A Review on IoT Based Smart Agriculture

Avali Banerjee[1],Surajit Basak[2], Koustab Maity[3], Debasis Banerjee[4]
[1,2,3]Guru Nanak Institute of Technology, [4]Accenture Services Pvt. Ltd.
[1,2,3]*157/F, Nilgunj Road, Panihati, Sodepur, Kolkata, W.B. 700114, India,*
[4]*Unitech Hi-Tech Structures Limited, Action Area 1 New Town, Rajarhat, Kolkata, W.B. 700156*

Abstract— The objective of review aims to identify the different platforms, networks and data processing protocols of IoT based smart agriculture for increasing in crop yield. As the world's population is increasing day by day and the production of food crops is not sufficient as per the requirement. Therefore, scientists and researchers are using IoT to increase production rates, because it is efficient, timely, and requires less human effort. Emerging technologies such as machine learning algorithms, energy harvesting, cloud computing etc. are reviewed in detail for analysing large data of different scale and considering the climatic impact by using real-time operation. The different types of network topologies and protocols used in IoT based smart agriculture along with security challenges are extensively reviewed. A detailed comparison of different type of sensors alongwith different types of emerging technologies used in IoT based smart irrigation system are discussed. Recent research challenges are also identified in the aforementioned domain.

Keywords—IoT Technologies, Sensors, Artificial Intelligence, Machine Learning, Fog Computing, Security, Agriculture.

introduction

Today, the most challenging task is to increase the rate of food production. As per records, it is estimated that in 2050 approximately 10 billion populations will depend on the agricultural products [1]. Environmental degradation which is caused by human beings affects the world's biodiversity which results in reduction of food crops. There is another factor to meet the current requirements is the insufficient workforce which affects the productivity level [2], [3]. Crop production is becoming essential not only for food but also for industry; in fact, many countries' economy highly depends on crops like cotton, rubber, and gum. Additionally, the market for bioenergy based on food crops has lately begun to expand. Prior to a decade, just the ethanol industry used 110 million tonnes of coarse grains, or around 10% of total global production. Food security is under jeopardy as food crops are being used for the production of bio-fuels, bio-energy, and other industrial purposes. The burden on already limited agricultural resources is rising as a result of these demands [4], [5].

So, Internet of Things (IoT) based smart farming is the new innovation which uses different techniques and technology at various level under one roof which lead to overcome the different challenges usually faced by the farmers [6]. It gives a complete roadmap to the new farm management concept [7]. Different parameters and factors in smart farming has been taken care such as smart irrigation system, proper utilization of fertilizers and pesticides, soil sampling and mapping and many more applications. The whole IoT system comprises of different kinds of sensors for obtaining data directly from the field such temperature, rainfall, humidity, light, pressure, etc., hi-tech communication networks for trans-receiving data for analysis and unmanned vehicles such as drones for observing the field conditions [7]. All the systems and devices are connected to each other in a single platform through internet connectivity and named as IoT. Its main usage is to boost the productivity level at a low cost, to reduce the wastes and the proper utilization of resources at a maximum level. Some Machine Learning (ML) Algorithms and Artificial Intelligence (AI) also help in taking appropriate decisions in right time [8]. Many research works are going on for the enhancement of crop yield based on IoT smart farming which signifies the importance of IoT. In this paper, an extensive survey on network technologies, different sensors, drones embedded system, network protocols, cloud computing, energy harvesting and different security issues has been done. Moreover, different kinds of data analysis in IoT architecture and associated applications, and challenges faced during the process have been discussed. The different techniques of data collection by the different kinds of sensors by IoT system and storing in the cloud based platforms for future analyzing are also studied in addition with different kinds of applications domains like controlling, monitoring, prediction and logistic. The rest of the paper is organized as follows. Section II presents the related works. In Section III we discuss the system model including different types of sensors, energy harvesting techniques, network topologies, cloud computing, various machine learning algorithms, communication protocols and different security issues. Finally the paper is concluded in Section IV.

I. RELATED WORKS

The related works for the IoT based smart farming may be summarized as follows.

A. Field Monitoring System

The advantage of this system is to reduce the agricultural waste by collecting accurate data from the field using different kinds of sensors. The soil is the most essential requirement for agriculture so the soil monitoring is the primary issue to understand the farming patterns and processes. Many smart sensors have been deployed in the agricultural field for monitoring the soil specimens which includes soil humidity, fertilization, moisture and temperature. An adequate quantity of fertilizer is required in the field to enhance the productivity level which will help to generate a test report for recommending the farmers. Hence the excessive use of fertilizers will be avoided. Moreover, soil contamination by deploying IoT technologies and the crop loss will be reduced [9]. Figure 1 depicts the crop monitoring system.

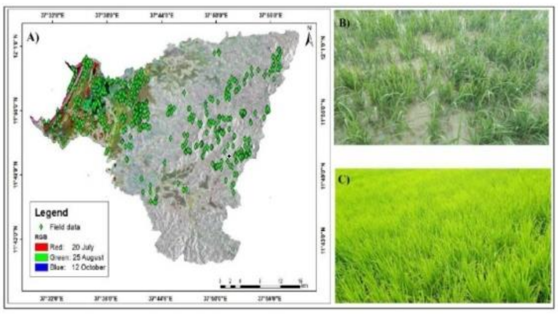

Figure 1. Crop Monitoring System [10]

B. Smart Irrigation Management System

By observing weather conditions and soil conditions the smart irrigation system can be optimize in various ways. Many smart sensors have been installed in the field to sense the weather forecasting data as well as the moisture level of the soil. The water pump will only start when the present moisture level of the soil is below the threshold value which will ultimately reduce the monthly irrigation cost and wastage of water resources is also prohibited [11] as shown in figure 2. Machine learning algorithms and open source technologies have been used for its intelligent operations to sense various soil and weather specifications. By using Message Queuing Telemetry Transport (HTTP) and Message Queuing Telemetry Transport (MQTT) protocols, the cost of irrigation system can be reduced to inform the user and the water quality is checked by the sensor nodes through wireless communication [12]. It computes both the physical and chemical hindrance of temperature, pH level, conductivity and oxygen. All the data is uploaded to the cloud server so that it can be viewed as per the requirement [13]. Wireless Sensor Network (WSN) can be used to develop simple irrigation system. The cellular technologies have been used by the advance system to control irrigation system and to store the data in the database system [14].

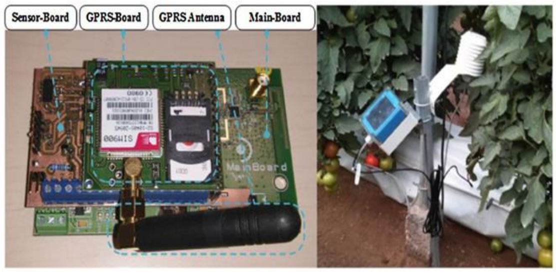

Figure 2. Smart Irrigation System [14]

C. Greenhouse System

Enormous greenhouse cultivation needs accuracy in the perception of controlling and monitoring of climatic conditions. IoT based Smart farming regulates the micro-climate conditions with a target of increasing the productivity level and also the quality of different fruits and vegetables in the green house environment. The hydroponics system is used for growing different crops efficiently by using machine learning algorithms. Many researches have been done to reduce the human resources and energy consumption. It is mainly focused on remote monitoring. Typical applications of green house systems are water management, plant monitoring and climate monitoring. A greenhouse smart agriculture system is depicted in [15].

D. Pest and Crop Disease Management System

This system console helps in monitoring different kinds of fungus and microbial bacteria and prevents the crops from them. Another usage of this system is to regulate the level of temperature and humidity in the field. Every year a hugeamount of crop gets destroyed due to different kinds of pests and crop diseases. Due to advanced technologies, the farmer gets alert about the pests and the prediction of crops diseases. This gives rise to more revenue generation as the crop is protected. At early stages, the recognition of crops diseases is very critical and costly so automatic detection of diseases is being used as it is more accurate and cheaper than the conventional method. These entire automatic disease detection system uses image processing method. The farm land which is located near the forest is set up with an IoT technology for observing the wild animals and to prevent the crops to get ruined [16], [17], [18].

E. Agricultural Drones

The applications of Unmanned Aerial Vehicles (UAV) such as drones are used in smart farming system. However the drones are used for remote sensing, imagery analysis of the large field with the help of high quality supervision camera and Global Positioning System (GPS) device cameras along with smart sensors. It takes 3-4 snapshots of a particular site from the top of the field and delivers it to the cloud storage for analysis. By using artificial intelligence system it adds the taken images and will make a single image to provide detailed analysis. Moreover thermal imagery is also used during the night time for locating the animals. All kinds of field monitoring, animal monitoring, spraying, screening, scouting reports and many more applications which are related to the agriculture are done by drones. Drones are integrated with Geographic Information System (GIS) for mapping and crop health imaging.

The two kinds of drones are wire based drone and wireless drone. The drones are very useful in large farms for observation of problem caused by bacteria and fungus. There are many applications of drones which are very useful in smart farming are sowing seeds, spraying pesticides and fertilizers on the crops, soil mapping, crops forecasting, fertility assessment, recognizing different kinds of weeds and many more [17].

The drones have high speed and good efficiency in spraying operations. The advantages of drones are plant counting, plant height and health, drainage mapping and weed pressure. Still there are many factors which restricts the benefits of IoT based smart farming system. The most important factor is getting the seamless connectivity in the field. As the agricultural practices are done in the rural areas where it is a challenging task to get a good network connectivity like 4G, 3G, Broadband connection, Wi-Fi. For real time operation it is mandatory to get efficient connectivity among all the sensor equipped devices.

System modelling

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The system model consist of different type of sensors, energy harvesting techniques, cloud computing, various machine learning algorithms, different network topologies with protocols and security aspects, as depicted in figure 3. First, the sensors will collect data from the agricultural field and a constant power supply is provided for proper working of all the sensor nodes by utilizing numerous energy harvesting techniques. After collection of data from the field, all the data are uploaded to the cloud server for proper storage. For prediction purposes, different ML algorithms are used for proper analysis of data and making exact decisions for it. For establishing connections between the cloud server and the IoT device different kinds of network protocols are used. All the concern security issues are also identified. Finally various emerging research challenges, based on smart agriculture IoT systems, are also discussed. Figure 3.

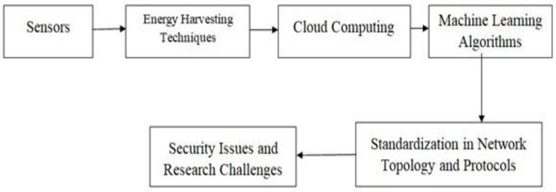

Figure 3. System Model

F. Sensors

The soil moisture sensor is one of the important sensors used in smart farming to determine the moisture level of the soil. It helps to understand the characteristics of the soil to get better yield. By using IoT technologies the crop efficiency get increases by using crop water stress index based irrigation system. The IoT system functions in a systematic way like huge data are obtained from the field where all the sensors are connected together with a wireless monitoring system. These huge data are transmitted to the data processing centre where all the data are being analyzed with the help of intelligent software. In addition, other data are also required such as weather data and satellite imaging for exact requirement of water to produce the irrigation index value as an output.

The moisture sensor and the temperature sensor are used to estimate the humidity level of the soil media and the heat of the air in the Greenhouse Management System (GHMS). GHMS will decide whether to turn ON or OFF the water pump for irrigation, fan for air circulation, and mist for adding water to the air based on the readings from the sensors. Various moisture sensors are used in smart farming to get the accurate results [19], [20], [21], [22], [23], [24]. A detail classification of various sensors used in NB-IoT is shown in Table I.

G. Energy Harvesting Methods

In wireless networks, energy consumption is the key factor for the battery operated sensor nodes. Energy harvesting is the only way to meet the demands for enough energy in distant places because it is very difficult to obtain a steady supply of electricity. Examples of such energy sources are solar, thermal, wind, kinetic, and electromagnetic energy. The sensor networks used for energy harvesting are known as energy harvesting wireless sensor networks. Three fundamental functions of energy harvesting wireless sensor networks are (i) data sensing, (ii) data processing and (iii) wireless communication for trans-receiving information. Due to antagonistic distribution of land, the replacement of batteries sometimes is very difficult and energy harvesting technologies have been introduced. It can harvest ambient energy from the sources and store in the battery for future requirement. The harvested energy may be obtained in the form of Radio Frequency (RF) energy and solar energy by using RF receiver and solar panel respectively. The energy harvesting system consists of conversion hardware, storage devices, energy collection element and power conditioning. The harvested energy is converted to the electricity, used to provide power to the sensor node or to charge the system batteries, by using conversion hardware and power conditioning. Energy collection elements estimate the amount of harvested energy. The unused harvested energy is stored in the storage devices following [29].

1) Radio Frequency (RF) Energy Harvesting Methods:

RF has controllable and predictable features. The sensor nodes are used to acquire the energy carried by radio waves and change into DC power to power the devices. It has advantage that it has flexible mechanism and the transferred energy is controllable by making it continuous. There are many factors that influences the RF harvested energy are distance between the source and receiver, source power, antenna gain and energy conversion efficiency. It is used in the urban and suburban areas due to its ambient energy sources. A lot of researches have been done on circuit design, operation design for radio frequency harvesting and transfer into cognitive radio sensor networks. According to Friis equation, the amount of power transmitted by the transmitter is not same as the power collected by the receiver following [30] and the references therein.

2) Solar-Based Energy Harvesting Wireless Sensor Networks:

Solar energy harvesting techniques are eco-friendly because they're predictable and abundant. Crystalline silicon is used to manufacture the solar cells. Solar cells are also designed by using nanotechnology based semiconductors which includes nanowires, nanorods, nanocrystal and nanodots. The efficiency of solar energy is affected by relative humidity, cloud cover, sun intensity, etc. Solar energy is used to generate power during daytime so that it can be utilized during the night time [31]. The compact size solar panels are attached with self governing WSN in solar energy harvesting wireless sensor network (SEH-WSN). SEH-WSNs are used to monitor temperature, environment and pressure, and measure light intensity and humidity, etc [31]. The primary components of the SEH unit are solar or photovoltaic (PV) cells, boost converter, maximum power point tracking (MPPT), energy prediction algorithms and battery/super capacitor storage, as shown in figure 4.

3) Wind Based Energy Harvesting Wireless Sensor Networks:

Wind based energy harvesting technology is another eco-friendly and reliable power source as it has enormous energy density and abundant in the environment. The kinetic energy

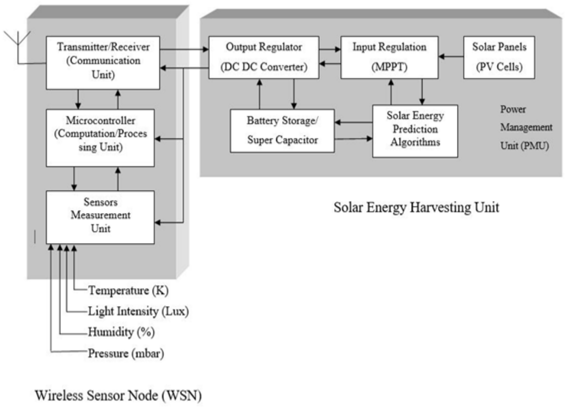

Figure 4. Block diagram of an SEH-WSN node

is converted into electric energy by using wind turbines to supply power to the sensor nodes. Due to its unpredictable and non-controllable features, it is brittle and unreliable [32].

The output may be enhanced by increasing the number of blades. The wind mill with six blades gives the greatest power. The other energy sources with the harvesting process are attached to obtain the constant power supply. The length of the blade of the wind turbine is also taken account as it affects the amount of power generation. The wind turbine having smaller blades produces more power than the larger blades. The wind turbine generates power as a function of load [33].

4) Thermal Based Energy Harvesting Wireless Sensor Networks:

The thermoelectric generator generates electricity due to temperature differences, known as the seebeck effect, where loads are attached over the heated and cold faces. The environmental requirements as well as thermoelectric materials are challenging for thermal based sensors. To measure the temperature gradient between a sheep's body and the environment, the thermal electric generator can also be mounted on a sheep collar. The performance of thermoelectric materials, the cross-sectional area of thermocouple legs, and the number of thermocouple legs determine thermoelectric generator efficiency following [34].

5) Piezoelectricity Energy Harvesting Methods:

Piezoelectricity is derived from a Greek word "piezo" termed for pressure and the word "electric" termed for electricity. Piezoelectric materials can generate a lot of voltage. Some examples are soft and hard Lead Zirconate Titanate piezoceramics (PZT- 5H and PZT5A), quartz, polyvinylidene fluride (PVDF) and barium titanate ($BaTiO_3$). Voltage can be collected directly from the material and post processing isn't needed. The dynamic forces are required to hold the output voltage. The disadvantage of piezoelectric sensors is unable to acknowledge of the static loads. While driving vehicles, the acceleration of tyres can harvest energy for self powered WSN [35]. With hybrid energy sources, constant power supply can be improved because each source can compensate for some fluctuations in energy transmitted to the device. All the aforementioned technologies are used in "Smart Agriculture" for management and power control of real objects in IoT.

6) Electrostatic Energy Harvesting:

By altering capacitance, an electrostatic energy harvesting device produces voltage. Applying an initial voltage to the capacitor is essential before the system generates energy. When external vibrations affect the amount of charge stored in the capacitor, a charge flow is created in the circuit and provides power to the sensors. Compared to other energy harvesting techniques such as electrostatic energy harvesting is very compatible with ICs and MEMS. A relatively advanced silicon micro-machined technology can also be used to create MEMS variable capacitors, which have many benefits including high Q, wide tuning range, noise cancellation, compact size, and poor quality. The minimum voltage or charge of variable capacitors still needs to be resolved even though electrostatic energy harvesting devices have excellent compatibility with IC and MEMS technology [36].

H. Clouds Storage

Earlier, the data can be accessed only from the particular data centre. Nowadays the data can be accessed across the globe by connecting the large amount of virtual servers together and directly allocated to a huge amount of storage, known as cloud. Edge and fog computing can be compared to a miniature cloud which is closer to the network's edge. Edge and fog computing symbolises the fusion of several network levels into integrated smart gateways. Edge and Fog computing provide various benefits including improved security, distributed local storage, and energy efficiency. More specifically, edge and fog computing can minimise network traffic as well as the computational and storage demands placed on cloud servers. It involves moving computationally heavy applications from the cloud to edge and fog layers and gateways, while increasing the reliance on local network smart gateways for more power-efficient sensor nodes. A fog-assisted IoT application comprises of additional layers between the sensor nodes and the cloud in contrast to standard IoT applications, which frequently depends on a three-layer design (sensor-cloudterminal). The number of edge/fog layers that are deployed might vary depending on the application and the nature of the data that is being collected [37].

1) Edge Layer:

Edge computing is a new category of computing that uses sensors and actuators to analyze data at the network's edge. With this idea, some applications and services that don't need a lot of computational power can be handled nearby the data source in the edge layer, eliminating the need for the fog or cloud over the network to process them. Edge computing can thereby enhance the data throughput, realtime processing, and reduce the computational load as well as volume of data to be send and received from fog or cloud data centres. The sensors will immediately request to analyze their data in the fog or the cloud, and this will accomplish hierarchically [38].

2) Fog Layer:

In order to extend the competency of cloud computing to the edge of the communications network, Cisco first put forth the fog computing concept in 2014. Data from IoT sensors is processed and analyzed by the fog layer, reducing latency for agricultural applications. Additionally, the fog layer is better than the edge layer at processing and analysing complex data [39]. Fog and edge both offer computing, networking, and storage between the sensor layer and the cloud layer. To process and analyze the agricultural data, close to the sensor layer, fog and edge layers perform well with the objective to minimize the latency and cost [39].

3) Cloud Layer:

IoT agriculture applications are facilitated by cloud computing, which is as important as edge and fog. It provides scalable on-demand computer resources and services (such as processing, networking, and storage). The cloud layer processes, analyses, and stores the agricultural data that is received from the sensor layer or the fog layer. There is an enormous data to process and analyze with cloud computing (like weather forecasting, fire warning, and soil drought analysis). Additionally, it might offer an expansive safe platform as well as affordable data storage services for IoT farm applications [40].

4) Edge Computing:

The edges of the IoT have data acquisition, analysis, computing, and processing technology to process, filter, and analyze data by edge computing, which offers intelligent services close to things or information sources. The amount of information that has to be processed has increased as a result of widespread device access. When managing such a massive data volume, a cloud server alone cannot deliver real-time response. The solution to the issue of data explosion and network slowness is edge computing. Fog computing, Cloudlet, and Mobile Edge Computing [40] are among the areas of edge computing research. The data layer, network layer, consensus layer, incentive layer, contract layer, and application layer are all parts of the blockchain technology infrastructure paradigm. Blockchain technology addresses data manipulation and centralized control of agricultural goods. The blockchain technology and smart contracts are used to gauge grain quality. To increase the openness and automation of the agriculture industry, a product traceability system built on a blockchain prototype has been proposed therein [41].

I. Machine Learning

Artificial Intelligence (AI) is divided into three parts such as Machine Learning, Deep Learning and Neural Networks. Machine Learning is a sub part of AI that uses different kinds of data and algorithms to train the machine to learn same as human beings with maximum accuracy. A detail classification of different types of machine learning algorithms in smart agriculture is represented in Table II.

J. Standardization in Network Topology and Protocols

Various farming attributes can be observed and controlled by implementing low power WSN topology. Some of the popular standardizations in network topology are IEEE 802.11 WiFi [57], LoraWan[56], WiMax [58], 2G/3G/4G-Mobile Communications Standards [59], LR-WPAN [60], RFID, ZigBee [61], MQTT [62], SigFox [63] and Bluetooth [64].

K. Security Related Issues in Smart Farming

The security modules of smart farming established on three requirements are access control, authentication and confidentiality of the users. The perception layer should be protected from external threats and the accumulation of data should be secured in network layer. The authorized users can access the data from the application layer. In the perception layer, the security problem is the physical layer security [65] along with information acquisition security. The physical layer security exploits the physical characteristics (e.g. multipath fading, propagation delay, etc.) of wireless channel to increase security. The leakage of information is another security problem as it contains location and sensitive information. The security assistance contains jamming, blocking in tag's frequency, data encryption, blocker tag use and tag destruction strategy. The sensor nodes and RFID's tags are not identical while utilizing intrusion detection policies, routing policies, encryption algorithm and key distribution policies. The data flows from the end device to the gateway so there is a possibility of data to get automatically uploaded to the cloud server [66]. The different security protocols are available for sensor nodes such as data filtering, cryptographic algorithm, identity authentication and data flow control mechanisms and many more. Replay attack, cheating, tampering and wiretapping are few security attacks for which authentication, confidentiality and integrity should be applicable [67].

Conclusions

Worldwide many researches are going on to increase the agriculture yield by introducing IoT technology. In this article, a complete survey on the implementations of IoT in agriculture is discussed. To increase the crop yield, the agricultural platform with various network architecture and topology are also included. Additionally, this study provides an extensive discussion on recent approaches in IoT agricultural devices/sensors, various applications of machine learning algorithms, cloud computing, energy harvesting methods and communication protocols. It also includes various challenges in agricultural IoT and security concerns for improvement of IoT in smart farming. Government has also initiated IoT in agriculture to enhance the crop yield. Also, various organizations have started investing and developing emerging techniques for smart farming by implementing IoT. Finally, it is contemplated that this entire survey will be very beneficial for the farmers, researchers, professionals, and various organizations related to IoT field and smart farming technologies.

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TABLE I. CLASSIFICATION OF DIFFERENT TYPES OF SENSORS USED IN NB-IOT

Sl. No.	Types of Sensors	Advantages	Disadvantages
1	Contact based Moisture Sensor [20-22]. Example: capacitive sensors and heat pulse sensors	• Simple measurement methods • Immediate results are obtained	• Probe needs to be inserted in soil • More manpower
2	Contact free based Moisture Sensor [23]. Example: soil moisture sensor	• Remote and large area measurements	• Bulk and complex
3	Soil Impedance Sensor [24]. Example: resistive sensor	• Water content at any depth can be determined. • High level of precision	• Unstable calibration. • Expensive
4	Fringe Capacitance Variations [25]. Example: MEMs motion sensor	• Determine soil water content at any depth • High level of precision	• Short term stability • Expensive
5	RH Sensors [26]. Example: optical hygrometer	• Inexpensive	• Very sensitive to chemical vapours and other contaminants
6	Volumetric Water content Sensors [14]	• Fast response time • Remote access available	• Small sensing area affected by soil conditions
7	Soil Temperature Sensors [27]	• The bridge circuit is not required • Quick response with temperature variations	• Expensive • Less absolute resistance
8	Soil PH Sensors [28]	• Determines the amount of primary and acidic solution	• Expensive • Glass electrodes

TABLE II. CLASSIFICATION OF VARIOUS MACHINE LEARNING ALGORITHMS IN SMART AGRICULTURE

Sl. No.	Application of NB-IoT	Machine Learning Algorithms	Advantages	Disadvantages
1	Smart Irrigation System to predict water requirement	Decision Tree Algorithm [42] Supervised Algorithm	• Generate uncomplicated and clear decision rules.	• High variance algorithm. • Highly time consuming

2	Prediction of Crop Yield	Naive Bayes [43] Supervised Algorithm	• Fast and time saving • Good for solving multi-class prediction problems	• Limits the applicability • Faces the zero frequency problem
3	Predict the paddy rice production	Classification and Regression Trees (CART) [10] Supervised Algorithm	• Categorical and continuous response is available. • Easy to handle both numerical and categorical data	• CART does not use combinations of variable in each split. • Non-parametric technique, high variance, low bias
4	Paddy Rice Productivity	Partial Least Square (PLS) [44] Supervised Algorithm	• Combines ILS's partial composition regression with CLS's complete spectral coverage.	• Calculations are slower. • Models are more abstract which is more difficult to understand and interpret.
5	Predicting Rice Yield Estimation	Principle Component Analysis (PCA) [45]. Unsupervised Algorithm	• Reduces the dimensionality of the datasheets • Removes correlated features • Improves algorithm performance	• Information Loss • Interpretable variable becomes less interpretable • Data standardization is must before PCA
6	Hydroponics farming can be done Efficiently	LASSO Regression [46] Supervised Learning	• Automatic features selection.	• Unbalanced biased coefficients • Difficult to estimate standard errors.
7	Paddy plant Disease Detection	AdaBoost Classifier [47] Supervised Learning	• Ease of use and less parameter tweaking	• High-quality data is needed
8	Recognition of paddy plant diseases	k-Nearest Neighbourk-NN [47-49] Supervised Learning	• No training period as the data itself serves as the model for future predictions. • Easy implementation of KNN.	• Does not function well with huge data sets • Sensitive to fluctuating and empty data
9	Recognition of paddy plant diseases	Support Vector Machine (SVM) [47][50] Supervised Learning	• SVM performs better when there is a large gap between classes and large dimensional spaces.	• Large data sets including more distortion and when the target classes are overlapping, the performance of SVM algorithm is not well efficient.
10	Predicting Rice Yield Estimation	Artificial Neural Networks (ANN) [51] Deep Learning	• Fault tolerance • Doesn't required programmed again while making decisions	• Hardware dependence • To function, the neural network needed training. • For large neural networks, more processing time is required.
11	Predicting Rice Yield	Convolution Neural	• No human supervision. • High accuracy.	• A lot of training data is required.

	Estimation	Networks (CNN) [52] Supervised Algorithm	• Image recognition. • Minimized computation.	• Relatively slower algorithm. • The training process takes long time
12	Predicting Rice Yield Estimation and Rice Growth	Random Forest Algorithm (RF) [51] Supervised Algorithm	• Regression and classification issues including missing values can be resolved with Random Forest.	• Complexity: Random Forest grows several trees and mixes their results. • Longer Training Period.
13	To generate paddy cropping pattern and to estimate paddy rice yield	Iterative Self Organizing (ISO) [53] Unsupervised Learning	• Not required to have prior knowledge of the data • Little user effort needed	• Taking too much time if the data is unstructured. • This algorithm may go uncontrolled and leave only one class.
14	Performing thepaddy growth stages classification	Support Vector Regression (SVR) [45] Supervised Learning	• Easy to customize and works effectively with nonlinear issues	• Application of feature scaling is required.
15	Estimating LAI of paddy ricefrom optimal hyperspectral bands	Multiple Linear Regression (MLR) [44][54] Supervised Learning	• Assessment of the relative impact of one / more predictor variables on the criteria value.	• Data employment in multiple regression model.
16	Predict the quality of rice	Fuzzy c means (FC) [55] Unsupervised Learning	• Fuzzy logic is more efficient to represent actual problems. • Hardware requirements for fuzzy logic algorithms are less.	• Wide-ranging validation and verification are needed for fuzzy algorithms. • Fuzzy control systems rely on the knowledge and skill of humans.
17	Classifying high-resolution images for monitoring paddy rice disease	k-Nearest Neighbour (k-NN) [47], [48], [49] Supervised Learning	• Swift, effective, and easy to grasp.	• It is necessary to manually select the neighbourhood size, ”k”.
		Minimum Distance Classifier (MDC)[56] Supervised Learning	• The benefit of the minimal distance approach is that all pixels are categorized and the classifier runs depending on the training set. It gives better outcomes than kNN.	• Prone to mistakes when every pixel is categorized, even those that are the lowest distance apart may be misclassified as distant; the minimal distance classifier method has this drawback.