

A Smart Irrigation Water Application System Based on Arduino Platform

Abstract

Water wastage, erosion, and crop water oversaturation has always been a problem associated with irrigation practice in Nigeria. A smart irrigation system based on Arduino platform was developed in this research to address this problem. The objective of the system is to automate water application to crops and at the same time optimize the use of water resources. The system consists of an Arduino module, data logger, LCD display, water pumps, water storage, moisture sensor, USB connector, and battery. A C++ program was written for the Arduino board so sense the moisture content of the soil, determine the wetness status and power the pumps for water application. The results of testing the system shows that the optimal use of irrigation water by the smart irrigation system was 97% more efficient than the traditional system and it can conveniently do irrigation at the rate of 0.063m³/ha. The system is recommended for large scale use especially for dry season farming.

Keywords: Irrigation, Arduino, Water, Automation, Smart System

1. Introduction

The importance of agriculture lies in its capacity to ensure food security and fulfill the nutritional requirements of growing populations. Through the cultivation of crops and the raising of livestock, agricultural practices guarantee a consistent supply of essential sustenance for individuals and communities. Throughout history, the cultivation of staple crops such as grains, vegetables, and fruits, alongside animal husbandry for meat, dairy, and fiber, has been crucial for human survival and well-being (Calicioglu et al., 2019). Crop cultivation typically occurs in regions with sufficient soil water availability. However, in arid areas and during dry seasons, inadequate soil water leads to crop withering. To enable year-round farming and maximize arid land utilization, the development of irrigation systems is essential (Biswas et al., 2023).

Irrigation, involving the artificial application of water to soil, has been adopted to support crop cultivation, landscape maintenance, and soil restoration in regions with arid climates or insufficient rainfall. It enhances the supply of moisture and nutrients to plant roots, lowers surface temperatures, and increases humidity levels (Tyagi, 2020). In the northern regions, rainfall is limited to the period between June and September, ranging from 500 mm to 750 mm. The remaining months experience hot and dry conditions, marked by high annual variation in rainfall that results in floods and droughts (Eruola et al., 2021). Consequently, farmers turn to irrigation to meet the escalating demands for vegetables, fruits, and food crops in response to a rapidly growing population. The northern region of Nigeria plays a pivotal role in food supply and income generation, providing vegetables and fruits like tomatoes, okra, onions, and peppers to the southern part of the country. However, irrigation practices in Nigeria predominantly rely on manual methods such as watering cans, manually operated water channels, and backpack sprinklers, leading to considerable water wastage during irrigation (Bashir and Kyung-Sook, 2018; Animashaun et al., 2020). Automated agricultural irrigation systems hold potential for accurate soil moisture management.

Conventional irrigation techniques, such as overhead sprinklers and flood-based systems, often saturate the lower portions of plants, including leaves and stems. This prolonged wetness creates a conducive environment for fungal infections. In contrast, modern drip or trickle irrigation involves precise and slow water application to specific parts of the plant root zone, preventing soil surface saturation and minimizing moisture stress (Shen et al., 2012). Automation equipment allows farmers to

reduce runoff due to excessive watering and avoid inappropriate irrigation times. This enhances crop performance by ensuring timely provision of water and nutrients (Pujara 2021; Ersin et al., 2016).

Given the challenges posed by climate change and population growth, the integration of electronic technologies into agriculture is essential for increased industry efficiency. Precision agriculture, enabled by electronic automation modules and sensor networks, offers a solution for resource optimization. Among its applications, irrigation systems play a crucial role due to their impact on farming efficiency. Recent advancements in control systems have led to the incorporation of informatics systems, microcontrollers, and new sensor transmission technologies in agriculture. These advancements contribute to more sophisticated and efficient farming practices (Javaid, 2015; Vallejo-Gómez et al., 2023).

The emergence of precision irrigation technology introduces a novel approach to water resource management, tailored to the unique needs of soil and plants. Traditional irrigation methods can lead to water overuse or inadequate supply. To ensure consistent and appropriate hydration, automated plant irrigation systems become imperative to regulate water intake based on optimal soil moisture levels specific to each plant type (Talaviya et al., 2020; El-Naggar et al., 2020). In this study, a smart irrigation system using an Arduino microcontroller was developed, constructed, and evaluated to implement precision agriculture.

2. Materials and Methods

2.1 The System Components

The smart irrigation system consists of the following components:

2.1.1 Arduino module

The Arduino module is a microcontroller that reads the input to the sensor and converts it to output displayed on the LCD. The irrigation system is controlled by the Arduino by turning on or off the water. This is done by sending a set of instructions to the control unit on the Arduino board. The Arduino module is shown in Figure 1.

2.1.2 Arduino LCD Display

The LCD (Liquid Crystal Display) is a type of display that uses the liquid crystals for its operation as shown in Figure 2. The moisture content, temperature and humidity are displayed on the LCD.

2.1.3 The Arduino data logger

The Arduino data logger is connected to the Arduino and it contains an SD card for data storage as shown in Figure 3. The results of the moisture content and time of turning on or off the pump are recorded and stored in the memory card. This can be extracted for further analysis.

2.1.4 Water pump

The water pump is shown in Figure 4 and it is used in this project to pump the water needed for irrigation from the main water tank through pipes.

2.1.5 The Soil Sensor Unit

The Soil Moisture Sensor (Figure 5) is used to measure the volumetric water content of soil. The YL-69 module was used in the design. It uses capacitance to measure the water content of soil (by measuring the dielectric permittivity of the soil, which is a function of the water content. It is simply inserted into the soil to be tested, and the volumetric water content of the soil is displayed in percentage.

2.1.6 Relays

Relays are electrical switches used to establish or break an electrical connection. 12 V relays are used in the automated irrigation system to connect and control the power supply to the irrigation pipeline valves as shown in Figures 5 and 7.

2.1.7 Jumper wires

Jump wire (Figure 6) was used to interconnect the components of the circuit, internally or with other equipment or components, without soldering.

2.1.8 Battery

The system is powered by a 12v lithium battery. The battery supplies power to the Arduino board, the relay and the data logger.



Figure 1: Arduino Module



Figure 2: LCD Display



Figure 3: Data Logger Module



Figure 4: Water Pump

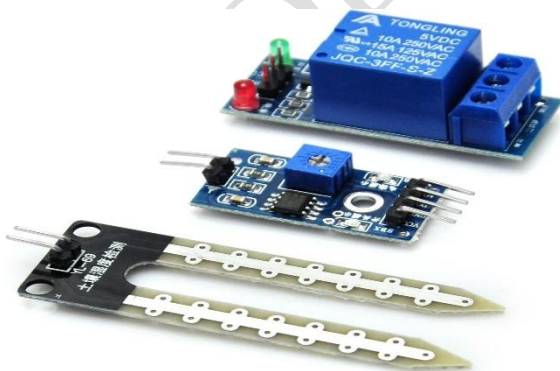


Figure 5: Sensor and Relay Module



Figure 6: Jumper Wires

2.2 Mode of Operation

Fig. 7 shows the electronic circuit and connection of the components of the irrigation system. A program written in C++ was uploaded to a memory card on the Arduino module. The program listing is shown in the appendix. The moisture sensors detect the moisture content of the soil through the soil electrical conductance property and sends signal to the Arduino module in order to take the hydrometric measurement of free-soil wetness. It will also detect the temperature and humidity from the environment and show this information in the Arduino display. When the wetness is below 30%, the Arduino module sends signals to the water pumps to supply water to the plants.

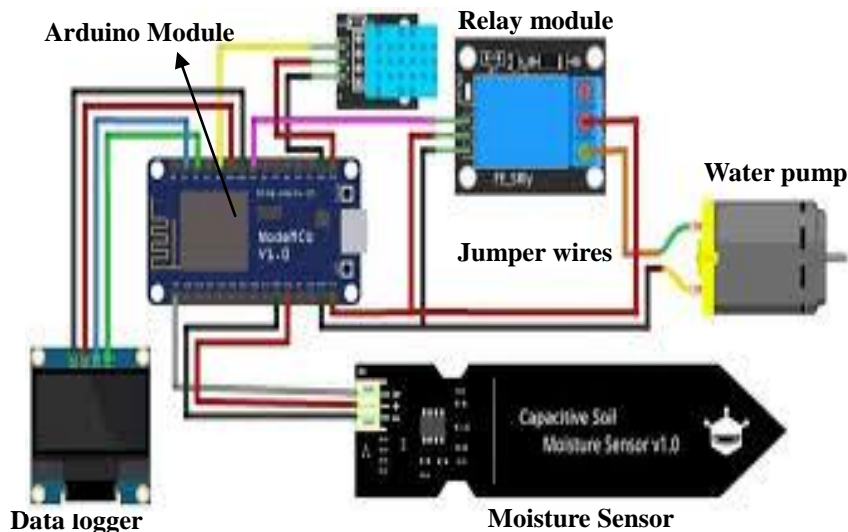


Figure 7: Electronic circuit diagram of the system

2.3 Experimental Setup and Testing

The automated irrigation system is tested by supplying water to four pots with each containing cowpea seedlings as shown in Figures 8 and 9. Each pot has a sensor dipped into the pot and also has a water pump connected to it. The water pumps are connected through pipe networks to a water storage. The water requirements for each of the four pots will vary because the saturated level of each pot is different. When the measurement of the moisture sensor in pot 1 drops below the minimum moisture level of 30% wet basis, it sends a signal to pump 1. This signal causes the power supply to the water pump to be altered, switching on the water pump and allowing water from the water storage to flow pot 1 only. When the measurement of the moisture sensor in pot 1 rises above the maximum moisture level 70% wet basis, it sends a signal to pump1, and triggers it to turn off the pump as well as the display unit for the water pump. This signal causes the power supply to the water pump to be altered, switching off the water pump and preventing water from the water storage to flow pot 1 only. This process is repeated for each of the pots at different intervals depending on the moisture content of the soil in the pots.



Figure 8: Experimental Set



Fig. 9: Testing of the system

3. Results and Discussion

3.1 Results

The results obtained from the test of the irrigation system is shown in Table 1. The moisture content (MC) in the table is the moisture content registered by the sensor after water application. Results were obtained for ten trials and for each trial the water application rate (AR) was calculated.

Table 1. The results obtained from the test of the irrigation system

S/N	Pot 1			Pot 2			Pot 3			Pot 4		
	MC (%)	Time (s)	AR (cm ³ /s)	MC (%)	Time (s)	AR (cm ³ /s)	MC (%)	Time (s)	AR (cm ³ /s)	MC (%)	Time (s)	AR (cm ³ /s)
1	81	2	25.50	85	3	18.33	77	3	15.67	72	4	10.50
2	74	2	22.00	67	3	12.33	90	3	20.00	66	6	6.00
3	82	3	17.33	70	4	10.00	90	3	20.00	68	3	12.67
4	66	4	9.00	74	5	8.80	90	2	30.00	72	3	14.00
5	75	3	15.00	81	2	25.50	85	2	27.50	88	4	14.50
6	69	2	19.50	76	4	11.50	81	4	12.75	69	2	19.50
7	80	3	16.67	72	3	14.00	76	2	23.00	73	2	21.50
8	90	3	20.00	69	4	9.75	81	2	25.50	81	2	25.50
9	90	2	30.00	75	3	15.00	76	3	15.33	66	3	12.00
10	70	2	20.00	85	5	11.00	66	2	18.00	89	3	19.67
Average	77.70	2.60	19.50	75.40	3.60	13.62	81.20	2.60	20.78	74.40	3.20	15.58

3.2 Discussion

It was observed that pot 3 had the highest water application rate of 20.78cm³/s while pot 2 had the lowest value of 13.62cm³/s. The average application rate was 17.37cm³/s. The difference in the

application rate might be due to the difference in the sensitivity of each of the sensors. It was also observed that the pumping of water was not turned off at exactly 70% moisture content programmed into the Arduino. The moisture content detected by the sensors and which was displayed by the LCD varied between 65% and 90%. This might be due to difference in sensitivity of the sensors and the differential flow of water through the soil in the pot. The average water application rate of the system in cubic meter per hectare ($0.063\text{m}^3/\text{ha}$) was 97% more efficient than the traditional application rate of $2.5\text{m}^3/\text{ha}$ for grain crops (Francelino et al., 2018; de Pinho Sousa et al., 2022).

4. Conclusions

A smart irrigation system using an Arduino microcontroller was designed, set up and tested in this study. The system can automate the application of irrigation water with minimal human intervention and also optimize water resource utilization for grain crop irrigation. Experimental results indicate that the system is 97% more efficient than the traditional method of irrigation of grain crops. The system is recommended for large scale irrigation project especially in the areas of limited water availability and during dry seasons.

5. References

- Animashaun, I., Oguntunde, P., Akinwumiju, A., & Olubanjo, O. (2020). Rainfall Analysis over the Niger Central Hydrological Area, Nigeria. Variability, Trend, and Change point detection. *Scientific African*, 8, e00419. <https://doi.org/10.1016/j.sciaf.2020.e00419>
- Bashir, A., & Kyung-Sook, C. (2018). A review of the evaluation of irrigation practice in Nigeria: Past, present and future prospects. *African Journal of Agricultural Research*, 13(40), 2087–2097. <https://doi.org/10.5897/ajar2018.13403>
- Biswas, B., Timsina, J., Mandal, K., & Naorem, A. (2023). Effects of different irrigation methods and mulching on yield, growth and water use efficiency of strawberry. [10.21203/rs.3.rs-2766264/v1](https://doi.org/10.21203/rs.3.rs-2766264/v1).
- Calicioglu, O., Flammini, A., Bracco, S., Bellù, L., & Sims, R. (2019). The Future Challenges of Food and Agriculture: An Integrated Analysis of Trends and Solutions. *Sustainability*, 11(1), 222. <https://doi.org/10.3390/su11010222>
- El-Naggar, A., Hedley, C., Horne, D., Roudier, P., & Clothier, B. (2020). Soil sensing technology improves application of irrigation water. *Agricultural Water Management*, 228, 105901. <https://doi.org/10.1016/j.agwat.2019.105901>
- Ersin, A., Gürbüz, R., & Yakut, A. K. (2016). Application of an Automatic Plant Irrigation System Based Arduino Microcontroller Using Solar Energy. *Solid State Phenomena*, 251, 237–241. <https://doi.org/10.4028/www.scientific.net/ssp.251.237>
- Eruola, A., Makinde, A., Eruola, G., & Ayoola, K. (2021). Assessment of the rainfall exceedance in Nigeria. *Nigerian Journal of Technology*, 40(4), 751–761. <https://doi.org/10.4314/njt.v40i4.22>
- Francelino, F. M. A., Coelho, F. C., Manhães, C. M. C., Oliveira, D. G. D., Neto, L. R., & Silva, M. P. S. D. (2018). The Effect of Different Irrigation Levels in Cowpea Production in the Mid-Northern Region of Tocantins—Brazil. *American Journal of Climate Change*, 07(04), 548–557. <https://doi.org/10.4236/ajcc.2018.74033>
- Javaid, M. S. (2015). Irrigation and Drainage - Sustainable Strategies and Systems. InTech. doi: 10.5772/58498
- Pujara, M. (2021). Solar Powered Smart Irrigation System. *International Journal of Advances in Agricultural Science and Technology*, 8(3), 48–56. <https://doi.org/10.47856/ijaast.2021.v08i3.005>
- Shen, Y., Gao, Y., Lin, J., Ma, J., Wang, Z., & Haapasalo, M. (2012). Methods and models to study irrigation. *Endodontic Topics*, 27(1), 3–34. <https://doi.org/10.1111/etp.12029>
- Sousa, D. P., Nunes, H. G. G. C., Ferreira, D. P., Moura, V. B., de Aviz, W. L. C., Santos, H. C. A., de Nova Pinto, J. V., de Oliveira Vieira, I. C., Fernandes, G. S. T., Silva, E. R. R., Belém, L. T., da Cunha Junior, J. B., de Lima, M. J. A., de Sousa, A. M. L., da Silva Farias, V. D., Santos, J. T. S., & de Souza, P. J. D. O. P. (2022). Performance of Cowpea under Different Water Regimes in Amazonian Conditions. *Horticulturae*, 8(4), 335. <https://doi.org/10.3390/horticulturae8040335>

- Talaviya, T., Shah, D., Patel, N., Yagnik, H., & Shah, M. (2020). Implementation of artificial intelligence in agriculture for optimisation of irrigation and application of pesticides and herbicides. *Artificial Intelligence in Agriculture*, 4, 58–73. <https://doi.org/10.1016/j.aiaa.2020.04.002>
- Tyagi, S., Sharma, B., Singh, P., & Dobhal, R. (2020). Water Quality Assessment in Terms of Water Quality Index. *American Journal of Water Resources*, 1(3), 34–38. <https://doi.org/10.12691/ajwr-1-3-3>
- Vallejo-Gómez D., Osorio M., & Hincapié C. A. (2023). Smart Irrigation Systems in Agriculture: A Systematic Review. *Agronomy*. 2023; 13(2):342. <https://doi.org/10.3390/agronomy13020342>

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