ENHANCING IRRIGATION SYSTEM IN NIGERIA VIA THE APPLICATION OF MICROCONTROLLER

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ABSTRACT

Over the years, irrigation has been used to ensure crop production, especially in Northern Nigeria where rain fall is always very scarce. However, the irrigation methods that have been in existence are manually operated. These include the use of watering cans, backpack sprinklers and water channels that have to be opened and closed manually. In all of these methods, a lot of water is wasted and human energy is highly utilized. In order to overcome the challenges posed by using manual irrigation system, this paper presents an automated irrigation system (microcontroller-based) for the Nigerian agricultural sector. A model for the drip-type irrigation system is presented in this paper. It has among other features; soil moisture sensor (used for determining the moisture level of the soil) and two water tanks (overhead and reservoir) with installed water level sensors. The sensors monitor the water levels in each of the tanks for optimum operation of the system. The system irrigates automatically so as to ensure adequate water supply to the roots of the plants and to avoid water runoff.

Keywords: *Agriculture, Automated Irrigation Mechanism, Microcontroller, Soil Moisture, Wireless Sensor Network,*

INTRODUCTION

Agriculture is concerned primarily, with the husbandry of crops and animals for food and other purposes. It is the basis upon which the development of stable human communities, such as rural and urban communities has depended on in many parts of the world (Malton, 1981; Prathyusha and Chaitanya, 2012). Crop farming is usually carried out in an area that has adequate soil water. In arid areas and during the dry seasons, there is insufficient soil water and crop dies off. For continuous farming throughout the year and utilization of farmland in arid environment, irrigation system was developed (Zella et al, 2006; Abhinav et al, 2011). Irrigation which is an artificial application of water to soil has been used to assist in the growing of agricultural crops, maintenance of landscapes, and re-vegetation of disturbed soils in dry areas and during periods of inadequate rainfall. It improves the supply of plant roots with moisture and nutrients, reduces the temperature of the surface and increases its humidity. In most parts of Northern Nigeria, an average annual rainfall of 780mm is experienced (Mohammed and Abdullahi, 2010). This leads to farmers resorting to irrigation as an alternative means of meeting the increasing demands for vegetables, fruits and food crops for the fast growing population. The northern part supplies vegetables and fruits such as tomatoes, okro, onions and pepper to the southern part for food and as sources of income. The method used for irrigation in Nigeria is based mainly on the use of watering cans and water channels that have to be opened and closed manually or backpack sprinklers. In this case, a lot of water is wasted in the process (Agbetuyi et al, 2017; Raju, 2012; Sowah et al, 2014). One of such methods is shown in Figure 1.

Figure 1: Manual Irrigation method (IFPRI, 2018).

Automated agricultural irrigation is a valuable tool for accurate soil moisture. The conventional irrigation methods like overhead sprinklers and flood type feeding systems usually wet the lower leaves and stems of the plants. The entire soil surface is saturated and often stays wet long after irrigation is completed. Such condition promotes infections by leaf mold fungi. On the contrary, the drip or trickle irrigation is a type of modern irrigation technique that slowly applies small amount of water to the parts of plant root zone. Water is supplied frequently, often daily, to maintain favorable soil moisture condition and prevent moisture stress in the plant with proper use of water resources. Farmers using automation equipment are able to reduce runoff from over watering saturated soils and avoid irrigating at the wrong time of day, which will improve crop performance by ensuring adequate water and nutrients when needed (Nagarajapandian, et al, 2015; Donald et al, 2007; Clark et al, 2013).

RELATED WORKS

Irrigations are of five types namely: sprinkler, drip or trickle, surface, sub and manual. Automatic irrigation carries out the operation of a system without requiring human involvement. The sprinkler, drip and surface irrigation can be automated with the help of detectors (computer, timers, sensors etc.) and electronic appliances. The major types of automatic irrigation systems come under the following categories: automatic irrigation system on sensing soil moisture content, solar powered auto irrigation system, Global System for Mobile communications (GSM) based automatic irrigation system and web based irrigation system (Elprocus, 2018). Parameters such as humidity, temperature, soil moisture, light, water level are considered.

Patidar and Belsare (2015), designed an automatic irrigation system using zigbee and GSM technology for soil moisture, temperature and humidity control. This was necessary to achieve sustainable use of water when the land is dry or when there is lack of rain etc. Sengottuvel and Hameed (2018), considered an automatic irrigation system using arduino for soil moisture and atmospheric temperature control in order to reduce labour and increase productivity.

Wireless sensor network has been considered in automatic irrigation where zigbee, internet of things, short message service (SMS), Arm-7, PIC18F4550, Atmega328 microcontroller, xbee, web platform, Wi-Fi, raspberry pi and MySQL database were used (Sanglikar and Puranik, 2016; Alamgir et al 2016; Balamuragan et al 2017; Kumar et al, 2017). These methods help to make life easier for the farmer by helping to save time and wastage of water. Some of the systems use solar energy or uninterruptible power supply for continuous operation.

Balla et al, 2017 designed and implemented an automatic irrigation system considering soil moisture. Three soil samples were considered in the work. The control circuit was realized using operational amplifier and timer, where the 555 timer was configured in monostable mode. In another study, Oborkhale et al, (2015) used Atmega32 microcontroller programmed using embedded C - language for the control circuit and a buzzer to attract the attention of the farmer.

In this paper, a model, automated irrigation system for Nigerian farmers is designed and developed. Drip irrigation was considered because distribution of water was done under low pressure localization using networks of water pipes in a pre-determined manner, and applied as small discharge to each plant or adjacent to the plant. It has many benefits such as increase yield, saves water, enables application of fertilizers etc. The parameters of interest were soil moisture and water level.

MATERIALS AND METHODOLOGY

The materials used in the design and development of the automated irrigation system are 12V DC water pumps, Soil moisture sensor, Water level sensor, Water tanks, Control circuit, Switching circuit, PIC16F876 Microcontroller and Sample of Farmland. The methodology adapted is in several stages. First, water level sensor unit was designed, followed by soil moisture sensor unit. The sensing units were integrated into a microcontroller and C^{++} programming language was used to implement the operation of each unit of the system. Proteus 8 was used to simulate the designed system, after which a prototype of the system was built. Finally, test was carried out on the system to check its functionality. The building blocks for the automated irrigation system are as presented in Figure 2.

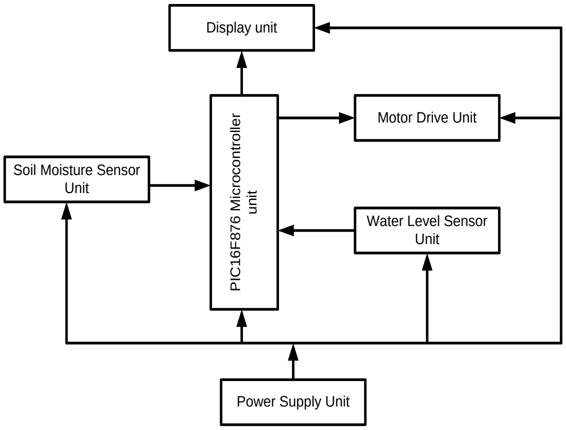


Figure 2: Block diagram of the automated irrigation system

System Analysis and Design

In this section, the design calculation of each unit of the building blocks is presented.

The Power Supply Unit

The power supply unit provides the required DC voltages for the entire system. It consists of the transformer, the rectifier, the filter and the voltage regulators. Figure 3, presents the circuit diagram for the power supply unit.

In this work, a 220/15V step-down transformer was selected. The circuit design is as follows:

The maximum voltage is given in (1); (Theraja and Theraja, 2005). Hence, the maximum primary voltage is calculated as thus:

$$V_{max} = \sqrt{2} \times V_{rms} \quad (1)$$

$$V_{p(max)} = \sqrt{2} \times 220 = 311.13V$$

while the secondary maximum voltage is

$$V_{s(max)} = \sqrt{2} \times 15 = 21.21V \quad (2)$$

The dc output voltage is given by (3):

$$V_{dc} = 0.636 V_{s(max)} \quad (3)$$

$$\therefore V_{dc} = 0.636 \times 21.21 = 13.49V.$$

The bridge rectifier was designed using diode type IN4001, with peak inverse voltage given by (Beaty and Fink, 2012).

$$PIV = V_{s(max)} = 21.21V \quad (4)$$

The filtering capacitance value needed in the power supply depends on the output current (I), ac mains frequency (f) and ripple voltage (Vr) and was determined thus:

$$C = \frac{I}{2 \, X \, f \, X \, V_r} \quad (5)$$

$$V_r = \gamma \times V_{s(max)} \quad (6)$$

where γ is the ripple factor.

For a full wave bridge rectification, using a ripple factor (γ) = 0.44,

$$\therefore V_r = 0.44 \times 21.21 = 9.33V.$$

From the transformer rating, I = 2A, f = 50Hz

$$\therefore C = \frac{2}{2 \, X \, 50 \, X \, 9.33} = 0.002144F = 2144\mu F$$

A standard value of 2200µF was selected and used in the design. Capacitors C_2 and C_3 of values $0.1\mu F$ were chosen based on the manufacturer's datasheet specifications. Fixed voltage regulators from the LM78XX series was used in the design. The LM7805 was used to supply 5V to the water level sensor, soil moisture sensor, microcontroller and the display unit; LM7812 was used to supply 12V to the irrigation and water pumps.

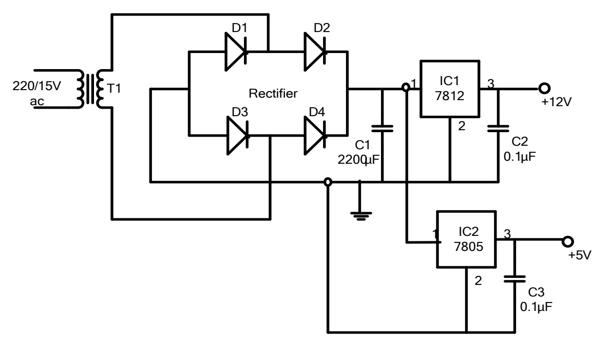


Figure 3: Power supply unit

The Water Level Sensor

This unit is used to monitor the level of water in both the overhead tank (for sprinkling) and the reservoir in order to ensure continuous operation of the system. It uses +5V supplied from the power supply unit and monitors two levels (i.e. High and Low) of water in the overhead (sprinkler) tank, while the third sensor probe is connected to the reservoir. Signal from each of the level monitors is sent to the microcontroller for processing. Figure

4, shows the circuit diagram for the water sensor level, where P_1, P_2 and P_3 are the sensor probes.

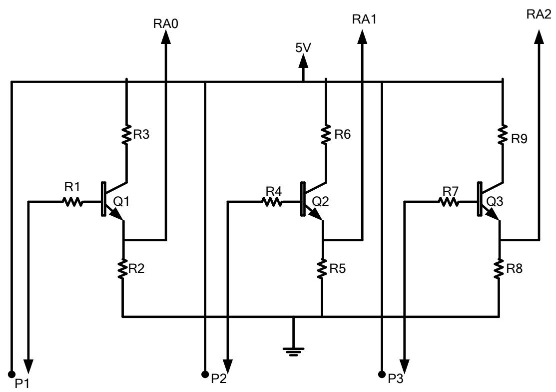


Figure 4: Water level sensor circuit

The circuit uses the NPN transistor switching operation principle. Transistors BC548 were used and configured in the common emitter mode (BC548 datasheet, 2007). The base resistor value was determined in the equations (7) - (10).

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} \qquad (7)$$

$$I_C = \beta I_B \qquad (8)$$

$$\frac{I_C}{\beta} = \frac{V_{BB} - V_{BE}}{R_B} \qquad (9)$$

$$R_B = \frac{\beta(V_{BB} - V_{BE})}{I_C} \qquad (10)$$

For values of $I_C = 10mA$, $\beta = 100, V_{BB} = 5V, V_{BE} = 0.7V$,

$$\therefore R_B = R_1 = R_4 = R_7 = \frac{100(5 - 0.7)}{0.01} = \frac{430}{0.01} = 43{,}000 = 43k\Omega.$$

A standard value of 47kΩ was used.

The microcontroller can take a maximum current of 25*mA;* hence, an emitter resistor is connected between the emitter and the ground. The emitter current is calculated thus, assuming I_{PIC} of 9*mA*:

$$I_C = I_E + I_{PIC} \qquad (11)$$

$$\therefore I_E = 0.01 - 0.009 = 1mA$$

The emitter resistor value is realized in equation (12):

$$V_{EE} = I_E \times R_E \qquad (12)$$

$$\therefore R_E = R_2 = R_5 = R_8 = \frac{5}{0.001} = 5 X 10^3 \Omega = 5k\Omega.$$

A standard value of 4.7kΩ was chosen for the design. Based on a collector current of 10mA, a collector resistor value is calculated thus:

$$V_{CC} = I_C \times R_C \qquad (13)$$

$$\therefore R_C = R_3 = R_6 = R_9 = \frac{5}{0.01} = 500\Omega.$$

Thus, a standard value of 470Ω was used in the design.

The Soil Sensor Unit

The Soil Moisture Sensor 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. The soil moisture sensor was selected because of its ability to give accurate moisture content of the soil. Figure 5 shows the soil sensor module used for this design.

Figure 5: The soil moisture sensor unit module

The Motor Drive Unit

This unit controls directly the closing and opening of the relay contacts depending on the signal it receives from the microcontroller, hence, the “ON” and “OFF” states of the water pumps. A transistor connected in common emitter mode is used as a switch. Figure 6, is the circuit diagram of the motor drive unit.

The transistor used was BC548 and was configured in the common emitter mode and its base resistor was determined thus:

$$R_B = \frac{\beta(V_{BB} - V_{BE})}{I_C} \qquad (14)$$

$$where, \quad I_C = 100mA, \beta = 100, V_{BB} = 12V$$

$$\therefore R_B = R = \frac{100(12-0.7)}{100 * 10^{-3}} = \frac{1130}{0.1} = 11{,}300 = 11.3k\Omega$$

Standard value of 10kΩ was used.

The relay chosen for this unit is a 12V, 20A relay which has the capability to handle the water pumps that they directly control.

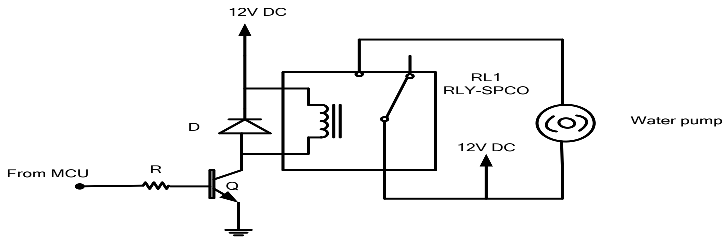


Figure 6**:** Circuit of Motor Drive Unit

The Microcontroller Unit

Microcontrollers are used in automatically controlled devices including power tools, toys, implantable medical devices, office machines, engine control systems, appliances, remote controls and other types of embedded systems. The microcontroller used for this project is PIC16F876 which has 28 pins (PIC Microntroller, 2009 and PIC16F876 1Microchip Technology).

3.1.6: The Display Unit

The Liquid Crystal Display (LCD) L044 was used as the display unit and is a 20 x 4 character display, interfaced with the microcontroller PIC16F876. The command register stores the command instructions given to the LCD, while the data register stores the data to be displayed on the LCD. Figure 7, shows the complete circuit diagram of the automated irrigation system.

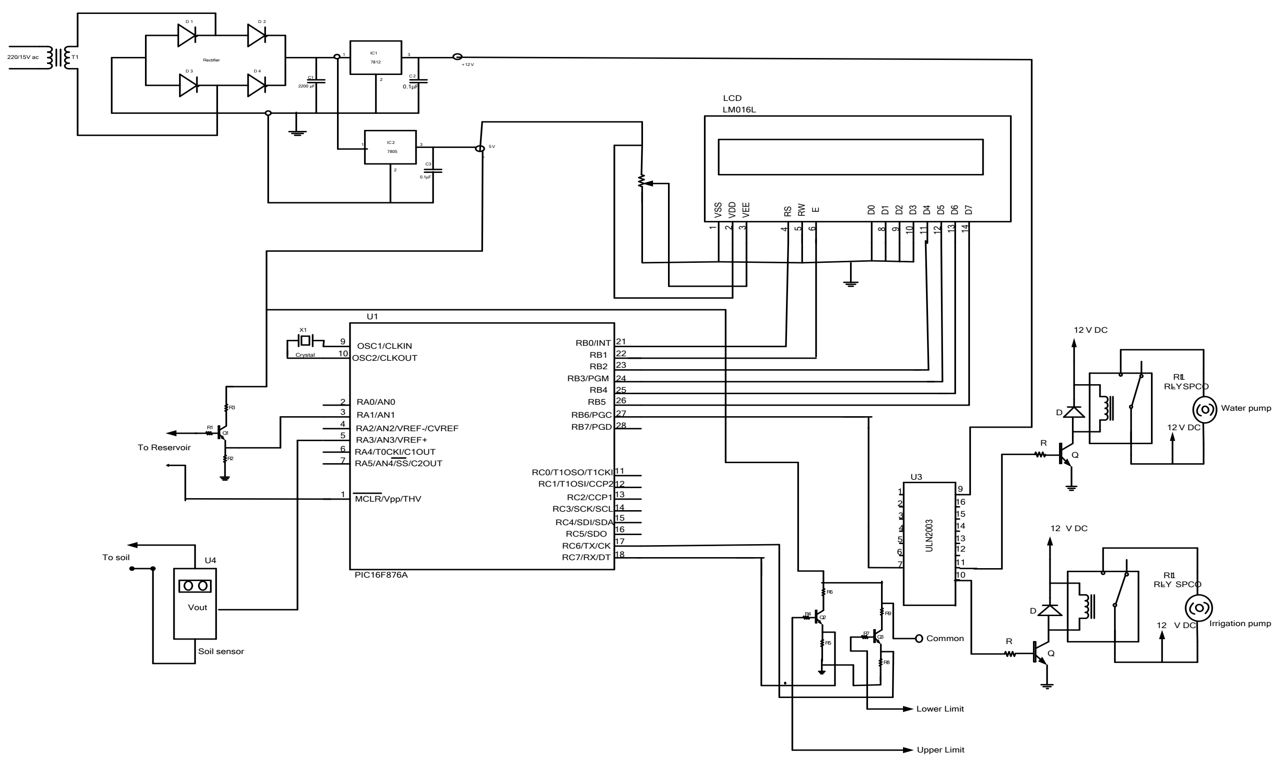


Figure 7: Complete circuit diagram of the automated irrigation system

System Operation

The sequence of operation of the automated irrigation system is as shown in Figure 8.

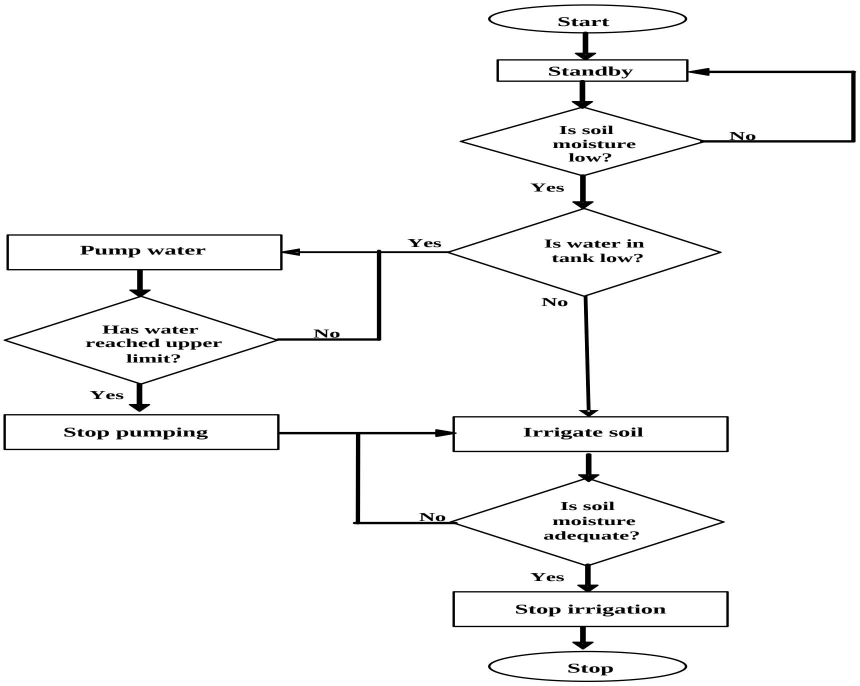
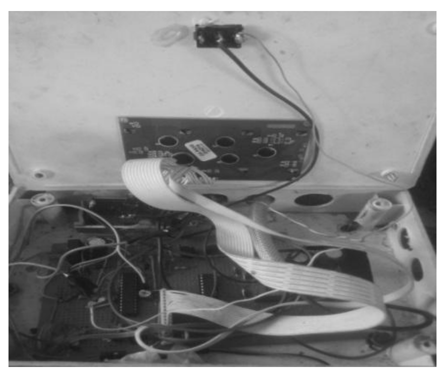


Figure 8: Flowchart of the automated irrigation system

DEVELOPMENT

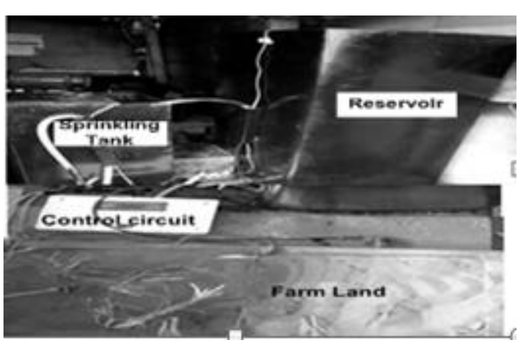
The designed circuit of the automated irrigation system presented in Figure 7 was first simulated on Proteus 8, after which the circuit was wired and a model developed as shown in Figure 9. The model was constructed on a metal base of 25 by 36 inches. Control circuit panel was encased in a plastic box of dimension of 6 inches in length, 4 inches in width and 2 inches in height. The tanks (reservoir and sprinkler) were built from metal sheets, while the field (farm land) contains soil with sample of plants for demonstrations as shown in Figure 10.



Side view

9(a) Wired System

9 (b) Control Circuit in Operation



Top view

Figure 10: Prototype of the automated irrigation system

Tests

Various tests were carried out on the prototype design to ascertain its level of functionality. A 20 litre demonstration tank was used as the water reservoir. The upper limit was at the 90% mark (i.e. 18 litres) while the lower limit was at 25% mark (i.e. 5 litres). A 30cm × 30cm sample field size with a depth/height of 10cm was used to determine the time required to irrigate the three soil samples used. In the first instance, the sprinkling tank was emptied and the field dry. This condition was sensed adequately and water was immediately pumped from the reservoir to the sprinkling tank and subsequently, the field was irrigated. On the other hand, the field was dry but with enough water in the sprinkling tank. Immediately this condition was sensed, irrigation of the field commenced, and automatically stopped when the required water content was met (as determined by the type of soil and plant). Results of the demostration carried out is presented in Table1

Table 1: Irrigation time for different soil samples

S/N	Soil Type	Level of Dryness (%)	Irrigation Time (min)
1	Sandy soil	100	3.0
2	Sandy soil	75	2.0
3	Sandy soil	50	1.0
4	Sandy soil	25	0.5
5	Loamy soil	100	4.0
6	Loamy soil	75	3.0
7	Loamy soil	50	2.0
8	Loamy soil	25	1.0
9	Clay soil	100	6.0
10	Clay soil	75	5.0
11	Clay soil	50	4.0
12	Clay soil	25	2.0

EVALUATION

From the demonstrations made, the performance of the automated irrigation system is evaluated as follows:

1. The sensitivity of the control circuit after test and adjustment is such that it can give input to the comparator circuit irrespective of the distance between the probes. Thus, the automated irrigation system can maintain its efficiency when used with large tanks.

2. The water level sensor unit performed very well as the system prompted the pumping of water immediately the water in the overhead/sprinkling tank reached the lower limit, and stopped pumping when the water reached the upper limit of the tank.

3. The results obtained showed that it takes much more time to irrigate a clay soil and lesser time to irrigate a sandy soil. This was confirmed by the results obtained in (Mohammed and Abdullahi, 2010) where the size of the sample farm was smaller than the one considered in this work.

CONCLUSION

A model of an automated irrigation system is presented in this paper for use by the Nigerian farmers in promoting modern technology in agricultural processes. The performance of this system during demonstrations showed high efficiency and reliability when in use. Integrating it into the agricultural sector of Nigeria, especially in Northern Nigeria where water is not always available, will guarantee all year round availability of water for plants with less human effort and an increase in farm produce.

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