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Design and Implementation of Automatic Field Irrigation System using Sensors

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Abstract: Agriculture needs 85 percent of the available freshwater and its requirement may increase in future. Hence, a system is needed to utilize water efficiently in agriculture. The automatic irrigation control system is used to achieve this aim.The modern drip irrigation system lessens a significant amount of water usage compared to the traditional methods. And some crops need variable amounts of water as it grow e.g. paddy. This paper proposes an automation of drip irrigation in which the smartphone initially captures soil image, calculates its wetness level and transmits the data onto the microcontroller through GSM module intermittently. The microcontroller decides the irrigation and sends the status of the field to the Farmer's mobile phone. The system is tested for paddy field for over a period of three months. It is observed from the experimental setup, that it saves nearly 41.5percentage and 13percentage of water compared to the conventional flood and drip irrigation methods respectively.

Keywords*:* Android application, Drip irrigation, GSM module, Microcontroller

I. Introduction

Water is a common and most abundant substance on the earth which is occurring naturally in the form of inorganic liquid. Agriculture is the most predominant activity in developing countries for food and other essential things used by living organisms to sustain and enhance their life. Agriculture uses 85% of available freshwater resources worldwide for cultivating the plants using traditional irrigation methods and it increases the demand for the water resources in day-to-day life as the population grows [1]. Tamilnadu has three distinct monsoons such as southwest, northeast and dry season and are prone to droughts. It is felt necessary to have a smart system for the efficient utilization of the available water. Farmers are also very much eager in adapting to the novel ideas and market forces. It is evaluated that agricultural yield has to reach 70% by 2050. The automation definitely brings out a remarkable achievement in future. In Tamilnadu, paddy constitutes 85.2% of total food grain production and it requires varying quantity of water at different growth stages. Flood irrigation is a technique that releases water until the entire field is covered, but the crop does not need that much amount of water during its entire growth span (i.e.) it requires only 50% and 25% of water in mid and early stages of cultivation compared to the fully grown stage. Hence drip irrigation is chosen to optimize the usage of water resources for improving the crop yield. The drip irrigation system is also known as micro irrigation which supplies water either directly to the root zone or soil surface through pressurized pipes, valves and drippers to make water drip slowly. Drip Irrigation system saves nearly 40–80% of water compared to traditional flood irrigation method. A general layout of drip irrigation system [2] is shown in Fig. 1 and drip irrigation based paddy cultivation [3] is shown in Fig. 2. An integrated site-specific irrigation controller with infield data feedback was proposed in [5], which assists in making the irrigation decisions and real time monitoring of irrigation tasks through Bluetooth communication. A low cost micro-controller prototype system was designed to monitor the soil, canopy, air temperature, and soil moisture status of the crop fields using appropriate sensors.

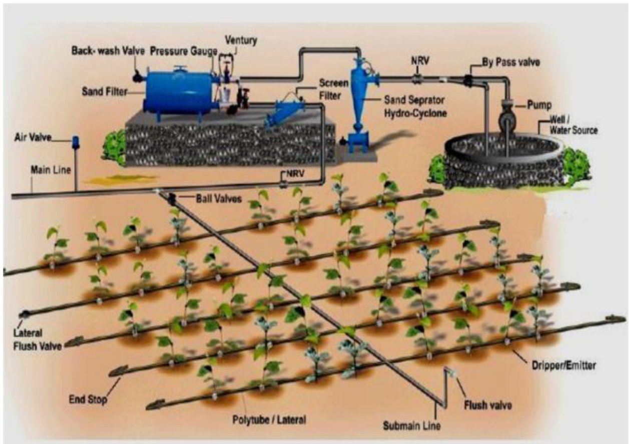


Fig.1. Drip irrigation layout.

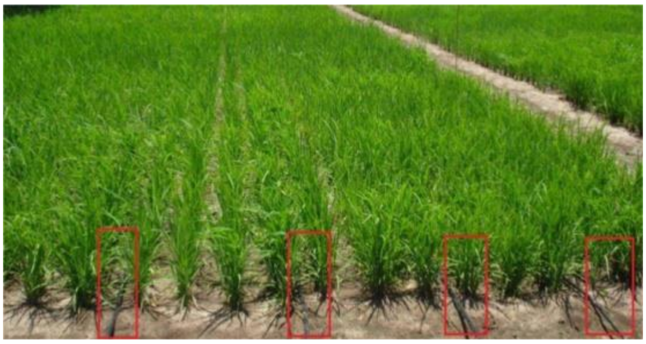


Fig.2. Drip irrigation in paddy cultivation.

In [6], PIC16F88 microcontroller was used to monitor the crop environments by collecting the data during the growing season. In [7], the authors investigated the usage of mobile phone Short Messaging Service (SMS) to prepare irrigation schedule by sending drip run time advices to the irrigators in Australia. Microcontroller based drip irrigation system [8] was designed using a smart sensor to monitor the environmental conditions of the agricultural field. The germination of diseases was detected by continuously monitoring the weather conditions such as temperature, relative humidity and soil moisture, and it was intimated through buzzer. This system also analyzed the drip irrigation in real time by using the received physical parameter values from the agricultural field. An automated irrigation system [9] was developed to utilize the water resource in the agricultural field. In this, sensors were placed in the root zone of the crops to measure soil moisture level and temperature, and wireless information unit were used to transmit the measured data to the web server via the public mobile network. In [10], the authors proposed an irrigation decision support system to manage the irrigation by evaluating the weekly irrigation needs of the plant using soil measurements and environmental parameters

With the development of sensor technology and network-based information technology, Wireless Sensor Network (WSN) plays a major role in healthcare applications, wildlife habitat monitoring, military applications, intelligent home monitoring and precision agriculture in a larger extent [20–22]. In [23], the authors discussed about the passively powered wireless nodes and its application in wide area using Radio Frequency Identification and Internet of Things. In [24], the authors pro- posed Remote Execution Unit (REU) architecture based on microcontroller to reduce the power consumption of Wireless Passive Node (WPN) for biomedical sensor applications. In [25], the authors developed an energy efficient architecture par- ticularly for the applications like environmental monitoring, structural and medical fields. WSN based clustering approach

[26]was utilized for Pest identification of coffee plantation. A system was proposed in [27] for monitoring the frequent changes in crops due to pests, soil moisture, droughts and floods in agricultural land with the help of a low cost WSN. In [28], the authors proposed a system to monitor the large-scale rainfall in real time with the help of WSN and transmit the recorded information periodically in a synchronized manner without any human intervention. In [29], the authors proposed a smartphone based irrigation system only based on the wetness of the soil and they have not concentrated on the other environmental parameters. We have introduced a new design based on the temperature, humidity, rain level and light in- tensity in addition to the wetness of the soil. It can be clearly said that this proposed approach has not been implemented elsewhere in the literature to the best of author's knowledge.

The rest of the paper is organized as follows: Section 2 describes the methodology and working model of the proposed system. The components and techniques used in the proposed methodology are elaborated in Section 3. Section 4 discusses about the results and analysis of the proposed smart irrigation system. Finally, we conclude the work in Section 5.

II. Proposed irrigation system

Generally, water requirement for paddy cultivation is not uniform throughout the life span. It is noted that only 50% and 25% of water were utilized during the mid and early stage of cultivation when it is compared to the fully grown stage. Efficient irrigation not only depends on the water requirement of crop cultivation, but also the environmental factors of the agriculture field. The environmental conditions need to be continuously monitored because the factors such as temperature, humidity, rainfall and moisture content of the soil will decide the amount of water required for the effective irrigation system.

2.1 Block diagram of proposed methodology

The proposed irrigation system based on smart sensor which consists of ARM microcontroller, smart phones, GSM mod- ule, sensor unit and motor control unit is shown in Fig. 3. The sensor unit comprises of temperature sensor, humidity sensor, light sensor and rain sensor which is used to monitor the environmental conditions by collecting the physical parameters such as temperature, humidity, light intensity and rainfall of the agricultural field. An irrigation application is developed for determining the wetness of the soil from the captured image and it is installed in the smart phone which is kept in a closed chamber having Transparent Anti - Reflective Glass (TARG) medium on one side of the chamber. The Global System for Mobile communication (GSM) module in the proposed irrigation system is used for sending and receiving the messages between the microcontroller and smartphone. Based on the data received from various sensors, the ARM microcontroller manages the irrigation by controlling the motor unit and periodically updates the information to the farmer.

2.2 Working principle of the proposed system

The entire workflow of the proposed irrigation system is given in Fig. 4. Initially, the proposed irrigation system begins with a soil image captured by the android application, which is installed in the smartphone placed within the closed cham- ber. The application converts the captured color images into gray scale images and calculates the histogram values of the converted gray scale images. From the histogram, the system decides that the soil is wet and doesn't need to irrigate when the total numbers of pixels present in the gray scale image exceed 5000 at pixel intensity in and around 200. Otherwise the soil is dry and responds according to the values received from the sensors integrated with the system. Based on the wetness of the soil and the rain sensor input, the ARM micro controller operates the motor through the motor control unit.

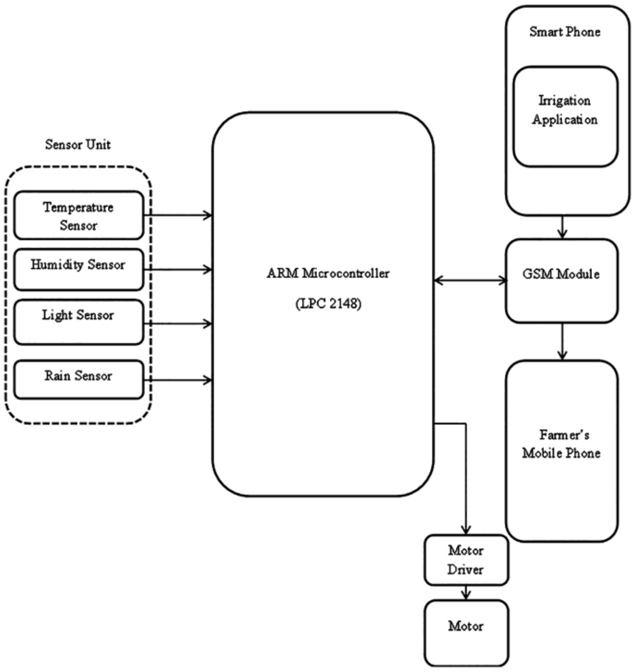


Fig. 3. Block diagram of proposed Smart Sensor based irrigation system.

III. Components and techniques used

3.1. Sensor description

3.1.1. Temperature sensor

The temperature sensor is used to find the temperature of the atmosphere by converting the physical parameter into an electrical voltage. The output voltage produced by the temperature sensor is linearly proportional to the instantaneous temperature (in degree Centigrade / Celsius). In the proposed irrigation system, LM 35 DZ temperature sensor is used which senses the temperature from −55° to + 150° C. It operates between 4 V to 30 V and linearly produces an output voltage of 10 mV per centigrade change in temperature. The analog output pin of the temperature sensor is connected to the input of Analog to Digital Converter (ADC) in ARM microcontroller. Fig. 5 shows the temperature sensor used in the proposed system with pin descriptions.

3.1.2. Humidity sensor

The humidity sensor is used to find the presence of water vapor in the air. The relative humidity is the common term used to measure the amount of water vapor in the air by adjusting the potentiometer in the sensor module and the value is inversely proportional to the amount of resistance at a fixed temperature. In the proposed irrigation system, HR 202 humidity sensor is used which senses the relative humidity in the range of 20% to 95% at a temperature of 0 to 60 degree Celsius. It operates from 3.3 V to 5 V and it can able to produce both analog and digital outputs. The humidity changes aremonitored by the digital output of the module while the accurate numerical value of humidity can be obtained by analog output of the sensor. Fig. 6 shows the humidity sensor used in the proposed system with pin descriptions.

3.1.3. Light sensor

The light sensor is used to detect the light intensity of the environment. The light sensor is a passive device which converts the light energy into an electrical energy. Light Dependent Resistor (LDR) is also a light sensor that increases its conductivity with a decrease in resistance for an increase in light illumination. In the proposed irrigation system, ORP12 Cad- miumSulphide photoconductive cell is used as a light sensor. Normally, the resistance of the cell is very high nearly about 10M▲'s for a dark spot (un-illuminated space). It can be reduced up to 100▲'s for a bright spot (fully illuminated space). Fig. 7 shows the light sensor used in the proposed system.

3.1.4. Rain sensor

Rainfall sensor is used to detect the rainfall in the field. The sensor has two modules such as rain detecting and control module. The control module is able to produce both analog and digital outputs while the digital output is used to detect the rainfall as well as the intensity of rainfall and can be measured from analog output. The rain detecting board has two separate PCB tracks in the dimension of 50 mm x 40 mm. The sensor board acts as a variable resistor which changes according to the water falls on the board (i.e.) the value ranges between 100K▲ i.e., in wet and 2M▲ i.e., in dry. In the proposed system, the raindrop sensor module PRD180 from Elecmake is used. The operating voltage is 3.3 V to 5 V and the current is less than 20 mA. Fig. 8 shows the rain sensor used in the proposed system

3.2. Microcontroller (LPC2148)

Fig. 9 shows the LPC 2148 microcontroller used in the proposed system. It is a commonly used IC belongs to the ARM 7 family manufactured by Philips. The controller is more economical and reliable for beginners and high-end application developers since it is preloaded with several intrinsic peripherals. Some of the important features are 8 to 40 KB on- chip static RAM, 32 to 512 KB on-chip flash memory and 128 bit wide interface allows 60 MHz operations. The operating voltage of the microcontroller is 3.3 V ± 10% (in the range of 3.0 V to 3.6 V).

3.3. Soil image processing

Soil image processing is a technique used to examine the nature of the soil by processing the captured images. The technique classifies the soil into different categories between completely dry to completely wet based on the wetness of the soil. The amount of wetness in the soil is estimated from the histogram analysis of the captured image. Typically, the images captured from the smartphone are in colour which is a mixture of three primary colours such as Red, Green and Blue (RGB). The captured colour image was converted into grayscale image (GI) according to [30], using Eq. (1)

$$GI = 0.2989 * R + 0.5870 * G + 0.1140 * B.$$

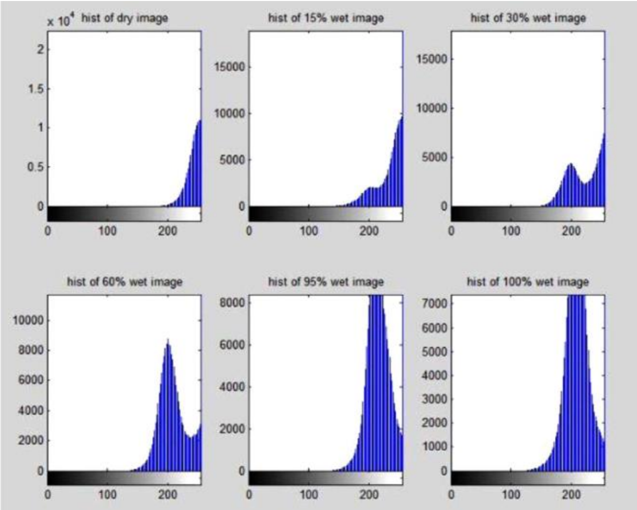


Fig. 4.Histogram corresponding to gray scale images.

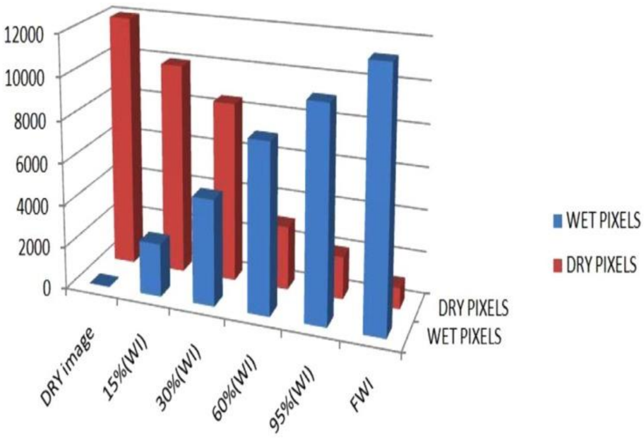
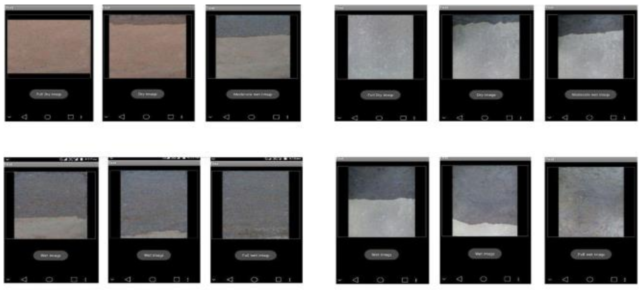


Fig. 5. Soil classification based on number of pixels.

A histogram is the process of counting the number of pixels at a particular pixel intensity of the grayscale image and the value lies between 0 and 255. The resulting histogram shows only a marginal difference between dry and wet pixels. In order to improve their differences, a setup is made to capture the image of a super-white paper with the same background of illumination and then subtracted from the grayscale image. The grayscale images of soil with different wetness level are shown in Fig. 10. Its enhanced histogram of the soil images are shown in Fig. 4.

From the histogram analysis, the wetness of the soil is determined by the total number of pixels present in and around the pixel intensity 200. Based on the number of pixels, the soil is categorized into six different types which are shown in Fig. 5. The categories of the soil and the percentage of wetness present in the soil are:

- No wet content - completely dry soil
- 15% wet content- dry soil
- 30% wet content- conditionally wet soil
- 60% wet content- moderate wet soil
- 95% wet content- wet soil
- 100% wet content- completely wet soil.



(a) Red soil with different wetness levels (b) Black soil with different wetness levels

Fig. 6. Images captured by smart phone application.

IV. Results and discussion

The proposed irrigation system consists of ARM microcontroller, sensors, smartphone, motor and GSM module. At a pre- defined time interval, the smartphone captures the image and sends the wetness of the soil to the microcontroller through a GSM module. Then the microcontroller decides the necessity of water to the field using the soil wetness along with the sensor values and transmits the information to the farmer through SMS.

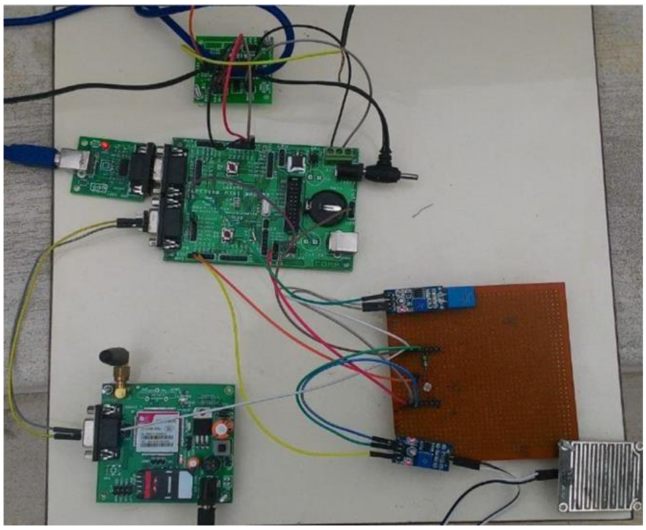


Fig. 7. Hardware setup of the control unit.

The control module of the proposed irrigation system is shown in Fig. 7.

The environmental conditions such as soil wetness, temperature, humidity level, light intensity, rain status and motor condition are shown in Fig. 7 and the information sent to the farmer mobile phone via SMS is shown in Fig. 8.

The prevailing climatic conditions of the agricultural field were observed using proposed irrigation system continuously for a period of 15 days in the month of March 2016 and its maximum and minimum values are plotted in the form of graph as shown in Figs. 9 and 10.

The proposed irrigation system is tested in the paddy field of area one acre and the amount of water required for differ- ent stages of paddy growth is calculated. The estimated amount of water for the proposed irrigation is compared with the existing irrigation systems and the values are tabulated in Table 1.

From the Table 1, it is noticeable that all the three irrigation methods utilize the same amount of water for the field preparation, and the proposed smart drip irrigation system saves a considerable amount of water for the remaining stages of paddy cultivation compared to the existing irrigation methods. The proposed system utilizes only 58.57% of water and saves 41.43% of water compared to the manual flood irrigation method, and also utilizes only 86.97% of water and saves 13.03% of water compared to drip irrigation method. In proposed smart sensor based irrigation system, the percentage of water saving is increased because it utilizes the environmental factors for switching ON and OFF the irrigation motor.

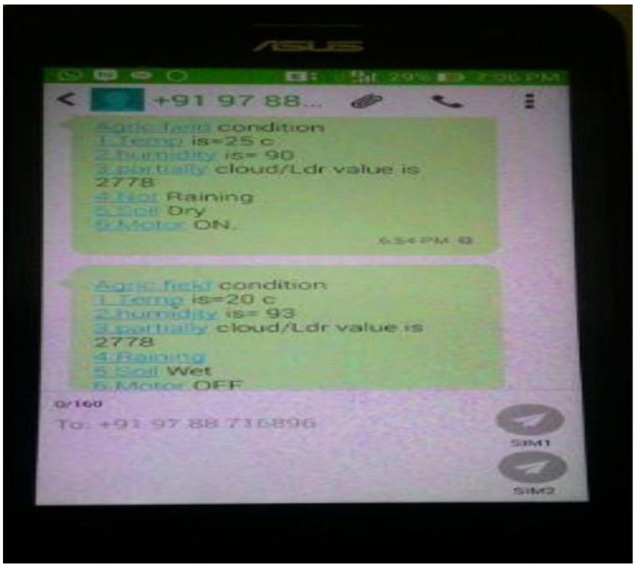


Fig. 8.Forwarded SMS information to Farmer's mobile phone.

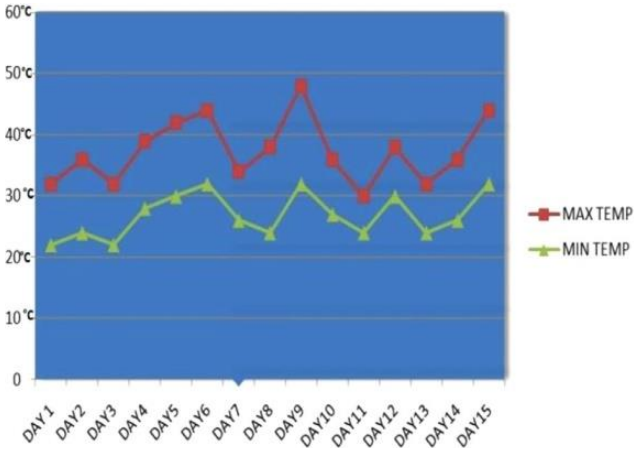


Fig. 9. Humidity (%)

Table 1Estimated amount of water for different irrigation techniques

Stages of Growth	Manual – Flood Irrigation (mm)	Drip Irrigation (mm)	Smart Drip Irrigation Method (mm)
Field Preparation	200 – 300	200 – 300	200 – 300
Planting	400 – 450	300 – 400	300 – 350
Flowering	400 – 450	100 – 200	100 – 150
Maturity	100 – 150	50 – 100	10 – 25
Total Span (100%)	1100 – 1350	650 – 1000	610 – 825
Average	1225	825	717.5

The average amount of water utilized for one acre of paddy cultivated land is shown in Fig. 20 and the percentile com- parison of water used for manual flood irrigation, drip irrigation and the proposed irrigation methods are shown in Fig. 21. From Fig. 21, it is evident that in all the categories of utilization, the proposed shows best among the remaining methods. With respect to the Flood irrigation, if it requires 100% of water level, then the drip and proposed smart system need only 67.35 and 58.57% respectively. Similarly, if the Drip irrigation requires 100% of water level, then with the proposed, it can be said that it is enough to have 86.97% to grow the paddy. When the proposed utilizes 100% of water level, then the remaining systems require higher percentage, i.e., 70% and 14.98% higher for the flood and the drip correspondingly.

Then, the average percentage of water needed for cultivating the crop for one acre of land for the proposed smart system in comparison with the traditional flood and drip irrigation system is represented in Fig. 22 as a pie chart. From the figure, it is clearly stated that the proposed system comparatively requires a lesser amount of water and it outperforms than the existing systems.

V. Conclusion

For the effective utilization of the water in agriculture, it is mandatory to have a system which can support the farmer and act as a guide to irrigate their fields. It is obvious that rainwater and the groundwater levels are decreasing day-by- day, thereby increasing the requirement of new systems to utilize the water resources effectively for agriculture. And it is a known fact that the economy and growth of a country purely depends on the agricultural income. Tamilnadu is found to be a major paddy growing state in India due to its favourable climatic conditions and it is a major source of food for the people. By considering all these factors, a smart sensor based system for drip irrigation is designed, implemented and tested particularly for the paddy. The smart sensor based automatic drip irrigation system is implemented in an acre of paddy field and it is observed that the experimental results are very much encouraging compared to the other state-of-art methods. The proposed android application of the smartphone captures the soil image, computes the wetness of the soil, and transmits the data onto the microcontroller through the GSM module present in it. The system decides the necessity of irrigation according to the values received by the microcontroller such as sensor outputs and the images captured by the smartphone. From the test results, it is observed that the proposed smart sensor based irrigation system consumes only 58.57% and 86.97% of water compared to the flood and drip irrigation respectively. It is seen that the proposed saves water nearly

41.43% when compared to the flood irrigation and 13.03% when compared to drip irrigation. Due to the non-contact and non-invasive setup, it is sure that the system will increase the productivity of crop and also it can aid the farmers in making decisions for the irrigation to improve the cultivation of the crops. By using the cutting-edge technologies in agriculture, the overall production cost of the crop will be reduced and the time can also be saved by reducing the human interventions in the irrigation. In future, the work can be extended to a large scale by incorporating the wireless sensor networks in the agricultural fields.

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