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

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***Abstract*—** By natural process, the world population will in- crease 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. Byusing this technique, farmers can directly connect themselves and control their felds and monitor their feld 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 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.

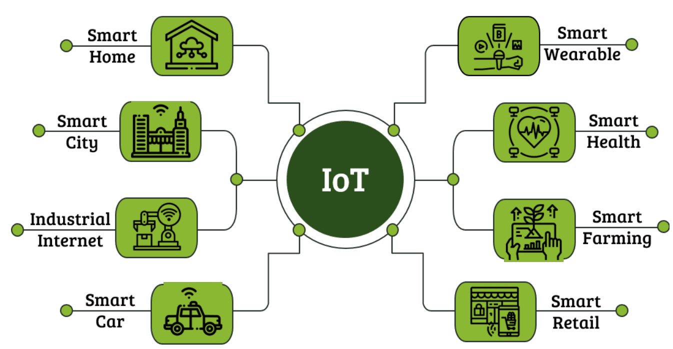

Fig. 1. Areas of the Applications of the Internet of Things (IoT)

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

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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.

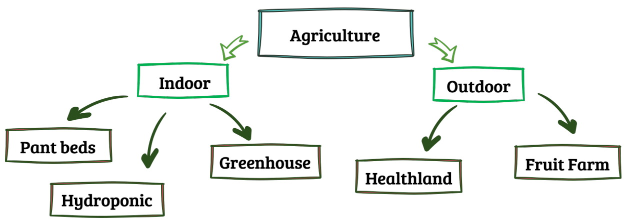

Fig. 2. Different Aspects of Agricultural Implementations

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.

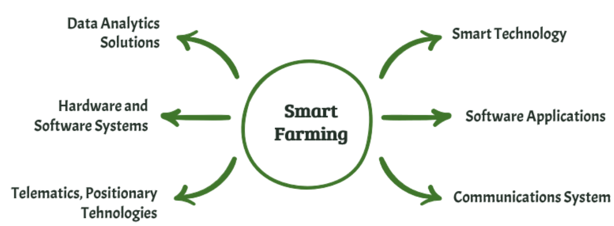

Fig. 3. Implementation Areas of Smart Farming

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.

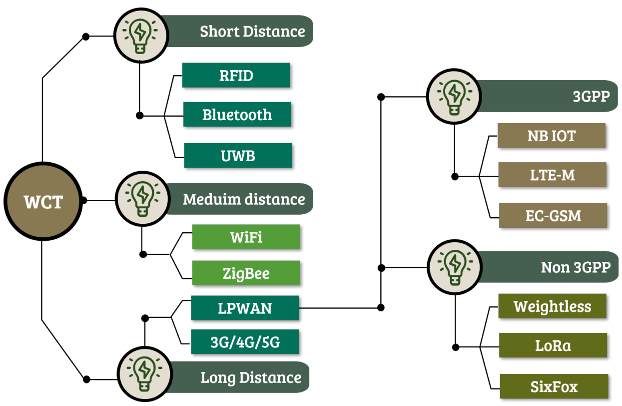

Fig. 4. Wireless Technologies Based on Range

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]

Begin
Section 1 Read the sensor values for humidity and temperature
Section 2 Compute heat
Section 3 Read the sensor values for soil moisture
Section 4 Conditions for turning ON/OFF the motor
End

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.

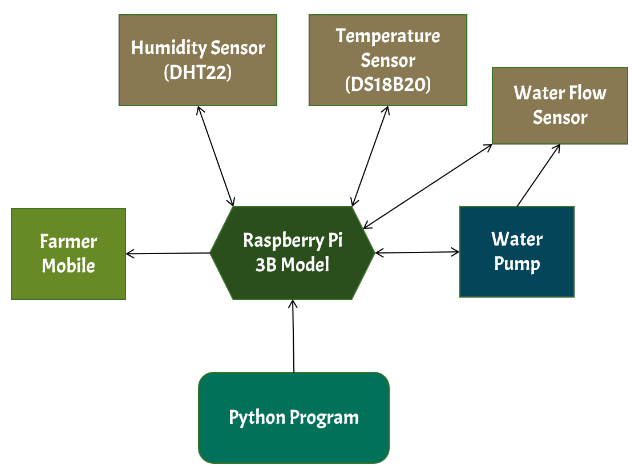

Fig. 5. Block Digram of Proposed model of [15]

[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]

which includes a perception layer, gateway layer, application layer and Araby et al. [16] attempted to anticipate late scourge sickness in potatoes and tomatoes. In the perception layer, they implemented a temperature measurement sensor, humidity measurement sensor, and moisture measurement sensor. There is a microcontroller called ESP8266 that is used to collect the sensor data and they used the MQTT protocol to send and receive data. Their proposed gateway layer connects the perception layer and the application layer and this gateway layer is implemented with a Raspberry Pi 3 microcontroller. They considered an application layer for the end-user and there is an online database named MySQL to store the data and there is a website where the end-user can view all the data. They used the day degree dataset and they tested SVM and Logistic Regression (LR) which are machine learning algorithms.

In Araby et al. [16], they mainly focused on cloud-based architecture and they focused on data transferring and data processing. In this work, there is no architecture for sensor implementation. They used NodeMCU which uses Wi-Fi but they could implement LoRa for a long wide area. They used MQTT which is used to send SMS to the user. The whole system could be automated using actuators.

A new agriculture process is presented in Santos et al. [17]. From this work, we learned about how Wireless Sensor Network (WSN) technology and mobile computing systems are helping for increasing the productivity of farming. [17] also discussed how future planning and punctuality are helpful for better production which helps a farmer for taking the necessary steps. The recommended agriculture production process is the last step of the prototype model of this work. This model can predict the current temperature, soil and water level, humanity, and the pressure of the air. This is might declare that the whole smart agriculture model is based on low power WAN approach and agriculture prediction server. Measurement of agriculture is related to some collected data, which come from different types of sensors and methodologies. In this process, data is transferred by the low-power WAN to LoRaLPWAN. At last, those data are transferred to the agriculture vaticinator server. In this work, Auto-Regressive Integrated Moving Average (ARIMA) is also used to measure the necessary things according to the situation of the harvest. The methodology also used the 24×7 alarm system and sort messaging technique for avoiding any kind of abnormality.

Santos et al. [17] dependent on low-power wide-area network and ARIMA technology. They could propose a methodology by which a farmer can control the land by using a mobile application only and directly monitor his land status properly. In our analysis, this methodology will much help but there has some perplexity that should be attempted. It is one of the smart techniques for carrying out the current status of the crops by using a smartphone. In the future, they could research more than one variety in different seasons.

Anupama et al. [18] are mainly developed based on a water management system and reserving a finite amount of water so that the farmer can use and reuse that water when it is needed. The total process is fully connected with the smart IoT. This model provides some soil, coriander seeds, and a plastic tray. Soil is mixed properly and besprinkle into the tray. Water is preserved at the bottom of the farm. When it is needed, the plants are absorbed the necessary water and the extra water is moving down to the bottom of the farm. The excess water is again reused by the plant when needed. In this farm, a moisture sensor collects the data and detects how much water should be needed in the farm air. According to the sensor value, water is provided to the farm which is called a Predefined Threshold Value (PTV). The pump is installed which is directly connected to the moisture sensor. When water is required by the crops, the moisture sensor displays the situation of the farm, and automatically the pump will start. By using this smart way, there is a need to provide extra work. Temperature sensor, humanity sensor, and water lever monitoring sensor also be installed on the farm for proper monitoring. Thus the total system is connected by using Wi-Fi network technology. Liquid Crystal Display (LCD) is used for lively monitoring of the current situation of the farm.

The total process of Anupama et al. [18] focused on how to irrigate water into the farm properly and reserve the water for reuse, which helps the farmer much. This process may be used for small farms and by using different types of sensors, it will make the total system much smart and more comfortable. Sensors are connected and properly managed the overall situation of the farm. To successfully monitor this system, it may need a spontaneously Wi-Fi network and a high voltage electric pump.

Izzuddin et al. [19] focused on urban farming techniques in Indonesia. Like in a developed country, the population of other cities around the world is increasing day by day. But the land area is decreasing. So, to fulfill the food tendency of a huge number of people, the urban farming technique is very requisite. In this work, as a microcontroller they used Arduino and the system also contains many sensors like humanity sensor, temperature sensor, soil moisture sensor, etc. All the sensors are directly connected to the microcontroller which is connected to a single-board computer (SBC). This SBC is developed according to the ARM board Raspberry Pi 3 b+ and used the 4G HAT internet network for communication. Then, the sensor collected many data and converted those data into an electric signal and becomes a digital data unit. The total system used solar power as an alternative use of electricity. Then all of the collected information is sent to the web server and SQL server where all of the information is reserved. All of the collected data are displayed and reserved in the web part. According to the sensor data, the area may be irrigated. Sensors are collecting the data spontaneously and send it to the Raspberry Pi. The data will be processed into the two main parts of Raspberry Pi. According to the data, the irrigation motor is turned ON or turned OFF automatically or manually based on the soil moisture.

The total experiment of Izzuddin et al. [19] depends on, how to handle smart urban farming by using IoT. Arduino is used as a microcontroller that is directly connected to the Raspberry Pi. Sensors are collecting the data. All of the data are stored on the web server. Lastly, Raspberry Pi started to process the data and according to the sensor data the soil was to be irrigated. Through this system, farmers monitor the total condition by using an LCD. In addition, irrigation is also controlled manually. The total experiment mainly depends on the solar power supply which is a much more eco-friendly technique.

The main focus of Ariffin et al. [20] is to cultivate mushrooms by using modern agriculture technology which is related to the IoT. By using their smart process, maybe other farmers can produce other kinds of vegetables or crops and develop the efficiency as like as productivity of their farm. Mushroom cultivation requires an optimal temperature and humidity. The total system design with three parts 1. Mushroom house, 2. IoT control box and 3. Web client interface. In the mushroom house, it can control the internal environment and protect the cultivation from the external elements. A pump is installed in the house so that it can control the temperature and humidity level in the house. The IoT control box contains the climate control system automatically. The water pump with an exhaust fan is controlled by electrical power. It must contain some sensors like humidity, water level, and temperature sensor which are connected by an internet gateway by using a wireless fidelity network system. This gateway immune connection from ISP like Asymmetric Digital Subscriber Line (ADSL) or Long-term Evolution (LTE) connection. By using this technology, a farmer can access the system from anywhere. To control the climate system, they can use MCU ESP8266 as a microcontroller. A special algorithm was set into the microcontroller so that it can easily manage and process the sensor data and control the water pump & exhaust fan manually. The special algorithm is developed according to the Arduino IDE (Integrated Development Environment). In this work, they could use the DHT22 sensor to provide the whole process input in the form of other sensor values. The status, temperature, and humidity values are displayed by an LCD monitor which is installed into the system. By using the web client interface, users can control the total system by using any kind of mobile device. The status, temperature, and humidity values are displayed by an LCD monitor which is installed into the system. By using the web client interface, users can control the total system by using any kind of mobile device.

Ariffin et al. [20] discussed the automatic climate control and monitoring system based on IoT which is commonly used for mushroom cultivation and their proposed methodology is given in Fig. 6. To measure the effectiveness of a such type of smart system, they control the environmental situation inside the farmhouse before and after the implementation of the whole system. According to the sensor data reading, the water pump and fan may turn OFF and ON. It is one of the easiest smart techniques where stockholders control.

A unique approach is presented in Kale et al. [21] with the help of IoT and Extreme Learning Machine (ELM) for smart agriculture. This paper discussed the prevention of Plant Diseases (PD) Nutrient Deficiency (ND), and food tendencies. Some sensors collect the necessary data and according to the data, it will help to decide the quantity of the fertilizer. Because imbalanced fertilizer decreases the production value and is much more effective for human and animal health. The whole system is divided into three phases 1. Image capture and processing, 2. Subset Selection (SS) according to the Genetic Algorithm (GA) and 3. Classification. In the first step, some images are captured by any kind of digital camera. Then humidity and temperature sensor collects the data and is directly connected with Arduino. All the images are sent to the Arduino by using wireless fidelity or Bluetooth network system. All the collected data is preserved in a Database. Then the data started to be analyzed. The method changed to implement a high-dimensional biomedical dataset and a real-time leaf disease dataset.

The methodology described in Kale et al. [21] is based on the internet and extreme mastering device for appearance after and tracking diverse types of Plant Diseases (PD), Nutrient Deficiency (ND), etc. This methodology also determines the temperature and humidity of the environment. The smart methodology was applied for the high-dimensional biomedical dataset and real-time leaf disease dataset. But smart water management should also be considered for the system.

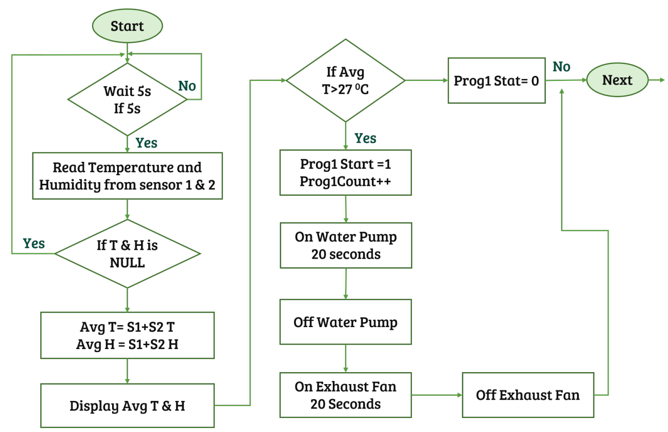

Fig. 6. Flow-chart of proposed system of [20]

IV. Review Analysis

In Section III, a total of 11 existing works are reviewed. Table III represents a short overview of these works and here we present what kind of microcontroller they used, what kind of sensors they used, what kind of wireless protocol they used, what are their advantages, and what are their limitations. This table will help the new researchers to compare their model to the existing model.

By considering Table III, we explored remote communication advances utilized in low-power and low-bandwidth country zone systems to decide which of them is most reasonable for keen cultivating applications. We moreover examined the relationship between security, control utilization of compelled IoT gadgets, and execution of remote communication based on a show of a keen cultivating framework with a sensor hub. The sensor hub was actualized by employing a microcontroller. Table IV summarizes the most contrasts between the specified conventions.

As file count and record amount increase, a database machine is needed to successfully manipulate this amount of information. Proper database control structures assist growth organizational accessibility to statistics, which in flip facilitates the cease customers percentage the statistics quickly and successfully throughout the organization. The total data

TABLE III
A COMPREHENSIVE COMPARISON AMONG THE EXISTING WORKS

Existing Works	Microcontroller	Sensor	Advantages	Limitations
[11]	• ESP8266 • Arduino IDE • Relay Module	• Soil moisture Sensor • Temperature Sensor • Humidity Sensor	• Cost Effective, Because: (i) Micro controller require low cost (ii) Sensors are available and cheap. • Error percentage is low because micro-controller works on sensor data and sensor are directly connected with environment	• The coverage area is short • Few more sensors can be addressed
[12]	• Raspberry Pi	• Temperature Sensor • Humidity Sensor • Rain • Solar Radiation	• Cost Effective, Because: (i) Raspberry Pi runs on a lower budget. (ii)It does not require user to have extensive programming • Solar panels are used to reduce the use of electricity	• Power consumption is high • Overall monitoring is difficult
[13]	• No	• Moisture Sensor • Temperature Sensor • Visual Sensor • Soil NPK Sensor • pH Sensor • Humidity Sensor • CO2 Sensor • Water Level Sensor	• Sensors are directly connect with the environment so that Accuracy is high • Cost Effective, because: (i) Sensors are available in market with low price.	• Specific Microcontroller isn't mentioned • Specific Wireless protocol isn't mentioned
[14]	• ESP8266 • Arduino Uno	• Soil pH Sensor • Moisture Sensor • Water Level Sensor	• Mobile application and web application are used to view and analyze data	• Working on only Rice field • Implementation cost is high
[15]	• Raspberry Pi 3 B Model	• Humidity Sensor • Water Level Sensor	• CC3200 is used to monitor temperature and humidity • Cost Effective	• Working only for small rural areas
[16]	• ESP8266	• Temperature Sensor • Humidity Sensor • Moisture Sensor	• MQTT protocol is used which runs on TCP/IP	• Human interference needed to apply actions
[17]	• ATmega328	• Temperature Sensor • Humanity Sensor • Air Pressure Measure Sensor • Water Irrigation Sensor	• LoRa includes little range, consumes low power and provides low cost connectivity • Forecasting demand of Auto-regressive integrated moving average is huge	• LoRa always require low and slow bandwidth system • It is very hard to dominate the total scenario by using a mobile application
[18]	• Arduino	• Soil Moisture Sensor • Temperature Sensor • Humidity Sensor • Water Level Sensor	• For Severe drought, this model is so much effective • Comfort for the farmer	• This system is mainly used for small farms. • The communication system fully depends on a Wi-Fi network system
[19]	• Arduino • Raspberry Pi 3 b+ as an SBC	• Solar Power • Soil Moisture sensor • Temperature Sensor • Humidity Sensor	• Arduino and Raspberry Pi 3 b+ contains low-cost tendency and it has huge processing power. • Easy to control the whole system very first • The solar system is much eco-friendly	• By using Raspberry Pi 3 b+, some graphics processors may be missing • This type of SBC does not support the windows • Internet connection with Arduino is difficult
[20]	• Arduino • MCU ESP8266	• Temperature Sensor • Humidity Sensor	• A lot of data may be processed at a time • The smart way to handle a mobile device	• As a power source, they can use solar panel which is much eco-friendly
[21]	• Arduino	• Temperature Sensor • Humidity Sensor	• Thinking about Plant Diseases (PD), Nutrient Deficiency (ND) is a unique idea	• Smart water management system is missing

TABLE IV
A COMPREHENSIVE COMPARISON AMONG THE DIFFERENT WIRELESS COMMUNICATION TECHNOLOGIES

Parameter	Bluetooth	Wi-Fi	ZigBee	LoRa	SigFox
Standard	802.15.1	IEEE 802.11 a/ b/ g/ n	802.15.4	802.15.4 g	802.5.4
Modulation	GFSK	OFDM, BPSK, QPSK, QAM	OQPSK	CSS	BPSK
Maximum Data Rate	2400 MHz	2400 MHz	868 or 915 MHz, 2400 MHz	133 or 868 or 915 MHz	ISM Band 433, 868, 915 MHz
Bidirectional	Half-duplex	Half-duplex	Halt-duplex	Halt-duplex	Half-duplex
Bandwidth	1 MHz	2.4 – 5 GHz	2 MHz	250 and 125 kHz	100 kHz
Transmission Range	8-10 m	20 – 100 m	10 – 20 m	5 km at Urban, 20 km at Rural	10 km at Urban, 40 km at Rural
Topology	Star	Star	Three, Start, Mesh	Star	Star
Power Consumption	Medium	High	Low	Low	Low
Cost	Low	Low	Low	Low	Low
Existing Works	[22], [23], [24], [25]	[22], [23], [4], [25]	[26], [22], [24], [25]	[27], [28], [22], [29], [25]	[30], [27], [29], [24], [25]

management system is controlled by many types of software which reduces the men's power. Data management software collects data from various sources and stores the data in a database. Then it can analyze the data according to the IoT-based methodology. In Table V, we discuss many data managing software around the world with their principal features. Many developed countries, they already implemented different types of IoT-based software which are helpful for modern agriculture.

IoT is a brand new boom engine of the data and communication generation industry that has grown worldwide influence. We reviewed many non-technical and technical works to study the modern-day popularity of scholarly discourse and carried out analysis sequence procedure fashions to evaluate the priorities for IoT research. In the modern era, many giant industries or companies are trying to develop this technology. It is very necessary to develop the productivity of recent agriculture, increase the number of crops and decrease human efforts by using a new technique called IoT. This technology can make our agriculture system more efficient. So, it is very important to do some research works on IoT in agriculture. In Table VI, we discuss many reputed industry companies who are doing their research on IoT and try to analyze their efforts in this field.

V. CONCLUSION

In this paper, we have discussed some important smart farming techniques which are used in modern technology named Internet of things (IoT). Also, we have briefly analyzed the advantages and future suggestions for modern farming techniques. The farming issues, future food challenges, properly irrigating the land, modern techniques on land fertilization, maintenance of the environmental situation, increasing crops growth value, minimizing the human effort, automatically monitoring the system, minimizing the investment, men power or limitation of the labor are the leading contradiction, which is faced by the urban and rural farmers is under development area around the world. Farming in a smart way is directly connected with big data analysis. Such type of farming according to the IoT is one of the optimal technologies which includes broad improvement expectations in the agriculture system.

TABLE V
SOME DATA MANAGEMENT SOFTWARE INFORMATION AND PRINCIPAL FEATURES

Company Name	Software Name	Head Office	Main Features
AGERpoint	AGERmetrix	Florida, USA	Scan and gather high-decision information by LiDAR and different type methodology [31], [32].
Agrivi	Agrivi	UK	Website based and mobile application dependent; Monitor weather condition, field area, crop, etc [32], [33].
Agroptima	Agroptima	Spain	All the field condition records are store in a mobile application; Data can be downloaded in pdf or excel format [32], [33], [34].
AgVerdict (Wilbur-Ellis)	AgVerdict	USA	Mobile and Desktop based application; Enable for providing data security, soil analysis, VRA 1 possibility, etc [32], [33].
John Deere	APEX TM JDLink	Illinois, USA	Always depends on online tools; Able to analyse farm condition, machine data, and agronomic data [32], [33].
New Science Technologies	Cropio	New York, USA	Able to monitor total area remotely; Provide web depended service and mobile application [32], [33], [34].
Smart Farm Software	Farm Management Pro	Ireland	Farm record, crops management, fertilizer distribution is managed by a mobile application; Desktop versions are not available [32], [33].
Proagrica	Farmplan	UK	Helps for vegetation management and enterprise policy; Exchange the sensor data, weather data etc [32], [33].
Agdata	Phoenix	Queensland, Australia	Farmer can draw a map on his area, add and update the data; Available in desktop and cloud [34].

TABLE VI
AVAILABLE INDUSTRY COMPANIES AND THEIR RESEARCH ACCORDING TO IOT IN AGRICULTURE

Industries	Research Solutions
Samsung	Samsung develops a IoT stage named Samsung Data Systems (SDS), which gives the relationship at a couple of IoT gadgets and communication protocols like Modbus, Zigbee, Bluetooth update service, MQTT, and LoRa which maintain WAN [35].
Microsoft	Research on data-pushed farming machine which resolving the troubles from cloud to the sensor. Also provides IoT-based data management system which helps a farmer to monitor his crops productivity and diseases [36].
AeroFarms	Always enable indoor farming methodology which is directly connected to plants into data by using the large data evaluation and artificial or synthetic intelligence technologies [37].
IBM	Provides AI-based technology which is known by Watson Decision. It always provides the suitable solution to broaden the sustainability and best quality by using IoT and AI methodologies [38].
Intel	Develops an IoT-based platform which is known by Infiswift, which helps a farmer to increase the productivity and efficiency of its farm [39].
Google	Provides a smart agricultural solution by developing the MIT media lab open agriculture initiative. By this platform, it helps to grow and reserve the healthy food and resolve the food tendency around the world [40].

This technology always collaborates with many sensors, uses various communication systems and applies different types of models and microcontrollers. By using that technique, the farmer can deeply analyze the data and monitor the whole process automatically and gain the best quality and good quantity of yields. The main goal of this review paper is to discuss the recent technologies and techniques which are applied for making agriculture smarter and which motivate new researchers to emerge the whole world solution of IoT-dependent smart farming.

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