

Applications of the Internet of Things (IoT) for Developing Sustainable Agriculture: A Review

Najmus Sakib Sizan, Diganta Dey and Md. Solaiman Mia

Abstract— By natural process, the world population will increase day by day. In rhythm, the tendency of the food will also be rising. So, it is a great challenge to supply food and increase its availability for the huge amount of people of the world, which helps to fulfill their fundamental civil rights. Nowadays, many agriculture-dependent countries are fully dependent on the orthodox agriculture process. To develop such types of conditions, people should attract to modern cultivation practices. In the modern era, the Internet of things (IoT) is an optimal solution for preventing such types of challenges. IoT can connect with neoteric agriculture technology. By using this technique, farmers can directly connect themselves and control their fields and monitor their field environmental conditions from anywhere around the world. By the use of unique forms of sensors, models, strategies, and technologies farmers can collect much real-time information and it helps a bearer to increase his productivity of farming. The goal of this paper is to reconsider some very recent works on smart and prompt agriculture processes. In this review paper, we have spoken about the techniques, and methodologies and summarized the state-of-the-art literature. We also made a comprehensive discussion and profound analysis of those recent works. Finally, we have given some future suggestions about smart farming techniques based on our discussion and analysis.

Index Terms—Internet of Things (IoT), Smart Farming, Sensor.

I. INTRODUCTION

INTERNET of Things depicts the arrangement of physical objects (things) that incorporate sensors, programs, and other innovations for the reason of interfacing and trading information with other devices and frameworks over the Internet. These devices run from conventional domestic objects to advanced mechanical apparatuses.

Fig. 1 represents the IoT applications that guarantee to bring colossal esteem into our lives. IoT applications cover

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a wide assortment of regions including transportation, shrewd agribusiness, air, promoting, inventory network, medical services, and foundation observing, and that’s only the tip of the iceberg. To accomplish total discernment, smart preparation, and solid transmission between the gadget and the data identification framework, all actual articles can be independently interconnected and addressable. With more current remote systems, prevalent sensors, and progressive computing capabilities, the IoT might be another wilderness within the race for its share of the wallet. IoT applications are anticipated to prepare billions of regular objects with networks and insights.

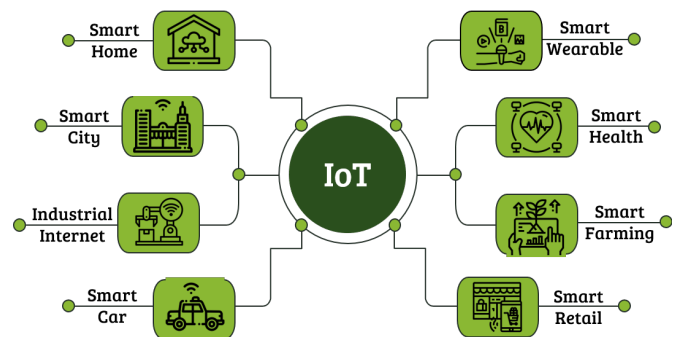


Fig. 1. Areas of the Applications of the Internet of Things (IoT)

Agriculture is the most studied field where IoT has been applied so far. Because this is an important area for ensuring food security as the world’s population grows rapidly [1]. Researchers started to apply ICT-based techniques in this area very early, which is useful on some levels but will certainly not solve our problems in the long run. So, now they are exploring IoT as an option for ICT in agriculture.

A. Problem Statement

More than 7 billion IoT (Internet of Things) devices are associated nowadays and it is predicted that this number will increase to 22 billion by 2025 [2]. With the world population growing exponentially, as per the food and agricultural organizations of the United Nations, the world should create 70% more food by 2050 [3]. As the area of agricultural land will

decrease and the natural resources will be depleted, the need to improve agricultural output has become important [3]. So it is a challenge that uses the best IoT technology, we can increase the system of increasing food production.

Traditional farming and precision farming are very different in every way. Traditional agriculture uses old and typical farming methods and uses the old equipment for the seasonal works and cultivation without any prior assessment of market demands, exchange rates, weather reports from the meteorological department, etc. Agriculture can be done in any kind of areas like indoor or outdoor and Fig. 2 represents the detail aspects of this field.

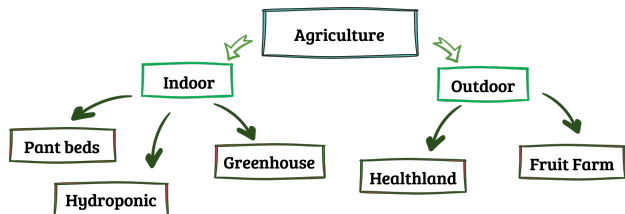


Fig. 2. Different Aspects of Agricultural Implementations

To upgrade agricultural development, IoT devices are acquainted with gathering and getting ready for the data in a drawn-out cycle that engages agriculturists to react quickly to create issues and changes in enveloping conditions [4]. Shrewd development takes after a cycle of activities as shown in the following.

- 1) **Observation:** Sensors record observational data from the yields, creatures, soil, or air.
- 2) **Diagnostics:** The sensor esteems are sustained to a cloud-facilitated IoT stage with predefined decision rules and models additionally called "business rationale" that finds the state of the assessed dissent and separates any deficiencies or requirements.
- 3) **Decisions:** After issues are revealed, the customer, as well as Artificial Intelligence (AI) driven parts of the IoT stage chooses whether area explicit treatment is crucial and if in this way, which areas are most explicit.
- 4) **Action:** After end-client appraisal and movement, the cycle goes over from the beginning.

Table I represents the abbreviations that are used throughout this paper. The rest of the sections are structured as follows: Section II explains the concepts of smart farming, Section III reviews some state-of-the-art existing works, Section IV presents the analysis of the existing works, and finally, Section V concludes the paper.

II. CONCEPTS OF SMART FARMING

During 21st century, for a better understanding of the smart agriculture system by using IoT, it is very necessary to know details about that. In this Section, some concepts regarding smart farming are described.

- 1) **Modern Farming Technique:** Smart agriculture technology is called the application or application of modern technology in agriculture for excellent production.

TABLE I
ABBREVIATIONS USED IN THIS PAPER

Acronym	Full Form
IoT	Internet of Things
ICT	Information and Communication Technology
AI	Artificial Intelligence
DSS	Decision Support System
WSN	Wireless Sensor Network
ARIMA	Auto-Regressive Integrated Moving Average
M2M	Machine to Machine
LPWAN	Low Power Wide Area Network
PTV	Predefined Threshold Value
LCD	Liquid Crystal Display
SBC	Single Board Computer
LTE	Long-Term Evolution
UAV	Unmanned Aerial Vehicle
LoRaWAN	Long Range Wide Area Network
WCT	Webnet Communication Technology
RFID	Radio Frequency Identification
UWB	Ultra-Wideband

Many smart and technology-dependent farms use many technological elements which help us in various stages for measuring and monitoring the condition of the soil, water level, pest control, etc. [5]. Such types of resources use different types of sensors like temperature, humidity, irrigation pump, air pressure, ground chemical condition, many cameras, GPS, and various types of communication systems. Savvy farming and exactness cultivating are taking off, but they might fair be the antecedents to more prominent utilization of innovation within the cultivating world and there are many sectors in smart farming which are given in Fig. 3. The smart agriculture market will have a revenue of USD \$10 billion in 2023 from the economic point of view [6]. On the other hand, smart farming will be able to increase food productivity during this time.

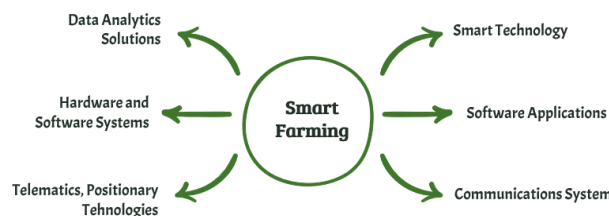


Fig. 3. Implementation Areas of Smart Farming

- 2) **Internet of Things:** IoT is a technology known as a set of networking devices, which can interconnect with each other, analysis the sensor data, and measure the current situation. Those devices are applicable for household work, agriculture, automobile industries, and even for general people. The idea of IoT is not new, but in the modern era, the acceptance of IoT has increased which mainly depends on modern technologies like improvement of hardware, an increase in internet connectivity, applications of wireless connection, big data mining, and development of AI. The authors of [7] discussed that smart farming with IoT systems is related to the other computer system which is may depend on

the limited computing capabilities, identification, and control of the total system by remote objects. Many network technologies exist and we can classify them by their working range and these are given in Fig. 4.

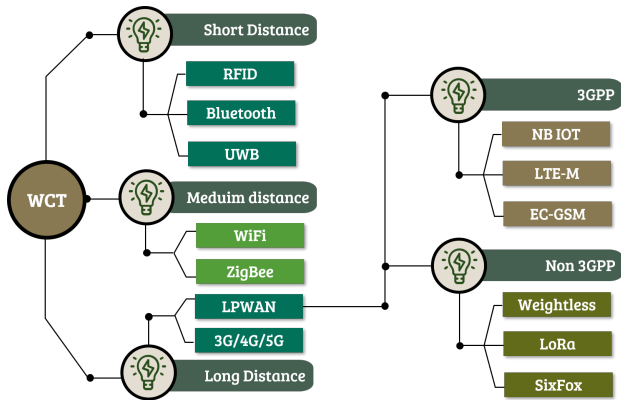


Fig. 4. Wireless Technologies Based on Range

3) **Intelligent Agriculture Technique:** [8] applied the IoT agriculture processes and discussed the four layers according to the element of IoT like device, network, service, and application. According to [9], [10], Table II represents the layers in intelligent architecture of smart farming.

TABLE II
DIFFERENT LAYERS OF THE SMART AGRICULTURE SYSTEM

Application Layer	Monitoring the whole system, water pumping, disease identification
Processing Layer	Sensor data collection, data analysis, data processing
Transport Layer	Different network protocol and hardware protocol.
Perception Layer	Different types of sensors, GPS and other vehicle.

III. LITERATURE REVIEW

In Podder et al. [11], the authors introduced a model named Smart AgroTech. In this model, they considered humidity measurement sensors, temperature measurement sensors, and soil moisture measurement sensors. In the beginning, they discussed some components that can be used in their proposed model. They divide their components into 5 different sections which are the technology section, controller section, sensor section, relay module, and water pump. In the technology section, they tried to discuss AI, IoT, and M2M. They discussed why they used IoT instead of M2M and AI. In the controller section, they tried to differentiate between ESP8266, Arduino, and Raspberry Pi and also tried to discuss why they used ESP8266 instead of Arduino and Raspberry Pi. In their Smart AgroTech model, they used only three sensors which are humidity measurement sensor, temperature measurement sensor, and Soil moisture measurement sensor. They used DHT11 for sensing temperature and humidity and for sensing soil moisture they used different soil moisture sensors and these sensors are discussed in the sensor selection section.

In the Smart AgroTech model, they used a switch platform called Relay Module. In the last section, they used an electric water pump motor. In Algorithm 1, the sensor value of the soil moisture sensor is read by using an analog pin of ESP8266. Then the percentage value from the analog read is calculated. In the end, the sensor value is sent to the web server for recording and monitoring. The conditions for turning on/off the pump the motor is ensured using the relay module.

Algorithm 1: Algorithm Described in [11]

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1 Begin
2 Section 1 Read the sensor values for humidity and temperature
3 Section 2 Compute heat
4 Section 3 Read the sensor values for soil moisture
5 Section 4 Conditions for turning ON/OFF the motor
6 End
    
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In the Smart AgroTech model shown in Podder et al. [11], they considered soil moisture level is 55% but it might be tough for any kind of crops or vegetables. There is no dataset of soil moisture level values on different crops or vegetables. In this model, they used only three sensors but for a better-automated irrigation model, some other sensors are needed like a pH measuring sensor. In Podder et al. [11], they didn't propose any data transmission model and there is no web application or mobile application interface where a farmer can control everything. In this work, they could implement Unmanned Automated Vehicle (UAV).

Some sensors underground and aboveground are implemented in Almalki et al. [12]. Data from the sensors are collected every 1 hour and then these data went to the cloud and every 12 hours the data was analyzed. The authors of [12] tried to implement a low-cost platform where they used sensors and a flying drone, and all the things are connected with cloud computing technology. There are two segments named space segment and ground segment. In the space segment, their drone technology includes a camera to capture the area and their drone model is DLI Quad-copter and LoRa module which is utilized to gather the information from sensors and send it to clouds for additional investigation. In-ground segment, there is a control station where the end-user can control everything. There is an underground sensor gateway that collects data from sensors that are implemented underground and there is a HOBO U30 weather station starter kit which is used to collect data from sensors that are implemented aboveground.

In the aboveground, they implemented a temperature sensor, humidity sensor, rain, and solar radiation sensor. To measure temperature and humidity, they used the S-THB-M008 sensor, to measure rainfall they use the S-RGB-M002 sensor, to measure solar radiation they use the S-LIB-M003 sensor and to measure soil moisture they use the S-SMC-M005 sensor. In the Drone-LoRa layer, they used LoRa technology to transmit the sensor data to the cloud. They used LG02 which is a LoRa gateway device it is an open-source dual-channel and is manufactured by Dragino. In Almalki et al. [12], they used Raspberry PI as the microcontroller. In the end-user layer,

they considered Hata empirical propagation path loss model to create a path between the ground station layer and cloud layer.

Authors used a drone in Almalki et al. [12] which sends all the data to the cloud for further analysis but the implementation of a drone can be costly and maintenance of a drone can be tough for the rural area people. In the sensor section, they used several sensors but they could also use a pH measuring sensor for better production. In this work, they used a Raspberry Pi microcontroller but this is costly. They could use ESP8266 instead of Raspberry Pi. To send the data from the drone to the cloud, they used LoRaWAN technology but they could use SixFog instead of LoRaWAN because the data rate and coverage area of SixFog are greater than LoRaWAN. They implemented their model in a specific area but if anyone wants to use this in other areas, then the result can be different.

Tripathy et al. [13] focused to implement IoT-based automated greenhouse farming. In Tripathy et al. [13], the authors used so many sensors like temperature, humidity, UV light, pH measuring, CO2 level, EC value, and measurement of insecticides or pesticides and they developed a system called Decision Support System (DSS) which controls all the activity related to the system. In this work, they center around rose cultivation. In data acquisition system, it consists of different types of sensors and there is a machine learning classifier named Support Vector Machin (SVM) for specimens to prevent diseases.

In the actuator management system, there is a Central Actuator manager which received all the instructions from the DSS and controls all the actuators. DSS has six parts which are a rule-based designed engine, central actuator manager, machine learning models, expert or agronomist, greenhouse workers, and a data repository. According to the DSS, there is an interface for the end-user to see and control everything and the user can get an in-app notification or SMS for any kind of interaction. In their case study, they tried to present the difference between the trivial approach and their “MyGreen” approach.

Tripathy et al. [13] developed “MyGreen” which is cost-effective and accurate. They implemented eight different types of sensors in their model. In this model, they mainly focused on the growth of roses in the Greenhouse and as a classifier they use SVM and its satisfaction accuracy is 91% and classification accuracy is 85%. It is only for Greenhouse but if we talk about outdoors, then the overall rate can be different. In this work, they proposed a DSS but there is no specific microcontroller and there is no specific wireless protocol to send the data from sensor to server.

Atmaja et al. [14] tried to discuss the communication system between the sensor and the database. All the sensors’ data will be sent to the database and they used Wireless Sensor Network (WSN) to transmit data. They used Raspberry Pi as a microcontroller. In their model, they used soil pH sensors and moisture sensors. Water pumps and sluice gates were also used, and all the things can be controlled through web and mobile applications. In their research method, the collected data from the sensors will be processed by Arduino then it will be sent to the server via ESP8266. They will utilize an

incorporated foundation of Linux Web worker, information base, and PHP which will be worked by ARM Linux development board with Apache, PHP, SQLite, and Raspberry Pi. To prove their efficiency, they tried to find out the difference between the actual meter value and sensing value and then they tried to find out the error percentage between them. To evaluate Raspberry Pi, they tried the different distances with barriers and without barriers, and they tried to find out whether it is succeed or failed. The communication system of smart agriculture has been discussed in Atmaja et al. [14]. According to their model, the sensor data will process by Arduino Uno and then ESP8266 series 01. Then it sends to the server. Their whole model is quite complex and costly. They used Raspberry Pi as a local server and there are many things implemented. They worked only for rice fields but this model can’t get the proper output for the other crops.

The authors of Sivabalan et al. [15] tried to utilize the use of water on land. In this paper, they executed a few sensors that are associated with the Raspberry Pi B model which includes a Wi-Fi 802.11 b/g remote module to limit the utilization of water and electrical energy which is shown in Fig. 5. In their model, they used a DHT22 sensor to collect humidity of the soil, a DS18B20 sensor to collect temperature, a REESS2 sensor to read soil moisture and they implemented a water flow sensor which is connected with Raspberry Pi. For the use of Raspberry Pi, they applied the Python module and this module also sends an SMS to the farmer for fertilizing schedule. To evaluate their model, they tried to find out the difference between systems using IoT and systems without IoT.

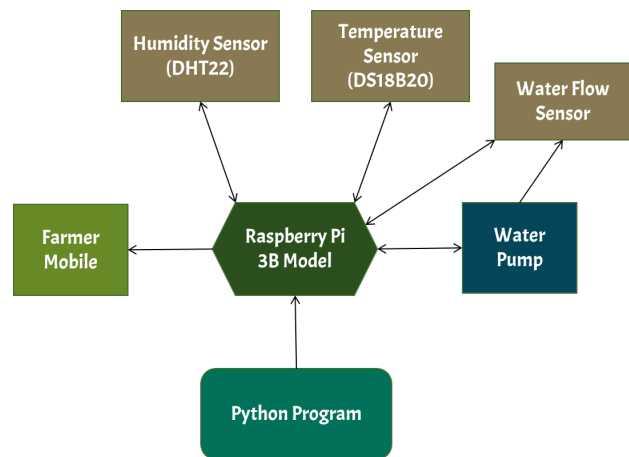


Fig. 5. Block Diagram of Proposed model of [15]

[15] introduced a utilized model for reducing the use of water and energy. In their three-layer model, it is cost-effective but effective only for small rural areas. They executed CC3200 to screen the temperature and humidity in the field and it is interfaced with the camera which takes the photo and sends it to the user through Wi-Fi but here they could use a data mining algorithm. In this whole model, they used Wi-Fi 802.11 b/g but if they use LoRa then this model could work for a long area.

A cloud-based architecture is shown in Araby et al. [16]

