app helps prevent significant losses. Additionally, the app supports farmers in managing finances, offering a tool to trade farming equipment for extra income and a budget calculator for financial planning [8].

M.Kalimuthu et al. have presented discussion to assist beginner farmers by leveraging Machine Learning, specifically the Naive Bayes algorithm, for crop prediction climate change is negatively impacting food production, leading to reduced yields and making it harder for farmers to forecast future crops. The study gathers seed data, focusing on key factors such as temperature, humidity, and moisture, to recommend the best crops for successful growth. To make this accessible, an Android mobile application is being developed where users can enter temperature data, with their location automatically detected, to initiate the crop prediction process [9].

Reviewing the above related work offer certain conclusive highlights of research problems too which are briefed as following:

i) Using the Support Tree Algae Algorithm (STAA), which combines Support Vector Machine, Decision Tree, and Artificial Algae Optimization, the system accurately predicts soil moisture with improved precision and reduced errors compared to traditional methods. Designed to be cost-effective and efficient, the system aims to assist farmers in better managing irrigation. But this research will not involve real-world testing and sensor integration for further performance enhancement.

ii) An IoT-enabled hybrid model that combines machine learning and deep learning techniques for smart agriculture, achieving up to 97% accuracy in classifying dry beans and soil types. Key results include 92% accuracy with the SVM-neural network hybrid model and 91% with the InceptionV3-LSTM model. But the efficiency of the model is less, and no secure data access mechanisms for IoT networks.

iii) Future advancements in agriculture are expected to incorporate next-gen technologies like artificial intelligence and robotics for full automation of farming tasks. Additionally, enhancing Smart Agriculture Yield and Fertilizer Optimization System (SAYFOS) to offer real-time, data-driven insights for better resource management will be crucial for sustainability.

iv) Farming is a rapidly evolving field with continuous opportunities for improvement. This application has significant potential, with features such as species recognition, video calls with farm specialists, and machine vision for crop health detection. Additionally, it can include market portals where farmers can find the best markets to sell their products, helping them make more informed business decisions.

II. RESEARCH METHODOLOGY

There are various research-based publications towards investigating problems associated with Smart farming with ML algorithms. However, there is a need to converge them to only core baseline enabling research techniques. Hence, a systematic review of literature has been carried out upon confirming the importance of smart farming and ML algorithms as core taxonomy of baseline methods. **Figure 1** highlights the adopted research methodology towards carrying out the systematic review of literature.

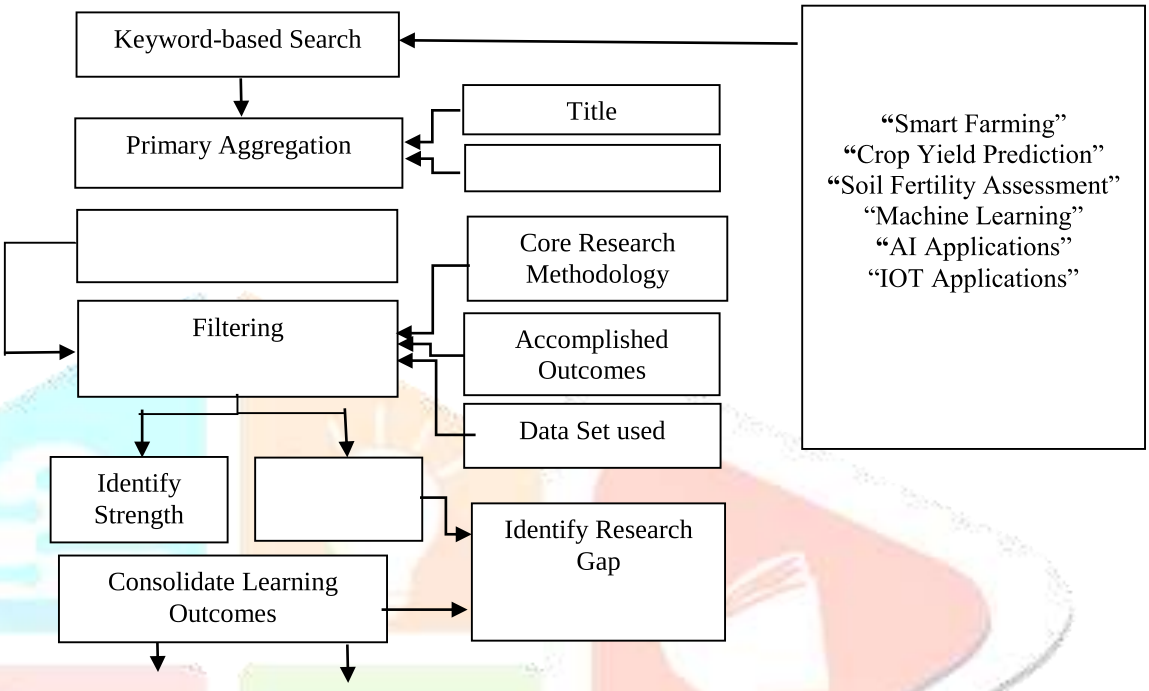

Figure 1. Adopted Method for Smart Farming Review Work

According to **Figure 1**, initially all the research manuscript has been collected using different types of keywords viz. "Smart Farming", "Crop Yield Prediction", "Soil Fertility Assessment", "Machine Learning", "AI Applications", "IOT Applications". All the aggregated manuscript has been initially screened based on information furnished in abstract and title, while all the duplicated research articles are removed. The remaining articles are further studied with respect to their core implementation methods and accomplished result.

The final outcome leads to contributory learning outcomes and research gap. The criteria for including the research articles are:

i) only implementation study papers with proper result accomplishment,
ii) the paper should include smart farming and ML based approaches as core implementation modules,
iii) papers published between 2020-2024 have been only considered for review.

The criteria for excluding the research articles are

i) no conference or theoretical discussion papers are involved,
ii) papers without any disclosure of dataset, iii) vague experimental background.

According to the **Figure 2**, To build an effective machine learning model for agriculture, various types of farming data need to be collected first, including crop data, soil data, weather data, fertilizer data, and weed data. Once the data is gathered, it must undergo preprocessing using techniques such as data cleaning, normalization, and feature engineering to ensure its quality and usability.

After preprocessing, the refined data is fed into machine learning algorithms such as Decision Tree, Support Vector Machine (SVM), Convolutional Neural Networks (CNN), Naïve Bayes, K-Nearest Neighbours (KNN), and Random Forest. These algorithms analyse patterns in the data and construct a predictive model.

Once the model is trained, it can be tested using new input data. When test inputs are provided, the model processes the information and predicts the most accurate results based on the learned patterns. This approach helps in making data-driven decisions for improving agricultural productivity and efficiency.

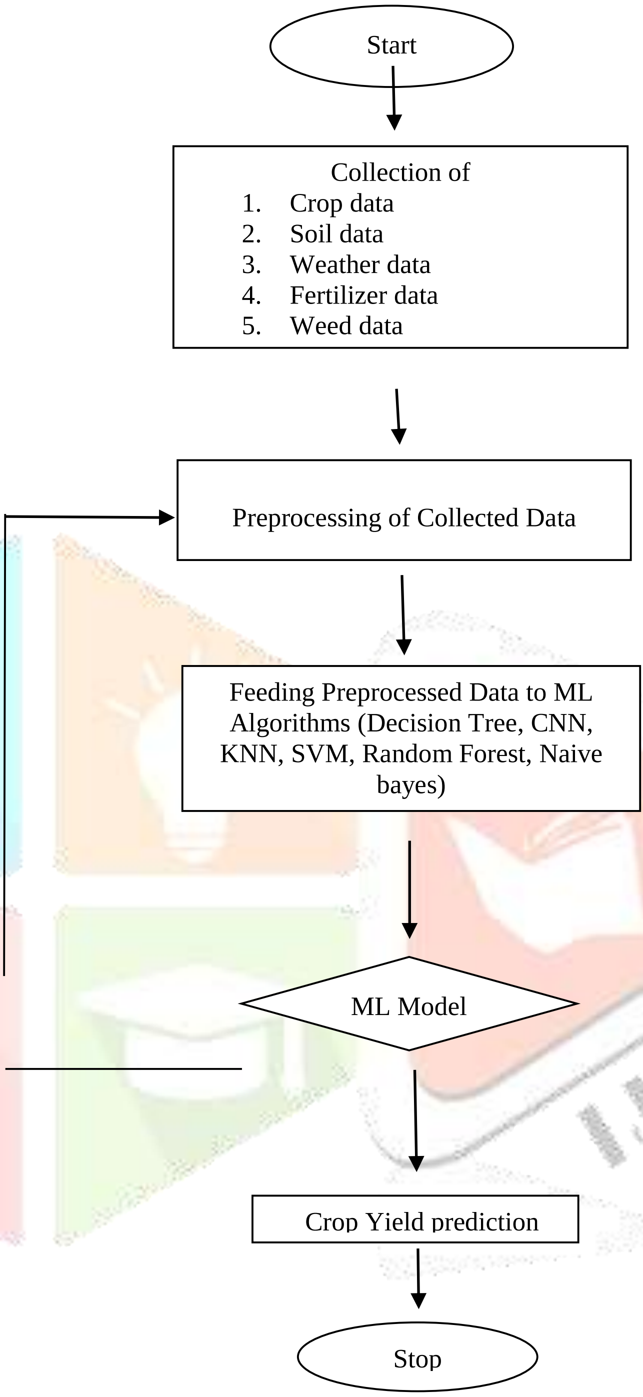

Figure 2: System Process Flow

According to the Table1. different machine learning algorithms like Decision Tree, CNN, Support vector Machine (SVM), Naive Bayes Algorithm, KNN, Random Forest are used to process the crop data and predict the accurate results. Decision Tree is Easy to interpret and handles both numerical and categorical data well, but prone to overfitting and instability, CNN is Excellent for image-based tasks with automatic feature extraction, but requires large datasets and high computational power, SVM is Effective for high-dimensional data with strong generalization, but computationally expensive and sensitive to kernel selection, Naïve Bayes is Fast and efficient for small datasets, but assumes feature independence, which may lower accuracy in complex cases, KNN is Simple and useful for real-time applications, but computationally expensive and sensitive to noise, Random Forest Robust and reduces overfitting by combining multiple decision trees, but is slow to train and less interpretable than a single tree.

Table 1. Advantages, Limitations of ML Algorithms for Smart Farming

Methods	Advantages	Limitation
Decision Tree	Decision trees are easy to visualize and explain, making them useful for non-technical stakeholders.	Decision trees can easily become too complex, capturing noise in the data and reducing generalization ability.
Convolutional Neural Network (CNN)	Recognizing objects, scenes, or animals in images (e.g., ImageNet Classification).	CNNs require significant computational resources, especially for large datasets and complex models.
Support vector Machine(SVM)	Works well when there is a clear margin of separation. Memory-efficient since it uses a subset of training points (support vectors).	SVMs do not provide direct probability estimates; additional calibration may be needed.
Naive Bayes Algorithm	Naive Bayes is computationally efficient and can handle large datasets quickly.	Naive Bayes cannot capture complex patterns and relationships between features, unlike algorithms like decision trees or neural networks.
K-Nearest Neighbour (KNN)	Unlike deep learning or decision trees, KNN doesn't require training; it stores the dataset and performs computations only during prediction.	KNN performs poorly when irrelevant or redundant features exist, as all features contribute equally to the distance calculation.
Random Forest	Random Forest generally provides high accuracy by combining the results of many decision trees. It's less prone to overfitting compared to a single decision tree.	Training a Random Forest with a large number of trees can be time-consuming and resource-intensive, requiring significant computational power and memory.

III. DISCUSSION

Farming is extremely important for the current generation because it is the primary source of food for our nation. As the population continues to grow, the demand for food increases significantly. However, due to the continued use of traditional farming techniques and a lack of awareness among many farmers, agricultural productivity remains low, which may not be sufficient to meet the needs of our expanding population.

In India, farming is not only used for food production but also plays a key role in manufacturing and as a major economic resource. Therefore, there is a strong need to shift towards smart farming practices. This includes identifying the most suitable soil for specific crops, estimating crop yield, and optimizing the use of water and fertilizers. By leveraging machine learning algorithms and modern technology, we can make farming more efficient, sustainable, and productive.

To enhance agricultural productivity and decision-making, we utilize various machine learning algorithms. Each algorithm provides different levels of accuracy in predicting outcomes such as crop yield, soil suitability, and disease detection. The accuracy rates observed for these models are:

- Naive Bayes – 99.48%
- Random Forest – 98.96%
- Support Vector Machine (SVM) – 98.57%
- Logistic Regression – 96.4%
- Deep Neural Network (DNN) – 95.9%

- Convolutional Neural Network (CNN) – 87.1%

Among these, Naive Bayes and Random Forest deliver the highest accuracy, making them particularly effective for smart farming applications. By leveraging these models, we can make more informed decisions in agriculture, leading to improved efficiency and yield.

Identified Research Gap: The current study has explored various machine learning algorithms like the Support Tree Algae Algorithm, Naïve Bayes, Decision Tree, and K-Nearest Neighbors (KNN), achieving accuracy above 90%. However, these models have been tested only on static datasets rather than real-time data. To bridge this gap, my research aims to extend these methodologies by leveraging real-time data for precision agriculture. The focus will be on enhancing crop yield, monitoring crop health, identifying weed plants, optimizing fertilizer usage, and providing timely recommendations to farmers, ultimately improving agricultural productivity and sustainability.

IV. CONCLUSION

The current study has explored various machine learning based algorithms, such as the Support Tree Algae Algorithm, Naïve Bayes, Decision Tree, and K-Nearest Neighbors (KNN), achieving accuracy above 90%. However, these models have been tested only on static datasets rather than real-time data. To bridge this gap, my research aims to extend these methodologies by leveraging real-time data for precision agriculture. The focus will be on enhancing crop yield, monitoring crop health, identifying weed plants, optimizing fertilizer usage, and providing timely recommendations to farmers, ultimately improving agricultural productivity and sustainability.and complete farming automation is the future enhancement.

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