Smart Sustainable Agriculture Using Machine Learning and AI: A Review

Chapter · May 2022

DOI: 10.1007/978-981-16-7952-0_42

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Abstract Artificial intelligence and machine learning are all about using data for efficient inferences and predicting the future and decisions. These decisions are made human-like, by machines; machine learning and big data are having a greater impact on the way we live. Scholars and scientists are looking at machine learning as a pioneer opportunity to create a positive impact in our day-to-day life, especially in the field of agriculture domains. The research reviews and project popular machine learning models used in the field of agriculture such as (a) crop management (crop yielding, fruit picking weed, and diseases detection), (b) soil management, (c) water management; the paper aims to introduce different types of machine learning methods and algorithms used in machine learning, and how machine learning reaches the agriculture, by implementing the machine learning into farmers by a remote sensor. The farmers will get benefited in decision-making such as risk reduction, quality seed selection, and easy monitoring with software. At the same time, the present study also focuses on the way artificial intelligence and IoT, if introduced in the agricultural sector, can boost the productivity of the sector sustainably.

Keywords Artificial intelligence · Internet of Things (IoT) · Big data · Machine learning · Smart sustainable agriculture

1 Introduction

Agriculture plays a vital role mainly in developing countries for economy wellbeing; this is the main source of income, employment, and also, it plays a significant role in international trade because the most developed country is not engaging much in the agricultural activities; it provides the large source of revenue to the government by transportation (majority of trains and trucks carries the agriculture products; finally, a very main point is food security.

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Y.-C. Hu et al. (eds.), *Ambient Communications and Computer Systems*, Lecture Notes in Networks and Systems 356, https://doi.org/10.1007/978-981-16-7952-0_42

Machine learning technology is an area of AI computer and is automatic data learning without human intervention; it has a greater impact on the global economy, especially machine learning made a huge difference in world trade mainly in communication barrier by making the availability of three hundred languages, banking and FinTech, (by making automatic communication with client and reduces the risk of abuse) and agriculture sector (crop management, soil management, livestock management, etc.).

The research aims to project and review different machine learning models used in the field of agriculture; the paper also introduces different terminologies and abbreviations used in machine learning such as BM Bayesian models, DL deep learning. The paper will be helpful to get an outline of how machine learning can be used in agriculture, and what methods are available in machine learning, especially for the same field.

The research explains the concept of machine learning and reviewed various machine learning techniques used in the agriculture field, to gain knowledge of AI techniques, and also, the paper aims to unfold the usage of IoT in agriculture to make a sustainable agriculture model.

1.1 Objective

1. To review various machine learning technology used in the agriculture field
2. To examine the application of the AI model for sustainable agriculture.

2 Literature Review

The article is divided into two levels one—the explanation of algorithm limited to the field of agriculture, level two is segregated into three general categories; namely, crop management, water management, and soil management. Crop management is categorized into crop yield, crop quality, and weed and diseases detection; the research is searched in Scopus, Web of science also in pub med, article considered the period from 2000 to the current year.

The article is structured as follows: part one explains the literature review of various machine learning models followed by reviews of crop management, water management, and soil management; part two applications of artificial intelligence and IoT in Sustainable Agricultural Practices are explained, part three discussion and conclusion.

3 Machine Learning

In simple term, machine learning is a data which teach the computer human-like, and these data are known as training data, which makes human work accurate and easy and improves the experiences; data in machine learning will be in four categories, numerical data, categorical data, time-series data, text [1]; to measure the performances of ML, various statistical tools are used to predict the result (Fig. 1).

Machine learning is widely classified into supervised and unsupervised data, supervised data is manually trained data whereas unsupervised data is the machines interpretation. Refer Table 1.

3.1 Machine Learning Algorithm Models

The machine learning algorithm is a code that runs on data and produces the decision-making output. The output or a result in a prediction made using the past experiences [2], e.g., in agriculture, weather prediction is made when the temperature is less than 17 degrees soil will get moist, and hence, it is not a good time to crop or yield, the research limit to unfold the explanation which is relevant to agriculture.

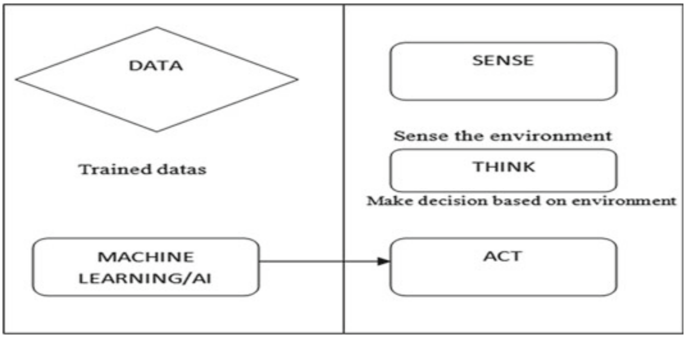

Fig. 1 Machine learning approach

Table 1 Authors model

Types of machine learning method		
Task learning	Explanation	Types
Supervised	Data are labeled and trained	(1) Regression-True/false
Unsupervised	Data are not labeled machine will make inferences of data with close similarity and association	(1) Association-rule-based approach (2) Cluster-similar object

3.2 Supervised Learning Models—Regression

Regression help to find out the relationship between two variable, and it is mainly used to predict the causal effect; regression is classified into typo types 1-single regression 2-multiple regression under which (i) linear regression (ii) non-linear regression is subcategorized in single the features, or variable will be one in case multiple variables; there will be more than one feature;, in machine learning regression has linear regression, polynomial, support vector, decision tree, random.

3.3 Classification-Bayesian Models (BM)

In Bayesian models (BM), probability is used for the output result; the Bayesian model can be used both in classification and regression; some of the Bayesian model algorithms are Naive Bayes, Gaussian Naïve Bayes, the mixture of Gaussian, Bayesian network [3] (Pearl, Duda & Hart).

3.4 Artificial Neural Networks (ANNS)

ANN is adopted and design similar to human brain neurons networks, which has an interconnection analyzing system or processing unit; the number of layers are arranged into (i) input layers (ii) hidden layers (iii) output layer [4].

A deep artificial neural network is also termed deep learning [5]. DL has multiple layers of processing data refer to Fig. 2; DL is a new algorithm in ML where data extraction is done by itself; this type of data is processed both in supervised, and unsupervised comprehensive deep learning is found in learning [6] research literature.

4 Machine Learning and Agriculture

4.1 Crop Management

The method of training the machine and producing the decision is widely used for predicting the future; machine learning is simplified human thinking with break down the complexity of the problem with easy future decision-making result; in that way, agriculture plays a very important role in the global economy; global crop yielding is an important part to address for global food security, predict and reduce the climate changes [7].

Crop yielding forecast is a significant agricultural hitch. The yield depends on weather settings (rainfall, high temperature, etc.), pesticide. Precise information

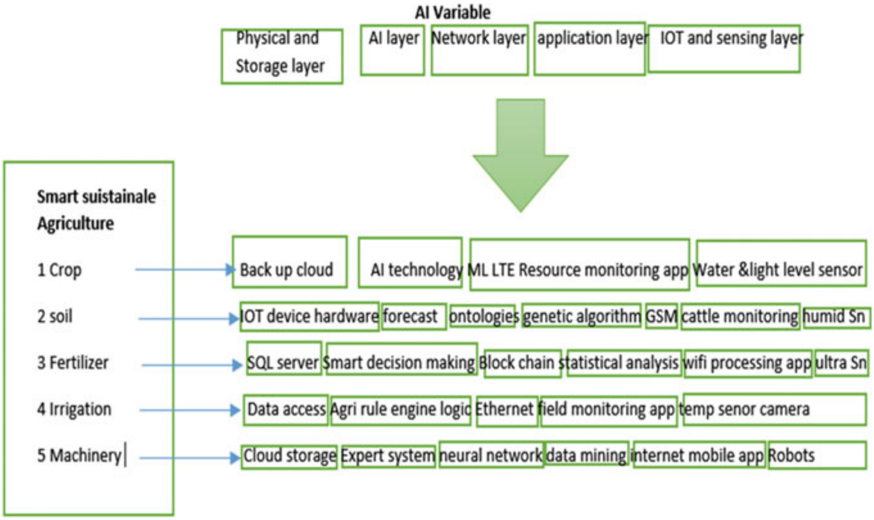

Fig. 2 Applications of artificial intelligence and IoT in sustainable agricultural practices. Authors model

regarding the past crop yield is significantly in decisions-making related to managing agricultural risk Ali et al. [8]. According to [7] he classified the crop management into (i) Fruit picking and forecasting (ii) Automatic fruit picking model green citrus detecting the ingrown citrus; in this circumstances, machine learning will provided information for growth and help the farmer for maximum yield [9].

4.2 Disease Detection

The common treatment for disease plant is spraying chemical in the farm; the major advantage of ML is that in traditional method chemical pesticide is sprayed in the enter farm land in order to prevent the diseases, but in ML, the trackers are attached with camera and computer will detect the diseased crop and spray only in that area instead of spraying chemicals exactly. Another technique under disease detection is detection of parasites in strawberry and spray chemicals in the field. The method of screening the bakanae diseases in crops the is to detect the disease and optimize the maximum yield, in wheat crop, wheat is prominent source used worldwide found the health wheat canopies based on genetically super nature imaginary data; another study. Lastly [10] found the disease detection method using the algorithm with image sensory. Found the method in CNN-based algorithm with image sensors.

4.3 Weed Detection

Weed is unwanted leaves grown, and it will take all the nutrients from the crops and plant; removing the weed is a major problem in agriculture; the first study of weed deduction in machine learning is found by Pantazi et al. [11] based on counter-based image sensor captured with drones (UAS) identify the *Carduus marianus,* and those were removed another study by Pantazi et al. [12] he categorized weed and main crop perfectly to be accurate in weed detection; lastly, the research reviews [13] weed detection by SVN in the plain crop.

4.4 Water Management

Water plays a vital role in agriculture management; it is difficult by a traditional method due to accuracy in prediction in climatic changes also balance in agronomical; the paper explores in evaporate transpiration (it is a period between the absorption of water by land to atmosphere and by evaporating it other surface plants) of the daily and monthly forecast; this system will help farmers to manage and store the water and plant the field accordingly, Mehdizadeh et al. [14] in his research he found that dried and semi dried land evaporates faster and causes a climactic changes ,to read the data of those climactic change he set up the weather forecast station and collected the data.

4.5 Soil Management

The soil is an important source for the continued existence on earth; the layer of the soil is used for planting, and other layers are used in soil fertility, microbes, etc., to predict climate change; soil temperature alone will play a major role in prediction. Firstly [15], the aim of the study is to find the soil dryness with data and evapotranspiration; the purpose of this study is to provide information for remote decision-making; another study done by Morellos et al. [16], he developed a self-evolution method which is called as SAE_ELM where the soil is tested with six different depth from 5 to 100 cm; the aim of the study is accuracy in soil management.

In agriculture AI, there are different model developed for managing farms (i) crops, (ii) water, (iii) soil management. Tables 2, 3, and 4 explain various models of AI in agriculture.

Table 2 Machine learning method for crop management

References	Crops	Type	Functionality	Method used	Algorithm
Crop management					
Amatya et al. [7]	Fruit picking and yield management	coffee	Categorized coffee fruit into ready for harvest, not fit for harvest lastly fruits which are matured by overseen for harvesting	Colored digital imagine	SVM
Sengupta and Lee [9]		Tomatoes	Segregated between green red and yellow tomatoes and picked which is ready for harvest	RGB image	Clustering/EM
Senthilnath		citrus fruit	Identify the number of ingrown in outside condition and grown in green gas	Digital image	ENG
[7]		cherry	identify fruit with foliage	RGB image	SVM
Pantazi	Crop	Wheat	yield predication	Soil parameter and satellite imagine sensor	ANN
zDiseases detection					
Pantazi	Crops	Wheat	Detecting yellow rust and nitrogen stressed	hyper Spectral reflectance and imaginary data	ANN
Moshou		Rice	Detecting fungus diseases like bakanae in rice seedling	Morphing and colure traits	SVM
Moshou et al.		Wheat	Detecting yellow rust and water stressed	Spectral reflectance	SVM/LS

(continued)

Table 2 (continued)

References	Crops	Type	Functionality	Method used	Algorithm
Ebrahimi et l. [17]	Fruit	Strawberry	Detecting patricides and thrips	Reign index	SVM
Weed detection					
Pantazi et al. [11]	weed	Weed	Detection of *Silybum marianum*	Spectral reflectance	ANN/CP
Pantazi et al. [12]		Weed	Diffracting weed 56% accurate and maize 100% accuracy rate	Hyper-spectral reflectance and imaginary data	ANN/SOG/MOG
Binch and Fox [13]		Weed	Grass versus weed	imaginary data	SVN

Table 3 Machine learning method for water management

References	Type	Functionality	Algorithm
Mehdizadeh et al. [14]	Evapotranspiration	Done with monthly mean with the arid and semi-arid region.	MARS
Feng et al. [18]	Evapotranspiration	Done daily, weekly, and monthly interconnected to weather forecast station (6) and trained and tested with trained data	ANN/GRN
Patil and Dika	Evapotranspiration	The same test was conducted with connecting with two weather forecasting stations, and data were tested	ANN/ELM

Table 4 Explains the machine learning method for soil management

References	Type	Functionality	Algorithm
Coopersmith et al. [15]	Soil drying	The study is to find the soil dryness with data and evapotranspiration; the purpose of this study is to provide information for remote decision	IBM/KNN
Morellos et al. [16]	Soil conditioning	Testing soil organic carbon, nitrogen, and moisture content	SVM/LS-SVM
Nahvi et al. [19]	Temperature	Where soil is tested with six different depth from 5 to 100 cm	ANN/SAE

4.6 Applicability of IoT and AI/ML in SSA practice

Smart sustainable agriculture [SSA] is becoming a need of the hour. The present-day pollution due to the chemical-based production of crops is spoiling the environment. Not only the environment but also the health of human beings and the formal community is at risk. If this scenario continues in the existing period, the chances of the slowdown of the economy will upsurge. This is because to satisfy the need of the ever-increasing population; the government needs to import the food product from other countries of the world.

Fortunately, the solution to this intense problem is known to the scientist. The applicability of modern technology to the field of agriculture can reduce the issue of pollution due to cultivation practice and will also lead to the availability of abundant food crops for the consumption of people. Artificial intelligence [AI] and machine learning [ML] along with the Internet of Things [IOT] can prove beneficial in reducing the adverse agriculture impact on the environment and people. Figure 2 explains the model for sustainable agriculture by using AI, adopting the AI IOT model and implementing in the field of agriculture will increase the yield; Usage of IoT in agricultural field will reduce the labor work and labor cost requirement in the field.

The above presentation of systematic layers is the essential component of SSA. The layers are described as follows:

1. Physical hardware and storage layer: This layer compromises of strong hardware required to store the virtual technology
2. AI and data management layer [DM]: This layer deals with various processes including in the segment of collection, from the SSA clouds.
3. Network layer: Networking between various components serves to fulfill the actual demand of the architecture. The networking panel uses the recent technologies to establish the connection of the flow of data from one aspect of the SSA model to other include Wi-Fi, Internet, and GSM/CDMA.
4. Security layers: AL algorithms are hindered in many cases by the security of the data inputs. The presentation layer will enable its functional capabilities in managing the dangers arising from malware, viruses, data theft related to all the SSA layers. In case of the absence of this layer, the entire process can give either defective conclusions or may altogether be unable to generate one.
5. Application layer: This comprises full or partial monitoring of the data flow and the implication of all the layers to the ultimate SSA layer. The data flow here is monitored using the integrated mechanism in agriculture applications including monitoring of cropping culture using a drone, disaster management, geographical area spread, potential acquaintance of area under cropping, and many more.
6. Internet of Things [IOT] and sensing layers: This is the most crucial layer applicable to the collection of data related to agricultural practices. It is using the sensor required to track the element directly or indirectly controlling the

agriculture parameters such as sensor sensing humidity, moisture, temperature, and biological elements.

7. Domain SSA layer: The base layer around which all the layers are rotating. Various agriculture domains are included in this layer which has to be modified with the help of other layers.

The growth of agriculture products in a sustainable manner is the need of the hour. Today all the possible experiments are carried out to come up with smart sustainable agricultural practices so that with putting pressure on existing natural resources and degrading the environment the cultivation period can be reduced along with the improvement in quantity, quality, volume, and variety of crops available for mass consumption. This can be achieved only with an integrated approach where IOT and AL/ML and be combined with SSA practices.

5 Discussion

General discussion—total number of the article involved in the study is 40, the search thread covered the partial crop management and water management and soil management in the popular method used between period 2015–2021; all the methods are briefly discussed in tabulation format; it is slightly unlike to cover the entire paper; the review research is value to threat and validity [20].

Specific discussion—search strategy is thin downed with the relevant scope of the research; a manual search is done with using the word-like machine learning and yield prediction with Google scholar engine, Scopus, and Web of sciences exclusion category was made like publication in another language, article which is not available open-source, publication before the period 2014; all those which comes before 2014 used for common algorithm terms for machine learning.

The study discussed the sustainable agriculture model by introducing IoT (Internet of Things) which makes the study novel in nature, besides the study, reviews machine learning models until 2021 which fill the review gap of past literature.

6 Conclusion

There are many algorithm models are used; the paper summarizes eight models in which crop management has SVM, EM, least square regression, cluster, SOG/MOG, SVN for soil management models like IBM/KNN, SVM/LS-SVM, and ANN/SAE are used; finally, for water management, MARS, ANN/GRN ANN/ELM is reviewed.

Machine learning is used in agriculture sector mostly in crop management predication in which majority study on crop yield prediction and diseases detections. Machine learning has shown a vast development in the field of agriculture sector like fruit picking, crop analysis from drones, and satellites with ninety-five percent accuracy weed eradication with digital imaginary camera and spraying the pesticides in the weed alone, real-time weather forecasting like seeing temperature, rainfall, and humidity with solar radiation; the prominent work ML can do to agriculture is autonomous tractors intelligent machines, decision-making with algorithms remote monitoring; the study shows that there is frequent usage of ANN, SVM for crop management as well as soil and water management, using machine learning in agriculture can develop the country as a whole for future study; the government scholar and experts should spread the usage of machine learning to real-time farmers and normalizing the machine learning like traditional study will save the farmers as well the impact of lands.

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