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Investigation Study of an Intelligent Irrigation System

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Abstract
Lately, Irrigation systems have gained substantial attention owing to the rising demand for water conservation and improved crop yield. Scarcity of water in the soil due climate change, degradation of land and availability of related resources in some topographies of the world. In this study, the potential for utilizing advanced technologies in the development of an intelligent irrigation system was investigated. A comprehensive review of the literature was conducted and framework was designed, which identified key considerations for the development of such systems, including the monitoring of soil moisture, weather conditions, and water quality. The various nodes and wireless technologies and electronic components utilized in the deployment of IoT-based irrigation systems were also explored, as well as the challenges and best practices for their implementation. These findings highlighted the importance of considering these factors in the development of intelligent irrigation systems, ultimately leading to improved water management, crop productivity and food security.

Keywords: Internet of things, Food Security, Irrigation System, Wireless Technologies

1. Introduction

Food insecurity is one of the modern world's challenges, and despite technical advances, farming still requires some level of water for optimal harvests [1]. Rainfall, the principal supply of farm water in many parts of the world, does not occur continuously throughout the year, hence irrigation is required to support farming. Irrigation is the process of delivering water to the soil to assist crop growth [2]. In agriculture, the soil must be moist enough to sustain crop growth; however, because rain does not fall all year in some geographical areas, an alternate watering system for the soil to maintain crop growth is required [3]. During these periods of insufficient rainfall, an automatic irrigation system helps re-vegetate soils in dry lands, it further helps maintain landscapes and supports the growth of crops. Two vital aspects of irrigation are being able to know the quantity of water needed by plants and the best time to water the farm. Automatic farm watering systems are created to make the task of watering farms easy for gardeners [4]. Many types of automatic watering systems exist; these include implementation around nozzles, tubes, sprinkler systems, and others [5]. Intelligent irrigation system enhances the numerous innovations in agriculture as indicated in Figure 1.1.

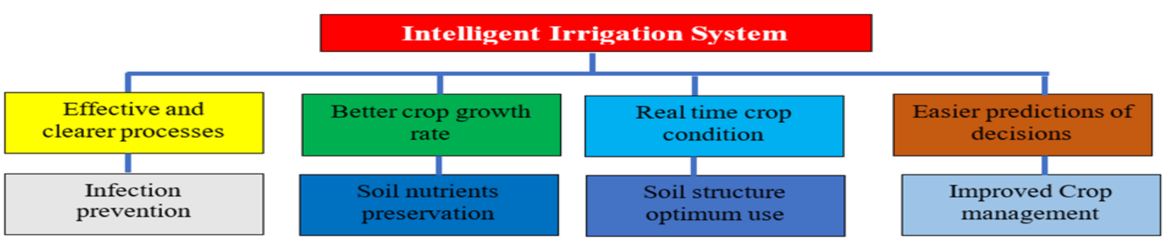

Figure 1.1: Overview of Intelligent irrigation systems.

The importance of food as one of man's basic requirements, it's necessity at least twice daily cannot be overemphasized for healthy living. With the expanding global population, there is a need for agricultural intervention through irrigation. This project investigates and designed a framework for the development of an automatic irrigation system that comprises moisture content measurement and a water dispenser to sprinkle water on the farm when the soil moisture level is low. Most farmers find it hard to keep plants alive and healthy albeit they enjoy nurturing them and the benefits they offer [6]. One of the challenging aspects of keeping the plants healthy and alive is the routine watering of soil which is usually done twice a day, morning and evening; and most times, gardeners forget or are sometimes not available to water the farm. This research attempt to solve this problem using automatic irrigation system. This work contributes to knowledge by designing an automatic irrigation system that is capable of measuring soil moisture levels and automatically providing the soil with water using a sprinkler. It turns on the water sprinkler when the moisture level drops below the standard threshold and turns it off once the soil is sufficiently irrigated. The framework designed is capable of measuring and monitoring the soil moisture level, automatic turn on and off water sprinkler based on the moisture level goes and the predetermined standard threshold using the concept of Internet of Things (IOT) [7].

2. Literature review

Articles related to this research were reviewed and discussed to provide a comprehensive investigative analysis for the proposed framework. Two broad ways of providing water for agricultural use; namely Irrigation and Rain-fed farming were investigated in this study. The method of applying water on-farm from rainfall is called rain-fed farming [8]. With the rain-fed method, there could be an insufficient supply of water but there are fewer chances of crop contamination unlike artificial water application (irrigation) which has a high risk of crop contamination. The dominant source of water resource in agriculture is the rain-fed agriculture for stable production of food and livelihood. With the climate change challenge, causing disruption of rain fall frequency; meeting food security requirement is fast becoming more challenging. Copping with the restrictions and chances of the existing climate inconsistency by stakeholders specifically regarding rainfall must be improved for future predictions of such situations [9]. Smart faming, intelligent irrigation system apparatuses and tactics are widely available to understand and solve problems associated with climate change inclined shortfall in raining. Applying these tools and measures will give room for development and more innovations in the context of food security and production.

The artificial application of water on farms through systems of sprays, pumps, tubes or sprinklers is called irrigation [10]. In areas with irregular rainfall, or when dryness/drought is expected, an irrigation watering system is preferred. Water is supplied to the entire field in some types of irrigation systems however the slow pace of implementation and limited coverage is a more reason for deploying an intelligent system for this purpose. There are many sources of irrigation water [11], [12]. These include, but are not limited to desalinated water, treated wastewater, reservoirs, lakes, rivers, surface water, wells or springs, groundwater to mention few.

Therefore, farmers have to protect these water sources against contamination to enhance food security. Great care should be taken by users of irrigation systems to not pump groundwater from an aquifer faster than it is being recharged. Although soil types play a vital role in the limited moisture rate of the soil [13]. Hower, other factors are also responsible for moisture loss in the soil that necessitated the importance of this study was revealed in the [14]–[19]. The evaporative suppression of soil moisture is critical to farm produce germination, it is experienced at different stages [17]. Rapid loss water at the surface of the soil might not meet the evaporative demand of plants [16]. This could be at the ground surface. On the other way round; the rapid decline in loss rate in the reservoir of soil, is also an intrinsic factor that coordinates the moisture flow at the soil surface [18], [20]. Moisture loss are not all dependent on the soil types only but could also be the slow rate of water absorption of the topography which sometimes lead to decreasing transfer of water vapour to the atmosphere [21]. This could increase or decrease the soil moisture holding capacity[14], [15]. Hence an intelligent irrigation system.

2.1 Types of irrigation systems

Depending on how water is being distributed on-farm, different types of irrigation systems [22] are considered including; Manual Irrigation, Sub-Irrigation, Lateral Move Irrigation, Center Pivot Irrigation, Sprinkler Irrigation, Drip Irrigation, Localized Irrigation and Surface Irrigation. These are discussed in the following sub-sections.

2.1.1 Manual Irrigation

In this type of irrigation system, watering cans are used through manual labour to distribute water on the farm. Simple yet effective methods for providing water to crops are manual irrigation systems. Systems for manual irrigation can be operated without specialized equipment and are simple to use. But in order to prevent water loss and crop failure, it's crucial that they are built properly. The systems feature low initial capital costs and strong self-help compatibility. They can be applied practically anywhere, although they are particularly well suited for arid regions with high evaporation rates. Although this type is very labour-intensive. Some of the advantages of manual irrigation system are highlighted; more efficient use of water (reduced loss through evaporation), carefully planned, considered, and guarantees a steady supply of water during the critical germination phase. Larger germination rates, greater quality, higher yields, and fewer pest attacks, it helps with pre-monsoon planting, low investment costs and can be constructed using locally available materials. Besides; demerits may include little training requirements for appropriate methodologies required, clogging may arise if water not well filtered.

2.1.2 Sub-irrigation

Subirrigation is the application of water below the soil's top layer in order to increase the water table in or close to the plant root zone. In watered desert or semi-arid locations where irrigation is frequently required to germinate crops, subirrigation is not frequently practiced [23]. It frequently goes hand in hand with controlled drainage or subsurface drainage. It is best used in areas with high water tables. A system of ditches, gates, canals and pumping stations. It is used to raise the water table and get water distributed across the land. Through hollow tube or open ditches, underground drainage reduces the water table and drains surplus water. Constructing a weir on the sewer system will allow you to control the depth of the water table [10], [23]. The water table is lowered during wet periods to keep the inner core waterlogged. Water is poured into the drainage system during dry spells to raise the water table and supply additional water for growing plants. Drained water may occasionally be kept and used for irrigation.

2.1.3 Lateral move irrigation

A set of sprinklers, wheels and a series of pipes are used for water distribution. The sprinklers are made to rotate with a mechanism built specifically for irrigation or hand-built. The water hose must be reconnected to the sprinkler after it has covered a certain distance on the field. This type requires more labour compare to other irrigation techniques but is less expensive [24]. Rectangular areas can be watered using lateral motion systems. Slope of the land: Center pivots can irrigate land that is highly undulating. To connect depression regions and to provide outflow for overflow after rainstorm events, some moderate earthmoving may be required. There are numerous sprinklers and nozzles on the market. More than 70% of irrigation performance is provided by sprinklers, which account for less than 7% of the entire expenditure. The easiest and least expensive sprinklers are fixed plate sprinklers. They are appropriate for pastures because of their low throw and average application rates that aren't too high as long as sprinkler spacing along the span-pipe is sufficient. Moving plate sprinklers have longer throws, more consistent droplet size, and improved uniformity of dispersion [24].

2.1.4 Center pivot irrigation

This system uses sprinklers that move in circular patterns on wheeled towers to achieve the distribution of water on the farm. The center pivot is the preferred irrigation system for farming due to its low labour and maintenance needs, ease, performance, and simplicity of usage. In this work, a comprehensive information on selecting a center pivot design, comparing prices, evaluating the efficacy of various water applicators, managing pivots, and using center pivot systems are not considered since intelligence and IOT is the focus. This system is best used in flat surfaced topographies. Understanding how much water is applied in inches is the key to effective management of the pivot. Total inches applied for various speed settings on the central control panel in the system is very important to track during their design. The center pivot system components include; Irrigation management on crop water requirement, grazing management – in the case of cattle grazing, the sprinklers must be positioned above the reach of the cattle to ensure there is no interference.

2.1.5 Sprinkler irrigation

Using a pump, a sprinkler irrigation system enables the delivery of water at high pressure. Through a small diameter nozzle installed in the pipes, it releases water that is comparable to rainfall. Due to the wide range of discharge capacities, water is disseminated through a network of pipes, sprayed into the air, and irrigates most soil types. In this system, high-pressure sprinklers that are mounted on moving platforms or at a central place on the farm are used to distribute the water [25]. This irrigation system consists of pumping station or Header Assembly, fertilizer tank, filtration system, pressure gauges, control valves, pump connector, sprinkler Nozzles and service saddle [26]. Wind and water pressure both have an impact on sprinkler applications' uniformity. Even a light breeze can significantly affect uniformity since sprinkler spray is readily blown around. Sprinklers can be placed closer together to lessen wind's effects. Sprinklers will only function properly when they are operated at the manufacturer's specified operating pressure. The distribution will be impacted by pressure readings that are either above or below the pressure readings. The most typical issue occurs when the pressure is too low. Pumps and pipes begin to wear out, causing distortion. As friction rises, pressure at the sprinkler decreases. As a result, the water jet does not disperse, and all of the water instead tends to fall in one spot outside of the wetted circle. A poor distribution will result from excessive pressure. As a result, a little spray forms and drifts toward the sprinkler. Advantages include absence of water conveyance, therefore reducing the passage loss [27]. It is usable in all kinds of soils excluding heavy clays and topographies, when you have very high plant population; sprinkler irrigation is the best to use. This irrigation method boost yield, lessen soil compaction, it is easy to operation due to its mobility and reduce labour cost.

2.1.5 Drip irrigation

One of the best method of delivering nutritious water to crops is drip irrigation [28]. The exact amount of water nutrients required by each plant is received per-time. This will facilitate optimum growth as it is delivered directly into the root zone of the plant. It enables farmers to increase yields while using less water, fertilizer, and energy. Runoff and evaporation are highly reduced in this type of irrigation system since drops of water are released at or near the root of plants. The micro-irrigation system is otherwise known as drip irrigation, this occurs by allowing water to flow into the roots of the plant above the surface of the soil or below the soil surfaces, potentially conserving water and nutrients. Water is applied into the root zone of the crop directly to enhance evaporation reduction [28]. Drip irrigation distributes water with the use of pipes, valves and emitters. It is more effective than other kinds of irrigation systems depending on the maintenance, installation and operation.

2.1.6 Localized Irrigation

This is a system where a tiny discharge is used for the application of water to each plant or the area around the plant while being distributed under low pressure through a network of pipes in a predetermined pattern. It uses 'driplines,' which are made up of tiny components called 'drippers,' water and nutrients are distributed across the field. Water and fertilizer are evenly applied to each plant's root zone over the entire field by the drops that each dripper releases, which are both water and fertilizer [29]. It is a low-cost irrigation system, however with some distinct demerits that affects its applications in wide range of usage. It has a plastic casing which requires perforation [28], [30]. The method has recorded success in some countries and found effective in the enhancement of crop growth and survival.

2.1.7 Surface Irrigation

This irrigation system is distinct compared to others due to the absence of mechanical pump. Gravity distributes water across the soil. Water application and distribution over the surface of the soil is solely by gravity. This is more or less the most common in major parts of the world and has remained unbothered from time memorial. It is often called flood irrigation. The distribution of water is not controlled and some argued its inefficiency, it requires a management at a substantial level. This kind of irrigation can be grouped into three categories namely; furrow, border strip and level basin irrigation.

Having investigated several traditional irrigation systems; the selection of irrigation system is a tedious task as the variation involved with the stakeholders are enormous. It depends on the soil, conditions of the climate, types of crops, knowledge and awareness of farmers, preferences of cost, availability of resources among others. Hence, we it is difficult to recommend a one system fits all situation. Application of technology and making it smart is definitely the way to improve this system and making the entire process smart. Better choices include micro-irrigation and sprinklers compared to irrigation on the surface and sandy soils. It is better to use surface irrigation in sandy and windy areas. The depth of surface irrigation is little and not realistic for surface crops. These are considerations of the proposed framework in this work for the enhancement of the entire irrigation system. The following section will consider some related works.

2.2 Related Work and Investigative Analysis

Several irrigations systems ranging from manual, smart and intelligent types of irrigation systems have been reviewed. From the basic ones to highly sophisticated and technologically advanced types. [31] worked on an automatic irrigation system that uses a dripping system. In their effort, water flows through the lateral lines and ends up at the mechanical device heads or at the irrigation electrode (drip) when a zone comes on. There are pipe thread inlets on the lower part of many sprinklers that allow pipe or a fitting to be connected to them. It is on top of the ground surface and head flush that the sprinklers are mainly used. With technology inclination in their work, yields are increased, labour costs are reduced and water losses are also reduced by the dripping method, it became widely used by farmers. Information is displayed to the farmer after the data have been acquired and processed by the system. The analogue signals from the sensor are converted to digital form by the analogue-to-digital converter (ADC) of the microcontroller. The status of the pump (ON or OFF) is displayed on the Liquid Crystal Display (LCD) and serial monitor for the user to view.

The authors in [23-24] presented an automatic irrigation system that monitors and controls the watering of soil based on temperature. The system utilizes smart sensors to measure the temperature of the soil and adjusts the irrigation schedule accordingly. This approach has the potential to conserve water and improve crop yields by ensuring that plants receive the optimal amount of water for their growth stage. Although no record of implementation was found, the system analysis provided a good result of the system presented. [34] conducted a review of the current trends in sensors and Internet of Things (IoT) systems for irrigation in precision agriculture. They identified the most commonly monitored parameters for irrigation systems, including water quantity and quality, soil characteristics, and weather conditions. The authors also discussed the most commonly used nodes and wireless technologies for implementing IoT and Wireless Sensor Networks (WSN) systems for irrigation. The work concluded that water management is crucial in areas with water scarcity and that advances in IoT and WSN technologies can be utilized in the development of affordable sensor-based irrigation systems. The authors proposed a 4-layer architecture for the management of crop irrigation and plan to further develop a smart irrigation system that evaluates water quality prior to irrigation based on this architecture.

Ragab, [35] developed an innovative IOT application together with a center pivot. The center pivot used is a mechanized irrigation system, it provides water for crops in a circular method around a center pivot. The technology deployed by [35] gives room for automating labour efforts, water management, rationalization of cost involved among others. The output of their system assists stakeholders in making informed decisions arriving from precise and real-time information received. Their system is easy to use but depends on too wide range of parameters as observed during review. The study proposed by [36], [37] addressed the need for labour-saving and water-saving technology in irrigation, a wireless solution for an intelligent field irrigation system. The system, was designed specifically for Jew's-ear planting, utilizes ZigBee technology and features a wireless design for easy installation and maintenance. The hardware architecture and software algorithms for the wireless sensor/actuator nodes and portable controller were described in detail. The system was evaluated for performance and was found to have high reliability and practicability after running smoothly for an extended period in the field. This study presents a methodology for establishing a large-scale remote intelligent irrigation system using wireless sensor network technology.

In the works of [38-39] developed an IoT-based smart irrigation management system that utilizes machine learning and open-source technologies to predict irrigation requirements for a field. This system is relevant to intelligent irrigation systems as it uses sensors to collect data on various factors that can impact irrigation needs, such as soil moisture, soil temperature, and weather conditions. By using this data to make predictions, the system can help optimize irrigation and improve water resource utilization. The study demonstrated the functionalities of an IoT-Based Smart Irrigation Management System. It is relevant to wide range of research on intelligent irrigation systems and the potential of various irrigation systems to for using IoT technologies and machine learning. This if implemented will improve irrigation efficiency. The use of weather forecast data in the system is noteworthy, as it shows the potential for incorporating real-time data into irrigation decision-making. The principles and methods used in this study can potentially be incorporated into research on intelligent irrigation systems.

In [40-42], a Low-Power Automatic Irrigation System was designed. It utilizes a wireless sensor network (WSN) for the collection of data from various sensors on the farm, such as soil moisture, humidity, and temperature. The system also includes a microcontroller to process the sensor data and determine the appropriate time to supply water to the crops. This system operates on low power and has a long range, making it an efficient and cost-effective option for automating irrigation.

It is important to note that; having investigated and analyzed various approaches to the development of intelligent irrigation systems, including the use of dripping systems, temperature-based control, wireless sensor networks, and the IoT. It has been observed that there is a wide range of effort that can still make this experience better for stakeholders practicing irrigation farming and other stakeholders using water to facilitate farming efficiency, crop security and water conservation.

3. PROPOSED METHOD

The method to be used for this framework, the schematics, block diagram, flow chart, and other relevant information are discussed in this section. Figure 3.1, is the block diagram consisting of the power supply unit, sensor unit, control unit, display and a switching unit.

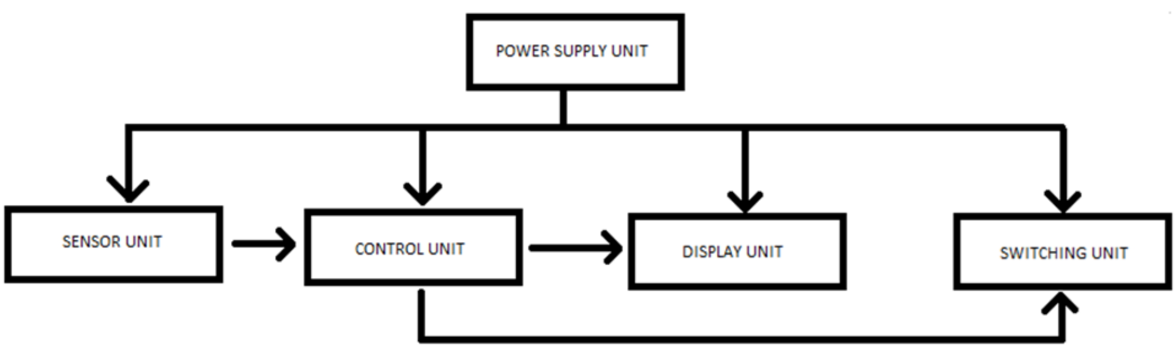

Figure 3.1: Functional block diagram of the proposed intelligent irrigation system framework

The corresponding circuit implementation for this proposed framework is designed using proteus. An ATmega328p Arduino microcontroller compactible with a micro-SIM is used for the design which is powered from the power supply unit, a water sensor compactible with a changing weather is considered for the implementation of this design other implemented components are the switching and display components as shown in Figure 3.2.

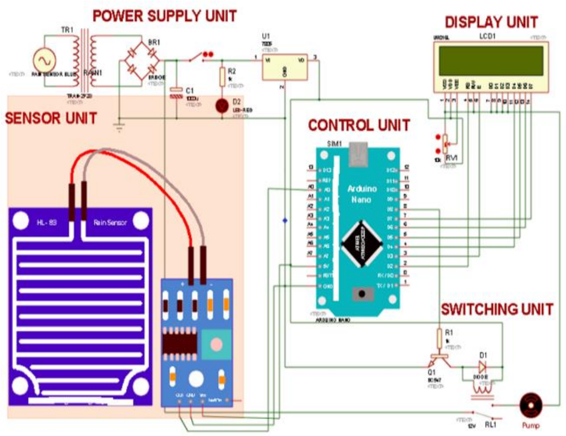

Figure 3.2: Circuit Diagram of an Intelligent Irrigation System

4. Discussion of Implementation Components

The implementation of an intelligent irrigation system ensuring effective crop growth and food security involves the use of several components and sensors. With regards to the sensitivity of its functions during scarce rainfall or no rainfall at all, this work considers the following components as the major aspect of the design. The power supply, switching unit, display and sensor units, bridge rectifier, electrolytic capacitor, relay, diodes and transistors as shown in figure 4.1.

Figure 4.1**:** Components of the proposed Intelligent Irrigation System

A 220-12v step-down transformer, bridge rectifier, 1000uF electrolytic capacitor, switch, 1k resistor, red LED, and 7805 voltage regulators are included in the *Power Supply Unit.* The step-down transformer takes in 220Vac from its primary winding and steps it down to 12Vac. The *bridge rectifier* converts the transformer's 12Vac alternating current (AC) output to direct current (DC). The dc output is then used to power the 12v water pump. The 1000uf *electrolytic capacitor* filters off ripples from the supply in order to smooth it. The *switch* is used to turn the device ON/OFF to save electrical energy or in times of maintenance. The red *light-emitting diode (LED)*is a power indicator. It shows when the device is ON/OFF. The 1-*kiloohm resistor* limits the amount of current that flows through the LED; thereby, protecting it. The 7805-voltage *regulator* produces a regulated 5Vdc from the rectifier's output. The 5v is used to power components like LCD, Arduino Nano and water sensors.

This Sensor unit is one of the major units in the proposed design, the device is highly compactible with water. The sensor, when stuck into the soil, measures soil moisture level using its revealed parallel wires. It is cost-effective and easy to use. Its output analogue signals can be directly measured from Arduino's analogue-to-digital converter. The specification of the sensor recommended for the implementation of the proposed framework include; weight: 3.5g, Size: 62*20*8mm, detection area: 40mm*16mm, voltage: DC3-5V, current: < 20mA, type: Analog/Simulation, operating temperature: 10~30 Celsius and humidity: 10%-90% with no condensation.

The control unit is made up of an *Arduino Nano* board which has an ATmega328p microcontroller mounted on it. It is programmed with C++ programming language in Arduino Integrated Development Environment (IDE). The microcontroller has openings for mounting male headers, a reset button, a resonator that is mounted on board, six analogue pins, six pulse width modulation (PWM) pins and 14 digital input/output pins. To give USB power and communication to the board, the six-pin header can be connected to a Future Technology Device International (FTDI) cable or Sparkfun breakout board. It is for partly permanent installations for exhibitions and objects that the board was designed for. This permits direct soldering of wires and the use of many kinds of connectors since it comes with headers that are not yet mounted. Arduino Nano is compatible with its pin layout. Some Arduino Nano boards run on 16 MHz 5v, while some run on 8 MHz 3.3v. The Arduino Nano board considered is SparkFun Electronics manufactured. A 16 x 2 Liquid Crystal Display makes up the *display unit*. It can fit 32 alphanumeric characters at once because it has 16 columns and 2 rows. The screen displays information about the system; such as soil moisture level, the state of the pump, and other vital information. It makes the system user-friendly and interactive. To control the entire functionality of the system is a *switching unit* made up of a 5v 10A relay, IN4007 diode, BC547 NPN Bipolar Junction Transistor (BJT) and a 1-kilo ohm resistor. The relay is a mechanical electromagnetic switch which is used in this project to turn the water pump ON/OFF.

Across the coil terminals of the relay is connected an *IN4007 freewheeling diode*. This diode offers protection against transient voltage. This is the enormous voltage stored within the magnetic field of the relay coil after it is energized. The diode offers the stored energy a discharge path to the ground; if left unattended to, the circuit components could get damaged by the transient voltage. A BC547 *transistor* assists to drive the relay by amplifying the power supplied to it. On its base is connected a *1-kilo ohm resistor* that limit the amount of current flowing through the transistor, thereby protecting it from damage. The proposed framework cannot be implemented without a few software requirements consideration which is used to programme the Arduino Nano board. The primary software is a *C++ programming language* Integrated Development Board (IDE). The complete flow of the proposed system is shown in Figure 4.2. Software implementation of the system and the algorithm is presented through the system flow.

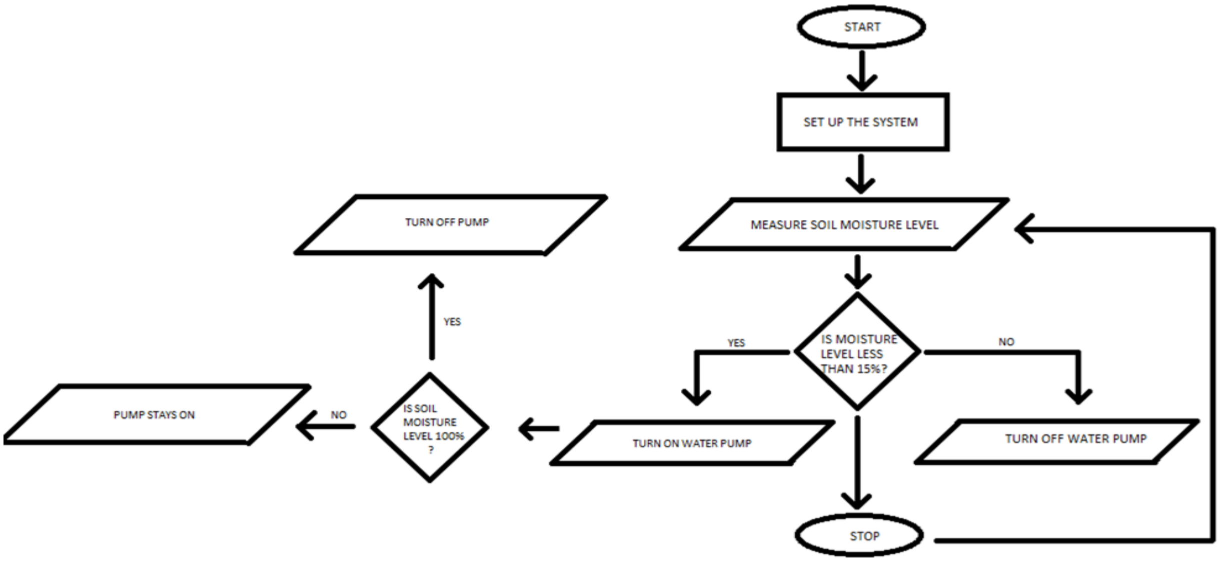

Figure 4.2: Implementation System Flow

The inclusion of additional components was carefully considered to optimize the performance and efficiency of the system. In the flow diagram, it can be deduced that the algorithm constantly gets soil moisture level readings from the water sensor; checks if the value is less than 15%. If the level is less than 15%, turn on the water pump and sprinkle water on the farm. While the water pump is ON, it keeps checking when the level gets to 100%, at which point the soil is sufficiently irrigated. It then turns OFF the pump to avoid water logging the soil. If the soil moisture level is not less than 15%, the water pump stays off. Figure 5 serves as a visual representation of the steps and processes involved in the system's operation, providing a clear and concise overview of the logic behind its functionality required for the implementation of this framework.

5. Conclusion

The place of irrigation in the general growth of plants in areas or seasons of scarce rainfall to enable plants absorb mineral nutrients from the soil cannot be overstressed. Investigation revealed that previous methods carried out are limited to specific irrigation methods. The novelty of the proposed framework is in the generic nature and the suitability in topographies of scarce water resources especially northern areas of the globe. A comprehensive investigation of irrigation system within the content of intelligent farming and Internet of things driven solution to rain scarcity in crop production is carried out in this work. Similar literatures were reviewed and a solid, efficient and precision driven framework is designed and proposed for future implementation of the intelligent irrigation system, including both hardware and software components. The proposed system is capable of measuring and monitoring the moisture level of the soil, turning on the water sprinkler when the moisture level goes below a predefined threshold and turning it off when the moisture level goes above the threshold to avoid water logging. The output of this work when implemented can served both domestic and commercial purpose. This system will contribute to knowledge by allowing stakeholders experience a great increase in income and production of secured food through irrigation. It will further reduce poverty and promotes economic growth.

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References

1. Nicholson CF, Stephens EC, Kopainsky B, Jones AD, Parsons D, Garrett J. Food security outcomes in agricultural systems models: Current status and recommended improvements. *Agriculturaol System*. 2021; 188: 103028.
2. CDC. Irrigation vs. Rain-Fed Agriculture. 2016. [Online]. Available from: https://www.cdc.gov/healthywater/other/agricultural/types.html
3. Veisi H, Deihimfard R, Shahmohammadi A, Hydarzadeh Y. Application of the analytic hierarchy process (AHP) in a multi-criteria selection of agricultural irrigation systems. *Agric. Water Manag.* 2022; 267: 107619.
4. Rohith M, Sainivedhana R, Fatima NS. IoT enabled smart farming and irrigation system. In: *2021 5th International Conference on Intelligent Computing and Control Systems (ICICCS)*, 2021. 434–439.
5. Ojha M, Mohite S, Kathole S, Tarware D. Microcontroller based automatic plant watering system. *International Journal of Computer Sciences & Engineering.* 2016; 5(3): 25–36.
6. Oki L, Fujino D, Faber B, Counties SB. Keeping plants alive under drought or water restrictions. 2015.
7. Adebisi KA, Abdulsalam JA. IoT smart home: implementation of a real-time energy monitoring pressing iron. In: *International Conference on Innovative Systems for Digital Economy| ISDE*, 2021. p. 7–18.
8. Cooper PJM, Dimes J, Rao KPC, Shapiro B, Shiferaw B, Twomlow S. Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change. *Agriculture, Ecosystem & Environment.* 2008; 126 (1–2): 24–35.
9. Adebisi AJ, Damilola BE, Olubayo BM. A multicriteria framework for selecting information communication technology alternatives for climate change adaptation. *Cogent Eng.* 2022; 9(1): 2119537.
10. Obaideen K *et al.*, “An overview of smart irrigation systems using IoT,” *Energy Nexus*, p. 100124, 2022.
11. Akinyemi JO, Souley SO. Monitoring the quality of some sources of irrigation water in different parts of Ogun State, Nigeria. *IERI Procedia*. 2014; 9: 123–128.
12. Paudel KP, Pandit M, Hinson R. Irrigation water sources and irrigation application methods used by US plant nursery producers. *Water Resour. Res.* 2016; 52(2): 698–712.
13. Adebisi J, Abdulsalam K, Leokadia NP. Combating consumer food waste--an exploration of information communication technology approach. *J. Digit. Food, Energy \& Water Syst.* 2023; 4(1):
14. Lemon ER. The potentialities for decreasing soil moisture evaporation loss. *Soil Sci. Soc. Am. J.* 1956; 20(1): 120–125.
15. Malhi SS, McGill WB, Nyborg M. Nitrate losses in soils: effect of temperature, moisture and substrate concentration. *Soil Biol. Biochem.* 1990; 22(6): 733–737.
16. Willis WO, Parkinson HL, Carlson CW, Haas HJ. Water table changes and soil moisture loss under frozen conditions. *Soil Sci.* 1964; 98(4): 244–248.
17. Golkarian A, Khosravi K, Panahi M, Clague JJ. Spatial variability of soil water erosion: Comparing empirical and intelligent techniques. *Geosci. Front.* 2023; 14(1): 101456.
18. Fonseca MRS, Uagoda RE, Chaves HM. Runoff, soil loss, and water balance in a restored Karst area of the Brazilian Savanna. *Catena*. 2023; 222: 106878.
19. Adebisi J, Abdulsalam KA, Ndjuluwa LN, Oshin O. Development of an Artificial Intelligence Driven Mobile Application for Medical Diagnosis and Consultancy. *Adeleke Univ. J. Eng. Technol.* 2023; 6(1): 1–9.
20. Adebisi J, Babatunde O. Green information and communication technologies implementation in textile Industry using multicriteria method. *J. Niger. Soc. Phys. Sci.* 2022; 165–173.
21. Singh V, Shukla S, Singh A. The principal factors responsible for biodiversity loss. *Open J. Plant Sci.* 2021; 6(1): 11–14.
22. Tasnim A. Irrigation - 8 Types of Irrigation Methods with Details. 2019. [Online]. Available: https://civiltoday.com/water-resource-engineering/irrigation/269-types-of-irrigation-methods
23. Bjorneberg DL. Irrigation Methods: In *Reference Module in Earth Systems and Environmental Sciences*, Elsevier, 2013. doi: https://doi.org/10.1016/B978-0-12-409548-9.05195-2.
24. Faria LC *et al.*, Irrigation distribution uniformity analysis on a lateral-move irrigation system. *Irrig. Sci.*, vol. 37, no. 2, pp. 195–206, 2019.
25. Yan H, Hui X, Li L, Xu Y. Development in sprinkler irrigation technology in China. *Irrig. Drain.* 2020; 69: 75–87.
26. Pair CH, Hinz WW, Reid C, Frost KR. *Sprinkler irrigation*. Sprinkler Irrigation Assn., 1975.

27. N. C. on P. A. in Horticulture, “Sprinkler Irrigation System,” 2020. [Online]. Available: https://vikaspedia.in/agriculture/agri-inputs/farm-machinary/sprinkler-irrigation-system
28. der Kooij S, Zwarteveen M, Boesveld M, Kuper M. The efficiency of drip irrigation unpacked. *Agric. Water Manag.*, vol. 123, pp. 103–110, 2013.
29. Vermeiren L, Jobling GA. *Localized irrigation: design, installation, operation, evaluation.* 1980.
30. Pais MS, Ferreira JC, Teixeira MB, Yamanaka K, Carrijo KG. Cost optimization of a localized irrigation system using genetic algorithms. In: *Intelligent Data Engineering and Automated Learning--IDEAL 2010: 11th International Conference, 1-3 September, 2010.* Paisley, UK: 2010. p. 29–36.
31. Raj Kumar SM, Mistri. Automatic Irrigation System. *Int. J. Sci. Adv. Res. Technol.* 2018; 4(5):. Available from: https://www.researchgate.net/publication/336495894_Automatic_Irrigation_System
32. Minhas PS, Rane J, Singh NP, Pasala RK, Fand BB, Maurya U. Annual Report 2012-13.” ICAR-NIASM, 2013.
33. Yumang NA, Paglinawan AC, Perez LAA, Fidelino JFF, Santos JB. Soil infiltration rate as a parameter for soil moisture and temperature based Irrigation System. In: *2016 6th IEEE International Conference on Control System, Computing and Engineering (ICCSCE)*, 2016. p. 286–291.
34. Garcia L, Parra L, Jimenez JM, Lloret J, Lorenz P. IoT-based smart irrigation systems: An overview on the recent trends on sensors and IoT systems for irrigation in precision agriculture. *Sensors*. 2020; 20(4):1042.
35. Ragab MA. IoT based smart irrigation system. *Int. J. Ind. Sustain. Dev.* 2022;3(1): 76–86, 2022.
36. Zhou Y, Yang X, Wang L, Ying Y. A wireless design of low-cost irrigation system using ZigBee technology,” in *2009 International Conference on Networks Security, Wireless Communications and Trusted Computing*. 2009; 1:572–575.
37. Paramanik S, Sarker K, Chatterjee D, Goswami SK. Smart grid power quality improvement using modified UPQC. In: *2019 Devices for Integrated Circuit (DevIC)*, 2019. p. 356–360.
38. Goap A, Sharma D, Shukla AK, Krishna CR. An IoT based smart irrigation management system using Machine learning and open source technologies,” *Comput. Electron. Agric.* 2018; 155: 41–49.
39. Campoverde LM, Tropea M, De Rango F. An IoT based smart irrigation management system using reinforcement learning modeled through a markov decision process. In: *2021 IEEE/ACM 25th International Symposium on Distributed Simulation and Real Time Applications (DS-RT)*, 2021. p. 1–4.
40. Raji RA. Effective Wireless Sensor Networks Utilizing Residue Number Systems and Intelligent Multi-Agent Technologies. Kwara State University (Nigeria), 2019.
41. S. Heble, A. Kumar, K. V. V. D. Prasad, S. Samirana, P. Rajalakshmi, and U. B. Desai, “A low power IoT network for smart agriculture,” in *2018 IEEE 4th World Forum on Internet of Things (WF-IoT)*, 2018, pp. 609–614.
42. Kumar S, Raja P, Bhargavi G. A comparative study on modern smart irrigation system and monitoring the field by using IOT. In *2018 International Conference on Computing, Power and Communication Technologies (GUCON)*, 2018, pp. 628–632.