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A REVIEW ON SMART AGRICULTURAL PRACTICES USING IOT AND MACHINE LEARNING

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Abstract : As new and advanced technologies emerge in this modern era, such as the Internet of Things (IoT), Artificial Intelligence (AI), Cloud Computing, unmanned drones, and advancements in sensing technologies, every field is attempting to equip and use these technologies to overcome losses and increase profits by reducing human intervention. These new technologies not only minimize human effort but also help to do things in sustainable agriculture, where we leverage technology such as IoT, machine learning, and cloud computing to assist farmers to create more revenues and lower losses by learning and analyzing data

***Keywords* – Internet of Things (IoT), Cloud Computing, Artificial Intelligence (AI), Smart Agriculture.**

I. INTRODUCTION

India is the world's third-largest agricultural producer, behind the United States and China. India is top in the net cropped area, followed by the United States and China. Agriculture is the primary source of income for the majority of Indians (about 58 percent of the population) [1]. Agriculture is the backbone of the Indian economy, accounting for about half of the country's GDP. As the world's population grows, we must develop more innovative agricultural methods to fulfill the needs of future generations. These practices must also be sustainable. Smart Agriculture is significantly more efficient than traditional farming methods. As technology advances, better irrigation and automation techniques become more common. Using today's latest technologies, farmers can monitor and control agricultural land, temperature, humidity, soil moisture, and other variables from anywhere in the world, eliminating the need for a person's presence.

II. MACHINE LEARNING

Machine learning is a sort of artificial intelligence (AI) that allows software applications to improve their prediction accuracy without being expressly programmed to do so. Machine learning algorithms predict new output values using past data as input[2]. There are four different types of machine learning algorithms.

2.1 Supervised

In supervised learning(SL), the computer is taught by using examples. In SL, the machine should be trained on a dataset with both desired Inputs and Outputs, and the algorithm should be able to figure out how to get to those Inputs and Outputs. The algorithm recognizes patterns in data, learns from observations, and generates predictions, while the operator knows the proper answers to the problem[3]. The three main types of algorithms that fall under SL are classification, regression, and forecasting.

2.2 Semi-Supervised

Semi-Supervised learning (SSL) is also like SL. Unlike SL, the SSL uses both Labeled and unlabeled data. The data which have been tagged or labeled forms labeled data and unlabelled lacks all theses. SSL learns to label unlabelled data by learning from a combination of labeled and unlabeled datasets.

2.3 Unsupervised

Unsupervised learning (USL) occurs when a system is trained without supervision on unlabeled data. Models, on the other hand, use the data to uncover hidden patterns and insights. It is comparable to the learning that occurs in the human brain while learning new things[4]. USL can do clustering and dimension reduction.

2.4 Reinforcement

In reinforcement learning (RL) the machine is given some prior set of actions, end values, and parameters. The RL algorithm seeks to explore different options and actions by setting rules. The algorithm continues to monitor and evaluate each outcome to discover the best answer. RL uses the trial-and-error method to instruct the machine so that it can learn from its mistakes.

III. Internet-of-Things

Internet of Things (IoT) describes the internet-connected network of physical objects "things" embedded with sensors, software, and other technologies to communicate and share data with other devices and systems[5]. IoT is mainly divided into three components.

3.1 Sensors

A sensor is an electronic device that provides a usable reading as output to a specified measurement. The sensor identifies or senses the physical materials or the quantity and converts it into human-readable data. There are more than 6000 different types of sensors present currently.

3.2 Connectivity

The data which is gathered from sensors should the transferred to the cloud. Here comes the connectivities role, this provides a medium to transfer data between devices. Wi-Fi, Low-power wide-area networks (LPWAN), cellular, Bluetooth cellular are commonly used technologies used to achieve connectivity.

3.3 Data processing

The data which is stored in the cloud is used to gain valuable information. By using different techniques, the received data can be processed for different uses like predictions and monitoring. The data gathered in the cloud is presented to the user via a user interface.

IV. Applications Where IoT And ML Can Be Implemented

4.1 Climate Management

The most essential key component that determines the stability of a crop in a specific place is the climate. The climate has a significant impact on the crop's yield potential. The climate of the region determines more than half of the variation in crops [6]. Growth, yield, development, rainfall, temperature, and solar radiation are all influenced by climate. Climate-Smart Agriculture makes use of new technologies to create ideal growing conditions for plants that are artificially regulated.

4.1.1 Climate-Smart Agriculture

Climate-smart agriculture (CSA) is an integrated method for managing landscapes crops, livestock, forests, and fisheries that addresses the interconnected concerns of food security and climate change. CSA seeks to achieve three goals at the same time [5].

4.1.1.1 Enhanced Productivity

In rural areas and 75% world's poor people rely mainly on agriculture for their livelihoods. CSA will help produce good food in better quantities than traditional ones, which boosts the incomes of the poor and makes their health better by improved nutrition in the food they produce.

4.1.1.2 Improved Resilience

CSA aids in the control and immunity of crops against pests and diseases. It also aids in overcoming vulnerabilities such as droughts and other climate-related dangers, as well as improving crops' ability to survive uncontrollable weather disruptions.

4.1.1.3 Reduced Emissions

For each calorie of food produced, CSA produces fewer emissions. Because it minimizes the amount of land needed to produce food, CSA indirectly aids in the reduction of deforestation and the development of more sustainable carbon absorption methods.

A unified vision and goal for CSA adoption is essential for success and aligning timelines of demands and outcomes is part of that vision and purpose. This can be hampered in part by a lack of awareness by farmers. Not only for scaling-up operations but also for small-scale uptake of new techniques, having a good understanding of what farmers need and want is critical. Farmers' needs must be prioritized in CSA scaling attempts and scaling up is more likely to occur if technology is truly appropriate[8].

4.2 Yield Management

Traditional farming methods are not able to keep up pace with the increasing population and their requirements. In the recent boom of technologies like AI, Cloud, and IOT, there has been a great change in yield production compared to traditional farming techniques. Precession agriculture can be implemented by using highly accurate and freely available weather forecasts and the available datasets, which are gathered from years of continuous data, now we can use the prediction algorithms to calculate and supply water that is exactly needed for the crop. This prior prediction helps farmers to reduce production costs and maximize crop yield.

4.2.1 Precision agriculture (PA)

PA is a management strategy for improving resource use efficiency, productivity, quality, profitability, and sustainability of agricultural production by gathering, processing, and analyzing temporal, spatial, and individual data and combining it with other information to support management decisions based on estimated variability. [9]. The main objective of PA is to define a decision support system (DSS) for the management of crops and help farmers to achieve high returns while maintaining the resources. By using Global Positioning Systems (GPS) we can achieve the following for PA :

- GPS-Computer guided tractors
- Electromagnetic soil mapping
- Crop yield data collection
- Soil sample collection
- Aerial Imagery
- Soil color Index maps
- Water level studies

The increased use of geo-referenced data has aided farmers in dividing enormous areas of land into smaller manageable zones, which may be utilized to cut water waste and run autonomous agricultural gear with great precision.There is a need to establish a system that automates agricultural processes like cultivation and irrigation, anticipates yields, and aids in better planning for systematizing agricultural product demand and supply around the world[10].

4.3 Soil Management

Like water and sunlight, the soil is also one of three essentials that plants and animals cannot live without. It is the source of nutrients, minerals, and water for plants also it helps plants as a medium to gaseous exchange between roots and atmosphere. Soil contains micro and macronutrients like magnesium, nitrogen, phosphorus, calcium, potassium, and sulfur which are essential for plant growth, these nutrients levels differ from region to region, In traditional agricultural practices farmers blindly follow the recommended doses of fertilizers for a particular crop in a region, but now by using IOT’s and different sensors now we can calculate the number of nutrients present in the soil and predict the correct amount required by using ML algorithms, by advancement in these technologies now farmers can apply only required fertilizers which is the cost-effective and best method to decrease soil pollution. Land management decisions require an understanding of the soil's aptitude and capability to support an ecosystem. Farmers can also utilize digital soil mapping (DSM) to learn about important soil features[11].

4.3.1 Digital Soil Mapping (DSM)

“The creation and the population of a geographically referenced soil database generated at a given resolution by using field and laboratory observation methods coupled with environmental data through quantitative relationships.” - The International Working Group on Digital Soil Mapping (WG-DSM) [12].

4.4 Disease Management

Plant disease is a disruption or modification of a plant's normal state that disrupts or affects its important processes. Plants of all kinds, wild and cultivated, are susceptible to illness. Although each species is prone to specific diseases, there are only a few of them in each situation. Plant diseases vary in occurrence and prevalence from season to season, depending on the pathogen present, environmental circumstances, and the crops and kinds produced. Some plant kinds are more susceptible to disease outbreaks, while others are more resistant[13].

4.5 Weed Management

Weed is a broad term for any plant that grows in an unwelcomed location. They compete for resources such as water, light, and nutrients with crop plants, resulting in fewer resources for the original crop plants. Weeds also attract bugs, which destroy the crops, resulting in a lower yield. In any case, weed control has evolved into a highly specialized activity. Weed management courses are taught at universities and agricultural institutions, and industry provides the essential technologies. Weed control is critical in agriculture for maintaining high levels of crop production. Weed detection has become easier in real-time over wide fields thanks to advancements in electronics and sensing technologies, as well as picture processing.

4.6 Water Management

The demand for food is increasing by the day, thanks to the current pace of population growth. Irrigation for crops consumes around 70% of all freshwater. Due to low rainfall or the geographical area of the crop, several places are experiencing water shortages. As a result, water management is becoming increasingly important on a global scale. With today's modern sensors, gathering data such as soil moisture, water level, and air humidity has never been easier. We can utilize IoT and machine learning algorithms to remotely monitor and supply only the amount of water that the crop requires, allowing farmers to reduce their water use in a sustainable manner.

V. LITERATURE REVIEW

5.1 Literature reviews based on IoT

5.1.1.1 In research by Nikesh Gondchawar and R. S. Kaikara, the authors created a system that performs weeding, spraying, moisture monitoring, bird and animal scaring, keeping vigilance, and other chores all performed by a GPS-based remote-controlled robot. Second, smart irrigation with intelligent control based on real-time field data is included. Finally, smart warehouse management, which includes temperature control, humidity control, and warehouse theft detection[14]. TABLE 1's hardware was used to integrate with IoT by the authors.

Table 1 Hardware used and uses

S. No	Hardware	Uses
1	AVR Microcontroller Atmega 16/32	Microcontroller Development Board
2	ZigBee Module	Wireless communication
3	Sensor LM35	Provide accurate temperature
4	Moisture sensor	Measures the water content in the soil
5	DHT11	Digital temperature and humidity sensor
6	Ultra-Sonic 40KHz	Obstacle detection
7	Raspberry Pi	Small computing and networking operations

5.1.1.2 In research work by Ashifuddin and Zeenat [15]. The authors created a system set up that gets live data like soil moisture and temperature from the field. By using the gathered data, the system controls high voltage electronic equipment placed on the farm without any human intervention. The authors used the hardware in TABLE 2 to incorporate IoT.

Table 2 Hardware used and uses

S. No	Hardware	Uses
1	Arduino UNO board	Used as a microcontroller
2	LM35 Sensor	Temperature sensor
3	VL95 Sensor	Soil moisture sensor

5.1.1.3 In the research work by Changmai, Sethavidh[16]. The authors created a system to farm Lettuce, IoT was employed to establish a smart farming strategy. Hydroponics is a way of growing plants without the use of soil, instead of relying on a liquid nutrient solution, which allows farmers to cut production costs. According to the findings, lettuces from the smart farm have a 36.59 percent higher weight, 17.2 percent more leaf, and 13.9 percent larger stem width than lettuces from a traditional farm. Smart farm lettuces have an 8.24 percent lower nitrate content[13]. TABLE 3's hardware was used by the authors to add IoT.

Table 3 Hardware used and uses

S. No	Hardware	Uses
1	Arduino Mega 2560	Microcontroller device
2	Ultrasonic Sensor	To measure water height
3	DSI8D20	Water Temperature Sensor
4	ESP8266 Wi-Fi	Wireless Connectivity
5	DHT21 / AM2301	Temperature & Relative Humidity Sensor
6	BH1750	Light Sensor

5.1.1.4 In research work by Nikhil R, Anisha,[17]. The authors designed a system to monitor the field for detecting wild-animal intrusions and used IoT and ML to implement smart agriculture techniques like irrigation. The authors used the hardware in TABLE 4 to incorporate with.

Table 4 Hardware used and uses

S. No	Hardware	Uses
1	Raspberry Pi-3	Used as a microcontroller
2	DHT11 Sensor	Temperature & Humidity Sensor
3	Moisture Sensor	To test the volumetric water content
4	USB Camera	To capture the images of all the wild animals
5	Infrared Sensor	To detect the water level in the tank
6	Rain Sensor	To detect rain droplets

5.1.2 Observations

By going through multiple research papers and reviews, we observed that the following 9 types of sensors are most used.

- Temperature Sensors
- Humidity Sensors
- Infrared Sensors
- Optical Sensors
- Proximity Sensors
- Pressure Sensors
- Gyroscope and Accelerometer
- Pressure Sensors
- Gas Sensors

5.2 Literature reviews based on ML

5.2.1 In research work by S.Veenadhari, Dr. Bharat,[18]. The authors created a simple user-friendly software tool named 'Crop Advisor' using the C4.5 algorithm to find outcrops yield of selected crops like Soyabean, Paddy, Maize, and Wheat in selected districts of Madhya Pradesh, India. The study indicated the potential utility of data mining approaches in estimating crop output based on meteorological input characteristics, according to the author. Prediction accuracy is greater than 75% in all of the crops and districts studied, indicating superior prediction accuracy. Any user can utilize the user-friendly web page built for estimating crop production by supplying climate data for their desired crop[18]. In paper by Savvas, Christos [19]. The authors implemented a prediction system using WEKA analysis by using different classification algorithms to perform precession agriculture practices. TABLE 5 shows the ML classifications and their accuracies.

Table 5 Classifiers used and their accuracy and false-positive rate

S. No	Classifier Name	Accuracy	False Positive Rate (FP)
1	Naïve Bayes Simple	88.18 %	0.16 (0.11)
2	ZeroR	88.18 %	1 (0)
3	OneR	91.59 %	0.13 (0.07)
4	J48	89.41 %	0.09 (0.11)
5	DecisionStump	89.13 %	0.05 (0.12)

5.2.2 In proposed research by M.Kalimuthu, P.Vaishnavi. The authors created software for predicting the best suitable crop for farming in a particular field, by using data gathered from GPS, soil moisture, and temperature sensors. "The proposed system follows the Naive Bayes classifier, the supervised learning algorithm consists of the four levels to calculate and predict the crop for the suitable climate in the phenomenon"[20]. And in research performed by Zeel Doshi and Rashi Agrawal, the authors created Agro Consultant, an intelligent system. Which analyses data such as sowing season, soil attributes, geographical location, temperature, and rainfall to aid Indian farmers in making before crop selection decisions. This would assure maximum output because the choice of crop to grow would now be influenced by the crop gathered in the previous cycle[21]. The results obtained are in TABLE 6 by using different algorithms.

Table 6 Algorithms used and their accuracies

S. No	Algorithm	Accuracy
1	Decision Tree	90.20
2	K-NN	89.78
3	Random Forest	90.43
4	Neural Network	91.00

VI. PROPOSED WORK

By using IoT, we created a smart agricultural Irrigation system and named it a smart agricultural machine shortly - SAM. SAM is a simple IoT machine that gathers data like soil moisture, temperature, the water level in the water source, and controls the water pump automatically and also it sends real-time data to the user wirelessly. TABLE 7 shows the hardware used to create SAM. And TABLE 8 shows the truth conditions used to control the water pump.

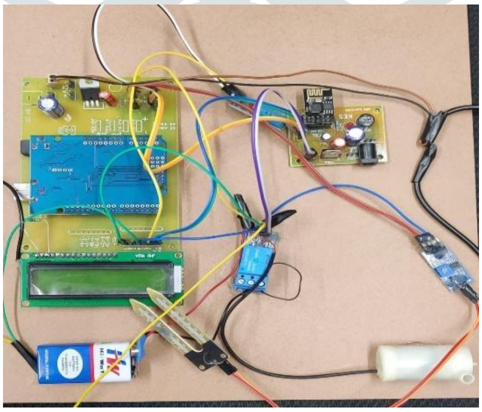

Fig 1 IoT Setup to control water pump for Irrigation

Table 7 Hardware devices used and their uses

S. No	Device	Uses
1	DHT 11 sensor	To detect temperature and Humidity
2	Water level Sensor	To measure the water in the storage.
3	Moisture Sensor	To detect moisture in the soil
4	Pump	To regulate water flow
5	Audriono Uno	For Calculations and Processing
6	Wi-Fi module	To send data to the user
7	2 x 16 Bit Display	To display the status of the system

Table 8 Truth table used for controlling pump

Water Level	Soil Moisture	Temperature	Pump Status
1	1	1	0
1	1	0	0
1	0	1	1
1	0	0	1
0	1	1	0
0	1	0	0
0	0	1	0
0	0	0	0

In the above TABLE VIII, the water level is set to 1, if the tank is full and 0, if the tank is empty. Soil moisture is set to 1 if moisture is detected and 0 if moisture is not detected. Temperature is denoted as 1 if the temperature is above or equal to 40^0C and 0 if the temperature is below 40^0C. Pump status is 1 if the pump is in running condition and 0 if the pump is OFF, SAM only turns on the pump in two cases:

- **Case i**. If the water level is full, Soil moisture is absent, and the temperature is above 40^0C.
- **Case ii.** If the water level is full, soil moisture is absent, and the temperature is below 40^0C.

By using ML we have created a Yield prediction system by taking the "Crop Production in India" dataset from Kaggle[6]. The data set contains 246091 values, and 7 columns named in TABLE 9.

Table 9 Dataset Description

S. No	Column Name	Description
1	Sate_Name	Name of the State
2	District_Name	Name of the District
3	Crop_Year	The year of the crop planted
4	Season	Describes which season (Kharif, Rabi..)
5	Crop	Type of the crop (Rice, Maize….)
6	Area	Area of agricultural field
7	Production	Total crop production (Yield)

5.2 Result

We have used two regression algorithms for predicting the yield, Random Forest and Decision Tree, and achieved 97% and 93% accuracy. And from Fig .1, and Fig .2, we can observe the actual vs predicted values by the algorithms.

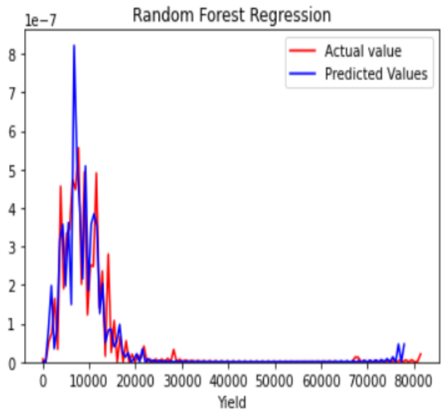

Fig 2 Actual vs Predicted values by Random Forest Algorithm

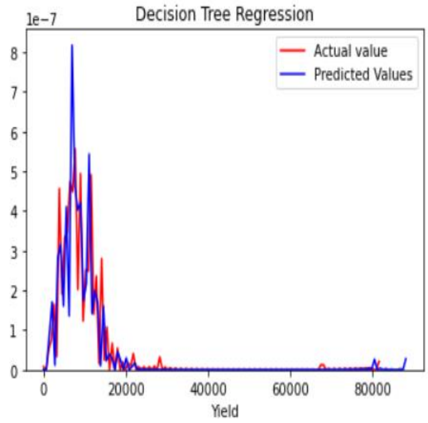

Fig 3 Actual vs Predicted values by Decision Tree Algorithm

VI. Observations

By going through multiple research papers and reviews, we observed that the most used ML algorithms in smart agriculture are Artificial Neural Networks (ANN), Deep Neural Networks (DNN), and Support Vector Machines (SVM). These three were used maximum for the purposes like disease detection, yield prediction, quality prediction, crop management, and weed detection.

VII. Future Scope

We can integrate both SAM and the ML model we have created to create a platform like a web application or application for smartphones for farmers so that they can monitor their crop's irrigation activity and also predict the yield for their crop. The future scope for these kinds of applications is very bright where farmers can get an idea of what is going on in the field by adding methods like smart fencing and crop selection to choose, which type of crop they should plant next..

IX. Conclusion

As the need for smart and sustainable innovations increases every day, smart agriculture practices must be used instead of traditional farming techniques. In India maximum farmers are uneducated and they lack behind in using smartphones/computers so, the researchers and creators must keep the techniques they created should be simple and easy to use even for an uneducated person. Most agriculture is performed in rural areas, every farmer there should use the smart applications for farming. In this way, we can limit the resources used and expenditure on the crop's so we can give our future generations a pollution-free and resource-rich future.

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