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Research Article

Comparative Study of Moisture Retention Capacity for Sandy, Loamy, And Clay Soil Using Automatic Irrigation System with Moisture Sensor and Message Alert

*Ismail Bello Abubakar[1], Yunusa Rabiu Magaji[2], Abubakar Abdullahi Umar[3], Dauda Yusuf Tofa[4], Bello Muhammad[5]

[1,2,5] Department of Electrical/Electronic Engineering Technology, School of Technology, Kano State Polytechnic, Nigeria.
[3] Department of Computer Engineering Technology, School of Technology, Kano State Polytechnic, Nigeria.
[4] Department of Science Laboratory Technology, School of Technology, Kano State Polytechnic, Nigeria.
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***Corresponding author:** Ismail Bello Abubakar
Department of Electrical/Electronic Engineering Technology, School of Technology, Kano State Polytechnic, Nigeria.

Abstract
Efficient water management is a major challenge in modern agriculture, especially in areas facing water scarcity and varying soil characteristics. This work presents the design and implementation of an automatic irrigation system with a soil moisture sensor and GSM-based message alert, aimed at comparing the water retention capacity of sandy, loamy and clay soils. The system is built using an ARDUINO UNO Micro controller, soil Moisture sensor, water pump, relay module, LCD display, and a SIM800L GSM module to enable real-time monitoring and communication with farmers. Experimental result shows that sandy soil has the lowest water retention, requiring re-irrigation within 3-4 hours, loamy soil retains moisture for about 22-24 hours, while clay soil exhibits the highest retention, lasting up to 48-72 hours and above. The system automatically detects soil moisture levels and alerts the farmer when irrigation is required, allowing timely and efficient water application. The findings is in line with soil water retention properties and demonstrate that the proposed system can help farmers reduce water wastage, improve irrigation efficiency and help to make irrigation decisions. This approach supports sustainable farming practices and enhances agricultural productivity through automation and precision irrigation.

Keywords: *Automation, GSM Module, Irrigation, Moisture sensor, Arduino uno.*

I. INTRODUCTION
One of the key technologies of precision agriculture is the control and accurate measurement of the soil moisture. For decades, the subject of soil moisture has been of great interest in agricultural system. Prior to advancement in agriculture, farmers have picked up and felt a handful of soil to determine the best time to plow his fields and to manually determine the amount of moisture measurement ranges from the method of feeling the soil to the use of complicated electronic equipment using radioactive substances. Such method includes the use of soil moisture sensors, sprinklers, drip lines, and micro controllers (such as Arduino or other Smart devices). The system will monitor soil moisture, weather conditions, and water levels, and then activate pumps or valves automatically [1].

Since the inception of precision agriculture, soil sensors have been used to measure the soil moisture level. The soil moisture sensors measure the volumetric water content of the soil by using electric resistance, dielectric constant, etc.

the farmer uses the information obtained from the soil moisture sensor to make adequate and accurate decision on how and when to irrigate or plough his farmland, today technological progress in communication, along with the information revolution has reduced the amount of work done by the famer and has since then increase yield [1].

The aims of this paper consist of a brief review of the recent scientific and technological components and sensors in precision agriculture and their application in crop and livestock farming. This review allowed us to realize how precision agriculture has been proven to be a highly researched and constantly evolving area due to the needs of farmers to use resources in a more enhance way.

II. RELATED WORKS

In this respect, a review of previous activities related to automatic irrigation system with water retention capacity of various soil types are going to be presented. At the end of the day, the deficiency of the various methods used are going to be carefully studied so that an improved approach will be applied to further enhanced modern farming systems for better productions.

In this regard, a paper titled "Comparative Study Between Automatic Irrigation System Using Soil Moisture Sensor and Conventional Flooding Method of Irrigation" was presented. In this paper, an automated irrigation mechanism which senses dampness of the moisture content of the soil and turn the pumping system ON or OFF was developed. The project achieved greater success in saving water and hence can be applied in a fully automated gardens and farm lands as well as areas with severe shortage of rainfall [2].

In another development, a paper titled "Comparative Study Between Automatic Irrigation System Using Soil Moisture Sensor and Conventional Flooding Method of Irrigation" was also presented. In this paper, an experiment was conducted to evaluate the change in soil moisture retention and wheat plant response to different irrigation practices (border, furrow, alternative furrow, gated pipe and surface drip) as well as their performances and water productivity at different soil depth. The results obtained indicates that, applying more irrigation water than can be store in top 60 cm of the soil profile will result in inefficient utilization of this water by winter wheat. Gated pipe and drip irrigation practices produce the highest of wheat grain and straw yield [3].

Also, another paper titled, "Microcontroller-based Automatic Irrigation System with Moisture Sensors" was presented. This paper represents the prototype design of microcontroller based automatic irrigation system which will allow irrigation to take place in sections. In this approach, watering is required however, sections of the soil with adequate moisture are bypassed. The work was successfully conducted and the result obtained indicates that, an automatic irrigation system can be implemented at relatively low cost and which is extremely user friendly because it requires only few keys in all to carry out a large number of operations and the operator is, at all times, apprised by the display of just what needs [4].

Moreover, a paper titled "Design and Implementation of an Automatic Irrigation System Based on Monitoring Soil Moisture" was presented. In this paper, the method employed is to continuously monitor the soil moisture level to decide whether irrigation is needed, and how much water is needed in the soil. A pumping mechanism is used to deliver the needed amount of water to the soil. System response tests were carried out to determine the time taken for the system to irrigate potted samples of different soil types having different levels of dryness. The results obtained showed that sandy soils require less water than loamy soils and clay soils require the most water for irrigation. This technique indicates that, Improving Irrigation efficiency can contribute greatly to reducing production costs of agricultural products while reducing the excessive use of water [5].

Indeed, a paper titled "Automation of Irrigation System Using ANN based Controller" was developed. The paper presents Artificial Neural Network (ANN) based intelligent control system for effective irrigation scheduling. The input parameters i.e., air temperature, soil moisture, radiations and humidity are modeled. Then using appropriate method, ecological conditions, evapotranspiration and type of crop, the amount of water needed for irrigation is estimated and then associated results are simulated. The proposed system is compared with ON/OFF controller and it is shown that ON/OFF Controller based System fails miserably because of its limitations. On the other hand, ANN based approach has resulted in possible implementation of better and more efficient control [6].

In a paper titled "Automatic Irrigation System Using Moisture Sensor" in this paper, the sensor sensed the level of the moisture content of the soil and enable the pump to either be switch on or off. If the level of the water content of the soil is low, there will be a higher resistance in the soil which means, the current passing through the so will be less hence, the pump will be switch on. On the other hand, when there is more water, the soil will conduct more electricity which means that there will be less resistance hence, the water pump will be switch off. Hence, an automatic irrigation system was developed which switched on or off depending on the water content of the soil. [7]

In another development, "Automatic Irrigation Scheduling on a Hedgerow Olive Orchard Using an Algorithm of Water Balance Readjusted with Soil Moisture Sensors" was developed. In this article, a remote sensing and soil mapping techniques were employed to establish regulated deficit irrigation (RDI) strategies. The regulated activities were conducted in the span of three years, with previous year deficiencies are taken care in the next coming one successively. The automated irrigation system has proven to be able to adapt to the particular conditions of the place where it is installed as well as the different growth stages of the crop, thus improving the key efficiency parameters in the plant growth economically [8].

Another paper "Automatic Plant Watering System" This system is implemented such that it uses the latest internet of things technology (IoT) which is helpful and leads to easy farming for the farmers. In this case, it will sense the soil moisture content of the plant, and if it is less than the threshold, then it will turn the motor ON automatically. If the soil moisture content of the plant has crossed the threshold, then it will turn the motor OFF automatically. Hence, a Smart Irrigation System was developed which is helpful in the sense that, it gives live readings of moisture content in soil and can then be irrigated automatically or manually. However, at the current state of system, it can only be used in Irrigation of Small Plants not fully grown tree or fully fledged farm. [9]

"Automatic Irrigation System on Sensing Soil Moisture Content" This automated irrigation mechanism turns the pumping motor ON and OFF on detecting the moisture content of the soil. In this system, an Arduino board ATmega328 micro-controller, is programmed to collect the input signal of changeable moisture circumstances of the soil through moisture detecting system. An automatic irrigation system used in soil moisture content was developed which primarily applicable to farmers and gardeners [10].

"Automated Irrigation system using Wireless Sensor Network" This paper presents a smart system which uses a soil moisture sensor that provides a useful information about the soil and transmit this information to centralized server that control water supply. The technique employed 3 sensors i.e., temperature sensor, light sensor and soil moisture sensor that transmit soil data to authorized persons pc using XBEE. Based on its application, this system proves to be useful in optimizing water system for agricultural productions [11].

This paper is aimed at comparing the moisture retention capacity of sandy, loamy and clay soils using automatic irrigation system with moisture sensor and message alert. And this device is expected to be developed and help the farmers to overcome problem that is associated with soil water retention in their farms.

III. DESIGN

The block diagram in figure 1 shows the detailed of the components used in the design procedure.

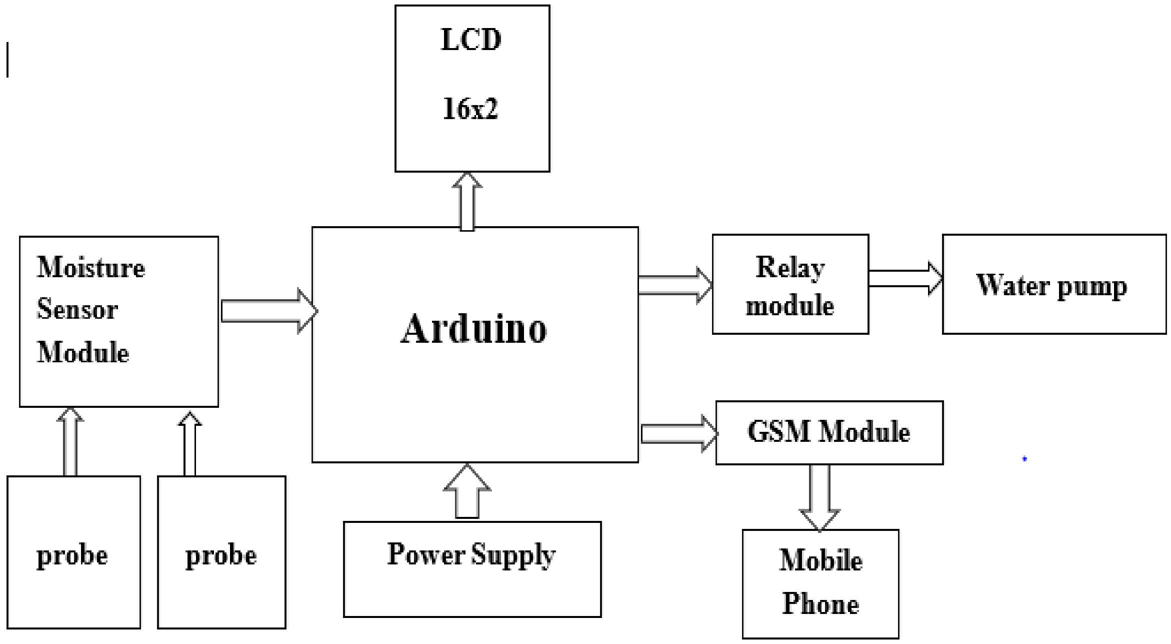

Fig. 1: Block Diagram of an Automatic Irrigation System with Message Alert

3.1 Arduino UNO

The Arduino Uno is an open-source microcontroller board based on the Microchip AT mega 328P microcontroller developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. Arduino Uno is a popular microcontroller development board based on 8-bit ATmega328P microcontroller IC, it consists other components such as crystal oscillator, serial communication and voltage regulator, etc. to support the microcontroller. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter. The Arduino control panel programmed by Arduino c and is based on Arduino, C and C ++

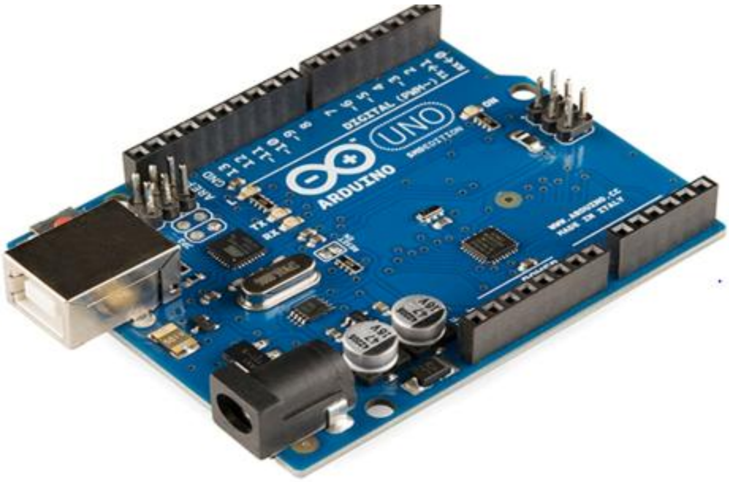

Fig. 2: Arduino Uno Board [12]

3.2 GSM Module (SIM 800L)

Sim 800L is a miniature cellular module which allows for GPRS transmission, sending and receiving SMS and receiving voice calls. From the view of the mobile phone network, they are essentially identical to an ordinary mobile phone, including the need for a SIM to identify themselves to the network. GSM is stand for Digital Cellular Network Communication which means that it provides a platform for mobile device to communicate with each other wirelessly. The GSM module is a specialized device that enables a device to send and receive data over the GSM network.

Fig. 3: GSM Module (SIM 800l) [13]

3.3 LCD Display

An electronic display that consists of segments of liquid crystal whose reflectivity varies according to the voltage apply to them. LCD (liquid crystal display) is the technology used for displaying status and messages. The most basic and commonly used LCD in circuits is the 16x2 display. LCDs are commonly preferred in display because they are cheap, easy to programmed and can display a wide range of characters and animations. LCDs are commonly preferred in display because they are cheap, easy to programmed and can display a wide range of characters and animations. A 16x2 LCD have two display lines each capable of displaying 16 characters. This LCD has Command and Data registers. The command registers store command instructions given to the LCD while the Data register stores the data to be displayed by the LCD.

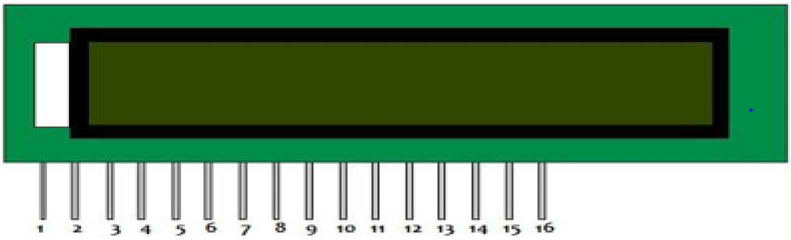

Fig. 4: LCD (16X2) [14]

3.4 Soil Moisture Module

The soil moisture sensor consists of two probes sensor made up of pure nickel. Nickel is used since it has fair conductive properties and also strength to get buried in the soil for long time. It will not get corroded in the soil. The length (L) of nickel probes is 9.5cm and width (W) of each probe is 0.7cm. The distance (d) between the two probes is 0.5cm the tips of sensor probes are designed in the shape of the triangle so that can be easily buried in the soil. The soil moisture sensor is used to measure the volumetric content of water. The two probes allow the current to pass through the soil and then it gets the resistance value to measure the moisture value.

The soil moisture sensor is often sensing devices embedded within some sort of insulation. The insulation may often be for electrical purposes - to isolate the sensor electrically. Soil moisture sensors measure the water content in soil. A soil moisture probe is made up of multiple soil moisture sensors.

Technologies commonly used in soil moisture sensors include:

- Frequency domain sensor such as a capacitance sensor.
- Neutron moisture gauges, utilize the moderator properties of water for neutrons.
- Electrical resistance of the soil.

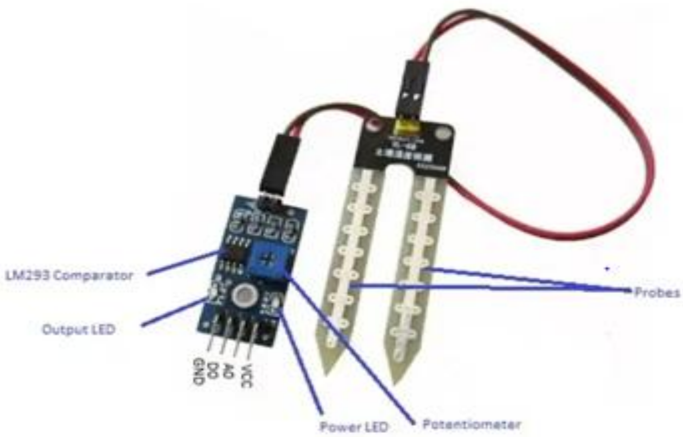

Fig. 5: Soil Moisture Module [15]

3.5 Water pump

A 5v submersible water pump is a device which has a hermetically sealed motor closed-coupled to the pump body. The whole assembly is submerged in the fluid to be pumped. The main advantage of this type of pump is that prevents pump cavitation, a problem associated with a high elevation difference between the pump and the fluid surface. rather than jet pumps, which create a vacuum and rely upon atmospheric pressure.

The water pump has two channels, one channel is connected to the water source and another is used to take the water to the area to be irrigated. The water pump is controlled by motor driver. a device that moves water through pipes by mechanical action. So, it is used to supply the soil with water. Hence, it is connected to Arduino through the relay module. This device operates according to SMS command sent by mobile the home owner to Arduino for irrigation the green area or turn it off to finalize the irrigation process.

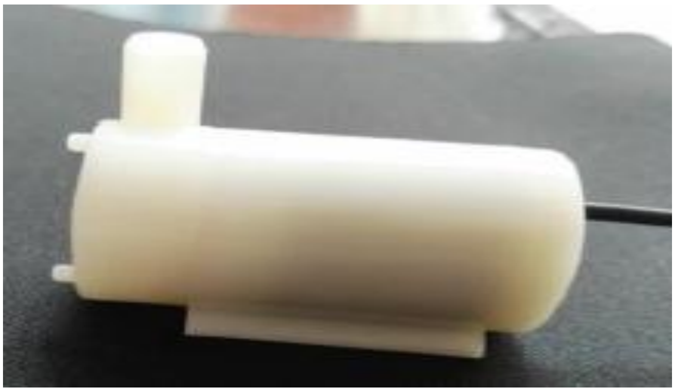

Fig. 6: Water Pump [16]

3.6 Relay module

Relay is an automatic electro-mechanical component that functions as a switch. The relay coil is energized by DC so that contact switches can be opened or closed. A single channel 5V relay module generally includes a coil, and two contacts like normal open (NO) and normal close (NC) and another pin common, GND, 5V VCC.

Fig. 7: Relay module [17]

3.7 Complete Circuit Diagram

Fig. 8 below shows the complete circuit diagram with all the modules connected together of an automatic irrigation system with message alert

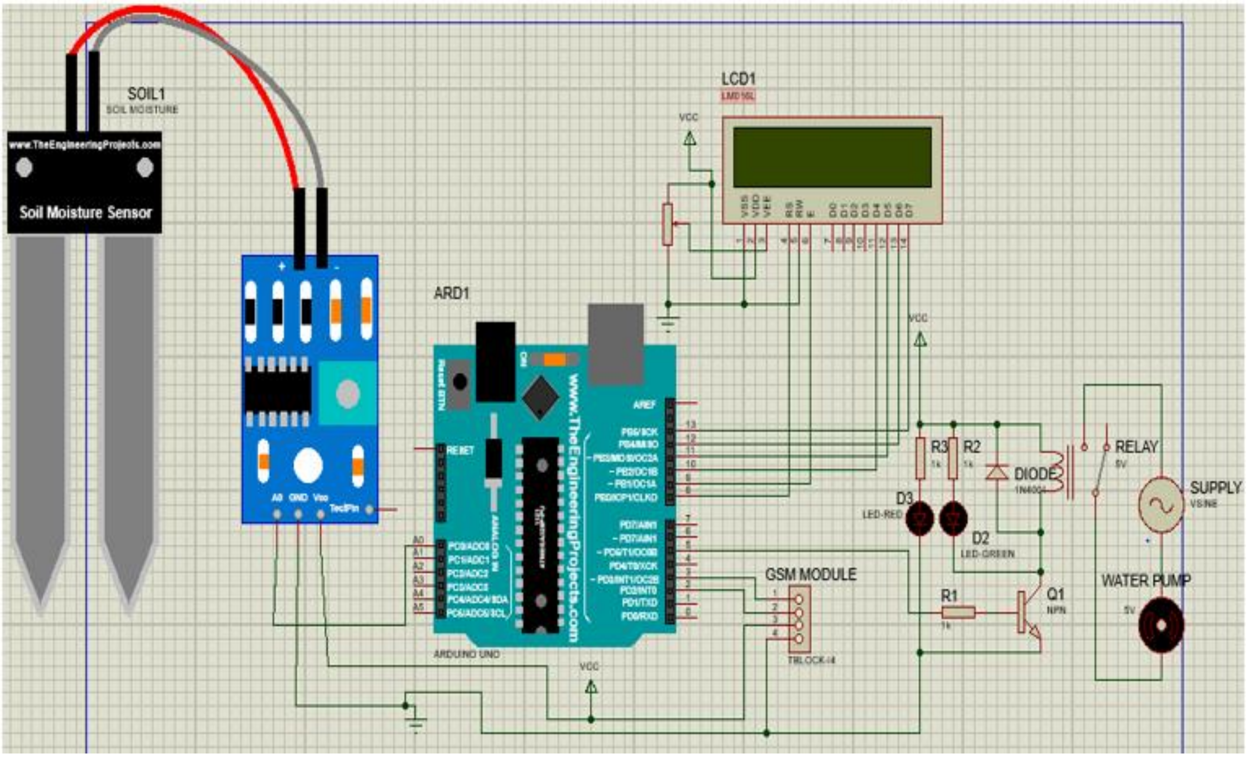

Fig. 8: Circuit Diagram of the System [19]

IV. RESULTS AND DISCUSSIONS

Fig. 9 shows the assembling stage of the components on Vero board that were used during construction of an automatic Irrigation System.

Fig. 9: Construction stage

Likewise, Fig. 10 shows the complete system hardware setup of an automatic irrigation system

Fig. 10: System Hardware Setup

Table 1.0 Soil samples and their water retention capacity

S/NO	SOIL TYPES	Drainage Rate (infiltration)	Time for Received alert from GSM Module to farmer
A	Sandy Soil	Very fast (up to 10 inches per hour)	3 – 4 Hours
B	Loamy Soil	Moderate (0.2 to 0.8 inches per hour)	22 -24 and little above that
C	Clay Soil	Very low (<0.2 inches per hour)	48- 72 hours i.e 2-3 days or more

As seen from the data obtained in the table above, for a sandy soil sample, the water drains within three to four (3 – 4) hours (around 10 inches per every hour) causing the Arduino send a signal to GSM module which generate and send message to the farmer indicating that, the soil is drained and need to be water again. The result support a known fact about Sandy soil which has large particles and large pore spaces, causing water to flow through it quickly, resulting in low water retention.

Similarly, for loamy soil, the water drained within a day (22 -24) hours (around 0.2 - 0.8 inches for every hour) and little above that, within this time, the GSM module generates the message and sent to farmers to indicate that, his farm land needed to be watered. This also is in-line with the known fact that, loamy soil, which contains a mixture of sand, silt and clay has medium pores that hold water more effectively, giving moderate retention. In addition, for a Clay soil the water drained within two to three days during which the GSM module generates and sent a message to the farmers indicating the need for the farm to be watered again. This also prove the known fact that, clay soil has very fine particles and tiny pore spaces, which trap water and slow drainage, producing the highest water retention.

In all the three cases above, the farmer if wish will send back the message to ARDUNO UNO from his phone through a GSM module. The Arduino then trigger the water pump to switch ON and water the farm land adequately. After the farm was adequately water to the level that, the Arduino through the soil moisture sensor sensed the water to be adequate, the process will repeat itself by telling the farmer that, his farm has the enough moisture needed. The farmer then resends the message back to instruct the system to switch OFF the water pump.

V. CONCLUSION

An automatic irrigation system with message alert was designed, developed and tested. Based on the results obtained as indicated in the table I can therefore conclude that, the aim of the project was achieved. This paper is aimed at comparing the moisture retention capacity of sandy, loamy and clay soils using automatic irrigation system with moisture sensor and message alert. And this device is expected to be developed and help the farmers to overcome problem that is associated with soil water retention in their farms.

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