IoT based smart irrigation system

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***Abstract*—It presents a smart irrigation system, which is used to optimize the usage of water and improve the productivity rate of crops in the Agricultural Sector. A Graphical User Interface (GUI) over the Blynk cloud server, was developed to control and monitor the proposed system. The developed system was evaluated over a period of 7 days and the outcomes were satisfying with a total of 300 ml of water for the 2 irrigations performed over 4 sections of the farm which were represented by 4 containers of 1,728 cubic centimeters each fully filled with Sandy soil. The soil was kept moisturized at an average value of 50%, with an average soil temperature of 29.89^{0} C, and with an average Ph concentration of 6 ppm. The vegetable used for the experiment, going by the name Caixin Green Stem, requires 8 to 12 days for the germination phase and that was achieved within 7 days only. The statistics illustrated that the smart irrigation system performs better than the traditional/manual irrigation method.**

Keywords— ***Induction under Blynk, cloud server, GUI.***

I. INTRODUCTION

Agricultural sector is one of the most important economic factors of a country and it needs an implementation of modern technologies applied efficiently that could simplify agricultural process and make them automated. Hence, bringing about the practice of smart farming. Smart farming is an innovation to the current agricultural techniques that has improved the production rate in a sustainable way. It is the application of connected devices and innovative technologies into agriculture. Internet of Things (IoT) devices are being employed for automatic monitoring systems [1-5]. The implementation of an IoT based smart irrigation system improves the agriculture system by monitoring and controlling the field in real-time as compared to the traditional irrigation system [6].

Smart irrigation systems offer a variety of advantages. The aim of this practice is to optimize and to reduce water wastage. And this is done by using wireless sensing devices that communicate with the smart irrigation controls and help inform the system whether the crop field needs water or not [7]. Smart irrigation systems allow to have a better control of the field as well as the irrigation need. They are cost efficient as they help in reducing water bills through intelligent control and automation. The system will optimize resources so that everything gets what it needs without needless waste. Therefore, this can be an asset for a good management of the resources which can be beneficial for the environment. The opportunity to save dramatically, have better control and be eco-friendlier while maintaining a beautiful field are just few of the advantages a smart irrigation system can provide [8].

The agricultural sector is today suffering of low productivity due to the non-consideration of appropriate irrigation tools and techniques when establishing plantations or farms. A good Irrigation system is the key point to the global productivity of a farm. Well irrigated crops represent 40% of the overall crop production while being cultivated on 20% on the total land surface.

Irrigation Is known to be the action of systematically supplying water to land with the aim of agricultural production. The common technical issue encountered with traditional irrigation techniques is the inaccurate distribution and application of water on the field which lead to low production, and another point is the wrong management of water resources. All these factors put together lead to the need of developing or designing modern irrigation techniques aiming to improve the efficiency of irrigation. However, the implementation of the right irrigation system requires a knowledge of the equipment such as, plant species, growth stages, the system design, root structures, soil composition, and land formation [9].

In summary, this work focused on the development of an IoT based smart irrigation system for crop control and monitoring. Physical parameters and climatic conditions such as water distribution, temperature, weather, soil moisture, etc., will all be monitored using IoT, weather cloud, and cloud computing system with the purpose of improving the rate of production and crop quality.

II. LITERATURE REVIEW

The researchers [10] proposed a smart water management system to overcome the problem of water insufficiency for different parts of Africa where irrigation is still practiced manually. The system comprises a soil moisture sensor and an ultrasonic sensor. The sensed information from the sensors are sent to the Atmega382 microcontroller here considered as the servo of the whole system in form of electronic signal. Based on the signal received the microcontroller then computes the appropriate action regarding the irrigation.

The monitoring system was proposed for irrigation that works in both manual and autonomous modes. This system has a server where data such as rate of irrigation, rate of plant growth, and the physical factors (temperature, humidity, soil moisture content, major air pollutants PM2.5, PM10, CO, NOx) are continuously uploaded for the purpose of machine learning. The manual mode consists in selecting the rate at which the water is released from the pumps, and for how long the watering will be done. In the autonomous mode, the system analyses the data previously uploaded in the server then decides the ideal rate of irrigation. It could be observed that the system comprises two processes consisting in receiving and transmitting data [11].

During the transmitting process, various parameters are collected from the sensors placed in the field such as temperature, humidity, and rate of plant growth. Once these parameters are collected, they are sent to the receiver part which in turn sends them to the server using a GSM module. The server considered as the servo of the whole system, direct which pump to deploy in a concerned area and predict whether the irrigation is necessary or not based on the analyses performed on the data continuously sent to the server from the field.

It was proposed a low-cost smart irrigation system along with monitoring of weather parameters and providing security to the field. The proposed method uses NodeMCU as micro controller, which is integrated with Ph sensor, PIR Sensor, Soil Moisture Sensor, Relay and DC Motor. Ph sensor used to determine the type of crops of be grown using the ph. value of the soil through the mobile phone. The watering mechanism controlled by a motor depends in the dampness level of the soil which is set to different threshold values for each operation [12].

The author also established a protocol for field protection which works using a the PIR sensor by detecting unusual motion in the field and notify the farmer through IFTTT. PIR Sensor will also be monitoring continuously and if anyone is detected email alert will be sent to the farmer through IFTTT. The climatic parameters like temperature, humidity, wind speed, clouds around the location of the crop can be taken from the open weather map API. This data is stored in the cloud for future reference and can be monitored through the mobile application provided to the farmer.

The authors Sahu and Verma proposed an automated smart irrigation system to control and monitor sprinklers operation to ensure a proper distribution of water based on the soil demand. The system comprises a Soil moisture sensor, humidity and temperature sensor all connected to a Raspberry Pi through a signal conditioning and comparator circuit. To control the water distribution, the variation in resistance from the output of the sensors are sent to both signal conditioning and comparator circuit where thresholds values are set based on different moisture level using a potentiometer. Therefore, the water motor is switched on when the moisture value, humidity and temperature are all above the moisture level and switched off when these values drop below using a relay. To drive the relay, the author used a driver circuit which converts low voltage to high voltage enough to direct the relay that needs 12 V to operate. The researcher has also provided a weather forecast report which allow the system to check the probabilities of rainy days on that area [13].

To optimize the existing plant monitoring system, it was proposed a system that control environmental parameter namely the air temperature, the soil moisture, and the air humidity using the basis of IoT integrated with the MQTT protocol for remote control of the operation [14].

The research on hydroponic system suggest usage of IoT (Internet of Things) for smart irrigation approach. Temperature, humidity data were obtained from created prototype. The system was able to obtain information of water flow and respectively controlled. IoT "ThingSpeak" platform was used to log the necessary data. The research results were satisfactory as the developed system was able to monitor as well as control to increase harvest efficiency of hydroponic environment. Controllers such as FGPA ("Field Programmable Gate Array") along with Raspberry Pi 3 B+ were used. BLDC motor was controlled by FGPA and obtained data from the field was updated through Raspberry to the IoT platform. As research states the input voltage increase was boosted by FGPA controller as well [15-16].

The system was proposed research based on smart irrigation system to control water storage was proposed. Water level sensor was used as a tool to identify the water level. A controller was used to control the process of water fill up, once there was a decrease in water level. The further development of additional stage of the system to obtained humidity of the soil was done by the researchers. Each of the data and steps of the controller was monitored by the farmer and had the ability to interrupt the system or overwrite the command. As per the results of the developed system, the water tank for irrigation maintained well and efficiently with or without supervision [17].

The another work was presented on the field experiment between two manual and automatic irrigation system namely traditional producer manual approach and optimised for the manual system and Watermark and Plant Care for the automatic system. The experiment focused on yield and fruit quality of strawberries. The results obtained from the experiment showed that during irrigation time the average daily volume varied between 1.1 to 1.2 litter meter square for the optimised irrigation system and 1.6 litter meter square for the traditional manual producer irrigation system. The author mentioned that the reduction of the volume of water during irrigation did not affect the yield and fruit quality. However, the optimised manual irrigation system could save as much water as the automatic irrigation systems but increased the workload [18].

The automatic system was proposed that aims to save time and conserving water by automatically providing water to the crops based on the water requirements. The watering of the plants is triggered based on the moisture level of the soil and the user will be notifying of all the operation over mobile phone. The sensing of the system is done using the sensors presented as follow, soil moisture sensor, photocell sensor, etc. Moreover, the system uses an android based application connected to an Arduino board and WIFI module for internet connection. The mobile app has a GUI where the data received from the microcontroller are displayed [19].

To develop an optimized irrigation system, the researchers in these literature reviews were mostly focused on using different controllers and sensors such as NodeMCU and Raspberry Pi, Atmega 382 controller with Arduino Uno, etc. Therefore, this work provides the significant solution to address the existing limitations by implementing an innovative approach that prioritize the uniform and accurate distribution of water on the field to improve the production rate of crops and the quality.

III. PROPOSED SYSTEM AND ITS OPERATIONS

The IoT based smart irrigation system proposed in this project comprises three main stage namely, the data acquisition phase, the control and monitoring phase, and the water irrigation phase. In the data acquisition phase, the sensed data in form of electronic signal collected by the sensors placed in the field will be transferred to the Arduino Board. The Arduino in turn will convert those signals from analogue to digital signal and send them to the GUI created over the Blynk cloud server used in this system to display the digital output from the Arduino. From the GUI, appropriate action regarding the irrigation will be taken according to the data collected from the field. Fig.1 shows the block diagram of the overall irrigation system.

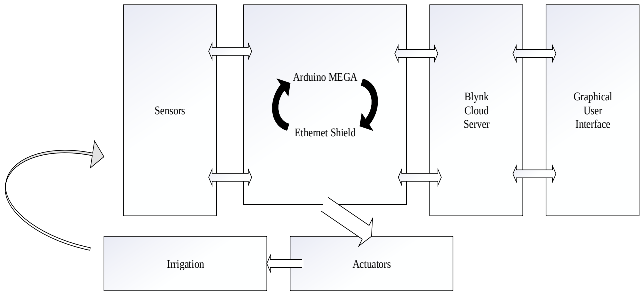

Fig. 1. General Block diagram

A) Data Aquistion

Fig. 2 shows the data acquisition diagram for the water irrigation system. The main objective of this project is to optimize the water irrigation system to prevent water wastage and improve the production rate and growth quality of the crops. To do so, the user must be able to control and monitor all the parameters and factors that affect either positively or negatively the health condition of the crops. These parameters are namely, the soil conditions (moisture content, soil nutrient, and ph. Value), the weather conditions (temperature, humidity, quality of the air, light intensity, and wind). Therefore, sensing devices are attributed to each parameter respectively with the only goal of collecting data and once those data collected, appropriate action will be taken into the control and monitoring phase.

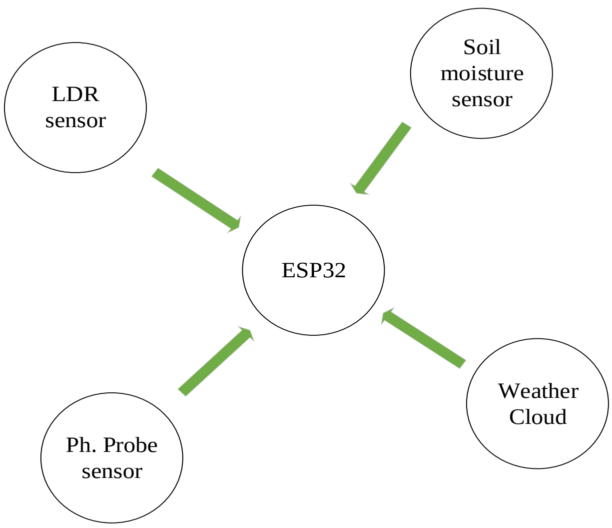

Fig. 2. Data Acquisition Diagram

B) Control and Monitoring:

Based on the data that will be collected from the sensors, the Arduino will send the received data to the GUI. From the GUI, the user will be able to act according to the data provided.

Therefore, the first step in the monitoring phase will be to check the availability of water in the tank. Whether there is enough water to perform the irrigation or not. This information will be provided by the ultrasonic sensor installed in the water tank. And if the water level is low, the solenoid valve controlling the water flow from the water source using a submersible pump to pump water, will release water in the tank until optimum level. Then comes moisture content of the soil, the watering operation is will be conditioned by the moisture content of the soil. If the reading from the moisture sensor is below the thresholds value in the system, then the solenoid valves controlled by the relay, will release water on the field until the moisture content rises above the threshold value. To keep track of the events, all the operation will be uploaded on the server to train the system for autonomous operation. After irrigating the fields, the data collected from the water flow sensor will continuously be uploaded to the server, so that the system will be able to determine the amount of water needed on the field for different moisture level.

Another important parameter of the irrigation operation are the data from weather cloud, the weather API provides information on the temperature, humidity, wind speed and direction, the weather in the location, and air pressure. Having knowledge of these information will be of use when planning the irrigation operation. For instance, if the weather cloud shows that at a given day and time rain will fall, then on that day the field will be irrigated from the rain fall. Furthermore, the ph. Probe sensor is implemented in the system the notify the user on which type of crop to grow based the ph. Value of the soil. Therefore, a data base with different types of crops individually associated with their respective ph. Value will be added to the system so that the user can refer to it.

Fig. 3, 4 and 5 illustrate the entire flow of the system from top to bottom. The system starts by collecting the data from the sensors on the field namely, the moisture sensor, the temperature and humidity sensor, the light intensity sensor, the gas sensor, the Ph sensor, the Ultra-Sonic sensor, the soil temperature sensor, and the weather forecast. Once those data are collected, they are displayed on the GUI of the system. Then comes the conditions that run the system.

The first condition is related to the weather forecast. If the weather forecast chances of rain on that specific day, the part of the system that controls the irrigation operation will be turned off temporally until the rain passes and the weather changes from rainy to clear cloud. But in the event where the weather forecast a clear and sunny day, the second condition comes in play which check on the moisture level of the soil. If the moisture level of the soil is below the required level, the system will check the third condition before irrigating the soil which is to check on the water level in the reservoir.

If the water level is above the threshold, the solenoids are turned On and water start flowing from the tank to the farm. But when the water level is below the threshold, the pump from the water source will be turned On, and water will start flowing from the water source to the reservoir until optimum level then the irrigation can start. But when the moisture level of the soil is at the required level, the system will keep on monitoring the environmental condition and save the data on a timely basis in an excel file generated automatically from the program.

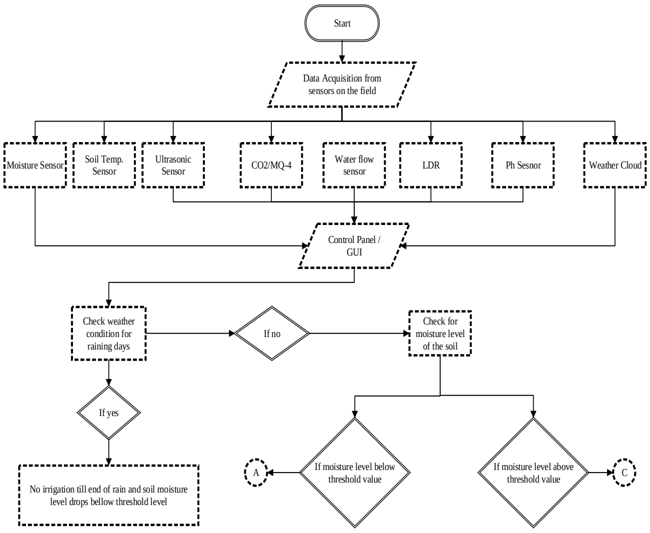

Fig. 3. Flow Chart-1

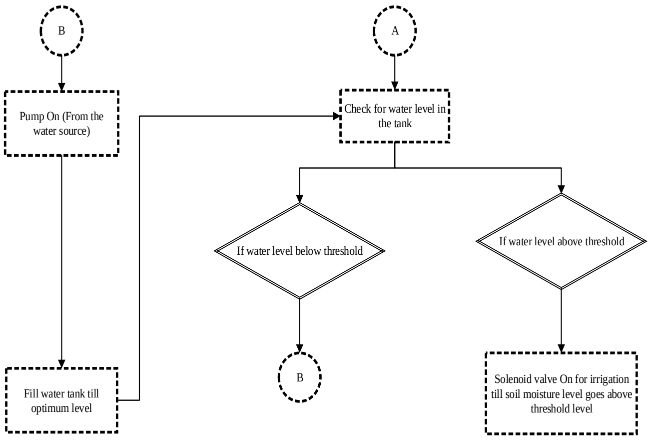

Fig. 4. Flow Chart-2

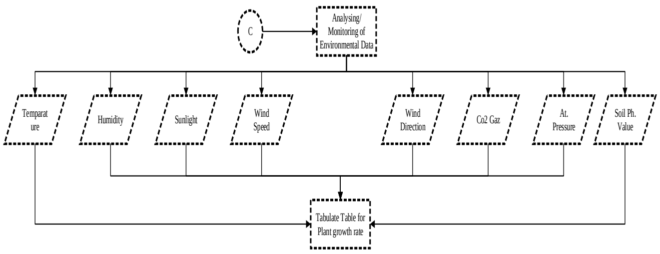

Fig. 5. Flow Chart-3

C) System Implementation

To achieve this goal, a set of sensors and actuators were put together to develop the system. The developed system comprises two main parts namely, the watering mechanism, and the data acquisition. However, before building the prototype for this system, some parameters were taken into consideration such as, the type soil to use, the type of plant to grow, and the size of the container of the soil. The choice of these parameters was done as follows:

- Type of Soil

The first step was to know the type of soil that will be used in the project. The choice of the soil was done based on the quality and acidity of the soil. Hence, Sandy soil was the best choice for the project as it contains good nutrient to grow vegetable and has an acidity level of 6.4 ppm.

- Plant to grow

The choice on the plant to grow was made based on three parameters, the type of soil chosen, the acidity level required and the germination time. Hence, the plant chosen for the project was Sawi Hijau which is vegetable that grows in Malaysia and needs warms temperature and an acidity level ranging between 5.5 to 6.5 ppm from the soil and on takes 8 to 12 days to germinate.

- Container for the soil

After getting the soil and the vegetable's seed, they needed a container. Hence, the containers chosen for the project were four cubic bowl of 1,728 cubic centimetres placed side by side with the soil added inside.

The watering mechanism was developed using submersible pumps, pneumatic tubes, water flow sensors, solenoid valves, and two water tank one representing the water source (groundwater) and the second one representing the water reservoir. The tank used for the water source is a cylindric bowl of 4087 cubic centimetres that contains 5v water pump with a maximum head of 80 cm that sends water to the reservoir through a pneumatic tube 40 cm long. The amount of water sent to the tank is measured using the water flow installed in between.

To deploy water on the farm, two conditions must be verified. First of all, the moisture level of the soil must at the lowest which means dry and secondly the water level in the tank must be above the required level for irrigation. The water flows from the reservoir to the farm through a piping network established using pneumatic tubes. The first tube goes from the tank to a 4-way manifold to which tubes are connected and leading to their allocated section of the farm namely section A, B, C, and D respectively.

Each section has a solenoid valve connect to it that controls the flow of the water into the soil. The solenoids valves run on a 12V power supply and are connected to a relay that controls the switch mechanism of the solenoids and the 2 water pumps. Hence, for the solenoids to deploy water in the soil, the system must verify the two conditions of irrigation and if they meet the requirements, water start flowing in the soil till the soil is humid enough.

The watering system described above is dependent of the data transmitted by the sensors on the field. The moisture level of the soil is collected using the soil moisture sensor placed in the soil and send the data collected to the microcontroller in this case an Arduino MEGA. Then comes the water level detection which is done using an Ultra-Sonic sensor placed on the top of the reservoir that transmit data to the microcontroller. The environmental conditions of the farm such as temperature, humidity, hazardous atmosphere, and intensity of the sunlight are given using a DHT 22 senor for the temperature and humidity, a MQ-4 module to detect hazardous element in the atmosphere, and an LDR sensor that measure the intensity of the sunlight. All these sensors are connected to the Arduino MEGA microcontroller which in return send the data received to the Blynk cloud where those data can be monitored and controlled on a remote desktop.

The data are sent to the Blynk Cloud using an internet connection established using an Ethernet shield in this case a GSM Module. The data are then displayed on a Graphical User Interface to allow interaction between the user and the system from afar. The user also receives live notifications and emails regrading all the action or activities regarding the irrigation. And to be able to evaluate the performance of the system, all the data are saved in a timely manner in an excel data sheet automatically from the GUI. A manual mode is also added to the system where the actuators, solenoids and pumps can be controlled manually using switch buttons installed in GUI of the system. The purpose of this facility is to be able to shut down the irrigation in an event of system malfunction.

IV. Performance Testing and Simulation Results

The overall performance of the developed system has been evaluated by conducting various simulations and relevant tests. The system was left running over a period of 7 days so that it could be exposed to different conditions and collect data that will be used for testing and evaluation of the system.

- *Water Consumption analysis*

One of the objectives of the project is to reduce the water consumption during irrigation will getting optimum result. Therefore, using an Ultrasonic sensor placed on the top of the water tank this test aimed to measure the amount of water that the system used over a period of 7 days while running. The reading on the flow of water are given using the water flow meter sensor placed in the system.

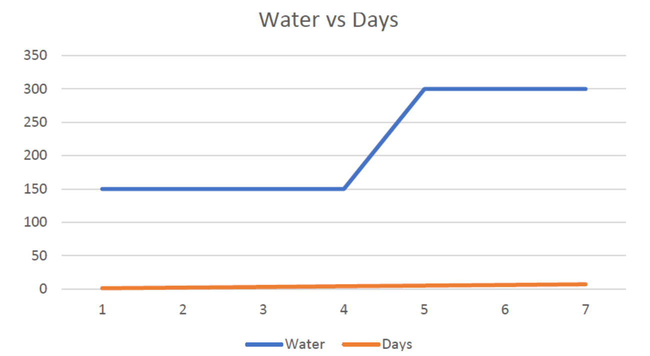

Fig. 6. Water Consumption Graph

There are two noticeable facts from the graph shown in Figure 6. There first one is that, over 7 days only 300ml have been used for irrigation. And the second fact is that irrigation happened only two times, on the first and fifth day. This could be explained by the fact that during given period the soil remained humid for the first 5 days before getting dry. Furthermore, the solenoid valves used in the system has a flow rate of 50ml/s and when switched on it deploys water for 5 seconds only before being turned off by the system. Over the 5 seconds, 150 ml of water were deployed into the soil which is enough to humidify the soil again.

- *Moisture test analysis*

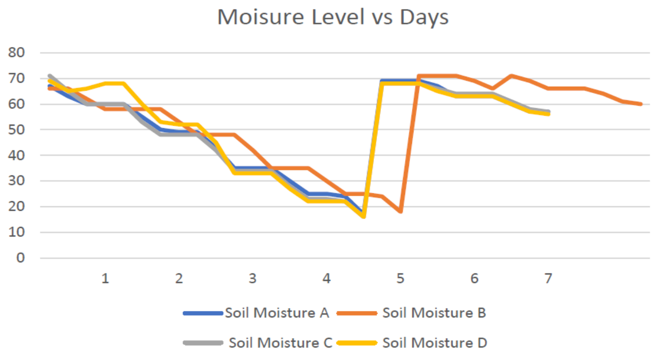

Fig. 7. Moisture level versus days

The aim of this test is check on the consistency of the humidity the soil. The goal is to have it humid during the whole experimental time so that the seed will be able to germinate properly. The moisture of the soil was obtained using the moisture sensor placed in the soil.

The plotted graph shown in Fig.7 representing the moisture readings over the days gives two principles details about what happen. Firstly, the changes in the moisture level of the Soil A, B, C & D. Secondly, it can be observed that the moisture has gone from down to up on the fifth day of the experiment. This can be explained firstly by the changes in temperatures which as an effect on the moisture of the soil. Fig.8 shows how the air temperature affects the moisture of the soil. An increase in temperature causes the moisture level in the soil drop while a low temperature keeps the moisture contain constant in the soil.

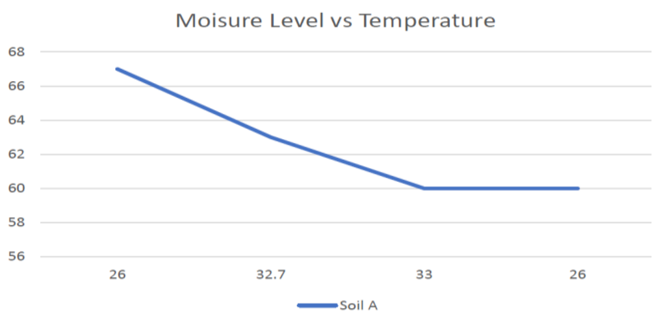

Fig. 8. Vibration reading on faulty condition

The change in direction in the graph from down to up can be explained by the fact that on the fifth day irrigation was performed due to the fact that the moisture of the soils has gone down and reaches the threshold value which activate the irrigation. The soil chosen for the project stays humid within 20 to 70%. That the reason why it can be seen from the graph that moisture is comprises within 20 and 70%. When it goes below, that means the soil is dry and when it goes above 70% that means the soil is flooded. Hence, the condition was set to stop the irrigation when the moisture reaches 70% and to start the irrigation when the irrigation goes below 20%.

- *Ph Value of Soil*

The Ph level of the soil is an important factor to the growth of the crop. This test is used to check on the consistency of the Ph of the soil over the 7 days. The Ph of the soil is obtained using the Ph sensor when insert in the soil.

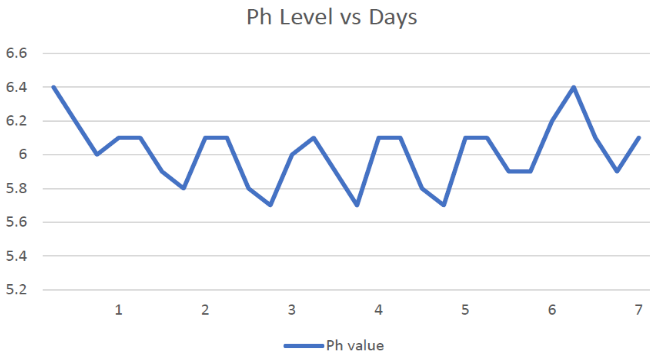

Fig. 9. Moisture level versus days

The graph plotted in Fig.9 shows an oscillation in the Ph value of the soil. This can be explained by the effect of the soil temperature on the Ph of the soil. An increase in temperature in the soil decreases the Ph of the soil. In ideal condition the Sandy soil has a Ph value of 6.4 ppm and the required Ph value for the crop chosen in the project ranges from 5.5 to 6.5ppm to grow in good condition. It is observed that value of the Ph oscillates between 5.7 to 6.4 ppm which is still acceptable for the seed to germinate within the required time.

- *Soil Temperature analysis*

In this test, the temperature of the soil is another important factor to the growth of the plant. The seed of the plant need to be in a warm environment to grow in good condition. Hence, the goal of this test was to try to keep the soil warm enough so that the seed could germinate as required. The soil temperature insert in the soil was used to measure the temperature of the soil.

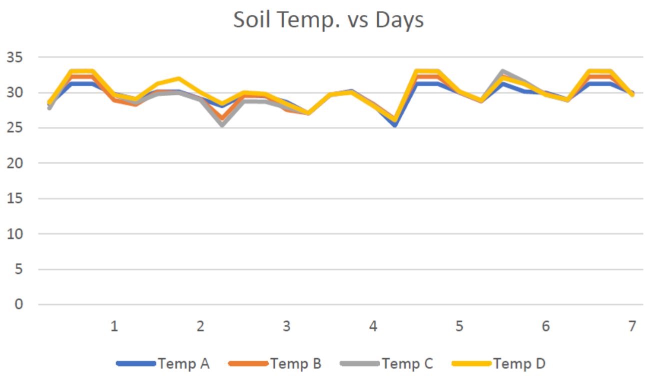

Fig. 10. Soil temperature versus days

The temperature of the soil is affected by two main external factors, the surface or air temperature and the humidity of the soil. The soil temperature is directly proportional to the surface temperature and inversely proportional to the moisture contain. Which means that when there is an increase in the air temperature, the temperature of the soil increases as well as shown in Fig.10 and when the moisture of the soil goes up, the soil temperature reduces and vice versa.

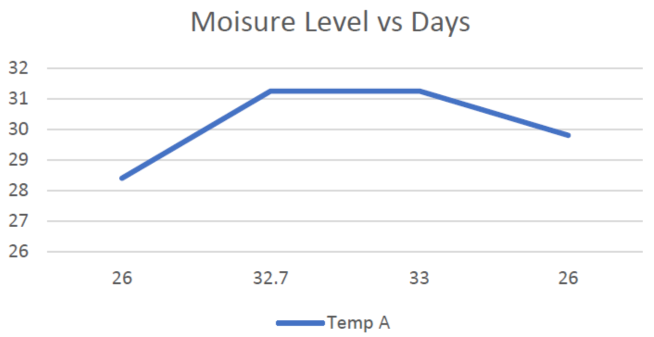

Fig. 11. Soil temperature versus Air temperature

The type of soil used in the project provide good result when operating within the range of 26 to 32 degree Celsius. Hence, by taking into consideration the factors affecting the temperature, the system tried to maintain the temperature of the soil within it ideal operating condition as shown in Fig.11. That was done by providing enough water to the soil to keep it moisturized so that even when the surface or air temperature is very high, the water inside the soil will create a balance. Because when the soil become too warm, the acidity level of the soil increases which is harmful for the seed or root of the plant.

V. Conclusion

A smart irrigation system to optimize the usage of water and improve the productivity rate of crops in the Agricultural sector is presented. It is developed the GUI over the Blynk cloud server for controlling and monitoring the system. The developed system was evaluated over a period of 7 days and the outcomes were satisfying with a total of 300 ml of water for the 2 irrigations performed over 4 sections of the farm filled with Sandy soil. The soil was kept moisturized at an average value of 50%, with an average soil temperature of 29.890 C, and with an average Ph concentration of 6 ppm. It has found that it requires 8 to 12 days for the germination phase and that was achieved within 7 days only. The statistics illustrated that the smart irrigation system performs better than the traditional/manual irrigation method.

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