

AN EVALUATION OF MACHINE LEARNING APPROACHES FOR PREDICTING CROP YIELD

Abstract

The use of machine learning (ML) methods in the analysis of agricultural sensor data obtained from sensor devices offers a solution to a significant challenge faced by the agricultural industry, namely yield forecasting. The Internet of Things (IoT) has several applications within the realm of digital agriculture, including tasks such as monitoring crop development, aiding in crop selection, and facilitating decision-making processes related to irrigation. The Internet of Things (IoT) is a paradigm that involves the integration of physical objects with the capability to collect and transmit data. In the realm of agriculture, the integration of sensors with the Internet of Things (IoT) serves to provide valuable support to farmers in optimizing their decision-making processes. This process is accomplished by using sensor networks. One of the primary advantages associated with the use of Wireless Sensor Networks (WSNs) in the context of Precision Farming (PF) is to the potential reduction in water and fertilizer requirements, coupled with an increase in crop yield.

Keywords: Crop yield, Internet of Things (IoT), Precision Farming (PF), Machine Learning (ML)

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I. INTRODUCTION

In India, agriculture is the primary source of income for the population. A little more than 70% of people work in agriculture. A crucial part of daily life is agriculture. For us, food is a need. We must create an enormous farming industry to provide food to others. India and other developing nations rely on agriculture. So, the growth of the Indian economy is dependent on agriculture. In precision agriculture, we may employ IoT to increase efficiency and production. Sensor nodes in the fields can collect agricultural data, which is then sent to a data server where it is processed and stored. IoT applications in agriculture are crucial in making functions accessible and appropriate. Precision farming, wildlife monitoring, and other uses are made possible by the combination of WSNs with IoT. The weather and environmental factors, such as seasonal temperature, daily temperature ranges, and water cycles between the soil and atmosphere, have a significant impact on crop growth, quality, and yield. Precision farming (PF) may use inputs including temperature, humidity, soil moisture, and pH value to maximise crop growth while using the fewest resources possible. We can anticipate rainfall, crop selection and production predictions, and agricultural disease predictions with the use of machine learning algorithms. Crop management in agriculture involves controlling insecticides, fertilisers, and irrigation for optimum development. For precise agricultural production forecasts, many authors provide a variety of ways using IoT-based WSNs and machine learning algorithms.

- 1. Overview of IoT:** The Internet of Things (IoT) is the interconnection of physical objects with the capacity to transmit data across a network without the need for human involvement.

Things (items) in the IoT may be anything, including sensors, people, cameras, computers, and phones. Any kind of data may be uploaded to the internet with these devices. IoT has several uses in agriculture, including "smart agriculture," which refers to uses of IoT solutions. The following facts explain why IoT technology is so effective.

- Device-based global connection.
- Minimising human effort is possible.
- More rapid access.
- Efficiency of time.

- 2. Role of IoT in Agriculture:** The use of Internet of Things (IoT) devices in the agricultural sector has the potential to improve crop productivity significantly. This technological advancement is often referred to as intelligent farming. IoT devices have been used for the purpose of monitoring the soil condition, temperature, and humidity of crops in agricultural areas. Internet of Things (IoT) sensors can provide instantaneous data pertaining to many agricultural aspects such as crop yields, rainfall patterns, insect infestation levels, and soil nutrition content.

- **IoT Application in Agriculture:** There are several types of Internet of Things (IoT) sensors and apps that can be effectively used within the agricultural sector.
 - Climate Condition Monitoring
 - Intelligent Greenhouse
 - The topic of crop water management is of great importance in the field of agriculture.

- Agricultural drones have emerged as a significant technological advancement in the agricultural sector.
- The conservation of fertiliser and chemical crop protection agents.

Precision farming, sometimes called precision agriculture, is a contemporary agricultural methodology that employs sophisticated technology and data analysis to enhance agricultural practices.

3. **WSN with IoT in Agriculture:** The topic of interest is a wireless sensor network, which refers to a network that operates without the need for physical connections and is composed of sensors. This network has a specific and well-defined topology. A wireless sensor network (WSN) is a network comprised of miniature electronic devices that are equipped with various types of sensors. The purpose of the wireless sensor network is to collect data from the aforementioned sensors. Wireless Sensor Networks (WSN) may be seen as a subset of the Internet of Things (IoT). Wireless Sensor Networks (WSNs) have the capability to establish connections with the Internet of Things (IoT).
4. **Precision Farming:** Precision agricultural (PF) or Precision Agriculture (PA) refers to a highly precise and technologically advanced agricultural approach that involves the use of AI (Artificial Intelligence) processed data for the purpose of planting, cultivating, and harvesting crops. Crop data plays a crucial role in predicting optimal strategies for various agricultural activities. The functionality of PF is contingent upon the integration of hardware, software, and IT services. Precision agriculture (PA) is a farm management method that leverages information technology (IT) services to optimize the production of plants and commodities.
5. **Machine Learning:** A computer programme is considered to possess the ability to acquire knowledge from experience E in relation to a certain task T and performance measure P , if its performance on task T , as evaluated by performance measure P , demonstrates improvement as a result of experience E . Arthur Samuel defines Machine Learning (ML) as a discipline that empowers computers to acquire knowledge and improve performance via learning, without the need for explicit programming. The primary objective is to enable computers to acquire knowledge autonomously, without the need for human intervention.

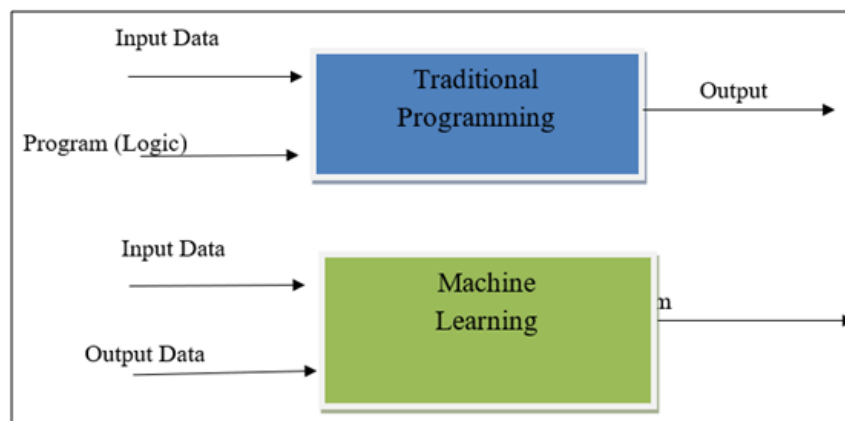


Figure 1: Procedure Traditional programming and Machine Learning

In the context of traditional programming, the input data and programmed logic are provided, afterwards executed on a computer, and provide an output as the resultant outcome. In the discipline of Machine Learning, input data and corresponding output are provided to the machine during the training phase. The machine then utilizes this data to generate a customized programmed or logic. This programmed may then be evaluated and tested during the testing phase.

Applications of Machine Learning

- **Image Recognition:** ML can be used for face recognition in an image.
- **Medical diagnosis:** ML methods and tools that can assistance in the diagnosis of diseases.
- **Prediction:** ML can also be used in the prediction systems.
- **Agriculture:** ML applications have been used in Agriculture like Selection of the crop and crop Yield forecasting, water forecasting, smart irrigation, Crop Disease Prediction.

Table 1: Various Applications of Machine Learning Algorithms in Agriculture

S. No	ML Applications in Agriculture	
	Field of Study	ML Algorithms
1	The process of selecting suitable crops and accurately predicting their yield.	Artificial Neural Network(ANN)
2	Weather Forecasting	Support Vector Machine (SVM)
3	Smart Irrigation	Depends on data dimension we can use Support Vector Machine (SVM) and KNN (K-Nearest Neighbor)
4	Crop Disease Prediction	ANN
		Regression Trees

Types of Machine Learning Algorithms: The many categories of machine learning algorithms are shown in Figure 2.

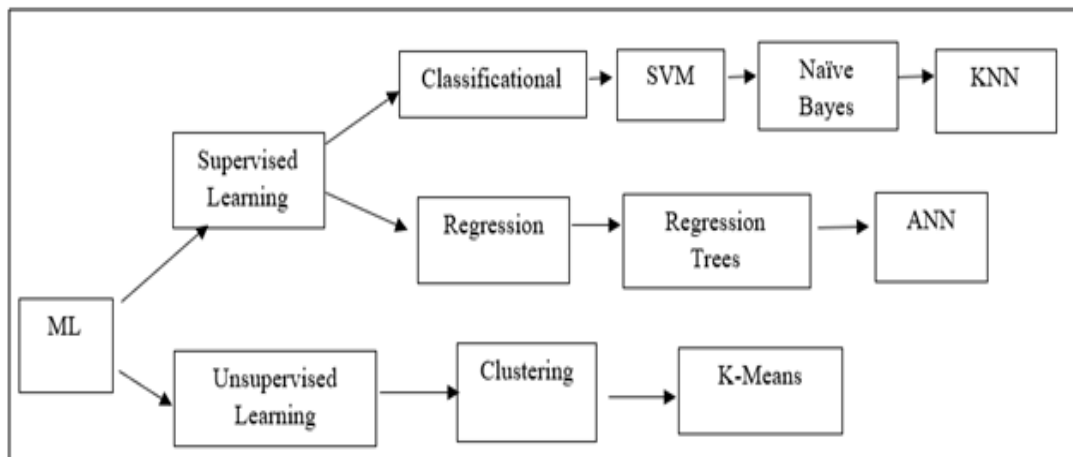


Figure 2: Categorical ML

6. Supervised Learning: In Supervised learning, a known data (label) is available for a certain dataset like training data. Means as an input uses the known and label data and it gives accurate and reliable results. Supervised learning is applied in classificational algorithms like Support Vector Machine (SVM), Naïve Bayes and K-Nearest Neighbors (KNN), regression types Algorithms like Regression trees and Artificial Neural Network (ANN).

7. Unsupervised Learning: Unsupervised learning refers to a branch of machine learning in which algorithms are designed to identify patterns, structures, or connections within a given dataset without the need for explicit supervision or labelled target variables. some essential traits and uses for unsupervised learning:

8. Characteristics

- **No Labels:** In contrast to supervised learning, which involves training a model using labelled samples with known outcomes, unsupervised learning operates on raw data that does not include explicit annotations.
- **Pattern Discovery:** The primary objective of these algorithms is to identify patterns, correlations, or clusters within the dataset. This process may include the identification of clusters of related data points or the reduction of data dimensionality.

9. Applications

- **Clustering:** Clustering is one of the fundamental applications of unsupervised learning. Clustering techniques are used to group data points that exhibit similarities, as determined by a specified similarity metric. The often-used clustering techniques include K-Means, Hierarchical Clustering, and DBSCAN. Some applications included in this field are customer segmentation, picture segmentation, and document clustering.
- **Dimensionality Reduction:** Dimensionality reduction methods such as Principal Component Analysis (PCA) and t-Distributed Stochastic Neighbor Embedding (t-SNE) are often used in unsupervised learning to decrease the number of dimensions in data while preserving significant characteristics. This technique is beneficial for the purpose of visualizing data and selecting relevant features.

10. General procedure for Crop Yield Prediction System: The methodology for predicting crop production is shown in Figure 3. The processing procedure involves selecting a specific crop and gathering data from various sensor nodes located inside the agricultural field. Data preprocessing refers to the process of preparing data for analysis by addressing issues such as redundancy and inconsistency within the dataset. The elimination of redundant data from sensory data can be achieved through the implementation of filtering techniques such as Kalman filtering. Once the noise has been removed from the sensed data, the resulting high-quality data can be transmitted to cloud or secondary storage devices, such as an SD card, via an IoT Gateway. Subsequently, machine learning algorithms can be applied to the stored data in order to predict crop yield.

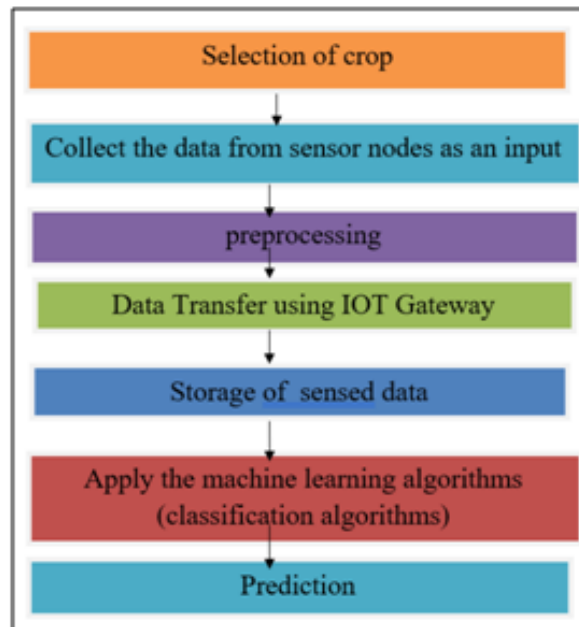


Figure 3: Flow chart Diagram of Prediction

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Section 2 provides an overview of the existing literature on crop selection and yield prediction, highlighting the many machine-learning techniques proposed by different authors in this domain. Section 3 presents a comparative analysis of the outcomes obtained by several writers who used distinct machine learning methods. In contrast, Section 4 offers conclusive remarks.

II. RELATED WORK

Hetal Patel and Dharmendra Patel (2016) [1], The authors put forward several data mining techniques, particularly classification methods, including J48, Simple Cart, and Naive Bayes algorithms, for the purpose of predicting harvest yields. These approaches, which are based on decision tree models, achieve accuracy rates of 89.33%, 85.66%, and 82.66% respectively.

D. Ramesh and B. Vardhan (2015) [2], The authors have put forward an approach for predicting agricultural production utilizing a combination of Density-based clustering algorithm and Multiple Linear Regression (MLR) for specific crops.

S. Nagini [3], This paper explains data analysis and considers designing of the various predictive techniques. In this paper, relative learning of several data analytics method

were regained. This helps us to refer what type of technique was finest suitable for our proposed system.

R. Kalpana [4], This study focus to search out proper data processing techniques to understand more precision and predict potential. Lastly, exploitation data processing systems in agriculture could be an up to date technique to find out the proper solution over the normal and traditional systems.

Sellam, et al [5], This study examines the impact of several environmental factors, including the Area Under Cultivation (AUC), Annual Rainfall (AR), and Food Price Index (FPI), on agricultural yield. The research focuses on analyzing the link between these variables.

Monali Paul, [6], The categorization process is conducted via a data mining approach. This article presents an analysis of cataloguing instructions and identifies their suitability for a given dataset.

N. Hema Geetha [7], The authors provided explanations on many methodologies, including Market-based Analysis, Association rule mining, and Decision Trees (DT).

Awanit Kumar [8], Authoer explain about K-Means algorithm and how it will be applied for analysing the data for maximizing the crop yield based on soil and weather data.

M. Gunasundari Ananthara [9], This article presents an exposition of the Bee Hive algorithm as a method for predicting harvest yield. This system is designed to handle a large-scale data file.

Thomas Truong [10], applying the support vector machine regression (SVMr) technique on raw data and process a raw data and forecast the result. SVM gives result but which is less accurate than other algorithms.

Giritharan Ravichandran [11], the author explains in this paper about Artificial Neural Network which is a successful tool and applied for modeling and forecasting.

Jagielska et al. [12], authors defined Yield forecasting which is an important problem in agriculture.

Veenadhari, [13], The Decision Tree analysis explains the paddy crop yield. The guidelines have been formed from the Decision Tree and which are applied to discovering context planned for maximum or minimum harvest efficiency.

Shalvi D [14], The Bayesian System is a crucial tool and extensively applied in data file of agriculture. The method succeeds for applications of agriculture which has been based on the Bayesian Network Technique. consequence display that Bayesian Networks are achievable and valuable.

Charles L. Hornbaker [15], A spatial methodology for estimating maize yields in the US Corn Belt has been constructed, using the Bayesian prior estimate model for each state within the belt area. This approach enables the incorporation of spatial smoothness among the regression coefficients, therefore mitigating the impact of noisy data across different regions

and enabling the development of accurate yield predictions. This aids in the development of a predictive model for in-season forecasting.

The combination of Information Technology (IT) and agriculture assist in prediction harvest yield. It is compulsory to create an appropriate technique will have some merits over the conservative prediction mechanism. A comprehensive study of different ML algorithms applied for different applications in agriculture as shown in below table 2.

Table 2: Machine Learning Methodologies used in Agriculture

Ref. No	Author	ML Methodologies	Applications
16	Chen C, Mcnairn H	Neural Network	Tracking Rice Harvests
17	Co HC, Boosarawongse R	Artificial Neural Networks (ANNs)	Forecasting Rice Export
18	Monisha Kaul M, Robert L	Artificial Neural Networks (ANNs)	Corn and Soybean Yield Forecast
19	Prasad PR, Begum SA	Regression and Neural Networks Models ¹⁹	Forecast of Crop Yield.
20	Dahikar MSS, Rode SV	Artificial Neural Network Approach ²⁰	Agricultural Crop Yield Forecast
21	Stathakis D, Savin I, Negre T	Neuro-Fuzzy Modeling	Crop Yield Forecast
22	Papageorgiou EI, Aggelopoulou KD, Gemtos TA	Fuzzy Cognitive Map learning approach	Yield Forecast in Apples.
23	Petridis V, Kaburlasos VG, FINK NN	Finken: a fuzzy interval number k-Nearest Neighbor classifier	The projected estimation of sugar output based on samples from various populations.
24	Salleh MNM	A Fuzzy Modelling of Decision Support System ²⁴	for Crop Selection
25	Papageorgiou EI, Aggelopoulou KD	Fuzzy Cognitive Map learning approach	Yield Forecast in apples
26	Veenadhari S, Mishra B, Singh CD	Decision Tree Algorithms	Soybean Productivity Modelling
27	Kumar AVTV, Rajini Kanth R	Data mining with the climate variable	Jowar Crop Yield in India
28	Priya SRK, Suresh KK	Regression	sugarcane yield using climatic variables
29	Shibayama M	Linear Regression	Forecasting Grain Yield of Maturing Rice
30	House CC	Nonlinear Regression	Forecasting Corn Yields
31	Matis JH, Birkett T, Boudreaux D.	Markov Chain Approach	Predicting Cotton Yields

32	Yiqun Gu Y, James W, McNicol M	Belief Networks	The topic of future crop production is of great significance in the field of agriculture.
33	Jain RC, Rama subramalliall V	Second Order Markov Chains ³³	Forecasting of Crop Yields
34	Hong-Ying L, Yan-Lin H, Yong-Juan Y, Hui-Ming Z	Time Series Techniques ³⁴	Crop Yield Forecast
35	Utkarsha P, Narkhede N, Adhiya KP	Modified K-Means Clustering ³⁵	Crop Prediction

III.COMPARISON OF RESULTS FOR DIFFERENT MACHINE LEARNING ALGORITHMS APPLIED IN AGRICULTURE

The performance of several machine learning algorithms in the field of agriculture is compared in table 3.

Table 3: Comparison of Various ML Techniques with Accuracy

Ref. NO	Name of the Author	Machine Learning Algorithms	Crop Type	Accuracy
1	Hetal Patel and Dharmendra Patel	The Classification Techniques like J48		89.33%
		Simple Cart		85.66%
		Naive Bayes		82.66%
36	D Ramesh, B Vishnu Vardhan	Multiple Linear Regression	Rice Yield	90%-95%
37	Sudhanshu Sekhar Panda, Daniel P. Ames , and Suranjan Panigrahi,	Neural Networks	Corn yield	95%
38	S.Veenadhari,Dr. Bharat Misra ,Dr. CD Singh	C4.5 Technique and Decision Tree	Soyabean, paddy, maize	For Soyabean=87% For Paddy=85% For Maize=76%
39	Jefferson Lobato Fernandes; Jansle Vieira Rocha	Harmonic Analysis of NDVI Time Series Algorithm	sugarcane	86.5%
40	A.T.M Shakil Ahamed, Navid Tanzeem Mahmood.	K-Means Algorithm for clustering And Classification Linear Regression, K-NN, ANN Method.	Wheat , Potato	90% - 95%

41	D Ramesh, B. Vishnu Vardhan	Multiple Linear Regression (MLR)	Rice Yield	90-95%
		K-Means algorithm	Rice Yield	96%

IV. CONCLUSION

This review paper investigates the use of Internet of Things (IoT) based Wireless Sensor Networks (WSN) and Machine Learning techniques for the analysis of Agricultural Data within the domain of precision Farming. Several researchers have proposed different machine learning algorithms in order to improve the precision and dependability of crop yield prediction in various agricultural domains such as paddy, sugarcane, wheat, potato, and soybean. Furthermore, a comprehensive examination is carried out to compare the results derived from the use of several machine learning algorithms on agricultural data.

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