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**Review Article**

# Innovation in Agriculture Advantages of a Remote Irrigation Monitoring and Control System

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**Abstract:** Globally, the irrigation of crops is the largest consumptive user of water. Water scarcity is increasing worldwide, resulting in tighter regulation of its use for agriculture. This necessitates the development of irrigation practices that are more efficient in the use of water but do not compromise crop quality and yield. Precision irrigation already achieves this goal, in part. The goal of precision irrigation is to accurately supply the crop water need in a timely manner and as spatially uniformly as possible. However, to maximize the benefits of precision irrigation, additional technologies need to be enabled and incorporated into agriculture. This Search discusses how Advantages of a remote irrigation monitoring and control system irrigation management will enable significant advances in increasing the efficiency of current irrigation approaches. From the literature review, it is found that precision irrigation can be applied in achieving the environmental goals related to sustainability. The demonstrated economic benefits of precision irrigation in field-scale crop production is however minimal. It is argued that a proper combination of soil, plant and weather sensors providing real-time data to an adaptive decision support system provides an innovative platform for improving sustainability in irrigated agriculture. The review also shows that adaptive decision support systems based on model predictive control are able to adequately account for the time-varying nature of the soil–plant–atmosphere system while considering operational limitations and agronomic objectives in arriving at optimal irrigation decisions. It is concluded that significant improvements in crop yield and water savings can be achieved by incorporating model predictive control into precision irrigation decision support tools. Further improvements in water savings can also be realized by including deficit irrigation as part of the overall irrigation management strategy. Nevertheless, future research is needed for identifying crop response to regulated water deficits, developing improved soil moisture and plant sensors, and developing self-learning crop simulation frameworks that can be applied to evaluate adaptive decision support strategies related to irrigation.

**Keywords:** Remote Irrigation Monitoring, Water scarcity, Agriculture, Soil, Plant and Weather sensors.

## Introduction

Globally, 70% of water use is applied in irrigation of crops, making irrigation the largest consumptive user of fresh water [1]. Over 80% of freshwater withdrawals in developing countries is applied in irrigation [2]. Irrigated agriculture provides 40% of the world's food from less than 20% of the cultivated area highlighting the importance of irrigation in global food security [3].

Irrigated crop production globally extends over 275 million hectares, with an estimated annual increase of 1.3% [2]. Global climate change may further increase irrigation water demand due to a greater variation in annual precipitation amounts [4]. Postel [5] suggested that irrigation will provide 46% of the global crop water requirement by 2025, which was computed as 28% in 1995, resulting in a decline of rain-fed agriculture. Food production in the developing world, notably in South, Southeast and East Asia, is at present heavily reliant on irrigation. The total irrigated area in Asia is 230 million ha, which represents over 70% of the global irrigated area. Of the 230 million ha of irrigated land area, 60% is



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located in China and India [3]. It is estimated that 75% of the grain production in China is dependent on irrigation [2]. Sarma [6] noted that India uses as much as four times more water to produce one unit of a major food crop as compared to the USA and Europe. This implies that an improvement in water use efficiency in the developing world would conserve at least half of the water presently applied in irrigation.

It is estimated that a water volume of 2630 km3 is abstracted yearly from surface and ground water sources for irrigated crop production. The absence of surface water sources in a number of communities has further increased the pressure on groundwater resources. This has resulted in the over-abstraction of global groundwater sources which is calculated to be as much as 163 km3 per annum [2]. A global shortage in freshwater sources is predicted unless action is taken to improve water management and increase water use efficiency. This has necessitated greater regulatory demands for environmental protection of freshwater [7]. It is reported that only half of the total freshwater volume abstracted for irrigation globally reaches the targeted crops [2]. These have brought about the need to devise procedures to use the limited water more efficiently while maximizing crop yield and quality.

Conventional irrigation practice involves applying water uniformly over every part of the field without taking into account the spatial variability in soil and crop water needs; this consequently leads to overirrigation in some parts of the field while other parts of the field are underirrigated [8]. The risks associated with overirrigation include surface runoff, deep percolation and leaching of nitrates and nutrients. Those associated with underirrigation are more subjective and include reduction in crop yields and quality, as well as inefficient use of fertilizer and other supplemental inputs for crop production.[9] The irrigation process requires a high level of 'precision' in order to optimize the water input and crop response, while minimizing adverse environmental impacts. Precision irrigation is an evolving field with active interest by both industry and academic researchers. It is conceptualized by some researchers as the use of efficient irrigation application systems, whereas others view it as the variable application of irrigation based on predefined maps or sensor feedback [10]. Smith *et al.*, [11] suggested that 'precision' involves the accurate determination, quantification of crop water needs and the precise application of the optimal water volume at the required time. This implies that varying water application spatially is not the sole requirement for the achievement of 'precision' in the irrigation process.

Hence, precision irrigation can be defined as the process of accounting for the field-scale spatial variability in crop water need and applying the right amount of water to match the spatial crop water need at the right time [9]. The advantages associated with precision irrigation include increased crop yields, improved crop quality, improved water use efficiency/savings, reduction of energy costs and reduction of adverse environmental impacts [12]. Pierce [13] viewed precision irrigation as a tool for improving sustainability in irrigated agriculture in terms of improved irrigation water use efficiency and improved environmental quality of irrigated fields.

The balance of several core aspects is however important for the successful implementation of a robust precision irrigation system. Implementing a precision irrigation system involves efforts on real-time monitoring of crop and soil conditions, scheduling irrigation and control of the irrigation application equipment. Research has been mainly focused on the sensing and control aspects of precision irrigation with much advancements in the last decade [12]. Research is limited, however, in the development of appropriate irrigation scheduling tools for the precision irrigation process [14]. Irrigation scheduling is the process by which a producer determines when to apply irrigation and the amount of irrigation water to apply [15]. Hornbuckle *et al.*, [16] suggested that the irrigation scheduling endeavour should be treated as an all-encompassing decision support system for irrigation management. A robust decision support system is important in the successful implementation of precision irrigation. The need for a decision support system capable of real-time management decisions of when, where and how much to irrigate while also considering uncertainty in climatic inputs, the time-varying nature of cropping systems, as well as equipment and operational limitations cannot be overemphasized. Rhodig and Hillyer [17] noted that the development of an optimal decision support tool for precision irrigation will involve the combination of appropriate modeling and management tools. The decision support tools available for precision irrigation management are presently inflexible and difficult to adapt to varying cropping scenarios [18]. Classification of remote control and monitoring systems.

To understand the method and technique used for the design of a generic remote control and monitoring systems wide variety of remote control and monitoring systems based on different technologies for different applications have been studied [18, 42]. From technical point of view this system can be classified on the basis of technology, processor used, tools, programming code etc. Table 1 shows the classification of existing system based upon different criteria.

**Technology used and Application**

Gao Guohong and Liu Yi introduced an application based on single chip computer (AT89S52) in agriculture and landscape irrigation system [19]. The system has many functional units like clock unit, alarm unit and the display module. This approach reduces the staff workload, improves effective resource utilization, increases crop productivity and thereby reducing the cost of agricultural products.

Vandana Dubey [20] proposed a wireless sensor network based remote irrigation control system and automation using DTMF code. In this approach, cell phone or landline phones are used for starting and controlling the irrigation and pesticide spraying. The implementation of wireless sensor network gives better result and thus makes the work very convenient and efficient.

A very efficient system that uses miscall/SMS for different message and command indication from system cell phone and user cell phones respectively was developed by Vasif Ahmed [21]. This system uses Bluetooth for data communication between microcontroller system and system cell phone but with a range of 10m.In this work, the temperature sensor gives output directly in digital form and have error detection capability. The system has real time clock to provide timing information. The system results in uniform distribution of water in fields at regular interval of time, reduced Labour cost, minimization of occurrence of motor faults, efficient use of water resources. Intimation about completion of task to the user can be send through miscall/SMS. The system can be implemented to any cell phone model. The system is convenient and of low operating cost due to use of miscall compared to SMS.

Li Wenyan proposed a design of wireless water saving irrigation system based on solar energy [22]. The system in work is composed of wireless sensor node, routing node and gateway node with lead acid battery that is recharged by solar cell panel. The main advantage of system is that sensor node can be added and deleted arbitrary and very easily and user can change the threshold of the irrigation according to the specific need of crop.

An advancement in the previous works is done where different sensor nodes and simple Functional nodes form a wireless network. This system was proposed by Zheng Yao and Guohaun Lou [23]. In this work, data collected by Zigbee wireless sensor network is transmitted to gateway node and PC through LAN or WAN. This system uses fuzzy neural network to control agricultural irrigation. The system provides optimal scheduling, improves productivity and better growing environment for crop.

Zeng Peng [24] introduced real time monitoring system for soil moisture content based on (ATmega128) microcontroller/OS-2 operating system serial data flash and time keeping chip, soil moisture sensor, RS-455 microcomputer and RS-232 transreceiver and a host computer. In this work, microcontroller unit with an operating system is introduced to enhance the performance irrigation and provide real time multitasking process capabilities. Advantage of system is that the user can set the work time on demand and around 15 year's data (with one sample one per hour) can be stored.

Lei Xiao [25] proposed a system that can real timely monitor the agriculture environment information using wireless sensor network. The system in work uses MSP430 microcontroller and CC2420 Wireless communication module. The main advantage of the system is that system is steady in performance and facilitated in operation.

Wireless sensor network for precise agriculture monitoring [26] developed for monitoring the western region special agriculture product has been proposed. The system in work has precision agriculture monitoring system that has WSN gateway and communication server. The system uses ATmega 128L microcontroller that supports Tiny OS software with AT86RF230 as radio frequency chip and AT45db041B as memory. The main advantage of system is that the user can access the website via graphical user interface and can easily get real time data send by the nodes and improve the productivity by managing and monitoring the growth period of the crop in farm land.

Another WSN based greenhouse monitoring and control system [27] where WSN, gateways, 14 sensor nodes, a management subsystem, 1 actuator node and 2 sink nodes are deployed in greenhouse. The system in work has WLAN APs that give long range wireless link between WSN and management sub system which is about 0.5 km far away from greenhouse. The system provides easy and user friendly interface to farmers with hand held devices like PDA and PC.

An advanced system based on WSN zigbee [28] and ARM processor has been proposed. The first layer of WSN node is made up of CC2430 chip integrated with 8051 microcontroller and 2.4 GHZ RF trans receiver. These nodes communicate with gateway nodes that are composed of CC2308 GPRS MODULE MC391 through RS232 bus. The system has advantage that it is low cost, flexible and has user friendly human-computer interface.

An advance system based on WSN that monitor environment condition for precise agriculture is proposed by Jianfa Xia [29]. The system y collects various environmental parameters using Telos B wireless sensor node that consist of MSP430F1611 and CC2420 chips. Data from these WSN is send to gateway node through RS232. System in work has a web based information transmitting and inquiring subsystem. The system uses Google map technique to give location information, green house environmental status and give real time voice and SMS alarm services. The whole system is powered by solar energy and storage batteries. The system is low cost and highly scalable. The system gives real time stable and accurate services for agriculture.

Most of the field control and monitoring system use PC and cell phones but Jzau Sheng Lin [30] proposed a system that use SOC platform as web server. The system uses zigbee technology based wireless sensor. The zigbee receiver has different sensors and a microcontroller unit (SPC061A) that polls each sensor quickly and receives the data. As the system use zigbee technique so it solved wireless transmission problem and thus replaces long cables of field signal monitoring system. The system used SOC (built in XILINX SPARTAN-3) that reduces cost and physical size of the whole system.

A WNS (wireless sensor node) based real time remote monitoring and warning system [31] has been proposed. The system is made up of wireless environment monitoring equipment (WEME) and mobile phone. WEME uses solar power for it's working and has multi pin data interface for connecting different sensors. The system has advantage of online information acquisition. The user can remotely enquire and can do real time monitoring.

Another system for remote sensing and control of an irrigation system using a distributed wireless sensor network [32] has been proposed. The system has in-field sensing stations for sensing different parameters of field land and weather station for sensing micro metro logical information. The system uses Bluetooth, TCP/IP technology for sending data wirelessly. The system uses user friendly decision making program (WISC) for controlled irrigation. The system gives a low cost solution for WSN.

Another zigbee based prototype used for irrigation control using wireless sensor and actuator network has been proposed [33]. The data is sent wirelessly through zigbee to the sink node. The system can transform the data in less time. The system provides addressing for sensor network and gives decision making and fault tolerance capability. The system is easy to deploy, cost effective and decreases the labor cost for watering.

An automatic irrigation system for rice cultivation is proposed by LL. Pfitcher [34]. The system has a supervisory system that use SCADA software for monitoring and control of irrigation pump and watering level. The transmitter module (DX80N2X2S2S) of sensor works at 2.4 GHZ. The wireless gateway (DX80G2M2S) receives the signal from sensors and sends the data to controller using MOD BUS Protocol. The system uses telephone communication through GPRS message to establish communication between controller (BCM2085B) and supervisory system. The system uses ultrasonic sensors (T30UFDNCQ) in field land.

As the system uses GPRS communication with DNP3 protocol this makes the system more reliable. System sends all warning conditions using alarm management feature of SCADA.

Another GSM based irrigation system [35] that uses solar energy to run motor which is controlled by PIC microcontroller (16F877A) has been proposed. The system can start/stop the pump and can provide water level information by sending SMS on GSM network. The main advantage of proposed system is that the cost of operation and maintenance of solar pump is negligible. The system can be operated from any place as it can be completely automized and works on highly reliable and efficient GSM network.

Rajeev G Vishwakarama [36] proposed a system where the farmer can monitor power on/off, voltage supply level of electricity and control up to 8 different devices by sending SMS on GSM network. The system uses GSM mobile phone that support AT command, AT-89C51 microcontroller, max 232 IC and LCD for monitoring the current reading of all the measured parameters. As the system does only on/off operation therefore for such applications AT-89C51 microcontroller is the best suited option among available one.

Another system of embedded wireless video monitoring system based on GPRS [37] has been proposed. Here image collection and compression is done on embedded Linux platform that support USB interface. The system uses Samsung's S3C2410 16/32 bit RISC microprocessor. To reduce total cost of the system the microcontroller includes separate 16 KB instruction, 16 KB data cache, MMU, LCD controller, Boot Loader, system manager, 3 channel UART, DMA, I/O port, RTC, ADC and touch screen interface. The system is highly reliable and widely used in the applications where there is requirement of high real time monitoring and control .

Another system based on GPRS technology with better application prospect [38] is proposed by Lu limei, Xu Lizhong. The system has sensor node to gathers hydrographic information and the sink node to receive the real-time data through the GPRS network. The system replaces the wired transmission with the wireless transmission, which reduces the installation and maintenance costs and improves the system reliability and efficiency to a great extend.

A Low cost soil moisture monitoring system is presented in [39]. The paper describes a PC controlled irrigation monitoring and controlling system with wireless communication. The design of the overall system provides consistent soil moisture measurements and allows automatic watering of the soil at a very low cost. PIC processor is used with Linux wireless system which used Amplitude Modulation to transmit data .

Another approach using GSM technology to communicate with the remote devices via SMS has been proposed [40]. This paper illustrates a technique for remotely reading electricity meter (both postpaid and prepaid) readings using SMS. As the data collection is based on SMS so the system is very quickly and efficiently and reliable.

A wireless sensor network (WSN) based system used for an intelligent temperature measurement system [41] has been proposed. The system in use has digital multipoint thermometers for temperature measurement. System uses an advanced RISC microprocessor (ARM) and Wireless Fidelity (Wi-Fi) technology for data transmission. A special data storage file system is accomplished for reading and writing SD card, as well as for the management of the data file by the FAT16 file system. Wireless sensor networks are easy to establish without using cables and offers a greater flexibility.

Another system on automation of free-standing greenhouse using supervisory control and data acquisition (SCADA) has been proposed. This system gives a kiosh type of approach to farmers. Kiosh monitors and governs entire green house operation.

From the above discussion, it is concluded that designing a remote monitoring and control system that fulfills all the requirements simultaneously is a complicated task. Every proposed system has its own merits and demerits. However, still there is possibility of designing an innovative cost effective and high performance system that can work optimally in different applications. An innovative GSM-Bluetooth based remote controlled embedded system for irrigation is proposed in this paper.

**IoT and Smart Systems Used in Irrigation**

**Communication Technologies**

With regards to the implementation of IoT devices, the used communication technologies could be considered as a vital and imperative point to attain successful operations. The communication technologies could further be regarded as being used in accordance with the environment where they will be applied [42]. The main technologies that are used in IoT for irrigation could be classified into two categories. One could be regarded as the devices that function as nodes and lead to forward or transmit small data amount at short distances along with having low consumption of energy. Consequently, the other devices are the ones that have the ability to transmit huge amounts of data over long distances, having high-energy consumption. There are various wireless standards that could be used in the communication of IoT devices and they could generally be classified between devices that communicate at long or short distances [43].

One of the most used and effective communication technologies has been identified to be Wi-Fi due to the possible accessibility for it. It has further been identified that the current low-cost devices for IoT mostly lead to support Wi-Fi, and while it has its limitations (area coverage and reach), it is regarded an effective overall method [44]. Global System for Mobile communication (GSM) further has been identified to be a widely spread wireless technology which provides long-range communication and all it requires is a mobile plan of the service provider which operates and functions in that particular area. Two other noticeable technologies that have been established more recently are Long Range (LoRa) and Message Queuing Telemetry Transport (MQTT). LoRa provides very long ranges, and this has led to make this technology highly feasible and useful for secluded areas that do not have any service. On the other hand, although MQTT has also resulted in being a widely spread protocol as it have low overhead and low power consumption, it is not being highly used for an irrigation system as yet [45].

**Benefits of IoT System in Irrigation**

There are various benefits associated with IoT systems in irrigation and some of them could be considered as overall water consumption reduction, high cost-efficiency, high performance efficiency, lesser energy consumption, lesser wastage of crops, and more [46]. Fig. 1 shows the benefits of using IoT in irrigation systems.

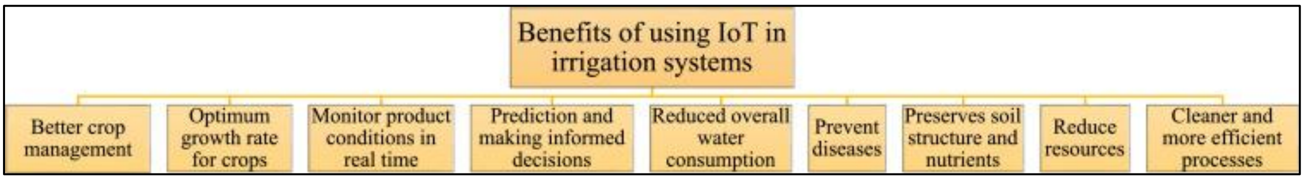



**Fig. 1: Benefits of IoT in irrigation systems**

One of the main benefits of IoT systems in irrigation is associated with the lower water consumption [47]. Also, most of the work related to irrigation is automated through such an approach, only the required amount of water is utilized for the irrigation process and lesser wastage takes place. In traditional ways of irrigation where most of the handling and operations were carried out manually, an ample amount of water was wasted in the irrigation process where human intervention was required [2]. With Smart irrigation, there is no or less human involvement and the resource of water is only used to the extent to which it is required only. Further, high cost-efficiency is one of the other benefits linked to it as lesser water utilization and precision in the process allows saving costs and overall expenses [48]. Energy consumption is also reduced significantly through the approach as machines have to run for a lower amount of time and planned intervals take place during the process that lowers the utilization of overall energy [49].

Moreover, resources are limited and businesses have to limit their costs to a certain extent, it is imperative to control the costs and save resources. With Smart irrigation, the factor of cost is taken into consideration and it becomes feasible to carry out related activities in an effective manner with lesser expenses incurred [50]. Lastly, one of the other advantages is that with higher efficiency in the irrigation process and water management, the plants and crops are only provided the needed amount of water, and this reduces the wastage of crops due to lesser or over the provision of water [51].

**Use of IoT and Big Data for Optimisation of Irrigation Systems**

It has been identified that IoT systems in general produce a huge amount of data because of monitoring varied parameters in real-time and IoT irrigation systems develops big data as well. Understanding the presence of big data, it has become essential and imperative to develop mechanisms that adequately assess and manage the data [52]. That fact that managing big data could be a difficult activity on the whole and may over-utilise nature resources, it has been suggested that there is a dire need of focusing more on sustainable management of big data. Some of the suggestions that have been understood in this regard have been identified to be using blockchain technology, discarding unnecessary data and only selecting the useful information, powering the devices through the use of solar energy [53], implement clustering techniques to lower the overall information volume, employing efficient algorithms and utilising sustainable resources. While big data could be of immense usage in the overall irrigation process, it is highly vital to ensure effective management and control of the information [54]. It has further been explored that while the collected data from the sensors provide ample information that could be used, the data analysis is critical to optimise the irrigation process in accordance with the weather and crop conditions.

Various organisations involved and related to the activity of irrigation are rightly able to gather the required information, but they fail to properly assess the data and deduce the useful outcomes out of it. This inability of analysis acts as a huge barrier in improving work efficiency and lowering the related risks to the activities [55]. Fig. 2 shows the barriers of smart irrigation.

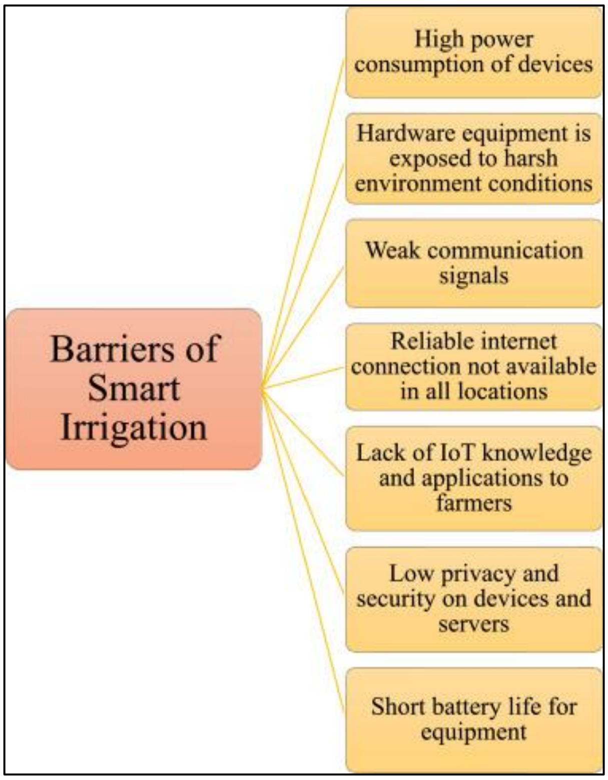



**Fig. 2: Barriers of smart irrigation systems**

Moreover, artificial intelligence (AI) is regarded as the technology which is being used by most the organisations for varied purposes. Through the use of AI, optimisation of available resources becomes more feasible along with gathering information related to the crops such as diseases or corrected growth of plants. A related technique in this to assess the collected data from the sensors to carry out the irrigation related activities is fuzzy logic. This technique is employed to enhance irrigation scheduling and managing the drainage [56].

One of the other techniques that is used in irrigation systems to carry out predictions is machine learning. The techniques of prediction are used to assess the amount of available water for irrigation. This allows improving the irrigation process through foreseeing the probable adversities that could take place and how the risks must be managed in order to ensure optimum work efficiency. Some of the benefits that could be linked with machine learning could therefore be regarded as water usage reduction, increased profits, and enhanced crop yields. With lowering the risks related to irrigation through the use of machine learning, it may become more feasible to attain effective performance along with providing financial benefits [57]. There are various issues to agriculture field like crop diseases, lack of storage management, pesticide control, weed management, lack of irrigation, and water management and all these issues can be resolved by using various artificial intelligence methods. Machine learning improves the overall activities and processes related to irrigation through algorithms and allow achieving the performance objectives. The machine learning further supports predictions for irrigation patterns which are mainly based on weather and crop scenarios. Predictions could be directly associated with the usage of machine learning as it assists in taking measures and adopting strategies considering the probable activities that may take in the future. These predictions therefore eventually allow taking necessary measures which could support the irrigation process in the long run [58]. Bannerjee *et al.,* [59] classified AI breakthroughs and provided a quick summary of major AI techniques and smart irrigation. Also, Chlingaryan *et al.,* [60] demonstrated a machine learning expert system that provides a flexible architecture for data driven decision making. Similarly, the development of a sustainable precision irrigation system was demonstrated through the effective management of sensed data about soil, plants, and weather [61-64]. Correspondingly, Elavarasan *et al.*, [65] investigated the integration of different machine learning models to find the optimal irrigation decision management. The precision irrigation systems could be used to control the changing environmental circumstances in an adaptive manner. Various machine learning applications have been studied in literature, namely crop management [50], livestock management , [66] water management [67] and soil management.

**Security and Acquisition**

The improvements and advances made in technology have led to develop ways through which new method for collecting data from the sensors deployed in the field have been established. While various advancements have been made and applied, one of the successful means of data collection from sensor nodes is through drones. The technology of drones has further allowed gathering new data that could not otherwise be attained in other ways like aerial images of fields [68]. One of the other ways of data gathering has been identified to be robots that lead to inculcate actuators and sensors to carry out different activities such as spraying water, soil moisture, scaring away animals or weeding. This technology of robots could therefore be used for the irrigation of areas because of their ability to travel to the required locations. The robots are also able to assess the soil moisture and include sensors that mitigate the probability of collision [69].

Robots have been identified to be one of the most efficient ways of carrying out activities related to irrigation and many organisations in the contemporary environment have been taking use of this technology. Improvements in robot technology are also being made along with their utility and implications. The wireless robot comprises both soil monitoring and environmental monitoring to be able to carry out tasks such as water spraying, moving through the field, and much more [70]. To enhance the navigation of robots for irrigation, the coverage path planning algorithm could be used which consists of a map of static elements and environmental data. Robot operating system could be further used to develop the control system of the robot that is divided into three main layers. The first layer leads to reading the data from sensors, the second layer carried out communication and the third layer focuses on performing path planning and decision making. Furthermore, in order to ensure sustainability and efficiency, the robots can be powered through the use of solar panels and ensure autonomy[71].

The implementation of IoT systems, ensuring security could become a difficult task as varied types of threats may lead to taking place. Some of the security threats that may take place and have adverse impacts are cloning, vulnerable software, leakage of private information, firmware attacks, routing attack, denial of service attacks, eavesdropping attacks, and many more. With regards to all of such threats, it has become essential to develop security measures that may mitigate the overall adversities [72] . The fact that data regarding the operations and functionality of organisations in the particular sector is highly imperative and critical, protecting it becomes extremely vital. While different techniques have been developed to lower the linked issues, one of the most effective methods is related to the blockchain technique. This is a technique that is applied to secure the systems of IoT, allowing safer communication and data storage [73].

Considering the industry of agriculture, it has been understood that technologies such as blockchain are used to secure mainly the supply chain. With regards to blockchain-related to IoT irrigation systems for agriculture, it is used for tracking and tracing information exchange of proposed smart watering system. As much as the security concerns have been rising over the past due to improvements in technology, the need to ensure better security is also equally critical [74]. Through the use of increased research and development, organisations have been focused on controlling the threats and making sure that malicious activities could be lowered in a significant manner. Further, the need for a secure storage system has augmented over the years, and as activities related to agriculture are becoming more automated inculcating technology, the probability and incidence of attack are also increasing majorly. Even though various organisations have successfully been able to control the threats, a continuous improvement approach through R&D may further provide the desired results [75]. Fig. 3 shows different types of sensors that can be used in smart irrigation system.


**Fig. 3: Smart irrigation system sensors, pictures taken from Wikipedia**

Laser or Light Amplification by Stimulated Emission of Radiation (LASER) is a device that emits light through a photo amplification process based on the stimulated emission of electromagnetic radiation. Its photons are of equal frequency and identical wave phase, where the waves overlap and may multiply each other, which causes a strengthening of the light beam. The process of interference of waves, can it be a constructive interference between its waves to turn into a light pulse of high energy and very coherent in time and space with a very small diffraction angle; Or the waves interfere non-constructively and the ligh disappears [76]. The first laser was built in 1960 by Theodor Harold Maiman at Hughes Research Laboratories, building on theoretical work by Charles Hard Townes and Arthur Leonard Shaw low.

**Laser Properties**

- **Directivity:** It is one of the most important characteristics of lasers, as the angle of diffraction of laser beams is very small, and therefore it can travel long distances without dissipating its energy or changing its direction. This property is used in many applications that depend on measuring near and far distances, and identifying targets with extreme accuracy, such as surveying systems.
- **Beam Intensity:** The laser beam is characterized by the fact that its cross-sectional size is very small, as it does not exceed several square micrometers, and since all the light energy emitted by the laser is concentrated in this small cross section, it will appear in the form of illumination or intense beam, so that the intensity of the beam emanating from the laser is greater. From the intensity of the light emanating from the sun, or lamps, and these rays can travel long distances without decreasing the intensity of their illumination, and this property is used in delicate surgical operations, and in treating diseases of the skin and eyes, and in drilling and cutting materials.
- **Monochromatic:** Laser light differs from other types of light, in that it consists of a band of narrow optical frequencies, where laser light appears in one color, and with a high degree of purity, while other types of light consist of visible spectrum colors, so this property is exploited, and Laser light in fiber optic communication systems, as a carrier of information.
- **Coherence and Coherence of Photons:** The optical frequencies resulting from laser beams are characterized by the fact that the photons of these rays are interconnected and coherent. Because it has the same structural phase and the same size of polarization, which are properties not found in any other type of light, and this property is used in optical interference, three-dimensional imaging, the study of the composition of materials, and the measurement of speed and distance.
- **The Possibility of Controlling the Laser Device:** Where it is possible to control the rate of the laser pulses that are fired, and the width of these pulses can also be controlled, so that they become suitable for some applications, and as mentioned previously, the less the width of the pulses, the greater the intensity of the light, and therefore it can be

exploited in many applications that require High light intensity, such as melting or vaporizing metals, cutting materials that cannot be cut by other means, or accelerating nuclear or chemical reactions.

**Experimental Work**

**Aim of the Work:** Precise control of the water level of agricultural lands remotely.

**Instruments**

Laser diode 2mw (632nm), optical transmission circuit, optical receiver circuit, 12 volt relay, electrical water pump, wooden base with (30-80cm) diameter.

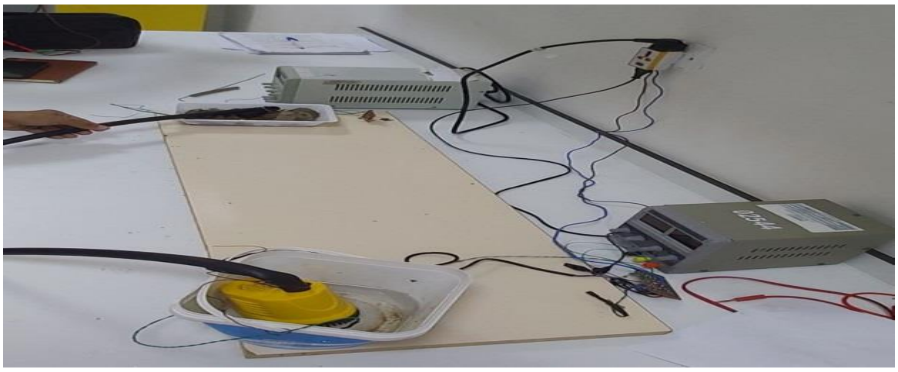


**Fig. 4: Irrigation control system**

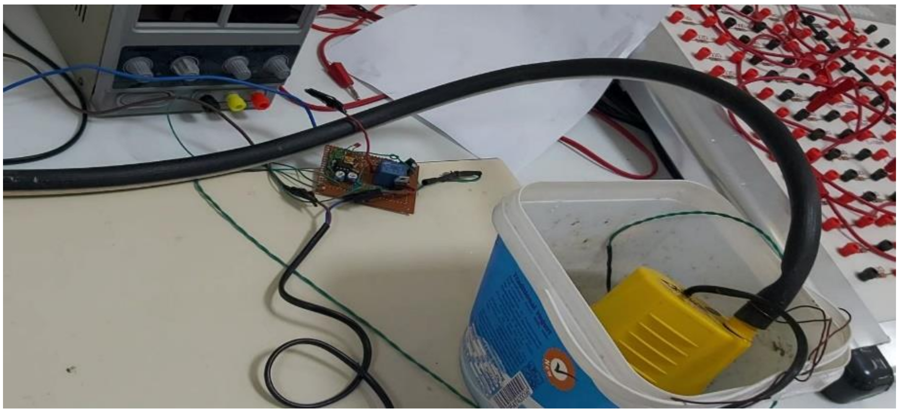
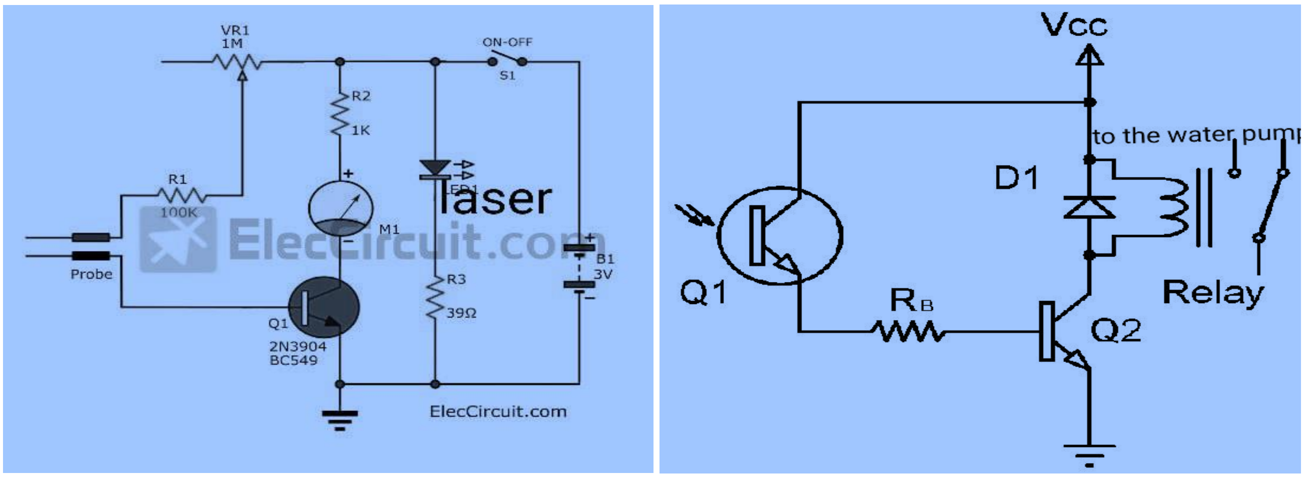


**Fig. 5: Water pump and receiver circuit**

**Fig. 6: The transmitter circuit and the land to be irrigated**

In this experiment, an electronic remote control system was adopted using laser beams, where a red laser with a wavelength of 635nm and a capacity of 2mw was used, and a moisture sensor dipped in the soil to be watered, and then a laser signal was sent to the irrigation system (Motor) by a laser beam and separated by a photodetector. The optical signal is converted into an electrical signal and amplified by an amplifier. And then it is connected to the irrigation system (motor), which in turn is connected to another system to sense the abundance of water, as without water it does not work. This system provides:

1. Increasing the rationalization of water consumption.
2. Reducing the number of workers.




(a) (b)

**Fig. 7: (a) Transmission circuit (b) Receiver circuit**

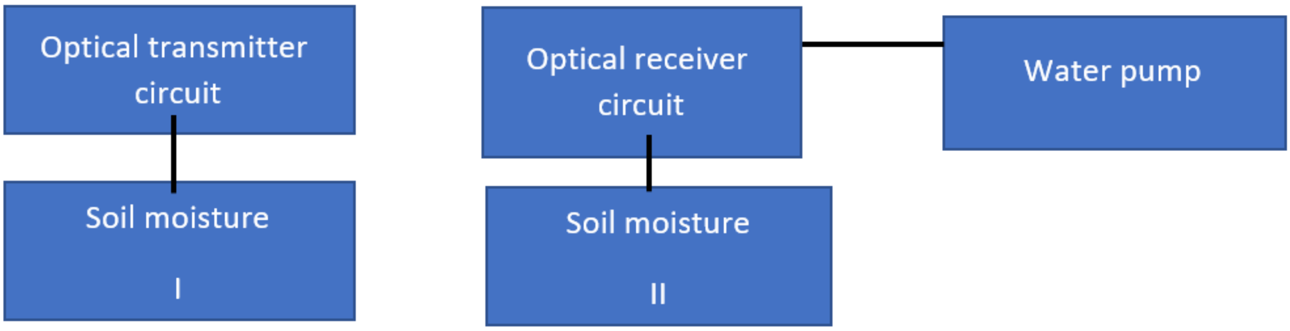



**Fig. 8: Block chart**

**Laser Diode**

A laser diode is electrically a PIN diode. The active region of the laser diode is in the intrinsic (I) region, and the carriers (electrons and holes) are pumped into that region from the N and P regions respectively. While initial diode laser research was conducted on simple P–N diodes, all modern lasers use the double-hetero-structure implementation, where the carriers and the photons are confined in order to maximize their chances for recombination and light generation. Unlike a regular diode, the goal for a laser diode is to recombine all carriers in the I region, and produce light. Thus, laser diodes are fabricated using direct band-gap semiconductors. The laser diode epitaxial structure is grown using one of the crystal growth techniques, usually starting from an N doped substrate, and growing the I doped active layer, followed by the P doped cladding, and a contact layer. The active layer most often consists of quantum wells, which provide lower threshold current and higher efficiency.

**Photodetector**

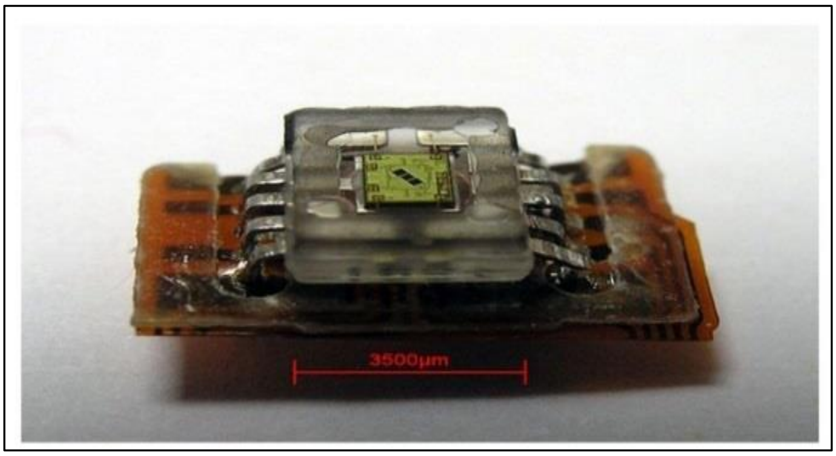



**Fig. 9: Photo detector**

Are sensors of light or other electromagnetic radiation [77]. There is a wide variety of photodetectors which may be classified by mechanism of detection, such as photoelectric or photochemical effects, or by various performance metrics, such as spectral response. Semiconductor-based photodetectors typically photo detector have a p–n junction that converts light photons into current. The absorbed photons make electron–hole pairs in the depletion region. Photodiodes and photo transistors are a few examples of photo detectors. Solar cells convert some of the light energy absorbed into electrical energy. And an optoelectronic device that is used to detect the incident light or optical power to convert it into an electrical signal is known as a photodetector. Usually, this o/p signal is proportional to the incident optical power. These sensors are absolutely needed for different scientific implementations like process control, fiber optic communication systems, safety, environmental sensing & also in defense applications. Examples of photodetectors are phototransistors and photodiodes. How photodetector works? Photodetector simply works by detecting light or other electromagnetic radiation or devices may by receiving the transmitted optical signals. Photodetectors that use semiconductors operate on the electron-hole pair creation upon the light irradiation principle. Once a semiconductor material is illuminated through photons that have high or equivalent energies to its bandgap, then absorbed photons encourage valence band electrons to move into the conduction band, so leaving behind holes within the valence band. The electrons in the conduction band perform as free electrons (holes) that can disperse under the power of an intrinsic or externally applied electric field. The photogenerated electron-hole pairs because of optical absorption may recombine & reemit light unless subjected to an electric field-mediated separation to give an increase to a photocurrent, which is a fraction of the photogenerated free charge carriers received at the electrodes of the photodetector arrangement. The photocurrent magnitude at a specified wavelength is directly proportional to the intensity of incident light.

**Soil Moisture Sensor**

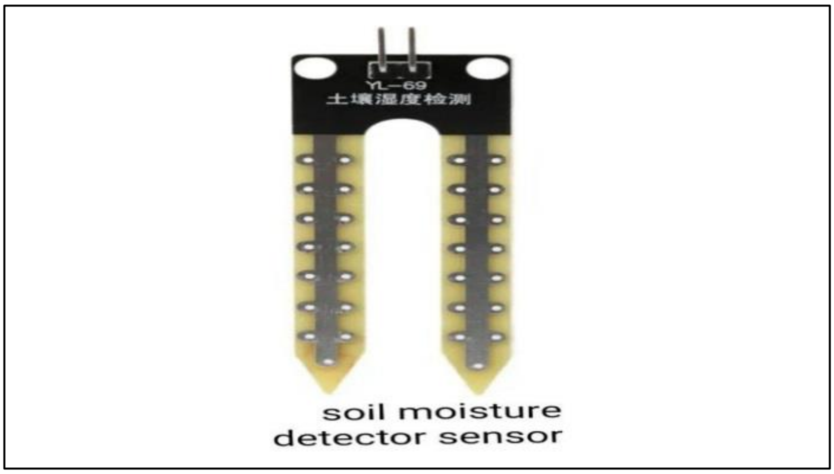



**Fig. 10: Soil moisture sensor**

This is a soil moisture meter, soil moisture sensor, water sensor, soil moisture for Arduino. With this unit, you can tell when your plants need watering by the soil moisture in the pot, garden, or patio. The two probes on the sensor act as variable resistors. Use it in your home's automated watering system, connect it to the Internet of Things, or just use it to find out when your plant needs a little love. Installing this sensor and its PCB will get you on your way to a green thumb boost!

The soil moisture sensor consists of two probes that are used to measure the volumetric water content. The two probes allow the current to pass through the soil and then obtain the resistance value to measure the moisture value.

When there is more water, the soil will conduct more electricity which means there will be less resistance. Therefore, the humidity level will be higher. Dry soil conducts electricity poorly, so when there is less water, the soil will conduct less electricity which means there will be more resistance. Therefore, the humidity level will be lower.

## CONCLUSION

Irrigation addresses various SDGs for the purpose of food security and reducing poverty. However, smart irrigation indicates a wider range of SDGs for the purpose of industry innovation and providing a more responsible consumption and production for food security. It has a direct influence on the current progress in SDGs. It provides the contribution of the smart irrigation system into the sustainable development. The water resources are based on irrigation expansion in order to enhance food grain production.

Moreover, water and food are two of the most essential commodities in the world, hence agriculture is vital to humanity since it uses water to provide food. Climate change and rapid population growth have put a lot of strain on agriculture, which effects the water resources that is critical for sustainable development. Thus, smart irrigation systems have been shown to significantly increase crop output and agricultural profitability. This approach supports the sector for a more productive, equitable and sustainable irrigation management and promotes the development of the SDGs.

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