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Using Arduino Based Automatic Irrigation System to Determine Irrigation Time for Different Soil Types in Nigeria

***Okoye F.A.[1], Orji E.Z.[2], Ozor G.O.[3]**

Computer Engineering, Enugu State University of Science and Technology, Enugu, Nigeria[1,2,3]

Abstract: In Nigeria, for crop production to have high quality yields, healthy irrigation water balance is important. Plants that are under-watered experience shortage in crop nutrient and on the other hand, plants that are over watered are defenseless to pest and diseases and few in some cases leads to the death of the plant. Also, plants that are over watered cannot withstand the hash dry season (harmattan) in Nigeria. The goal of this research paper is to use control engineering principle and concepts to provide an automatic irrigation system for clay, loamy and sandy soil which are more common in Nigeria. The automatic irrigation system is controlled using Arduino UNO which is embedded with an ATmega328P micro controller. The Arduino microcontroller is programmed to send an interrupt signal to the irrigation system depending on the moisture level of the soil. The moisture content of the soil is checked using the soil moisture sensor. The moisture sensor sends an interrupt signal to the micro-controller whenever there is a change in the soil moisture and the micro-controller on the other hand checks the water level in the over-head tank water storage using water level sensor, then activating or deactivating the watering system accordingly. The water level and other important data status are displayed on a 16×2 Liquid Crystal Display (LCD). The system was used to compare the irrigation time and sensor reading for clay, loamy, and sandy soil. The result shows that irrigation time is not the same for all three soil types. Clay soil requires more irrigation time than loamy soil, followed my sandy soil which has the least irrigation time. The proposed system helps in improving plant growth, reduce costs, minimize water wastage, reduce lab our, and monitoring overheads.

Keywords: Arduino, automatic irrigation, moisture sensors, soil, automation

1. INTRODUCTION

The growing population of Nigeria demands increase in crop production. In agriculture, irrigation is an essential process that influences crop production. Irrigation of crops is usually a very time consuming activity; to be done in a reasonable amount of time, it requires a large amount of human resources based on the size of the farm. Traditionally, in Nigeria, all these steps are executed by humans [1]. Currently in Nigeria, some systems use technology to reduce the number of workers or the time required to water the plants [1]. With such systems, the control is very limited, and many resources are still wasted.

Generally, in developed countries, farmers visit their agricultural fields periodically and remain present during the irrigation to manually navigate water to the respective fields [2]. This irrigation method takes lot of time and effort particularly when a farmer need to irrigate multiple fields distributed in different geographical areas.

There is need for improvement on the existing or old forms of irrigation. An automated irrigation system needs to be developed to optimize water use for agricultural crops. An intelligent automatic irrigation system has to have all the components that automatically monitor and control the level of water available to the plants with very minimal human intervention. In this paper, an automated irrigation system was developed having a control system which can be powered by a battery to operate the water pump without human intervention. The advancement has even taken place to switch on or off the water pump automatically depending upon the soil moisture level in the respective agricultural fields. The system includes moisture sensor, water level sensor, i2C LCD display, buzzer, LED indicators and Arduino Uno board.

The automatic system should perform the following functions for clay, loamy and sandy soil:

i. Continuously monitor the amount of soil water available to the plant based on the soil type.
ii. Determine if watering is required for the plants.
iii. Monitor also the water level in the over-head tank water storage.
iv. Supply exact amount of water required for the plants.
v. Turn off the water pump when the required amount has been delivered to the plants.

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2. LITERATURE REVIEW

Sandeep Kaur et al [3] proposed an Automatic Irrigation System (AIS) for different crops with Wireless Sensor Network (WSN) deploying sensor nodes in the agricultural field. Sensor nodes sense the soil temperature, sunlight, pH, relative humidity and groundwater parameters and different types of soil and crops at one time. Then sensor nodes send the sensed data to base station, where the data can be analyzed and meaningful data stored in the database and this data help the AIS in decision like: whether a crop requires water or not and the amount of water required by the plant. Although, the proposed AIS will reduce the wastage of water and save crop from unconditional seasons like rainfall condition and over irrigated and less irrigated conditions, but the drawbacks are numerous like if the base station is compromised, the entire system fails and sensor nodes are expensive.

N. Siththtikumar et al [4] prototyped a low cost automated water irrigation system for home gardens using Arduino Uno, LCD, moisture sensors, solenoid valve, flow sensor and pipe lines. Moisture sensor array embedded in garden will sense the water level continuously, When water level goes low, the solenoid valve attached to the pipe line system will automatically open allowing water to flow to the garden via pipe line network. On the other hand, if the water level is sufficient enough the solenoid valve automatically closes restricting water flow to the garden. The LCD display will show the amount of water used in liters by sensing the water flow by the flow sensor also it shows the flow rate and temperature in the garden. The system is low cost and efficient for small garden but it needs improvement in other to act base on the soil type.

3. METHODOLOGY

Our proposed system was designed in such a way that it constantly monitors the soil moisture level. The system responds accordingly when the moisture level is low by watering the soil with the exact amount of water needed if enough water is available in the over-head water tank and then turn off the water supply when the required level of soil moisture is attained. The reference level of soil moisture content was made to be adjustable through the program for the three most common soils in Nigeria (sandy soil, loamy soil and clay soil).

3.1. System Block Diagram

Figure 1 is the block diagram of our proposed automatic irrigation system. It comprises of an Arduino UNO microcontroller board, a soil moisture sensor, a water level sensor, an i2C LCD, a buzzer, light emitting diode (LED) indicators, a relay, and a 12V water pump. The Arduino board can be powered using a 5V to 9V DC battery, an AC adaptor or solar panel while a separate 12V battery is needed for the water pump.

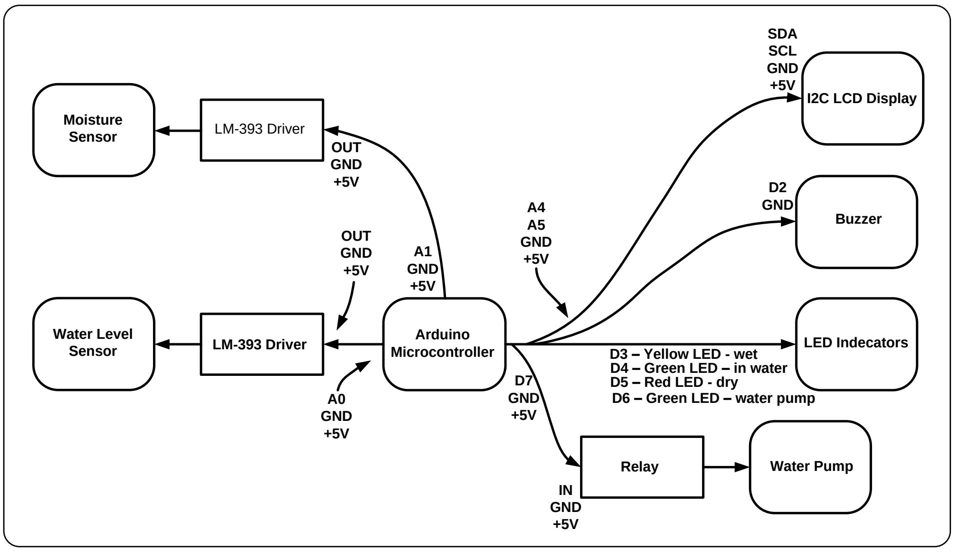

Figure: 1 Block diagram of the proposed system

[5] YL-69 soil moisture sensor was used having probes made from corrosion-resistant material which can be stuck into soil sample [6]. In this project, a 12v water pump was used to supply exact amount of water to the soil samples. The water pump capacity and water channels helped us to compute the volume of water required for irrigation per time. Considering the response time of the water pump and water volume required per irrigation instance the required irrigation time was determined.

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3.2. System Hardware

The automatic irrigation system performs moisture sensing and control activities without the manual observation and attention in the agriculture site. The following are the main hardware components used in the project.

3.2.1 Water pump

A 12 V DC water pump was used in the project and was powered from a 12V DC battery. The pump was able to supply 250cm^3 of water in 10 seconds. The required irrigation time was calculated as follows:

$$P_c = \frac{V_p}{T_v} \quad (3.1)$$

$$T_{irr} = \frac{V_{irr}}{P_c} \quad (3.2)$$

$$V_p = 250 \text{ cm}^3$$

$$V_{irr} = 200 \text{ cm}^3$$

$$P_c = \frac{250}{10} = 25 \text{ cm}^3/\text{s}$$

$$T_{irr} = \frac{200}{25} = 8 \text{ s}$$

Where
P_c = Pumping capacity of the pump
V_p = Volume of water pumped
T_v = Time taken to pump water in seconds
V_{irr} = Volume of water required to irrigate the soil sample
T_{irr} = Required time for irrigation
It is this time T_{irr} in mind that the control subsystem was designed.

3.2.2 Soil moisture sensors

A soil moisture sensor is a device that measures the volumetric water content (VWC) of soil [7]. Water content can be directly measured using a known volume of the soil and a drying oven. The volumetric water content, θ, is calculated [8] via the volume of water V_w and the mass of water m_w.

$$V_w = \frac{m_w}{\rho_w} = \frac{m_{wet} - m_{dry}}{\rho_w} \quad \textbf{(3.3)}$$

Where:
m_{wet} is the mass of the sample before drying in the oven
m_{dry} is the mass of the sample after drying in the oven
ρ_w is the density of water

3.3. System Software

To be able to interpret the different states (level of dryness) of the soil and water level as prompted by the soil sensor and water level sensor respectively, the Arduino microcontroller was programmed using Arduino Integrated Development Environment (IDE).

The informal high-level description of the operating principle of our automatic irrigation system is as follows:

READ sensor value
COMPARE sensor value with set threshold
IF sensor value > maximum set value
IF water tank is empty
TURN-OFF pump
DISPLAY water tank empty on LCD
ELSE
TURN-ON pump
DISPLAY soil condition on LCD
LIGHT dry soil LED
ELSE IF sensor value < maximum set value > minimum set value
TURN-OFF pump
DISPLAY soil condition on LCD
LIGHT moist soil LED
ELSE IF sensor value < minimum set value
TURN-OFF pump

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DISPLAY soil condition on LCD
LIGHT soggy soil LED

Figure 2: System Pseudo-code

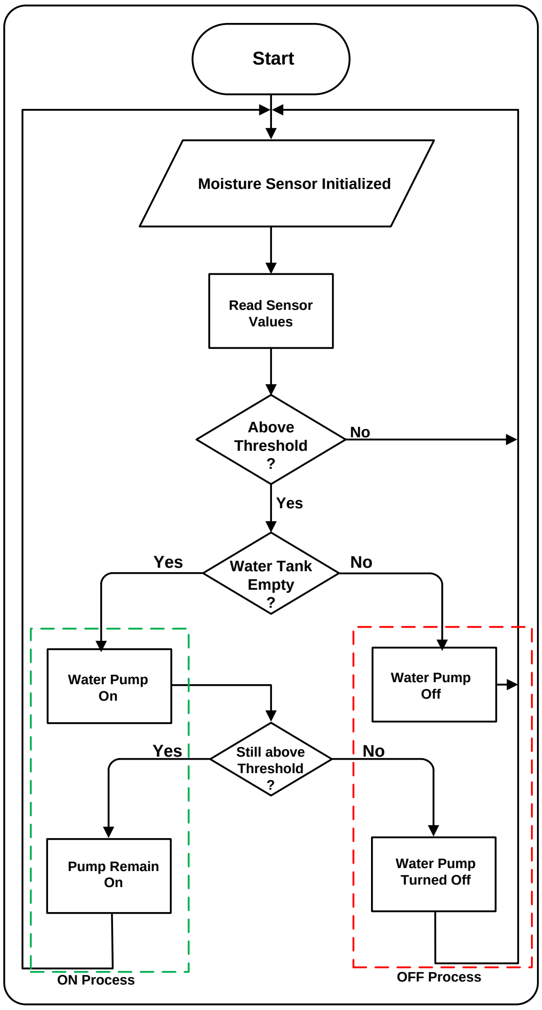

Figure 3: System flow diagram

Flow diagram of our proposed system is shown in figure 3, after the moisture has been initialized, it checks if the moisture value is above the set threshold, if so it checks the availability of water in the water tank. The tank is manually filled in event of empty tank and the water pump in off state to prevent pump damage. If enough water if found in the tank the system automatically on the water pump and continuously checks the moisture value on the soil sample. The water pump is turn off when the moisture value drop below the set threshold.

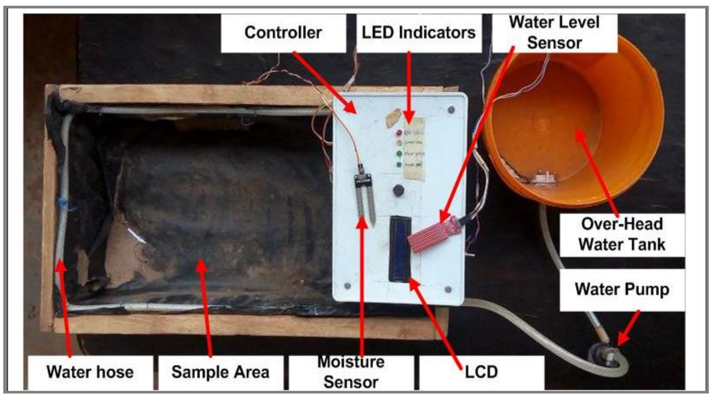

Figure 4: Automating Irrigation System in Nigeria for Clay, Loamy, And Sandy Soil

The working principle of our automatic irrigation system for three common soils in Nigeria as shown in figure 4 is: With the system all powered up, soil sample is placed in the sample area and the moisture sensor is then placed in the

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soil to determine the moisture content of the sample. If the moisture is low, the system with the aid of water level sensor placed in the over-head tank checks if there is enough water to irrigate the sample. If enough water is found, the water pump is on to irrigate the sample through the hose until the moisture level is <700VWC or >=300VWC and it then turn off the water pump. All readings are displayed by the LCD and the moisture states (soggy, moist and dry) of the soil sample is indicated the LEDs.

4. RESULTS

The system prototype was tested using three different soil types (clay, loamy, and sandy) and each soil type has five samples at various degree of dryness in percentage (100, 75, 50, 25, and 0) see table 1. The soil (clay, loamy, and sandy) was measured in equal amount of 300gramms with 100% dryness to form one sample and water was added in steps to form the remaining four samples. The sample box was divided into three to contain 300gramms of soil. The moisture sensor probe whose length in 4inches is placed in the soil sample and information such as irrigation time(s) and moisture sensor reading (VMC) of the system was taken and recorded as shown in table 1.

Table 1: System recorded information

Soil Type	Soil Sample	Soil Dryness (%)	Irrigation Time (s)	Sensor Reading (VWC)
Clay	C1	100	18.0	1020
	C2	75	11.5	714
	C3	50	5.5	563
	C4	25	3.9	297
	C5	0	1.8	271
Loamy	L1	100	15.0	1021
	L2	75	10.5	576
	L3	50	5.0	355
	L4	25	3.2	239
	L5	0	1.6	200
Sandy	S1	100	8.0	1020
	S2	75	5.5	356
	S3	50	4.5	229
	S4	25	2.7	236
	S5	0	1.1	200

Also information such as irrigation time(s) and moisture sensor reading (VMC) from table 1 was used to plot graphs in figure 5 and figure 6 using MATLAB.

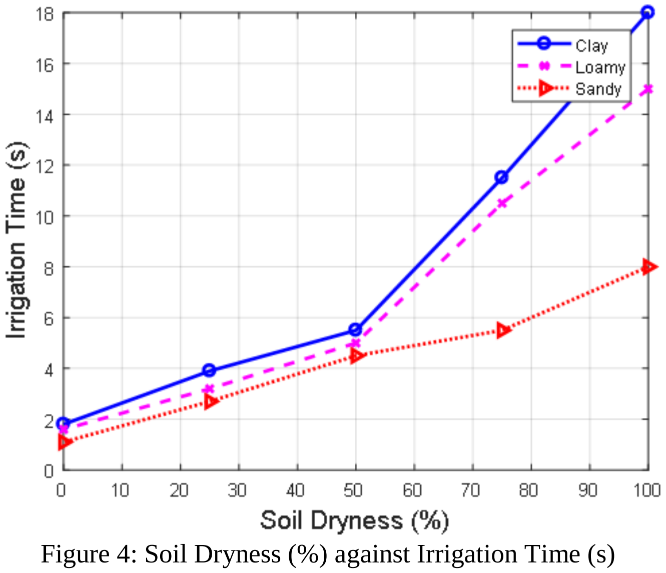

Figure 4: Soil Dryness (%) against Irrigation Time (s)

The graph in figure 5 shows that we have a linear irrigation system with respect to soil dryness of the respective individual soil types (clay, loamy, and sandy). That is, there is a linear relationship between the degree of dryness of the soil and the time taken to irrigate the soil sample. The higher the percentage of soil dryness the longer time it takes to irrigate the soil. It can be deduced from figure 4 that at 25% dryness, it takes 3.9, 3.2, and 2.7 seconds to irrigate clay,

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loamy, and sandy soil respectively. Also, at 75% dryness it takes our system 11.5, 10.5, and 5.5 seconds to irrigate clay, loamy, and sandy soil respectively. It shows that irrigation time is longer in clay soil followed by loamy soil and the least, sandy soil.

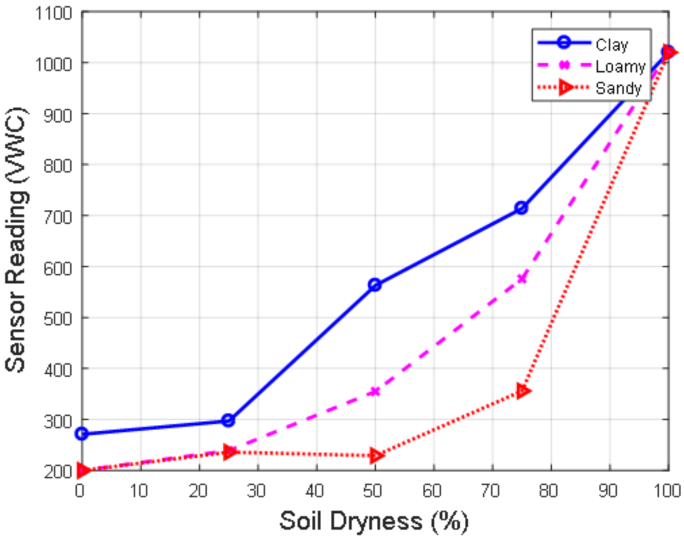

Figure 6: Soil Dryness (%) against Sensor Reading (VWC)

Figure 6 is a plot of soil dryness (%) against sensor reading (VWC) and the sensor reading was obtained from Arduino integrated development environment (IDE) serial monitor. The sensor readings for the three soil samples (clay, loamy, and sandy) are almost the same 1020, 1021, and 1020 (VWC) respectively when they are 100% dried. But at 50% dryness, the sensor reading becomes 563, 355, and 229 (VWC) for clay, loamy, and sandy soil respectively. From this it can be said that the moisture sensor used was able to detect the moisture content of individual soil types at various degree of dryness.

5. CONCLUSION

Automating irrigation system in Nigeria for clay, loamy, and sandy soil was prototyped and presented in this paper. Our system will reduce water wastage and allow crops to survive harsh dry season (harmattan) in Nigeria. It will also help to manage situation like over-irrigated and less- irrigated conditions. The irrigation system can also be adjusted through re-programming the control system to suit a particular soil type because our research shows that irrigation time differ on soil type. The advantages of our automatic irrigation to farmers include saving money, water, conservation of labour and overall convenience.

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