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# Automation in scheduling irrigation: A review of concepts and latest recommendations in technology

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**ABSTRACT**

Automatically operated equipment or machines or systems with no or minimal manual intervention is referred to as automation. Automation facilitates in minimizing the requirement of manual labour, bring precision to the production process and save time with several other benefits. Generally, an automation system engages sensory systems, feedback control processes, and automatic actuating devices. Indian economy is highly dependent on agriculture. Automation has been well taken in the country in recent years in several production sectors including agriculture. With changing climate, and decreased availability of resources such as human labour, water, land, etc. in the agriculture sector the realization is to make the various agricultural processes efficient not only in input application but also in timely execution. In this endeavor, attempts have been made to automize the water application process for irrigating different crops. Irrigation use is one of the critical input resources in Agriculture which demands its judicious as it also has the demand for drinking for a billion-plus country. Precision agriculture technologies in irrigation water management use sensors and controllers to preciously deliver the right amount of water at right time and maintain the moisture to the optimum level. An automatic irrigation system as compared to manual irrigation can save water and maximize productivity. Irrigation systems such as drip, sprinkler, the surface can be automated with help of timers, sensors or computers, or mechanical appliances. Automation of irrigation enhances water use efficiency and reduces the use of resources energy. This review attempts to highlight concepts of automation, recent developments, and the experiences of researchers while automizing various irrigation modules.

***Keywords:*** Automation, irrigation, internet of things (IoT), artificial intelligence (AI)

## INTRODUCTION

Automation not only facilitates production processes to occur automatically with no or minimal intervention of human labor but also provides an opportunity for automated monitoring. With the advancement in science, automation of a wide variety of job functions has been feasible such as robotics, cyber security, wireless applications, and banking. Improved quality, consistency, saving of time, metric visibility, enhanced operational efficiency, better governance, reliability, reduced turnaround times and reduced costs of operations can be some of the major benefits due to automation. To accomplish these tasks one can use different types of automation depending upon specific needs (Ghodake and Mulani *et al*., 2018; Kehal, 2019). Broad categories of automation types, their brief methodology, advantages, and disadvantages are compiled in Table 1.

Various automation processes have been well adopted in many industrial sectors for a long. In the agricultural sector, decreased availability of

**Table 1.** Broad Categories of Automation

| Categories | Methodology, Advantages, and Disadvantages |
|---|---|
| Fixed | This method is used when we need large-scale productivity for the long life cycle of products. It engages specific purpose equipment to automate a repetitive sequence of tasks, processing, or assembly operations. Although the installation of this method is high but running cost is low with greater efficiency but the units must be replaced when new tasks need to be completed. |
| Programmable | It is used when batch production is needed with various options. Automation can be implemented in a programmed manner. This is also a user-friendly method with a low cost for a large batch. New schemes set for different products take a larger setup time. The main advantage is in terms of greater flexibility to deal with the variation of designs. This type is best suited for batch production of a variety of designs. In comparison to other types, this produces fewer units because of the changeover-time between functions. |
| Flexible | For varying demands, this method is most suitable having the highest unit cost relative to fixed and programmable. This type enables automatic and rapid changes to programmed sequences, such as the production of design variations, with virtually no downtime. |

manpower and labour has increased awareness and need for enhancing resource use efficiency, time management, and optimum use of natural resources (Kansara *et al*., 2015, Katariya *et al*., 2015). This has opened gates for automation in agriculture as automation can be used for nursery planting, crop seeding, crop monitoring, and analysis, fertilizer application, practicing irrigation, weeding and spraying, thinning and pruning, tillage, harvesting, and milking. These are a few of the examples where automation can be useful in saving resources and energy.

Most of these operations require a set of technologies in combination for performing automatically. Agriculture is the largest sector that is affected by many types of natural hazards including climate change-related events, insects pests incidences, nutritional deficiencies, and natural resource degradation including soil erosion and biodiversity loss etc. Among these, climate change becomes the greatest challenge to agriculturists. Increasing competition from other sectors for various natural resources has forced the agricultural sector to seek precision farming and resource conservation. Precision farming involves the application of inputs when and where they are needed within a stipulated period. Overall, the objective is to enhance resource use efficiency and this has become the third wave of the modern agriculture revolution. To increase the supply in less time and less energy and to promote the quality of agricultural products, automation has proved itself a milestone, now termed smart farming. Smart farming / Farm automation is the technology that makes the agricultural system more efficient in respect of production cost, use of energy, and time. Also, when considering the environment, new technologies are increasingly being applied on farms to maintain the sustainability of farm production. The recent technologies in the field of sensors and wireless networking are a boon for agriculture systems that not only recuperate the traditional agriculture system but also increase the production quantity and quality. Although these technologies are fairly new, various processes in industries are adopting these approaches quickly to replace the traditional agriculture approach. This paper reviews the present state of the art of automation techniques and their effectiveness with the main focus on irrigation.

### Types of automation systems in irrigation

The automation for irrigation systems can be of different types depending upon requirements. Some of the major automation system concepts adopted are a) volume-based automation b) time-based automation, c) real-time feedback system, and d) sequential and non-sequential automated irrigation system. In the case of volume-based automation, a preset amount of water can be applied by using automatic volume-controlled metering valves, but in the case of time-based automation, the time to apply a particular volume of water is estimated which gives the duration of irrigation required for each unit. The required information is fed to the controller along with the system start time. Once the clock displays the start time of the program, the controller sends signals which in turn starts the pump and the first valve in the sequence. Once the operating duration of the first valve is over as per the information fed in the controller it either stops or switches on to the next valve. Once the operation of the last valve is over, the controller stops sending signals to valves and pump which closes the system operation. The real-time feedback system is based on the actual dynamics of the plant and its root zone which reflects soil moisture status. Sensors are employed which provide the real-time soil moisture status to the controller which further controls the irrigation network control. Based on the type of control, the automated irrigation systems are also classified into two categories: sequential and non-sequential type. In sequential type, the field is divided into different sub-units, which are irrigated one after the other in a particular sequence. Whereas in the non-sequential systems the sub-units are irrigated randomly based on the plant water needs and operated electrically with or without programming with the possibility of utilizing feedback information from the field for remote control. A sequential system can be operated hydraulically or electrically. Hydraulically operated systems are generally suited for low discharge rates whereas, electrically operated systems can be operated from remote locations, and irrigation is time-based. Further, one can have a combination of both also. Non-sequential systems are generally fully automatic to a greater extent as compared to sequential systems. The irrigation can be applied in different quantities and at different times in response to a predetermined program or based on the soil water content. Non-sequential systems are further classified as feedback control, inferential control, and a combination of both with time-based control. The main components of the feedback control system are sensors for soil moisture, weather monitoring parameters, electronic control unit (comparators /microprocessors/computer), and solenoid valves. The sensors are connected through an interfacing circuit to the central control unit, which could be a microprocessor or a computer with a program to schedule irrigation or a comparator circuit. Based on the soil moisture status (measured by soil moisture sensor) of a sub-unit the decision to start and stop irrigation is taken by the controller.

**Types of control in automation**

The control theory or system analysis of mathematical techniques used to model how one component controls the activity of another component is an interlinked system. Mainly two concepts have emerged in automation of control a) open control loop system, and b) closed control loop system (Boman *et al.*, 2002). In the case of an open-loop system, the decision for irrigation is planned based on the amount of water to be applied and its time of application. Based on this the controller is programmed, and irrigation is practiced as per the desired schedule. The basis of decision-making is, either, time or volume. The execution is done with the help of a timer, which commands the start of irrigation and termination either based on a preset time or specified volume of water applied. These types of systems are typically low in cost. The drawback of this system is their inability to respond automatically in real-time mode, hence to achieve high levels of irrigation efficiency these types of system requires frequent resetting. On the other hand, a closed-loop control system receives feedback from sensors. In this case, a general control strategy is being developed by the water user then based on that control system executes the irrigation scheduling based on the data received from sensors. The system requires continuous feedback of the data of environmental parameters as well as system parameters.

**Emerging Developments in automation**

The section further discusses some of the emerging techniques which are used in automation for communicating, data collection, handling, and processing.

**A. Automation Techniques**

**1) Microcontroller (Arduino) Based Irrigation Systems**: This system incorporates the information and signal into different equipment and sensors. The input from sensors is recorded by a microcontroller and further output is generated and communicated to the control unit.

**2) Internet of things (IOT) Based Irrigation System**: IOT system is the advanced version of the microcontroller-based automatic irrigation system (Venkata and Gunturi *et al.*, 2013). Just like microcontroller based system adopted sensor technology, IOT also utilizes these sensors in a very well manner and allows farmers to monitor and maintain the moisture level and other useful factors (humidity, nutrient value, temperature, *etc.*) remotely at any time (Kansara *et al.*, 2015, Veronica and Francisco, 2020).

**3) Distributed Wireless and Remote Sensor Networks for Irrigation System and Control**: The recent development of communication and signaling are much more helpful in the development of wireless sensor-based irrigation systems (Kim *et al*., 2008) through which irrigation systems are electronically controlled by programming and updates the georeferenced location from different global positioning system (GPS) and wirelessly communicates to the end-user at the base station. Kim et.al. 2008, highlights the graphic user interface-based software approach that offers stable remote access to the field condition and real-time control. The system designed has five in-field sensing stations to monitor soil moisture, soil temperature, air temperature whereas a nearby weather station monitors air temperature, relative humidity, precipitation, wind speed, wind direction, and solar direction distributed across the field that is wirelessly transmitted to the base station. Martinez *et al.* (2014) and Vuran and Silva (2009), reported monitoring of wireless networks where underground communications over 30 m distance were possible which further can be enhanced up to 80 m by using higher transmission power. A wireless network can be of two types, a) terrestrial wireless sensor networks (TWSN), and b) wireless underground sensor networks (WUSN). Terrestrial wireless sensor networks (TWSN) is a typical wireless sensor network deployed over the surface of field anywhere for agricultural applications with near about 100 m communication range and frequency varies from 868/915 MHz - 2.4GHz. TWSN is low in energy consumption as well as initial cost. Information can be sent efficiently with a lower antenna size. Wireless underground sensor networks (WUSN) is buried under the ground either in the shallow topsoil (0-30 cm) or in the subsoil (below 30 cm), but the latter has a lower communication range (~0.1-10 m). It has a smaller frequency range comparative to TWSN (433MHz, 8-300 kHz). WUSN has higher energy consumption and cost as compare to TWSN and also has a larger antenna size requirement.

4) **Google-Assistant based IOT for Irrigation System**: This is the next modified version of automation in irrigation with the assistance of Android and Google (Manjusha and Mounika, 2018). Data of different parameters like:-dampness, nutrients and pesticides, etc. is routinely refreshed on a website page utilized by ADAFRUIT (Adafruit is a *cloud service* platform designed by the Internet to display, respond, and interact with user's project data). A framework consisting of a soil moisture sensor, microcontroller with WiFi module (NODEMCU), and a solar panel for power supply is designed for irrigation purpose. IFTTT (if this then that) is a free web-based service is used in this system to create applets, a chain of conditional statements. Here this applet is used to send an email message. Further according to the email message pump may switch on or off.

5) **Artificial-Intelligence based Irrigation System**: It is a kind of simulation of human intelligence in machines that can be programmed to think like humans and imitate their actions (Veronica and Francisco, 2020). A machine simulated with AI exhibits mannerisms associated with a human mind such as learning and problem-solving. Neural networks have a remarkable ability of self-organization and adaptive learning. There are two learning techniques, supervised learning and unsupervised learning. Robotics autonomous systems (RAS) and agri-farming machinery replace human labor and produce effective benefits in quality and productivity (Manivannan and Priyadharshini, 2016). Artificial intelligence fed machines like drones and robots are used for sensing purposes that are localized by GPS modules and the location of these robots/drones are tracked using google maps (Tanha *et al*., 2020). GPS modules sense and localize the robots used for sensing and feeding the command. The data from the robots is fetched through Zigbee wireless protocol. Nowadays, there are too many sectors where artificial intelligence is used in form of drones, robots, and some small machinery systems. In agriculture, some of the applications are pesticide spraying, crop monitoring, mapping, remote sensing, spraying fertilizers etc (Tanha et. al. 2020).

### B. Communicating Modules in automation

**1. Bluetooth Module:** It is a wireless communication protocol, used to exchange information between two devices and is free to use in the wireless communication protocol. The range of the Bluetooth is less than the other wireless communication protocols like WiFi and Zigbee (Amith *et al*., 2018). The Bluetooth operates at the frequency of 2.41 GHz and is also used in many small ranges of applications. Broadly Bluetooth is of three different types and classified as, a) Class 1, where output range is about 100 mW and exchanges information between two devices spaced within 100 m, b) Class 2, where the output range is about 2.5 mW and works for 10 m, and c) Class 3, where the output is about 1 mW and the distance between two devices can be about 10 cm. Hence based on the uses different classes of Bluetooth can be used.

**2. Zigbee:** Zigbee is developed as an open global standard to address the unique needs of low-cost, low-power wireless IoT networks. It is mainly built to control the sensor networks and follows IEEE 802.15.4 standard for wireless area network (WPAN) (Amith *et al.*, 2018). It uses a physical and media access control layer to handle many devices at low data rates. The structure of this system comprises three different types of devices *i.e.* ZigBee coordinator, router, and end device. The coordinator generally involves in handling and storing the information while receiving and data operations, the routers are intermediate devices that allow passing the data to and fro to other devices, whereas, end devices are generally engaged in communicating to the parent nodes. The Zigbee system generally covers a range of 10 – 100 meters. It supports multiple network structures, which mainly include star, tree, and mesh networks and is also low cost and low powered.

**3. Wi-Fi module:** The WiFi module is a component that handles the communication with all of the wireless devices connected to it. It modulates the radio waves then passes the data to the next component in the router. The ESP8266 WiFi Module is a low-cost WiFi chip with self-contained SOC having an integrated TCP/IP protocol stack that can provide any microcontroller access to a WiFi network. This module is capable of hosting an application or offloading all WiFi networking functions from another application processor. The module has a powerful onboard processing and storage capability which facilitates integration with the sensors and other application-specific devices. The ESP8266 supports APSD for VoIP applications and Bluetooth co-existence interfaces, it contains a self-calibrated RF allowing it to work under all operating conditions and requires no external RF parts (Amith *et al.*, 2018).

**4. RF module:** It is an electronic device used to transmit or receive radio signals between two devices wirelessly. It has two components a). transmitter and b). receiver. The module is capable of transmitting signals up to a range of 500 feet with frequency ranging from 30Khz to 300Ghz. The signals of this module can travel long distances hence it is suitable for long-range application (Amith et. al. 2018).

Based on the above literature different automation techniques and communicating modules are compared and compiled and presented in Table 2 and Table 3.

**Automation in Irrigation Scheduling**

Considering the recent trends it is observed that automizing the irrigation system is in topmost priority in the agricultural sector as the timely application of water and in the right quantity is the key to achieve the production objective. For this purpose soil moisture sensors and wireless communication have played a major role to achieve the significant target leading to optimum use of not only water but also the energy used to provide irrigation. The use of advanced technologies contributes to higher water savings and application efficiency in comparison with the conventional irrigation scheduling methods when designed, maintained, and used properly (Mulas, 1986). In this endeavor, most of the automation techniques are used for irrigation scheduling as efficient water management is a major concern. As automation not only facilitates the practice of irrigation on a real-time basis based on the availability of soil water within the crop root zone (Ojha *et al.*, 2015) but also facilitates in practicing high-frequency and low-volume irrigation (Abraham et al., 2000). Various studies have recommended using automated irrigation systems for remote in-field sensing and variable-rate irrigation control (Kim *et al.*, 2008). In recent years soil moisture sensors have been employed for the efficient and automatic operation of irrigation systems besides electrical irrigation controllers which have been promoted in an attempt to facilitate controlled irrigation (Davis and Dukes, 2016). Though they differ in their accuracy and reliability, however, they all depend on modern electronic sensors, which are capable of collecting and analyzing data, and making decisions on when to start/stop irrigation. These sensors transmit the decisions to the irrigation controller, which controls the irrigation system. Automation is typically achieved by a centralized decision-making control device supported with a set of hardware to executes irrigation commands and sensors for input to make decisions. The major components of automation of irrigation systems are controller, control valves, metering pumps, flow transducers, sequencers sensors, master relay, etc. The user has a choice either to automate the pumping unit or to automate

**Table 2.** Comparative Analysis of Automation Techniques

| Parameters | Microcontroller (Arduino) Based Irrigation Systems | IOT Based Irrigation System | Distributed Wireless and Remote Sensor Networks for Irrigation System and Control | Google Assistant based IOT for Irrigation System | Artificial Intelligence based Irrigation System |
|---|---|---|---|---|---|
| Method | Basic mode of automation is used like microcontroller ESP8266, Arduino and ATMEGA, etc. | Internet of things (IOT) system uses GSM with micro-controller that uses wireless communication network. | Terrestrial Wireless sensor N/Ws and Wireless underground Sensor N/Ws are approached in the basic system design. | In this microcontroller is assisted with wifi module NODEMCU and cloud service ADAFRUIT, web based service IFTTT (if this then that) for automatic irrigation purpose. | AI based system designing and modelling that uses Neural networks with learning and programming the drones and robots like human. |
| Complexity | Represents the basic model of a system. | Introduces IOT system with base model. More complex than the first one | As it is used for large-scale functioning complexity increases. | Less complex as compare to TWSN and WUSN as most of the software and data are part of GOOGLE. | Most complex as the utilization of Artificial Intelligence technology needs expertise. |
| Speed/ Time Delay | Moderate working speed as it is a basic system. | Little bit slowly because of dependency on wireless communication network. | Slow because it is associated with large systems. | Comparatively fast as most of the data is stored in Google. | Provide Moderate Speed |
| Efficiency | Low | High | Moderate | High | High |
| Area where used | For a very small system | For medium irrigation system | For large agriculture system | For large irrigation system | For Very Large System |
| Transmission Range | 8 - 20m | < 50Km | entire GSM coverage area | < 50Km | Entire GSM coverage area |
| Frequency Band | 869/915Mhz-2.4Ghz | 2.4Ghz | 2.4Ghz | 2.66 Ghz | 2.4Ghz |
| Cost | Low | Medium | High | High | Highly costly |

**Table 3.** Comparison of Communicating Modules

| Features | Bluetooth | Wi-Fi modules | Zigbee | RF module |
|---|---|---|---|---|
| Range | 10 meters | 100 meters | 10-100 meters | 150 meters |
| Frequency range | 2.4 GHz and 2.483 GHz | 2.4 GHz and 5.0 GHz | 2.4 GHz | 30 KHz & 300 GHz |
| Flexibility | Supports a limited number of users | Provides supports to a large number of users | Can connect up to 65000 nodes | Supports a large number of users |
| Modulation technique | GFSK (Gaussian frequency shift keying) | OFDM (Orthogonal frequency division multiplexing) and QAM (Quadrature Amplitude Modulation) | Direct Sequence Spread System (DSSS) | ASK, OOK, FSK, DSSS |
| Data Rate | 1 Mbps (maxm upto 2 Mbps) | 7 Mbps (max upto 13 Mbps) | 250 Mbps | 1 Kbps to 10 Kbps |

the irrigation network. In the case of the pumping unit, the irrigation controllers control the pump operation, whereas, in the case of the irrigation network the irrigation controllers control the pumping unit as well as control valves of the irrigation network. Recent advances in electronics have made soil water sensors available for the efficient and automatic operation of irrigation systems (Dukes *et al*., 2010). Electrical irrigation controllers have been developed by several manufacturers and have been promoted in an attempt to reduce over-irrigation (Davis and Dukes, 2016). Most of these irrigation controllers can compute the amount of water applied based on ET and climate conditions also (McCready *et al*., 2009; Ghobari *et al*. 2017). They depend on sensors, which are capable of collecting and analyzing the data and making decisions on when to start and stop irrigation. The introduction of low-cost controllers and diverse systems for automation and monitoring have opened new opportunities for the adoption of automation and data loggers by a broader group of researchers and practitioners (Ferrarezi *et al*., 2015, Nemali *et al*., 2006, Debnath *et al*., 2016, Mohanraj *et al*., 2016). On the other hand use of sensors with high built-in resolution embedded chips and user-friendly electronics (Srinivasa *et al*., 2011, Wu, 2012, Devika *et al*., 2014, Ferrarezi *et al*., 2015) have provided cost-effective and robust opportunities in the field of automation.

Zaher *et al*. (2018) introduced an Automated Smart Solar Irrigation System (ASSIS) which was water as well as electricity efficient. The ASSIS is powered by solar panels and can be implemented either on large or small scales. The system uses a distributed network of sensors to detect the moisture content of the soil. These sensors are connected wirelessly to a control unit. The control unit is responsible for controlling and monitoring the irrigation process while performing other functions. The irrigation decisions are based on the weather conditions. The system was demonstrated to operate a drip system for providing irrigation as well as fertigation. They also reported that the use of a microcontroller in this system provided versatility to the proposed design, users can remotely control the proposed ASSIS via their laptops and/or smartphones, in addition to receiving notifications in the form of SMS or e-mails. Anitha (2016), have designed to develop an automatic irrigation system that controls the operation of the pumping unit by sensing the moisture content of the soil. The study has demonstrated the use of an 8051 series microcontroller which is programmed to receive the input signal of varying moisture conditions of the soil through the sensing arrangement. An op-amp has been used as a comparator which acts as an interface between the sensing arrangement and the microcontroller. Pfitscher *et al.* (2012), highlighted the implementation of a rice irrigation system based on SCADA (Supervisory Control and Data Acquisition) and wireless communication. The irrigation system is automated for rice cultivation. They have demonstrated the use of an ultrasonic sensor to monitor and control the water level in the crop and a GPRS system for communicating and control the system remotely. Jagtap and Shelke 2014, highlight an automatic irrigation system based on the concept of WSN and GSM. It can be remotely controlled and monitor. ZigBee module is used to communicate between the soil moisture sensor and controller. The system can be controlled remotely through an Android smartphone. Gulhane *et al.* (2015), have demonstrated the use of ZigBee wireless communication technology and microcontrollers to automate the irrigation system. Muneeswari *et al.* (2017), have designed a smart irrigation system by using IoT. The system is automatized by using a microcontroller with a moisture sensor and water flow management. The data gathered by the sensor is transmitted to a data monitoring system over a wireless network using WiFi. They also highlight that the system is beneficial and works cost-effectively, needs minimal maintenance, and power consumption is reduced to a great extent. Vij *et al.* (2020), proposes automation of irrigation systems using IoT. The proposed use of distributed wireless sensor network (WSN) covering different locations in the farm and transmitting data to a common server. Machine learning (ML) algorithms are used to predict irrigation patterns based on crops and weather scenarios. Several studies have also focused on increasing irrigation efficiency in automated irrigation systems (Munoz-Carpena and Dukes, 2005). It has been reported that automated irrigation system contributes to higher water savings and water use efficiency in comparison with conventional methods, if designed, maintained and used properly (Mulas, 1986; Sample *et al*., 2016). An automatic irrigation control system can potentially optimize water management by sensing soil water conditions. Several researchers have also reported saving of resources and water besides overall convenience with automated irrigation (Gore *et al*., 2014; Ghobari *et* *al*., 2017). Dassanayake *et al*., 2009, reported that automated irrigation technologies evaluated in Egypt, conserved water up to 38 percent over that of conventional irrigation. Yildirim and Demirel, 2011, highlights that the recent trend is to shift from a manual system to automatic operations in a pressurized system. Energy savings, reduced labor cost, and control in fertilizer application are among some of the major advantages of adopting automated techniques. Ghobari *et al*. (2017), highlight that automated irrigation systems resulted in the advantage of water-saving and crop yield by utilizing 26 percent more water than the conventional irrigation control system. These experiences reflect that automation can facilitate not only the precise application of scarce resources like water but also contribute to saving of input costs by reducing the use of manpower.

## CONCLUSION

The use of electronics in agriculture has demonstrated its utility for diverse uses with opportunity in saving of the inputs and saving of energy/manpower as well as time. The introduction of electronics has facilitated to automate various agricultural processes such as the application of water and fertilizer precisely. This way automation has demonstrated its utility to enhance agricultural productivity as well as minimizing the cost of production. Irrigation is one of the critical input resources in agriculture which demands the judicious use of water. Precision agriculture technologies in irrigation water management use sensors and controllers to preciously deliver the right amount of water at right time and maintain the moisture to the desired level. An automatic irrigation system as compared to manual irrigation can save a significant amount of water and maximize productivity. Electronics modules such as microcontrollers, wireless and remote sensing, Internet of Things (IoT) and Artificial Intelligence (AI) have opened new opportunities to perform various agricultural operations efficiently. Further communicating modules such as Bluetooth, Zigbee, Wi-Fi, and RF modules have opened new gates to perform different agricultural operations even from remote locations or fully independently. The use of these techniques, concepts, or modules independently or in combination, will certainly increase in the future and has the potential to help achieve the objective of doubling the farmer's income.

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