

A Survey on Machine Learning Applications in Agriculture

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Abstract

Agriculture, which is regarded as the fundamental basis of the economy, has a major impact on a nation's economic growth and its GDP (gross domestic product). Agriculture is most commonly associated with the production of essential crops. The farmers undergo several challenges in each stage of crop production, including soil preparation, seed selection, spotting of disease, irrigation problems, predicting yields, weed control, etc. This study presents an in-depth study of the recent advancements in the agricultural sector using machine learning (ML) techniques. Machine learning is nowadays used in almost every stage of the agricultural process. The study presents a detailed review of the different machine learning methods employed in agriculture, including the advantages of using the techniques and the challenges incurred in their adoption. The study further provides a comparison and contrast of different machine learning techniques to make it more informative for future researchers.

Keywords: Artificial Intelligence (AI), Machine Learning (ML), Agriculture, Support Vector Machine (SVM), Random Forest (RF), Artificial Neural Network (ANN).

1. Introduction

Agriculture is often referred to as the art and science of harvesting natural resources for human use as well as financial gain. It is the source of food production for any society [14]. Many people depend on agriculture for both commercial production and local production, as it serves as the core of food security. In India, agriculture is the primary sector and contributes significantly to the economic growth of the nation and its GDP. Many industries that are the

backbone of the country rely on agriculture for their raw supplies. Above all, it supports national endeavors by producing food and other agricultural goods. Land cultivation and animal and plant breeding are all known as agriculture; they provide all the essential requirements that are necessary for improving and maintaining human life. Agriculture is the major source of employment for people living in rural areas, especially in developing nations like India. The productivity and production of agriculture determine the socioeconomic welfare of India's 1.3 billion (45%) agriculturally dependent population. As a result, agriculture plays a significant role in the national economy [15]. The term "traditional agriculture" refers to a backward farming method that heavily relies on local knowledge, traditional tools, organic fertilizer, natural resources, and farmer cultural beliefs. The traditional methods were best suited for large fields and also ended up with reduced yield, nutrient depletion, deforestation, soil erosion, etc. The farmers had to face many difficulties, starting from soil preparation to the final harvest. The variety of issues faced by farmers include pest infestation, inconsistent irrigation, incorrect land management, etc. Moreover, apart from the above-mentioned issues, there are other factors by which the agricultural production system is being forced into a new paradigm. These are the rapidly increasing population, declining acreage, depleting natural resources, unpredictable climate changes, and changing consumer demands. The new paradigm is expected to be highly efficient, increase productivity, be capable of withstanding climate change, and also be sustainable [16]. Artificial intelligence has the potential to handle all the above-mentioned challenges and expectations. Systems that employ AI have been shown to be the best among these options in terms of accuracy and robustness [1, 2].

1.1 Artificial Intelligence in Agriculture

The agricultural cycle is very complicated as the farmer has to possess knowledge about crop rotation, the time to plant and water the crops, managing pests and disease, the proper fertilizer to be used, weed control, and finally the time to harvest [16]. Artificial intelligence has emerged as a promising paradigm in almost every stage of the agricultural process. It helps the farmers know about the nutrients present in the soil and plan the crop rotation properly; offers a weather report, enabling the farmers to know the right time for planting; automates the process of watering by collecting the moisture level of the soil; continually observes the plant growth and notifies the farmers about pests, diseases, and weeds; prescribes the proper remedial

measures; and also helps the farmer in deciding the optimal time for harvest. The figure.1 shows the different stages of agriculture in which AI is involved.

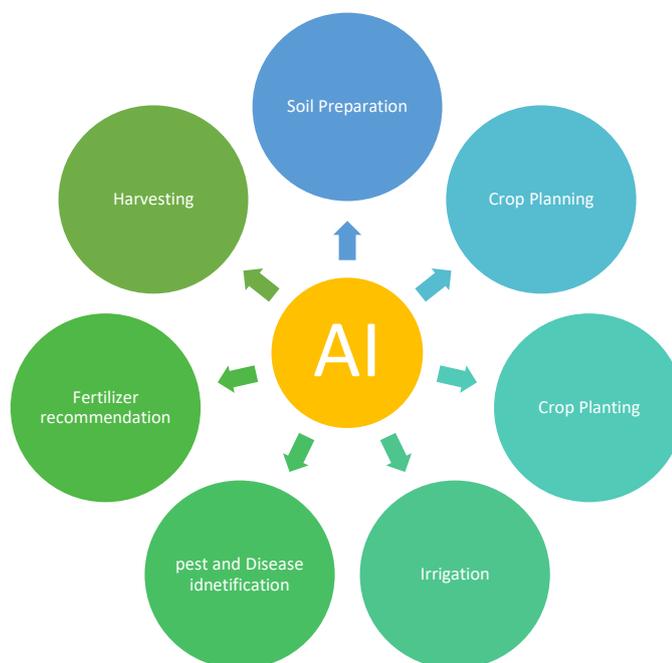


Figure 1. AI in Agriculture [17]

The proposed study aims to offer an in-depth review of the intervention of different types of machine learning in their different stages. The study in its following section defines what machine learning is, its different types in section 2, The intervention of machine learning in agriculture in section 3, the comparison and contrast of different machine learning algorithms in section .4 and the conclusion in section 5.

1.2 Machine Learning Techniques

Machine learning (ML) is the subfield of AI that facilitates machines to learn from their experiences. The scientific study of algorithms and statistical models that computer systems employ to carry out a particular task without being explicitly programmed is known as machine learning (ML). These algorithms are employed in many different fields, including predictive analytics, image processing, data mining, and more. The most important advantage of machine learning is the ability of algorithms to perform tasks automatically once they have learned how to handle data. To put it simply, machine learning (ML) uses simple algorithms to extract information from a dataset without the need to write code or run the program manually [18]

ML algorithms do not rely on predefined equations as a model; instead, they use computational techniques to learn directly from datasets. The model can be used to classify as well as test data by making predictions after learning process is complete. . ML algorithms could be trained even to handle complex problems. The figure.2 below shows the different types of machine learning algorithm and its categories.

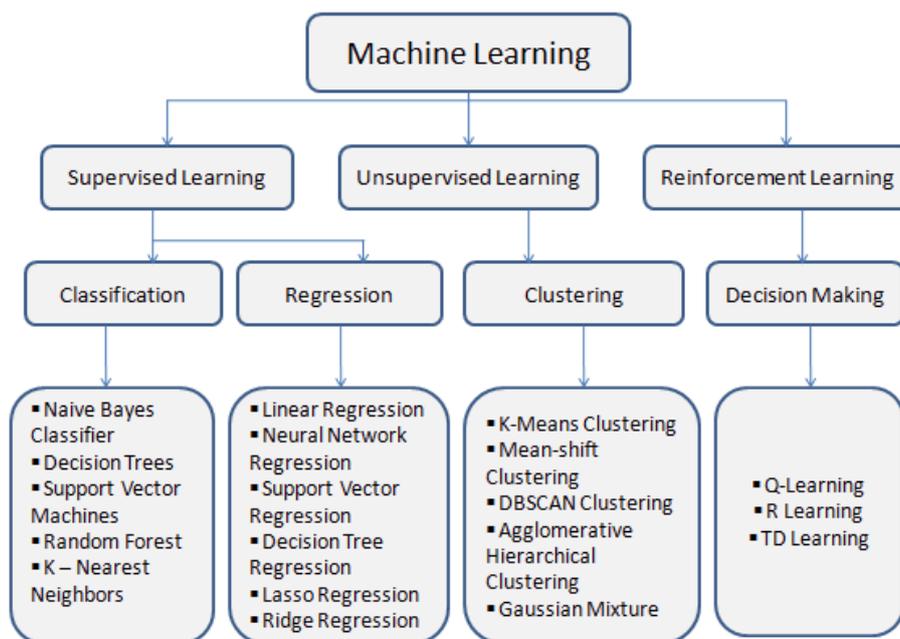


Figure 2. Types of Machine Learning Algorithms [2]

In this research work the use of Machine Learning classification algorithms in agriculture is studied and a comparing and contrast of few supervised machine learning algorithms are such as, K-nearest neighbour, Random Forest, Support vector machine etc are presented. The main objective of the study is to present an in-depth review about the uses of machine learning algorithm in different stages of agriculture including soil classification, disease spotting, yield forecasting, weed control and irrigation management.

2. Machine Learning Use Cases in Agriculture

In Agriculture, ML can help to Classification of soil, Detection of diseases, Irrigation Management, Prediction of Yield, Controlling the Weed.

2.1 Classification of Soil

The soil is one of the basic requirements of agriculture. When it comes to crop selection, nutrient management, irrigation, erosion control, disease and insect control, and general land use planning, soil classification becomes paramount. This section delves into some of the existing works that have applied machine learning techniques to soil classification.

The insufficiency of the conventional method has led to the integration of machine learning in soil classification. Soil classification helps the farmers know about the essential nutrients that are available in the soil and enables them to decide which crop is suitable for the soil. It gives the essential details about the soil, including the pH, salinity, organic matter, potassium, sulfur, zinc, boron, calcium, magnesium, iron, manganese, etc. This study mainly concentrates on the use of machine learning algorithms such as support vector machines (SVM), K-nearest neighbor (KNN), artificial neural networks (ANN), etc. in classifying the soil content. The soil classification is usually done by processing the colored images of the soil samples and extracting features like color, texture, different soil types, etc. Rahman et al. [21] predict the soil types and suitable crops for the soil employing KNN, SVM, and bagged trees. In his study, the author came up with the result that SVM performed better with 94.95% accuracy compared to the other methods. Bhattheirharya predicted the differences in soil using the SVM, ANN, and decision tree in their paper. The classification results showed that ANN performed well for clay and peat, the decision tree performed better, but the accuracy was moderate, and the performance of SVM was very poor. Rao et al. [23] explain in their study how soil samples are classified and graded using SVM-based methods based on many scientific parameters; crop classification for suitable soil is part of soil classification. Saranya, N., et al. [7] illustrated the macro- and micronutrient classification of the soil to anticipate the kind of crop that can be grown in a given soil type. Numerous machine learning methods were employed, including logistic regression, bagged trees, support vector machines (SVMs), and K-Nearest Neighbors (k-NN) to perform the classification. The comparison results proved that SVM was better than the other methods studied. Based on the study done in the above literature, it was found that MLs were highly used for soil classification, and from the results observed, it was seen that the performance of the SVM outperformed other methods in most of the cases except a few.

2.2 Spotting the Diseases

Plant diseases frequently originate from pests, diseases, and insects and can significantly reduce yield if left unchecked. The crop must be healthy for the best yield; hence, crop monitoring requires very sophisticated techniques. [8]. One of the main causes that has an indirect impact on the rapid decrease in the quantity and quality of agricultural goods is crop disease. There are numerous insecticides on the market to both reduce disease and increase output. However, it is challenging, tedious, and costly to identify the present disease and an efficient pesticide to control the infected disease. [8] The leaves are the major part that suffers from the plant disease. Anuradha Badage et al. use the Canny Edge detection algorithm to identify a particular disease. In the early stages of crop disease, it is detected by using the Canny Edge algorithm. After the model is trained using ML approaches, it can assist in making informed decisions about diseases. Various crops were provided as input to the training model. There are several good crop images and crop images with defects taken into account for each crop. Set the cutoff point for every crop. Train the model so that it will select the appropriate action for all sorts of crops. The farmer is advised to use pesticides as a therapy to treat and manage infected diseases. Ahmed et al. [24] in their manuscript suggested the ensemble model for detection of plant disease using machine learning models like random forest-nearest neighbors, neural networks, support vector machines, linear regression, and Naive Bayes and found that the ensemble model outperformed the other state-of-the-art individual ML models that were used. Varshney et al. [25] in their manuscript, based on a transfer learning methodology such as deep learning, developed a novel method for detecting plant leaf diseases. CNN was utilized for extracting features, while SVM was used for classification. This method proved to be very successful in terms of cost, data efficiency, interpretability, robustness, and overall performance. The study proved that the combination of standard machine learning with deep learning and image processing techniques provides a strong and adaptable method that has the advantages of tackling a range of problems in crop disease detection.

2.3 Crop Yield Forecast

In agriculture, the selection of the best crop for a good harvest is a major challenge. When the perfect crop is chosen with all the necessary vitamins, a tremendous yield can be expected. ML will give a good result when it comes to picking the correct crop to produce and

predicting the yield of the crop. The crucial feature of yield prediction is soil categorization. SVM and RF are used for predicting the crop yield for rice, wheat, soyabean, and dry chilly. The algorithms also suggest corresponding fertilizers for crops. For prediction of crop yield, RF has an accuracy of 97.48%, while SVM has an accuracy of 99.47%. SVM produces better yield prediction results.

2.4 Weed Control

Weed detection is the major problem that arises in every crop. Based on the weed, the final yield can be defined. Weeds are the main threat to crop production. To minimize the weed, the yield will be good; pesticides are not working on the crop by default as minimum. Herbicide use is considerably reduced when weeds are identified using ML models. The majority of ML techniques for weed identification involve digital pictures as input data. [12]. Once the image features are extracted and selected, the classification model can be built. To identify the weeds, ML methods such as SVM and ANN are used. Among these methods, SVM has the best accuracy to perform weed detection.

2.5 Irrigation Management

With every crop, water management is essential. We can use the water more effectively by employing ML techniques, allowing the extra water to be used for another crop. We can supply the water on a daily or weekly basis, depending on the crop and kind of soil. In an automated water dripping system for agriculture [8], a study [7] used sensors for soil temperature, moisture content, and pH to determine the soil water content level.

The primary advantages of an automatic irrigation system are water and energy correction, while the cost is high. Machine learning techniques, including SVM, RF, ANN, and KNN, are used in irrigation systems. By using SVM, it will be handling both linear and non-linear data. In most cases, the SVM model performs slightly better than the ANN model. Apart from using machine learning, the method also depends on sensors and other devices to collect real-time data about the moisture of the soil in the field. The use of IoT and the cloud further enables the farmer to have time-to-time updates about the field.

3. Discussion

The study emphasizes how crucial agriculture is to economic growth and how it directly affects a country's GDP. The study provides a framework for comprehending the urgent need for innovations and advancements in this industry by recognizing the vital significance that agriculture plays in the economy. The identification of obstacles that farmers encounter at different phases of crop production provides an essential context for the investigation. These difficulties, which range from disease identification and yield prediction to soil preparation, demonstrate the intricate and varied nature of problems faced by anyone working in agriculture. The integration of machine learning (ML) techniques across several stages of the agricultural process is the main emphasis of this study. Through an examination of recent developments, the study illuminates how machine learning is evolving into a vital instrument for tackling the difficulties encountered by farmers. This integration represents a revolutionary turn in agricultural methods toward accuracy and efficiency. The benefits of using machine learning in agriculture are fully examined in this study. These benefits could include better decision-making, more efficient use of resources, and higher yield via process optimization. The research highlights the potential benefits that machine learning (ML) technologies might bring to the agricultural landscape by emphasizing the positive consequences. The study gains depth by considering obstacles to the implementation of machine learning techniques. For stakeholders, obstacles including those related to technology, expenses, and the requirement for specialized knowledge are crucial. It becomes imperative to address these issues if ML is to be successfully implemented and widely used in agriculture. The paper serves as a useful resource for future researchers by integrating knowledge on the benefits and difficulties of various machine learning techniques. It offers a starting point for the creation of more focused and successful machine learning applications in the field of agriculture, promoting an ongoing cycle of innovation and advancement. The study does an in-depth study and contrast of various approaches, going beyond just presenting machine learning algorithms. Future researchers will find this analysis to be very insightful as it guides them in choosing the best machine learning approach given the particular needs of the agricultural context. The table .1 below shows the Comparison of ML algorithms in Agriculture. The Figure.3 shows the performance analysis of accuracies of different machine learning models.

Table 1. Comparison of ML Algorithms in Agriculture

S.no	Articles Referred	Categories	Crop	Dataset used	Algorithm	Accuracy %
1	[21], [23], [7]	Classification of Soil	-	Synthetic	SVM	86.35
				Synthetic	KNN	87.2
2	[7],[8]	Crop Yield Forecast	Rice, Jowar	Real-time	SVM	91.1
				Real-time	RF	88.5
3	[12]	Weed Control	Paddy, wheat Soyabean	Real-time	SVM	89.40
				Real-time	SVM	95.07
4	[8],[24],[25]	Disease Spotting	Variety of Crops	Real-time	ANN	85.1
					Ensemble Model	95.28
5	[8],[7]	Irrigation Management	-	Real-time	ANN	84.56
					SVM	97.46
					RF	89.52
					KNN	90.43

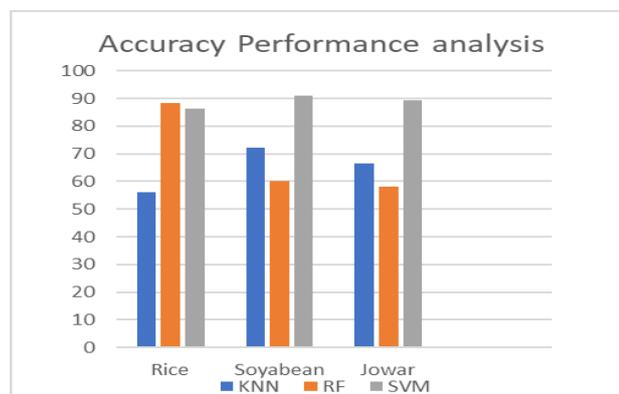
**Figure 3.** Performance Analysis

Table 2. Illustrates the benefits and the challenges of using the machine learning in the agriculture

Table 2. Benefits and the Challenges of Using the Machine Learning in the Agriculture

	Benefits	Challenges
Soil Classification	Precise classification, Increased efficiency, Reduced resource wastage, better crop selection, improved yields and reduced risk of crop failure.	The dependability of ML models may be impacted by inconsistent, inaccurate, or missing values in soil data.
Crop yield prediction	To maximize total agricultural productivity, farmers can make well-informed decisions about market strategy, resource allocation, and planting dates.	Crop production prediction is influenced by a number of variables, such as pest infestations, soil quality, and weather. It is difficult to combine these many elements into a single, cohesive model.
Weed classification	A reduced dependency on chemical inputs, cheaper expenses, and a smaller environmental effect due to the targeted treatment of weed-infested areas. By allocating resources wisely, farmers can improve operational efficiency while saving money on labor and time.	The wide range of species and growth stages that weeds display makes it difficult to compile a comprehensive dataset for efficient weed categorization. Since weeds and crops frequently grow next to one another, it can be difficult to tell the difference between the two in the images or sensor data.
Irrigation Management	Enhanced water resource management, less water waste, and more efficient use of water. Optimal moisture levels lead to improved crop quality and higher yields,	It's possible that many farmers, especially in underdeveloped nations, have restricted access to sophisticated sensor technologies or computerized

	which boost farm profitability overall.	irrigation systems. Irrigation management model efficacy can be impacted by external factors such as abrupt weather changes or unforeseen fluctuations in water availability.
Disease Spotting	Early detection, Timely intervention, precise prediction	Inconsistent or biased datasets, lack of up to date information about disease

Using machine learning (ML) in agriculture has several benefits, including enhanced productivity and resource management as well as environmental preservation and sustainability. These advantages are probably going to increase as technology develops, which will help agriculture become more productive and sustainable in the future. The above mentioned challenges could be overcome in the future by using advanced techniques, implementing data quality assurance measures, utilizing ensemble learning techniques and transfer learning techniques. Further developments in machine learning methods and the availability of more varied and superior datasets will also help to overcome these obstacles in the future.

4. Conclusion

ML algorithms provide farmers with optimal decision making and suggestions. By using the latest technologies, almost everything can be automated, from sowing to harvesting the crops. The use of ML in agriculture helps minimize manpower. The study presents an in-depth review of the use of ML in agriculture, a comparison and contrast of different ML models, and the benefits and challenges of using ML models in agriculture. From the study, it was found that the SVM was most widely used in all types of processes and showed better performance, except in a few cases.

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