SMART PLANT IRRIGATION: AN AUTOMATED SOLUTION FOR EFFICIENT WATER MANAGEMENT

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ABSTRACT

We present in this chapter the automatic plant watering system, which is among the most applied and the most useful automated systems nowadays. This helps assist people in their daily life by reducing or fully substituting their effort. This system uses sensor technology along with microcontroller and other electronics in order to behave like smart switching system which senses soil moisture level and irrigates the plant if necessary. This work aims to show that someone can easily make own and cheap automatic plant watering system in just few hours by connecting certain electronic components and other materials required. We connected all the required materials just as shown in this paper in our experiment so that we will be able to test whether our system will work properly or not. Although that system, designed in that way, would be the most apt for household use as the answer to some every day and familiar problems, a broad range of possibilities in implementing these systems to form a long-term solution to most of the agricultural and medicinal issues, some of them most pressing, dangerous, and vital, such as undernourishment and air pollution. This system, being one of the possible agricultural solutions, can be very helpful in keeping vegetables and other useful and specific plants watered for bigger harvest, which enables farmers from all around the world to breed crops of these plants which are the most wanted and the most commonly used in diet. These systems can be used for the purpose of cultivating certain plants that are famous and well known by their ability to remove air pollutants and therefore reduce the concentration of toxic pollutants in the air as well the occurrence of respiratory diseases. Some of the ideas are quite challenging and demanding, such as grouping plants of similar variety and characteristics into complex connections of plants, called "Internet of plants.". There are also many other possibilities like using more than one sensor or solar power supply for experimental purposes, but the fact is however, that, independently of the materials used and the way in which they are connected, this type of automated systems can be very helpful in solving very wide of human-related problems nowadays.

Keywords: *Automated Irrigation System, Soil Moisture Optimization, Sustainable Agriculture, IoT in Agriculture, Plant Growth Efficiency.*

1. INTRODUCTION

Today is the age of advanced electronics and technology, and by this, human life has to be simple and uncomplicated. So now, it demands many types of automation systems, which can automatically replace or reduce human efforts in daily activities and works. Here we introduce one such system, named as an automatic plant watering system, which is actually a model of controlling irrigation facilities using sensor technology to sense soil moisture with a microcontroller to make a smart switching device to help millions of people. Can we automatically water our home and garden plants without disturbing our neighbors when we decide to go on vacation or somewhere else for a long period? Since irregular watering leads to mineral loss in the soil and might end up with rotting the plants, can we then somehow know if the soil really needs to be watered and if so, when exactly do we have to water the plants? Is it possible in any way from remote location to manage our plants to be watered? These are some questions that one can hear very often, and an answer to all of them is encouraging and affirmative, since advanced technology gives us an extremely wide range of possibilities nowadays. Actually, there is a very simple and economical solution for all these questions and perplexities. The requirement of the solution is just a little bit of knowledge in electronics as well as that knowledge relating to botany and plant physiology in the form of unique intersection between biological engineering and electronics.

2. LITERATURE REVIEW

Youness Tace, Mohamed Tabaa, etc., in the year 2022 said the work done is the prediction of irrigation, starting from the creation of a database using a data acquisition card with multiple sensors (Soil humidity sensor, temperature and humidity sensor, rain sensors) and the Node- RED platform in their paper [1]. Thanwamas Kassanuk, Malik Mustafa, etc., in the paper "An Internet of Things and Cloud Based Smart Irrigation System." said that Plants absorb water from saturated soil and, through the ET process of transpiring water into the atmosphere while sucking in nutrients dissolved with water in the soil for roots development. The system uses sensors for collecting real-time data concerning irrigation, saves it in cloud data owner issues a command, and dependent upon the results, necessary action is taken in the year 2021 [2]. In the year 2021 M., Nugraheni, M. & Suyoto, S. (2021), etc., in the paper. Said that the work was to design the Internet of Things for small gardens inside houses using Wireless networks and sensors [3]. In the paper "Automated irrigation system based on soil moisture using arduino board." in year 2020, A. Hamoodi, S., N.Hamoodi, etc., said that In this following work, solar irrigation plant is proposed with an automated controlled system. The data about the proper level of water in engineering technical college-Mosul Garden are collected by moisture sensor and update [4]. Md. Sajid Abbas, etc., in 2019 said in their paper "Automatic Plant Irrigation System" that it monitors the soil moisture content with a soil moisture sensor and the water level of the tank with a float switch. A solar powered automatic irrigated system that would use water in more organized way which will prevent excess water loss and minimize the human efforts [5].

Senpinar, etc., in their paper "Automatic photovoltaic irrigation system" in the year 2019 said that the work done is to pump the required water flow to one, or more than one, irrigation sector depending on the generated PV power, the power required for irrigation of each of these sectors and the volume Amount of water required to irrigate such sectors. [6]

In the year 2019 Md Sajid Abbas, Md Aswer Mohiddin, etc., in the paper "Automatic plant irrigation system" said that This paper deals with an automatic irrigation system senses the moi sture content of the soil and automatically switches the pump when the power is on. In this project, an automation of farm irrigation and soil moisture control by Arduino using soil moisture se nsor and L293D module [7]. In the paper "Smart crop-field monitoring and automation irrigation system using IOT." In the year 2019 Rajeshkumar N, Vaishnavi B, etc., said that a low complex circuitry precision agriculture irrigation system is developed. Two sensors and raspberry pi microcontrollers are successfully interfaced. All observations and experimental tests prove that the proposed system is a complete solution to field activities, irrigation problems [8]. In the year 2019, Saparso, & Ramadhani, etc., said in their paper "Time based automatic system of drip and sprinkler irrigation for horticulture cultivation on coastal area." That Automatic watering system based on the supplying schedule with Arduino minimum system could be built from the desired time of scheduling irrigation. The system also controls the water level in the reservoir and measures the condition of soil moisture. Test results prove that the system is able to work according to the given program flowchart designed. This system offers flexibility and accuracy in respect of time set for the operation of a sprinkler and drip irrigation [9]. Sadiq, Mohammad Tanvir, MA Munaim Hossain, etc., in the year 2019 in their paper “Automated Irrigation System: Controlling Irrigation through Wireless Sensor Network” said that the automated irrigation process system involves an arrangement of sensors in the cultivation of field, Wireless transmission of the sensor data using RF transmitter and a control system to evaluate the data to our required level and manage proper running of the irrigation pump [10].

In the paper “A review on solar based plant irrigation system” Khandare, S., Alone, said that the model always makes sure there is enough level of water in the paddy field avoiding under irrigation and over-irrigation. Farmerscan make remote ON/OFF switches for themotorby their cell phones evenfrom anywhe re. Password protection has secured the system for a restricted number of users. Solar power makes sure of the adequate supply of power to drive the system in the year 2018 [11]. C Ashwini, Diparna Adhikary, etc., in their paper “Automatic irrigation system using Arduino” said that by using this system doesn't require a lot of man power and time. By using an app farmer can operate the system from distant places. Thus, this system can be very useful in areas where wateris in short supply in the year 2018 [12]. C. M. Devika, K. Bose and S. Vijayalekshmy in the year 2017 in their paper “Automatic plant irrigation system” said that this system uses AtMega328 microcontroller. It is programmed to sense the moisture content if the soil over a period of time. When the moisture content is less than the limit which is predefined, it will start supplying the desired amount of water till it reaches the limit. So, when the soil is dry the pump will automatically water the fields [13].

In the year 2017 Bishnu Deo Kumar, Prachi Srivastava, etc., in their paper “Microcontroller based automatic plant irrigation system” said that the ATMEGA 328 microcontroller controls the entire system and provides interrupt signals to the motor. A temperature sensor and humidity sensor is connected with internal ports of micro-controller using comparator, whenever there will be fluctuations in temperature and humidity of environment these sensors senses the change in temperature and humidity and gives an interrupt signal to the microcontroller, thus themotor will get activated along with this, buzzer is used in this to indicate that pumpis on [14] Chirag Soni, Dashrath Das Vaishnav, etc., in the year 2017 in their paper“Microcontroller based automatic plant irrigation system” said that using this system, farmers will get protection while doing the inrigation work in extriemely odd weather conditions, hard work of repeated assembly and will get rid of Poisonous reptiles. The system works even at night and doesn't require the physical presence to run this system. [15]

In the paper “Automatic plant watering system” Abhishek Gupta, Shailesh Kumawat, etc., said that in this project, they construct moisture sensors measure the moisture level of the different plants. So, then the microcontroller instructs the water to be released or stopped as per when the humidity is high or low in different plants in the year 2016 [16]. In the year 2015 in the paper “Agarian- Automatic plant irrigation system” explains that reduces soil erosion and nutrient leaching. Prevents the chance of plant disease by keeping foilage dry [17]. L Oborkhale, AE Abioye, etc., in their paper “Automatic plant irrigation system” said that This control system is based on ATMEGA32 microcontroller, programmed using embedded C language. Inputs are the signals from four sensors namely soil moisture sensor using hygrometer module, water level sensor using the LM 324 Op-amp was here configured as comparator, light sensor with the aid of Light dependent resistor and temperature sensor using LM 35. The microcontroller processes the input signals by utilizing the control software embedded in its internal ROM to generate three output signals, using oneof the output signals to control a water pump that irrigates the garden, the second output signals to control a water pump that draws water from the river to the reservoir or storage tank while the other to switch a buzzer that alerts the gardener when there is shortage of water in a tank that supplies the garden. This project can be applied in any type of agricultural area where there is the r eadiness of water for irrigation in the year 2015 [18].

Venkata Naga, Rohit Gunturi in the year 2014 in their paper "Microcontroller based automated irrigation system" said that nn this project, an effort has been made to automate farm or nursery irrigation in such a way that farmers could apply the right amount of water at the right time regardless of the availability of labor to turn valves on and off. In addition, with automation equipment, the irrigation farmers can avoid the issue of runoff from overwatered saturated soils and the poor timing of irrigation, as improve d crop performance will be seen on the farm through ensuring enough supplies of water and nutrients by the plants when necessary. The Microcontroller based automated irrigation system consists of moisture sensors, analogy to digital converter, microcontroller, relay driver, solenoid valve, solar panel and a battery. This system can be used in the areas where electrical power is difficult to obtain. This system is eco-friendly and it uses a renewable source of energy [19]. Mr Sundar Ganesh in his paper "Efficient Automatic Plant Irrigation System using ATMEGA Microcontroller." In the year 2013 said that this system saves Labour cost and water and gives the highest return for the least amount of water [20]. In the paper "Microcontroller based automatic plant irrigation System." Venkata Naga Rohit Gunturi said that this system saves extra waters, Continuous water helps to improve growth, water delivered only where it's needed, Saves time and helps to control fungal diseases in the year 2013 [21].

In the year 2007 Cáceres, R., J. Casadesús, etc., in their paper "Adaptation of an Automatic Irrigation-control Tray System for Outdoor Nurseries." Said that this project uses The irrigation-control tray method (1CT), The prototype was used to water plants in the entire experiment (18months). It has been shown that there are no significant differences (Probably<5%) in growth between plants located in the microperforated mesh and plants located in the irrigation-control tray [22]. Benzekri, Azzouz, etc., in their paper "PC-Based Automation of a Multi-Mode Control for an Irrigation System" in 2007 said that the system uses in-situ soil water. Potential measurements, the weather condition parameters, and the set points data provided by the user decide when and how much water to apply to the irrigated field. A microprocessor-based data acquisition and distribution controller system is used by under the supervision of the host computer that monitors soil moisture content, and, the climatic parameters. A bi-directional serial link allows the host computer to receive, store, and display in real time the overall status of the system on the screen of the PC [23]. Abraham, N., Hema, etc., in the year 2006 in their paper "Irrigation automation based on soil electrical conductivity and leaf temperature." Said that the experiment was performed at Malappuram district of Kerala, India.The soil at the site was sandy loam. Two experimental plots were selected, each of area 2 m × 2 m.The sensor using brass plate as electrode and washed sand as the porous medium had showed nearly a constant trend in the relationship between resistance and soil moisture content in alltrials [24]. In the paper "Automatic Irrigation Based on Soil Moisture." from the year 2005 Muñoz-Carpena, R., etc., said that This irrigation controller has been developed that uses a voltage signal [25]. In the year 2001 Ayars, J. E., Schoneman, etc., said in their paper "Managing subsurface drip irrigation in the presence of shallow ground water." That five different types of drip irrigation tubing installed at a depth of 0.4 m with lateral spacings of 1.6 and 2 m on 2.4 ha plots of both cotton and tomato. Approximately 40% of the cotton water requirement and 10% of the tomato water requirement were fulfilled by shallow (<2 m) saline (5 dS/m) ground water [26]. Munoz-Carpena, R., Bryan, H., & Klassen, etc., in the year 2003 explained that A research and demonstration project was conducted on a commercial tomato farm, Pine Island Farms, Miami, Fla from their paper [27].

In the year 2000, Noble Abraham, P.S Hema, etc., in their paper “Irrigation automation based on soil electrical conductivity and leaf temperature.” Said that the measurement of resistance in the field using gypsum block showed that when the polarity across the electrodes changed, the resistance readings [28]. In the paper in the year 1998 AU - Singels, A., AU - Kennedy, etc., said that all sugarcane grown in the Burdekin is irrigated. Most farms are irrigated by flooding the furrows between the rows of cane, which is labour and water intensive but relatively cheap to establish. Drip irrigation comprises rows of plastic tube buried underground that deliver water directly to the roots of the plant through tiny emitters that regulate water flow. It uses much less water than traditional farming, increases its yield, and improves water quality that runs off a farm [29].

3.1. MATERIALS REQUIRED

Although there are some companies selling these systems made in various ways, there exists a simple way in which one can build his or her own plant watering system in just a few hours if all required materials are available alongside with basic required knowledge of electronics. For the sake of building this system, one will need to appropriately connect the following:

- ❖ ESP32 DEV KIT V1
- ❖ Capacitive soil moisture sensor V2.0
- ❖ DHT11 Sensor
- ❖ 0.96″ OLED Display
- ❖ 1k 0.25watt Resistors (R1-R6) – 6 no
- ❖ 1N4007 diode
- ❖ BC547 NPN Transistor
- ❖ TIP122 NPN Transistor with heat sink
- ❖ LEDs 5mm – 4no
- ❖ 7805 voltage regulator with heat sink
- ❖ 2-pin Push Button – 2no
- ❖ 2-pin Terminal connectors (2 no)
- ❖ 3-pin Terminal connectors (1 no)
- ❖ 5V DC Buzzer
- ❖ 100uF 25V capacitor (C1)
- ❖ 100nF 330nF AC capacitors (C1, C2)
- ❖ 12V DC pump or solenoid valve
- ❖ 12VDC Supply

3.2. WORKING PROCESS

The working principle to this system is connecting the embedded soil moisture sensor in the plant to the Arduino microcontroller, which is attached to other electronic components indicated above. Measurement is done by the sensor with information and parameters forwarded to the microcontroller regarding the status of the soil moisture, to control the pump. If the soil moisture is below a certain level, the microcontroller sends a signal to the relay module, which turns on the pump and some water reaches the plant. The microcontroller stops the operation since the pump delivers enough water to the plant. The supply has a role to play to power the entire circuit and the applied voltage has to be well within the input supply range for the microcontroller which is that is between 7V to 12V. A relay module, in simpler words, refers to an easily understood circuit built with some simple transistor, multiple resistors, diodes, and of course the relay and these are under digital control of the microcontroller. Since the complete system needs to be placed in a small box, Arduino Nano is the best microcontroller in view of its dimensions and performance.

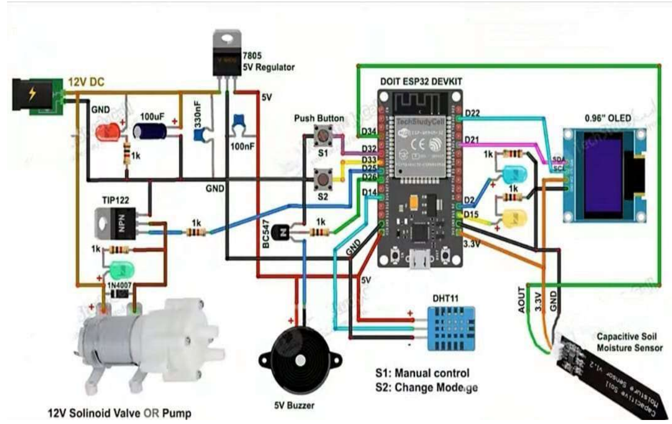

Figure 1: Circuit diagram of the system

The soil moisture module comprises two parts: amplifier circuit and probes. This module has digital and analog outputs, where digital output is set to logical 1 when the threshold is activated. The threshold is set by the potentiometer. Analog output offers the real time information pertaining to the moisture in the plant and this output is made use of in the system. Water pump is linked to the relay module, and it only functions whenever the relay module receives an instruction from the microcontroller, whose working principle is illustrated via flow chart diagram given below as well as through the following pseudocode:

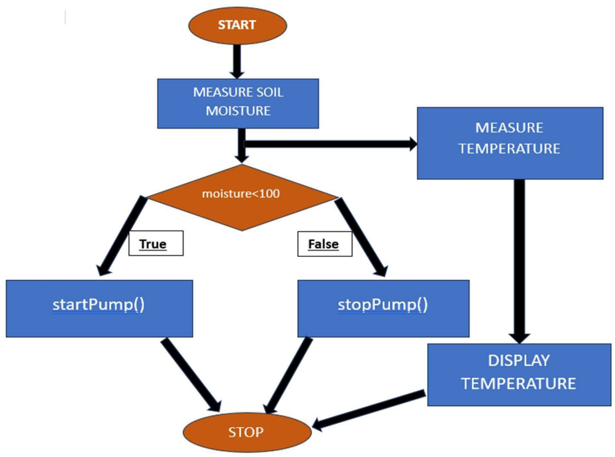

Figure 2: Flow Chart to show the logic of the system

In Figure 2 the flowchart shows the system logic, for controlling the pump whe n soil moisture levels become low enough and displaying the temperature reading.
Here are the steps with explanations on how to navigate the flow:
Start: The process starts from the "START" node.

Measure Soil Moisture: First, it measures the soil moisture.

Decision: Moisture < 100:

If the soil is dry, meaning the moistures in the soil levels are less than 100, the system follows the path to the True branch then starts the pump by starting the function startPump().

If the moistures in the soil levels range from 100 or more to indicate sufficient moisture, the system follows the path to the False branch then stops the pump.
Temperature Measured Regardless of the condition o f the pump, temperature is measured by the system as well.

Temperature Display Measured temperature is displayed in order to monitor it
STOP The process ends in the "STOP" node.

4. RESULTS

Below is the result of our experiment shown in Figure 3 in the form of the overall representation of our tested automatic plant watering system based on Arduino microcontroller and sensor technology. It can be concluded from the picture below that the system has been designed and successfully tested in a successful way. Also, functionality of the system along with overall behavior of the plant was observed in the next 30 days and was in results of good as was expected and wished. As a result of our observation, we found that the plant kept its homeostasis of the very desired, regular, healthy manner without any deficiency shown by the plant. Once the sensor detected a need for water, the microcontroller signaled the pump to begin watering the plant until it had delivered enough volume of water.

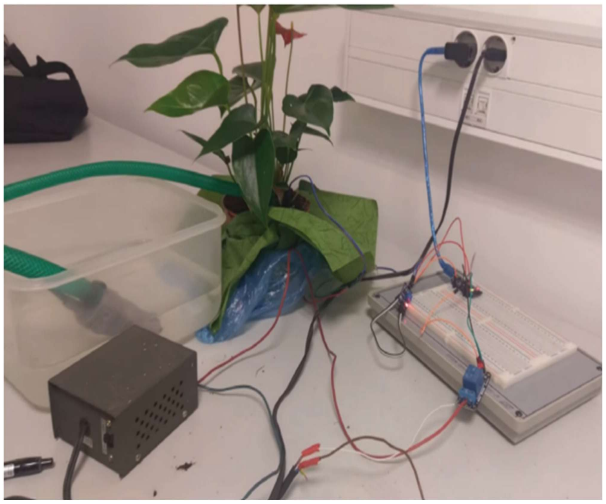

Figure 3: Result showing the working of the system

4.1. METHODOLOGY USED

This system manages a water pump based on soil moisture levels while monitoring and displaying temperature readings. Here's how it works in detail:

Process Start:

The process initiates at the "START" node, which initializes the system. This means that all the required components, like sensors and controllers, will be ready to work.

Measuring Soil Moisture:

After initialization, the system measures the soil moisture using a moisture sensor. This is the most important step because it will tell whether the soil is moist enough or needs to be watered. The moisture sensor gives a value that the system analyzes.

Decision Based on Moisture Level:

The system checks whether the measured moisture in the soil is less than the threshold defined. In this case, the threshold is 100, which means the minimum amount of moisture acceptable for the soil:

If Moisture < 100 (Dry Soil):

The system will read it as the soil is dry and needs water. This system calls the startPump() function to start up the water pump so that the soil will be adequately moistened.

If Moisture ≥ 100 (Sufficient Moisture):

The system identifies that the soil is already moist. It then invokes the stopPump() function to shut off the pump, saving water and other resources.

Temperature Measurement:

Regardless of whether the pump is turned on or off, the system also measures the ambient temperature by using a temperature sensor. This step enables monitoring environmental conditions, which may affect plant growth and soil conditions.

Displaying Temperature:

The system displays the measured temperature. It will give an output that can be used by farmers or operators to monitor the surrounding environment and make a decision if necessary. This means that it makes things transparent, providing useful information on the conditions in which the system operates.

Conclusion of the Process:

Finally, the system reaches the "STOP" node that indicates this particular run of the process is over. Now, it can stay idle or continue the process depending upon its program to continuously monitor and control the irrigation.

4.2. CONTRIBUTION AND USES

The farmers from all around the globe would be able to grow and breed the crops and plantations of those plants which are the most crucial, wanted and consumed at the moment in the diet. Besides obvious and some listed benefits and utilities in the field of agriculture, this system has many applications for medical purposes.

This system may be used as a medical solution in cultivating some plants that are effective in removing air pollutants and also prevent and reduce respiratory diseases and lung dysfunctions, which will contribute to better air and living quality. Therefore, using this system people are able to automatically irrigate and cultivate medically significant and famous plants such are medical herbs, weeping fi g, ferns etc., which contribute to the reduction of dangerous, harmful and toxic air pollutants and pesticides like CO, CO_2, formaldehyde, benzene etc. Also, it would make someone able save the money on medicine. The above-mentioned problems include such lengthy procedures as the use of water for plants manually. Moreover, the problem of overuse of water is there as, at times, while giving water to plants manually, people end up providing more water to a plant than it requires and leads to several adverse effects.

5. CONCLUSION AND FUTURE POSSIBILITIES

Though it looks more challenging and demanding, there are many other possibilities such as developing complex connections of plants of similar variety or so-called »Internet of Plants«. Another idea for an experimental venture is using more than one sensor, though there are also many other experimental and challenge-like ideas such as using solar power supply, timer for setting irrigation system etc. However, regardless of the way used to construct it, there is no doubt that this system can be very helpful in solving many problems, from those that seem harmless to those that are on the scale of the most important and most dangerous ones for human population. By means of this system, it is possible to control the amount of water released from the process of watering the plant. Although it can be very useful for humanity in general, it will perhaps benefit most the agriculturists, craftsmen, and botanists.

REFERENCES

[1] Youness Tace, Mohamed Tabaa, Sanaa Elfilali, Cherkaoui Leghris, Hassna Bensag, Eric Renault, Smart irrigation system based on IoT and machine learning, Energy Reports, Volume 8, Supplement 9, 2022, Pages 1025-1036, ISSN 2352-4847.

[2] Thanwamas Kassanuk, Malik Mustafa, Dr. Prashant Panse, Sivanand.R, Khongdet Phasinam, Thakur Santosh. (2021). An Internet of Things and Cloud Based Smart Irrigation System. Annals of the Romanian Society for Cell Biology, 20010–20016.

[3] Astutiningtyas, M., Nugraheni, M. & Suyoto, S. (2021). Automatic Plants Watering System for Small Garden. International Association of Online Engineering.

[4] A. Hamoodi, S., N.Hamoodi, A., & M.Haydar, G. (2020). Automated irrigation system based on soil moisture using arduino board. Bulletin of Electrical Engineering and Informatics, 9(3), 870-876.

[5] Md. Sajid Abbas | Md. Aswer Mohiddin | N. Y. S. Pavan Teja | Ch. Nanda Kumar "Automatic Plant Irrigation System" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-3 | Issue-3, April 2019, pp.12391241.

[6] Senpinar, A. Internet-/Arduino-controlled PV automatic irrigation system for clean environment. Int. J. Environ. Sci. Technol. 16, 5185–5196 (2019).

[7] Md Sajid Abbas, Md Aswer Mohiddin, NYS Pavan Teja, Ch Nanda Kumar International Journal of Trend in Scientific Research andDevelopment 3 (3), 1239-1241, 2019.

[8] Rajeshkumar N, Vaishnavi B, Saraniya K, Surabhi C. Smart crop field monitoring and automation irrigation system using IoT. Int Res J Eng Technol (IRJET). 2019

[9] Sudarmaji, A., Sahirman, S., Saparso, & Ramadhani, Y. (2019, April). Time based automatic system of drip and sprinkler irrigation for horticulture cultivation on coastal area. In IOP Conference Series: Earth and Environmental Science (Vol. 250, p. 012074). IOP Publishing.

[10] Sadiq, Mohammad Tanvir, MA Munaim Hossain, Ken Fahmidur Rahman, and Ahmad Sayeed Sayem. "Automated irrigation system: controlling irrigation through wireless sensor network." Int J Electr Electron Eng 7, no. 2 (2019): 33-37.

[11] Khandare, S., Alone, A., Patil, S., & Raut, P. (2018). A Review on Solar Based Plant Irrigation System. International Research Journal of Engineering and Technology (IRJET), 5(2), 1516-1518.

[12] C Ashwini, Diparna Adhikary, Amisha Mishra, Shruti Duggal Int. Res. J. Eng. Technol. (IRJET) 5 (10), 2018

[13] C. M. Devika, K. Bose and S. Vijayalekshmy, "Automatic plant irrigation system using Arduino," 2017 IEEE International Conference on Circuits and Systems (ICCS), Thiruvananthapuram, India, 2017, pp. 384-387, doi: 10.1109/ICCS1.2017.8326027.

[14] Bishnu Deo Kumar, Prachi Srivastava, Reetika Agrawal, Vanya Tiwari, International Research Journal of Engineering and Techn ology 4 (5), 1436-1439, 2017

[15] Chirag Soni, Dashrath Das Vaishnav, Deepak Bairwa, Harshit Mittal, Harshit Vijayvargiya, A Vijavargiya, Vikram Singh Int J Tech Res Sci, 2017

[16] Abhishek Gupta, Shailesh Kumawat, Shubham Garg, Imperial journal of interdisciplinary research (IJIR) 2 (4), 1123 -1127, 2016

[17] Tanveer Anand International Journal of Computer Applications 975, 8887, 2015

[18] L Oborkhale, AE Abioye, B Egonwa, T Olalekan, IOSR Journal of Computer Engineering (IOSR-JCE) 17 (4), 99-111, 2015

[19] Venkata Naga Rohit Gunturi, International Journal of Advancements in Research & Technology 2 (4), 194-198, 2013

[20] Mr Sundar Ganesh, International Journal of Emerging Trends in Electrical and Electronics (IJETEE) 7 (1), 49-52, 2013

[21] Venkata Naga Rohit Gunturi, International Journal of Advancements in Research & Technology 2 (4), 194-198, 2013

[22] Cáceres, R., J. Casadesús, and O. Marfà. "Adaptation of an automatic irrigation-control tray system for outdoor nurseries." *Biosystems engineering* 96.3 (2007): 419-425.

[23] Benzekri, Azzouz, Kamal Meghriche, and Larbi Refoufi. "PC-based automation of a multimode control for an irrigation system." 2007 International Symposium on Industrial Embedded Systems. IEEE, 2007.

[24] Abraham, N., Hema, P. S., Saritha, E. K., & Subramannian, S. (2000). Irrigation automation based on soil electrical conductivity and leaf temperature. Agricultural Water Management, 45(2), 145-157

[25] Muñoz-Carpena, R., & Dukes, M. D. (2005) Automatic Irrigation Based on Soil Moisture for Vegetable Crops: ABE356/AE354, 6/2005.EDIS, 2005(8).

[26] Ayars, J. E., Schoneman, R. A., Dale, F., Meso, B., & Shouse, P. (2001). Managing subsurface drip irrigation in the presence of shallow ground water. Agricultural Water Management, 47(3), 243-264.

[27] Munoz-Carpena, R., Bryan, H., & Klassen, W. (2003, December). Automatic soil moisture-based drip irrigation for improving tomato production. In Proceedings of the Florida State Horticultural Society (Vol. 116, pp. 80-85).

[28] Noble Abraham, P.S Hema, E.K Saritha, Shinoj Subramannian, Irrigation automation based on soil electrical conductivity and leaf temperature, Agricultural Water Management, Volume 45, Issue 2, 2000, Pages 145-157, ISSN 0378-3774.

[29] TY - JOUR, AU - Singels, A., AU - Kennedy, Aj, AU - Bezuidenhout, Cn, PY - 1998/01/01,SP - , T1 - IRRICANE: A simple computerised irrigation scheduling method for sugarcane, VL - 72, JO - Proceedings South African Sugar Technologists' Association.