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DEVELOPMENT OF AUTOMATED INTELLIGENT DRIP IRRIGATION SYSTEM

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ABSTRACT

The need for water for irrigation of agricultural crops in our country is growing from year to year, and this situation may cause current problems in the future. Therefore, for the rational use of available water resources in agriculture, an effective system that meets modern requirements is needed. A modern drip irrigation system significantly reduces water consumption compared to traditional methods.

This article proposes an intelligent automated drip irrigation system for irrigating crops, in which a smartphone first takes a picture of the soil, calculates its moisture level, and from time to time transmits data to the microcontroller via a GSM module.

The microcontroller decides whether the crops need to be watered or vice versa and sends the field status to the farmer's mobile phone. The intelligent system was tested in cotton fields for three months. Experience has shown that irrigation of cotton using the developed intelligent system saves about 42% and 15% of water consumption compared to traditional and drip irrigation methods.

Keywords: agriculture, soil, conventional irrigation, drip irrigation, smart drip irrigation, water flow, sensor, GSM module, microcontroller, android app.

INTRODUCTION

In most regions of the world, as well as in our region, including our country, the need for water resources is growing, and the water shortage is growing from year to year. Until 2000, low water was observed every 6-8 years, but in recent years this process has been repeated every 3-4 years.

At the same time, consumers are well aware of the lack of water, especially in the lower reaches of rivers and away from canals and other sources of water [2].

The country is working effectively to increase the productivity of irrigated lands based on the economical and rational use of water resources, to further improve the standard of living of the country's population by expanding food production, improving the quality and filling the domestic market [3].

Given the importance of using advanced irrigation water-saving technologies in improving the efficiency of water use, the leadership of our country supports the development of this area.

In particular, the Decree of the President of the Republic of Uzbekistan dated December 11, 2020 No. PP-4919 "On measures to further accelerate the introduction of water-saving technologies in agriculture" was adopted.

In the last two years, special attention has been paid to the introduction of water-saving technologies in the cultivation of crops. As a result of state support, in 2020 alone, water-saving technologies were introduced on an additional 133 thousand hectares. However, the growing scarcity of water and the growing demand for water resources require a sharp increase in the efficiency of water use in agriculture [1].

To efficiently use the available water resources, the irrigation system must be intelligent. Farmers also want to adapt to market relations, simplify the work process, use advanced technologies and make them more efficient. In our country, areas under cotton are mainly irrigated. As we all know, cotton needs different amounts of water during the growing stages. An analysis of water consumption during the entire period of cotton growth shows that in the early and late periods of maturation, it needs 20% and 30% less water than during the flowering period. Today, in order to optimize the efficient use of water consumption, the drip irrigation method is being introduced in our country. Drip irrigation is also known as micro-irrigation, in which water is slowly applied to the root zone of a plant or to the soil surface through pressure pipes and drip equipment. The drip irrigation system saves about 40-80% of water compared to the traditional irrigation method. The general scheme of the drip irrigation system [2,4] is shown in Figure 1, and the cultivation of cotton based on drip irrigation is shown in Figure 2.

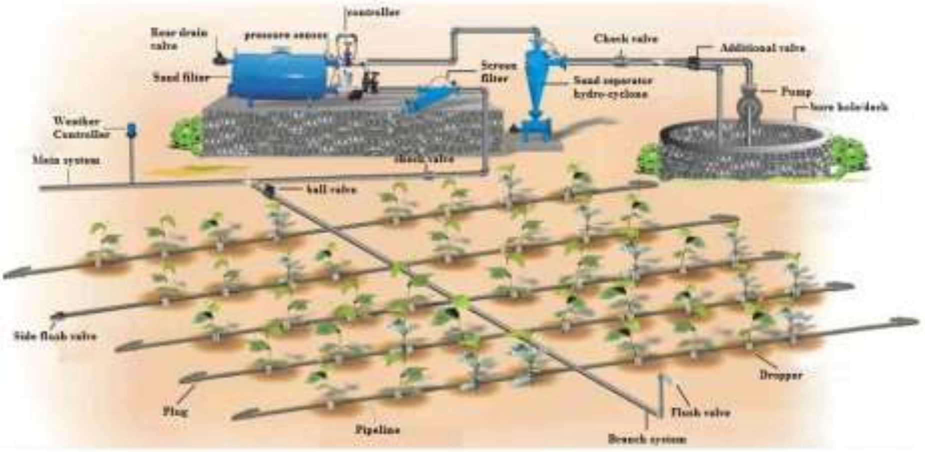


Fig. 1 Drip irrigation system.

The drip irrigation system saves a significant amount of water compared to conventional irrigation [5], which means that conventional drip irrigation requires 6000 m^3 of water per hectare, while drip irrigation uses only 3600 m^3 [6].

In recent years, the groundwater level has been gradually decreasing, which requires the automation of irrigation systems for the efficient use of water resources, and at present, most researchers are focusing on the automation of irrigation systems.

Offered in an integrated Irrigation Manager [7] linked to field data to help make irrigation decisions and track irrigation tasks in real time via Bluetooth connection. An inexpensive prototype of a system with a microcontroller was developed to monitor the condition of the soil, air temperature and humidity of crop areas using appropriate sensors. In [8], PIC16F88 microcontrollers were used to monitor the crop field environment by collecting data during the growing season. In [9], the authors recommended using a short message service (SMS) for a mobile phone to prepare irrigation schedules, sending prompts to field irrigators about the timing of the use of drip irrigation systems.

A drip irrigation system based on a microcontroller [10] was developed using an intelligent sensor to monitor the state of the environment in an agricultural field. The development of diseases was revealed by constant observation of weather conditions such as temperature.

Fig. 2 Cotton growing based on drip irrigation system.

In the literature [11], an automated irrigation system has been developed for the efficient use of water resources in agriculture. To measure soil moisture and temperature in the root zone of crops, sensors were installed and a wireless information unit was used to transmit the measured data to a web server via a common mobile network. In [12], the authors proposed an irrigation decision support system for irrigation management by estimating weekly irrigation needs of plants using sensors measuring soil and field environmental parameters. An analysis of the literature shows that the authors proposed an irrigation system based mainly on soil moisture; they did not pay attention to other environmental parameters. In this article, we propose a new irrigation system based on temperature, humidity, rainfall and light intensity in addition to soil moisture. It should also be noted that the proposed irrigation system is based on the best scientific ideas of the authors.

The rest of the article is organized as follows: Section 2 describes the methodology and working model of the proposed system. The components and methods used in the proposed methodology are detailed in section 3. Section 4 discusses the results and analysis of the proposed smart irrigation system. Finally, Section 5 generalizes the case.

2. PROPOSED IRRIGATION SYSTEM

The article mainly provides data on the water consumption of cotton, one of the main crops of the country's crops, and its irrigation system. In general, if you look at the process of growing cotton, the level of water demand before it ripens varies. It is noted that less water is consumed in the initial and final stages of cotton cultivation (by 15% and 12%) than during the recharge period.

Irrigation efficiency depends not only on the need of crops for water, but also on the environmental factors of agriculture. Environmental conditions must be constantly monitored as factors such as temperature, humidity, rainfall and soil moisture determine the amount of water required for an efficient irrigation system.

2.1. Flowchart of the proposed irrigation system methodology

The proposed smart sensor-based irrigation system, consisting of ARM microcontrollers, smartphones, a GSM module, a sensor unit and an engine control unit, is shown in Figure 3. The sensor unit consists of temperature, humidity, light and rain sensors that are used to monitor environmental conditions. environment by collecting parameters such as temperature, humidity, light intensity and rainfall of the agricultural field. An irrigation program has been developed to determine soil moisture from an image and will be installed on a smartphone stored in a chamber protected by transparent reflective glass (TARG - TransparentAnti-ReflectiveGlass) on one side of the chamber. The Global Mobile for Mobile Communications (GSM) module in the proposed irrigation system is used to send and receive messages between the microcontroller and a smartphone. Based on data from various sensors, the ARM microcontroller controls irrigation by controlling the motor unit and periodically sends updated data to the farmer.

2.2. The principle of operation of the proposed system

The entire operation of the proposed irrigation system is shown in Figure 4. Initially, the proposed irrigation system begins with an image of the soil taken by an Android application installed on a smartphone placed inside a closed (protected) chamber. The application converts the resulting color images to grayscale images and calculates the histogram values of the modified grayscale images. Based on the histogram, the system determines that the soil is wet and does not need to be watered if the total number of pixels on the gray scale exceeds 5000 with a pixel intensity of about 200. Otherwise, the soil will be dry and will react in accordance with the values obtained from the sensors integrated into the system . Based on the soil moisture and rain sensor input, the ARM microcontroller controls the motor through the motor control unit. Based on the soil moisture and rain sensor data, the ARM microcontroller controls the motor through the control unit.

The mode of operation of the proposed irrigation system is divided into three main categories depending on the soil moisture and the input signal of the sensor unit.

They consist of the following:

1. The soil must be wet - the engine must be in the **OFF** position.
2. The soil is dry and precipitation is possible - the engine must be in the **OFF** position.
3. The soil is dry and rain is not possible - the engine must be in the **ON** position.

The irrigation system continuously captures the image of the soil and monitors the condition of the irrigated lands, repeatedly repeating the process described above at a specified time interval, taking into account sensor data. After the process, the status of the irrigation process is periodically updated via SMS to the farmer's mobile phone.

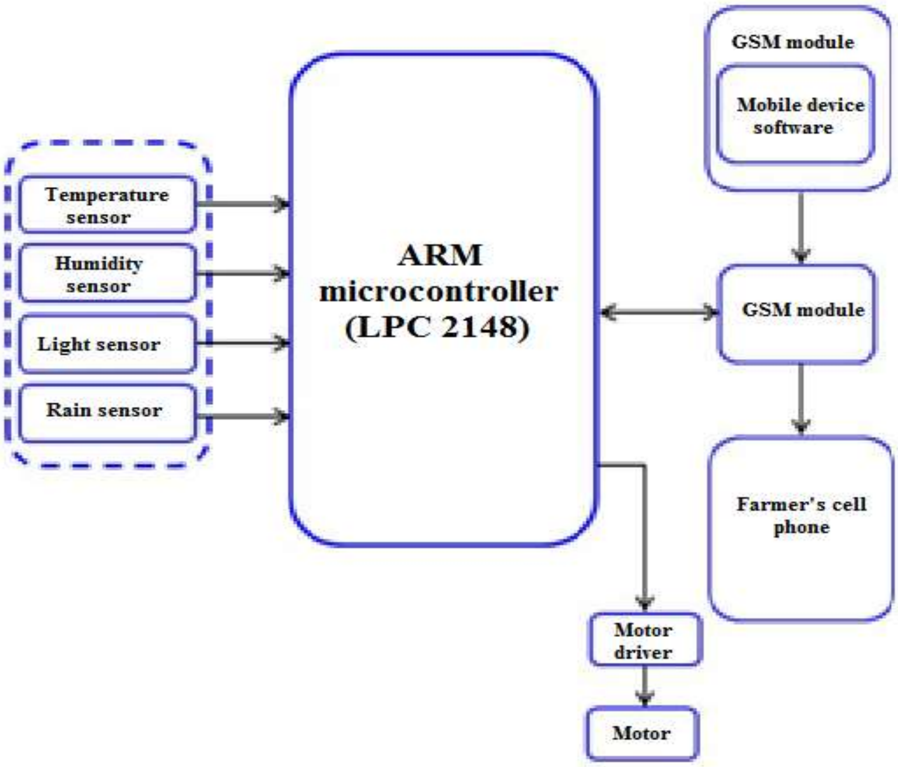


Fig. 3 Block diagram of the proposed intelligent irrigation system based on sensors.

3. APPLICABLE COMPONENTS AND METHODS

3.1. Description of sensors

3.1.1. Temperature sensor

The temperature sensor is used to determine the temperature of the atmosphere by converting a physical parameter into electrical voltage. The output voltage generated by the temperature sensor is linearly proportional to the instantaneous (instantaneous) temperature (on the Celsius scale). The proposed irrigation system uses a temperature sensor LM 35 DZ, which measures the temperature from -55° to +150°C. It operates from 4V to 30V and provides a linear output voltage of 10mV for every 100 degree (Celsius) change in temperature. The analog output of the temperature sensor is connected to the input of the analog-to-digital converter (ADC) on the ARM microcontroller. On fig. 5 shows the characteristics of the temperature sensor rod used in the proposed system.

3.1.2. Humidity sensor

The humidity sensor is used to detect the presence of moisture in the air (water vapour). The proposed irrigation system uses an HR202 humidity sensor that detects relative humidity from 20% to 95% at temperatures from 0°C to 600°C. It operates from 3.3 V to 5 V and has both analog and digital output pins. Changes in the humidity level are controlled by the digital output of the sensor, the exact digital value of humidity can be obtained through the analog output of the sensor. On fig. 6 shows the characteristics of the moisture sensor pin used in the proposed system..

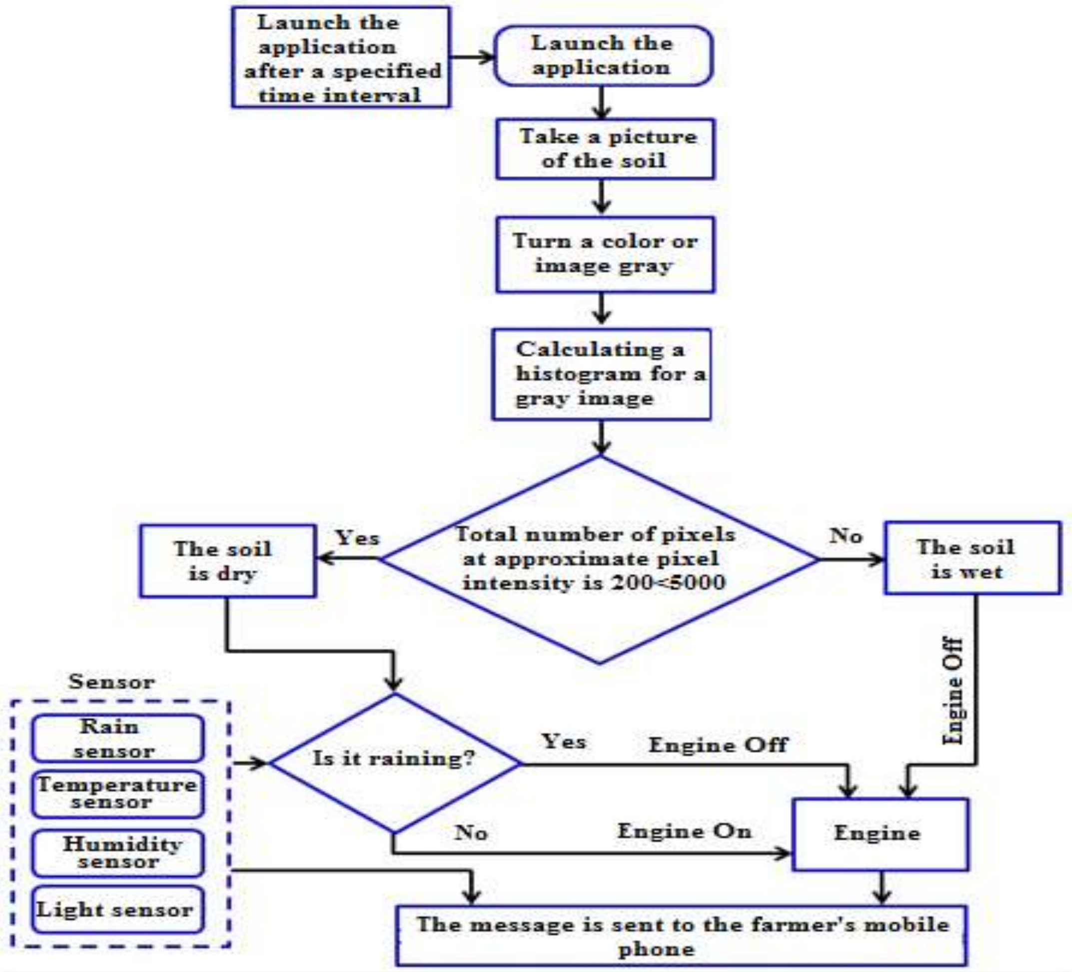


Fig.4. The operation process of the proposed smart sensor irrigation system.

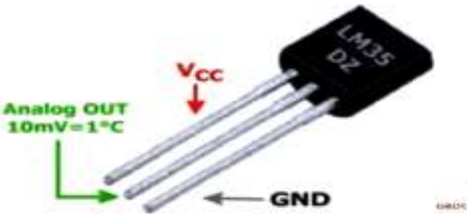


Fig. 5 Temperature Sensor

Fig. 6 Humidity sensor

Fig. 7. Light sensor

3.1.3. Light sensor

The light sensor is used to detect the intensity of ambient light. The light sensor is a passive device that converts light energy into electrical energy. Light Dependent Resistor (LDR) is also a light sensor that increases its transmittance by decreasing resistance to increase illumination. The proposed irrigation system uses a cadmium sulfide-based ORP12 photoconductive cell as a light sensor. Typically, the cell resistance is very high, around 10 MΩ for a dark state (unlit space). For the light state (fully lit area), its resistance is 100 Ω.

On fig. 7 shows the light sensor used in the proposed system.

3.1.4. Rain sensor

The rain sensor is used to detect rain in the field. The sensor consists of two modules, such as a rain sensor and a control module. The control module has analog and digital output contacts, the digital output is used to detect precipitation and rain rate, and the amount of precipitation can be measured using the analog output. The rain detection board has two separate tracks for 50mm x 40mm printed circuit boards. The sensor board acts as a variable resistor that changes depending on the amount of water entering the board, i.e. 100 kΩ wet and 2 MΩ dry. The proposed system uses the Elecmake PRD180 raindrop sensor. The rated voltage is between 3.3V and 5V, and the current value is less than 20mA.

On fig. 8 shows the rain sensor used in the proposed system.

3.2. Microcontrollers (LPC2148)

On fig. 9 shows the LPC2148 microcontrollers used in the proposed system. It is the most widely used microcontroller in the ARM 7 family manufactured by Philips. Some important features are on-chip static RAM from 8 to 40 KB, on-chip flash memory from 32 to 512 KB, and a 128-bit interface allowing operation at 60 MHz. Microcontroller operating voltage 3.3V±10% (3.0V to 3.6V).

3.3. Soil images processing.

Soil imaging is a technique used to study the nature of the soil by processing the resulting images. The technique divides them into different categories depending on soil moisture. The amount of moisture in the soil is determined based on the histogram analysis of the resulting image. Typically, smartphone images are made up of colors that are a mixture of three primary colors such as red, green, and blue (RGB). The resulting color image was converted to a gray image (GI - grayscale image) using equation (1) according to [13].

$$GI = 0{,}2989*R + 0{,}5870*G + 0{,}1140*B \qquad (1)$$

Fig.8. Rain sensor.

Fig. 9. LPC2148 Microcontroller.

image of dry soil image of 15% wet soil image of 30% wet soil

image of 60% wet soil image of 95% wet soil image of 100% wet soil

Fig. 10. Grayscale images.

A histogram is the process of calculating the number of pixels of a given pixel intensity of a gray image, with values ranging from 0 to 255. The resulting histogram shows only the marginal difference between dry and wet pixels. To determine their differences, the image is set to white paper with the same background, and then a gray image is displayed. Gray images of soils with different levels of moisture are shown in Figure 10. A histogram of soil images is shown in Figure 11.

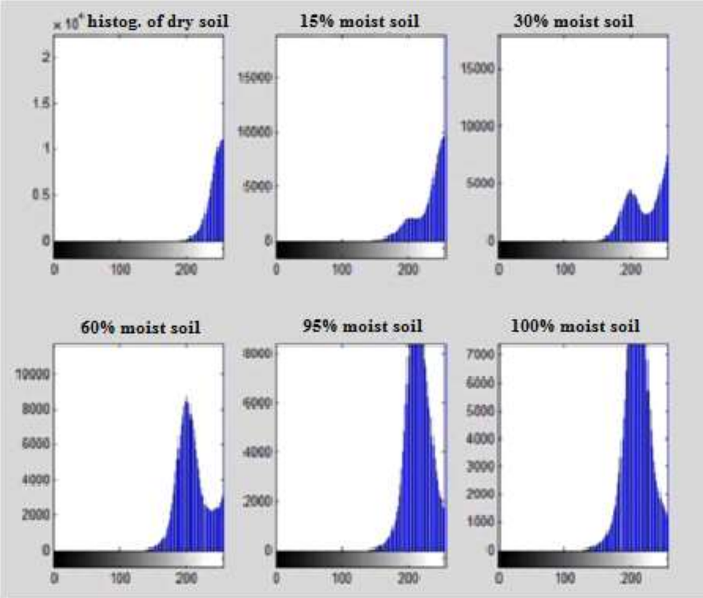


Fig. 11. Histogram corresponding to images on a gray scale.

Histogram analysis allows you to determine soil moisture by the total number of pixels with an intensity of about 200 pixels. According to the number of pixels, the soil is divided into six different types, as shown in Figure 12. Soil categories and soil moisture content:

- No moisture - absolutely dry soil
- 15% wet - dry soil
- 30% moist - conditionally moist soil
- 60% moist - moderately moist soil
- 95% wet - moist soil
- 100% wet - completely wet soil.

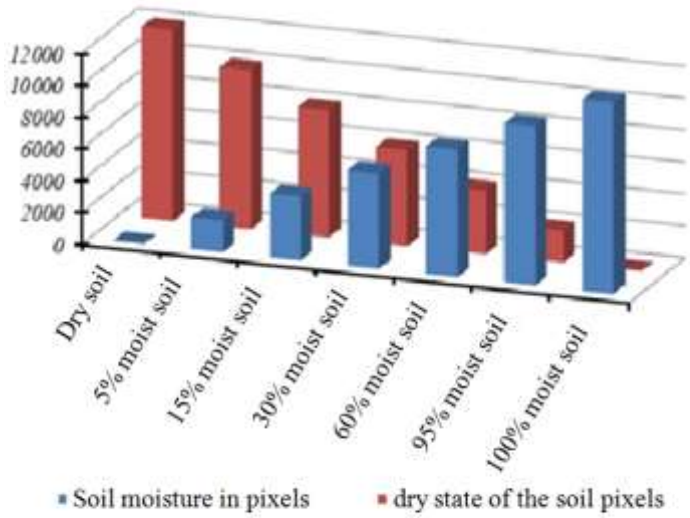
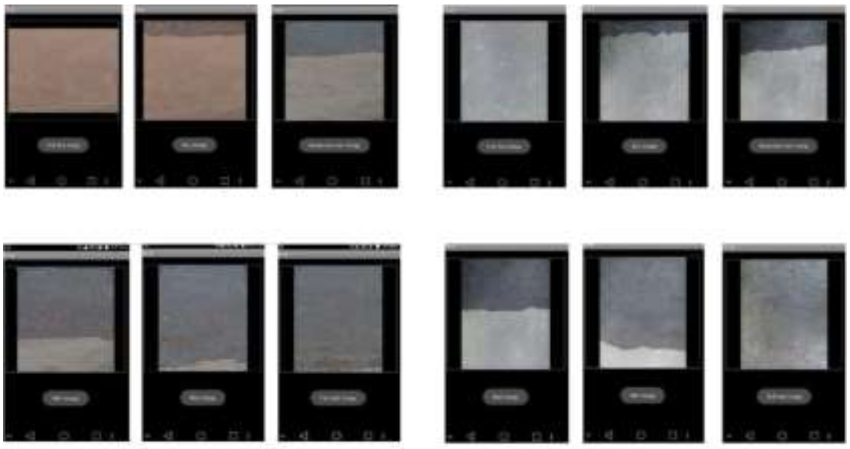


Fig. 12. Soil classification by the number of pixels.

3.4. App for irrigation system

The application was developed using a Java computer program in the EclipseSDK 3.6.2 compiler and converted to an Android software package as an .apk file. The developed application is mounted on a smartphone, which is placed in a sealed, waterproof rectangular box with TARG ohm (transparent anti-reflective glass) on one side of the box, and the smartphone camera must be pointed at TARG in order to take a ground picture.



a) Red soil with different moisture levels. b) black earth with different levels of humidity

Fig. 13. Images taken through a smartphone application.

At a user-defined interval, the app launches the smartphone's camera module and takes a picture, which is used to estimate the amount of moisture in the soil. The application changes the RGB image to gray and determines the moisture percentage by calculating the histogram. Then the moisture percentage is transmitted to the microcontroller via the GSM module, and the image, soil moisture percentage, date and time are stored in the smartphone's memory to create a log file. Pictures taken with a smartphone camera and its humidity level are shown in Figure 13, and the installation of a rectangular TARG a (Transparent Anti - Reflective Glass) is shown in Figure 14.

Fig. 14. Install TARG.

4. RESULTS AND DISCUSSION

The proposed irrigation system consists of ARM microcontrollers, sensors, a smartphone, a motor and a GSM module. After a specified time interval, the smartphone takes a picture and sends soil moisture data to the microcontroller via the GSM module. The microcontroller then determines if the field needs to be watered using soil moisture and sensor readings and sends the information to the farmer via SMS. The control module of the proposed irrigation system is shown in Figure 15.

The environmental conditions such as soil moisture, temperature, humidity level, light intensity, rain condition and engine condition are shown in Figure 16, and the data sent via SMS to the farmer's mobile phone is shown in Figure 17.

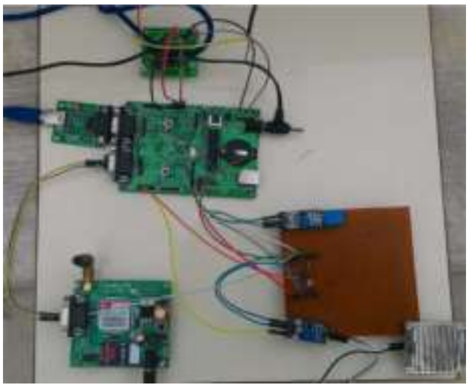


Fig. 15. Setting up the hardware of the control unit.

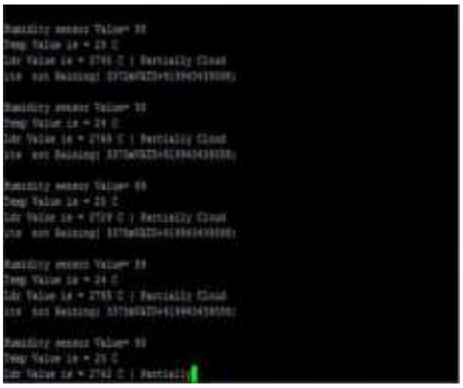
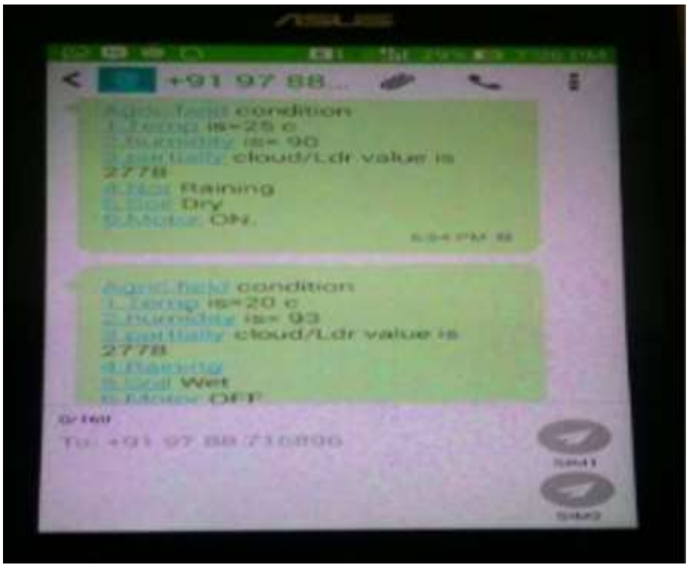


Fig. 16. Monitoring of an intelligent irrigation system.

For 15 days in July 2021, the climatic conditions of the agricultural field were continuously monitored using the proposed irrigation system, and its maximum and minimum values are plotted graphically in Figures 18 and 19.

The proposed irrigation system was tested in a one hectare cotton field and the amount of water needed for the various stages of cotton growth was calculated. The estimated amount of water for the proposed irrigation system is compared with existing irrigation systems and the values are shown in Table 1.

As can be seen from Table 1, the proposed intelligent drip irrigation system significantly saves water at all stages of cotton cultivation compared to existing irrigation systems. The proposed irrigation system accounts for 58.9% of water consumption with conventional irrigation and 41.1% of it, and with drip irrigation 83.82% and water savings of 16.18%. As a result of monitoring field conditions (soil conditions) in the proposed intelligent sensor irrigation system, the percentage of water savings due to turning the electric motor on and off will increase.



Agri.field condition
1.Temp is=25 c
2.humidity is= 90
3.partially cloud/Ldr value is 2778
4.Not Raining
5.Soil Dry
6.Motor ON.

Agri.field condition
1.Temp is=20 c
2.humidity is= 93
3.partially cloud/Ldr value is 2778
4.Raining
5.Soil Wet
6.Motor OFF

Fig. 17. SMS information sent to the farmer's mobile phone.

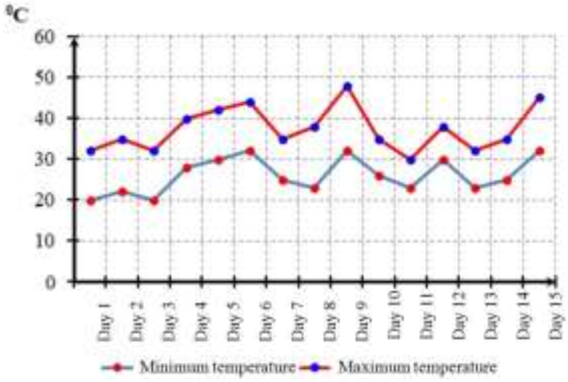


Fig. 18. Temperature (°C).

Fig. 19. Humidity (%).

1- Table Estimated water consumption for different irrigation methods

№	Growth stages	Traditional irrigation method (m³/hectare)	Drip irrigation method (m³/hectare)	Intelligent Drip Irrigation Method (m³/hectare)
1	Beginning of flowering	930	650	550
2	Flowering - fruit formation (stage 1)	1140	800	670
3	Flowering - fruit formation (stage 2)	1140	800	670
4	Flowering - fruit formation (stage 3)	1140	800	670
5	Flowering - fruit formation (stage 4)	1140	800	670
6	Cotton maturation	850	600	500
7	Total water consumption in cotton growing	6340	4450	3730
8	Average water consumption in cotton production	1056	742	622

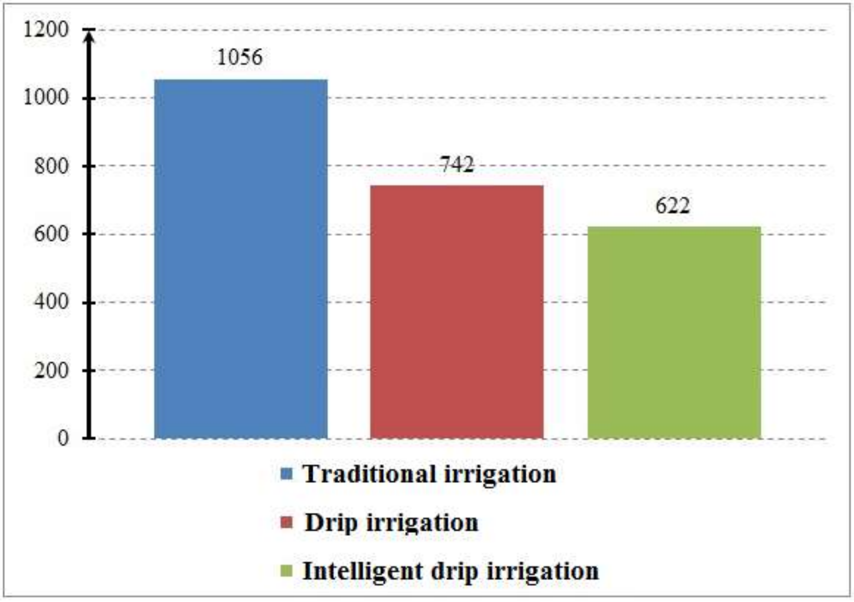


Fig. 20. Water consumption for different irrigation methods.

The average amount of water used per hectare of land used to grow cotton using the above irrigation methods is shown in Figure 20, and the percentage of water used by irrigation methods is shown in Figure 21.

Figure 21 shows that the proposed method is the most efficient of all irrigation methods.

Assuming 100% water consumption with the traditional irrigation method, with the drip irrigation method and the proposed method, the water consumption is 70, 27 and 58.9%, respectively.

If we take the water consumption with the drip irrigation method as 100%, then it is enough that the consumption by the proposed method is 83.82%. If we assume that the proposed method uses 100% water consumption, then the other irrigation methods require more water consumption, i.e. 69.77% and 19.29% more water consumption, respectively, than conventional irrigation and drip irrigation methods.

The average percentage of water required to grow cotton per hectare of the proposed smart system compared to conventional irrigation and drip irrigation is shown in Figure 22 as a pie chart. The figure shows that the proposed system requires less water than other methods.

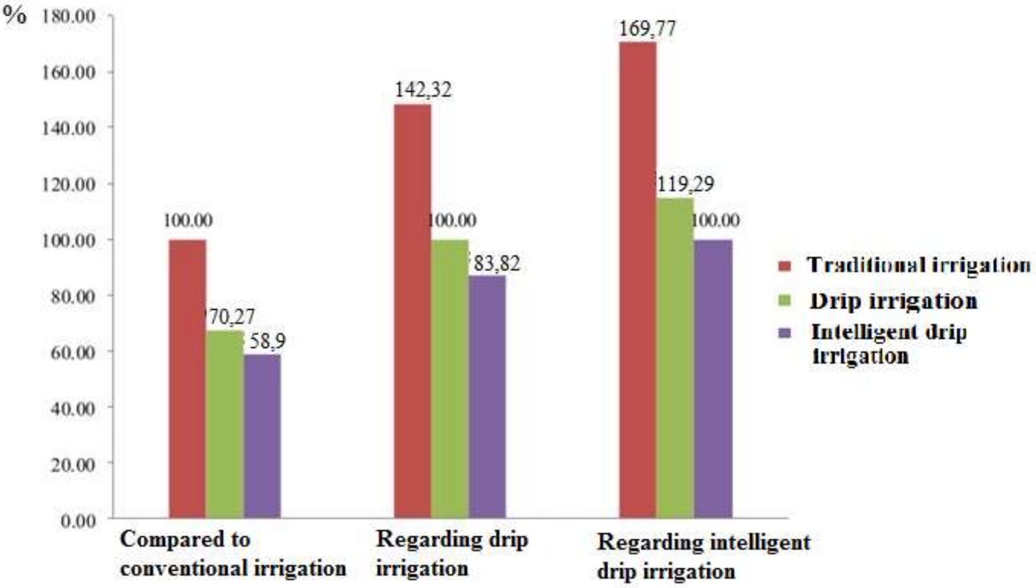


Fig. 21. Percentage of water use for various irrigation systems.

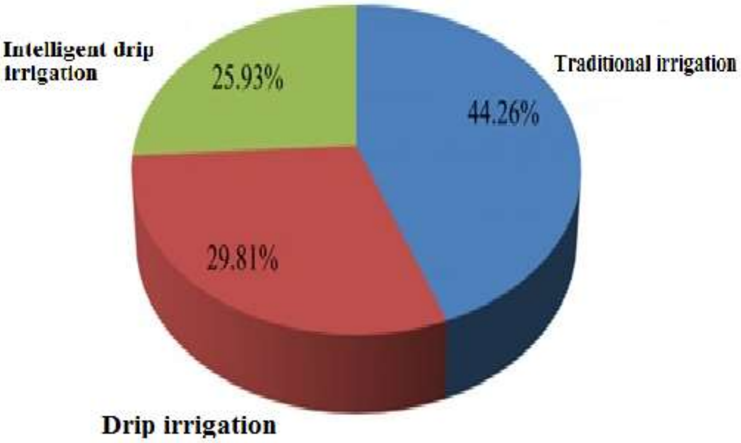


Fig. 22. Norm of water consumption for irrigation of 1 hectare of land under cotton cultivation (%).

5. CONCLUSION

We all know that the level of precipitation and groundwater is decreasing from year to year, which increases the need for new modern irrigation systems for the efficient use of water resources in agriculture. In a sense, the economy and growth of our country also depends on income from agriculture. Given these factors, a sensor-based smart irrigation system for drip irrigation is essential. The sensor-based smart automatic drip irrigation system discussed in the article was implemented and tested on one hectare of cotton field, and the results of the experiments proved to be more effective than other irrigation methods. Android smartphone app in smart irrigation system takes a picture of the soil, calculates the soil moisture and transmits the data to the microcontroller via the GSM module in the system. The system decides whether irrigation should be based on data received by the microcontroller, such as sensor data and images taken by a smartphone, or vice versa. According to the test results, the proposed intelligent sensor irrigation system provides 58.9% of the water consumption in a conventional irrigation system and 41.1% of it, 83.82% of the water consumption in a drip irrigation system and 16.18% of it, saves water. Monitoring of field conditions (soil conditions) in the proposed intelligent sensor irrigation system allows you to save water and electricity consumption by turning the electric motor on and off.

In addition, as a result of the application of this proposed intelligent drip irrigation system in agriculture, the overall cost of production will be reduced, as well as the time of the irrigator will be saved..

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