PROJECT REPORT

ON

"SMART IRRIGATION SYSTEM"

Submitted in partial fulfilment of the requirements for the partial completion of

MAJOR PROJECT [16EC8DCMPJ]

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM

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Department of Electronics and Communication Engineering

B.M.S COLLEGE OF ENGINEERING

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DECLARATION

We undersigned students of final semester B.E in Electronics and Communication Engineering, BMS College of Engineering, Bangalore, hereby declare that the dissertation entitled "SMART IRRIGATION SYSTEM", embodies the report of my project work carried out independently by us under the guidance of Mr. Harish V. Mekali, Assistant Professor, E&C Department, BMSCE, Bangalore in partial fulfilment for the award of Bachelor of Engineering in Electronics and Communication from Visvesvaraya Technological University, Belgaum during the academic year 2019-2020.

We also declare that to the best of our knowledge and belief, this project has not been submitted for the award of any other degree on earlier occasion by any student.

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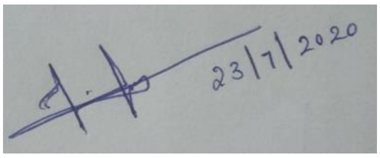
CERTIFICATE

This is to certify that the project entitled **“SMART IRRIGATION SYSTEM”** is a bonafide work carried out by **Nitesh M S** (USN:1BM16EC003), **Nitish N** (USN:1BM16EC073) **Prajwal Vishwanath** (USN: 1BM16EC080) and **Varun K V Ithal** (USN:1BM16EC118) in partial fulfillment for the partial completion of MAJOR PROJECT[16EC8DCMPJ] during the academic year 2019-2020.



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1.

2.

DEDICATION

This Work Is Dedicated To All The Farmers Of The Nation

ABSTRACT

India is an agriculture based country. Ancient people were completely dependent on the agricultural harvesting. Agriculture is a source of livelihood of majority Indians and has a great impact on the economy of the country. In dry areas or in case of inadequate rainfall, irrigation is a challenging problem. So, it needs to be automated for maximum yield and handled remotely. Increasing energy costs and decreasing water supplies demands the need for better water management. Irrigation management involves a complex decision making process to determine when and how much water to apply to a growing crop to meet specific management objectives. So, efficient water management plays a critical role in the irrigated agricultural cropping systems. A low cost alternative solution for efficient water management which is currently in use is drip irrigation system.

In this project, we are going to devise a product which controls the moisture level of soil in the roots of the crop so as to supply required water to the crop automatically based on the moisture level of the soil and also by applying the virtual water concept, which will result in maximum yield of the crop. Specifically, four moisture sensors at different root depths are used to measure the moisture content in the root of crop at different levels, and this data is sent to our website and so that we can monitor the growth of crop remotely through a data visualization platform (website) and also to keep a documentation on growth of crop. Based on the moisture content of the crop we water the crops if the moisture content drops below a defined minimum and stop watering the crops when the moisture content goes above the defined maximum values.

We also interface a weather station to our product, which will monitor the different weather parameters such as Wind Speed and Direction, Temperature, Humidity, Rainfall and UV Index. These parameters are tracked continuously and are also updated to a website to generate datasets which can be used for weather prediction in the future. These datasets can also be fed to the Evaporation Transpiration (ET) equation to measure the quantity of moisture that is both transpired by a plant and evaporated from the soil and plant surfaces.

ACKNOWLEDGEMENT

Any achievement, be it scholastic or otherwise does not depend solely on the individual efforts but on the guidance, encouragement and cooperation of intellectuals, elders and friends. A number of personalities, in their own capacities have helped us in carrying out this project work. We would like to take this opportunity to thank them all.

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We would like to share the joy completing the project to all the team members of NGX Semiconductors**.** We thank all our professors for providing the basic knowledge without which this project wouldn't have been possible. Last but not the least we thank our family and friends, who made their valuable support compelled us to maintain a standard throughout our endeavour.

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CHAPTER 1: INTRODUCTION

1.1 Introduction

Agriculture is one of the most basic, yet one of the most important occupations in the world. India is basically an agrarian society where around 60 percent of land area is cultivated for agriculture and about 50 percent of the population directly or indirectly depends on agriculture for their livelihood.

Agriculture needs water in huge amounts. It is the most water consuming industry. More water will be needed to produce more food to meet the future demand. But increasing competition for water and inefficient irrigation practices constrains future food production. 70% of water is used for Agriculture while 22% for industrial use and 8% for domestic purpose. In many developing nations irrigation requires over 90% of water withdrawn from available sources for use. When we look for efficient irrigation methods, Drip Irrigation is the most efficient, followed by Sprinkler Irrigation, and the least efficient method is Surface Irrigation. However, 94% of the application methods of irrigation water at field level currently are of the category of surface irrigation, wherein the water is spread over the field by gravity.

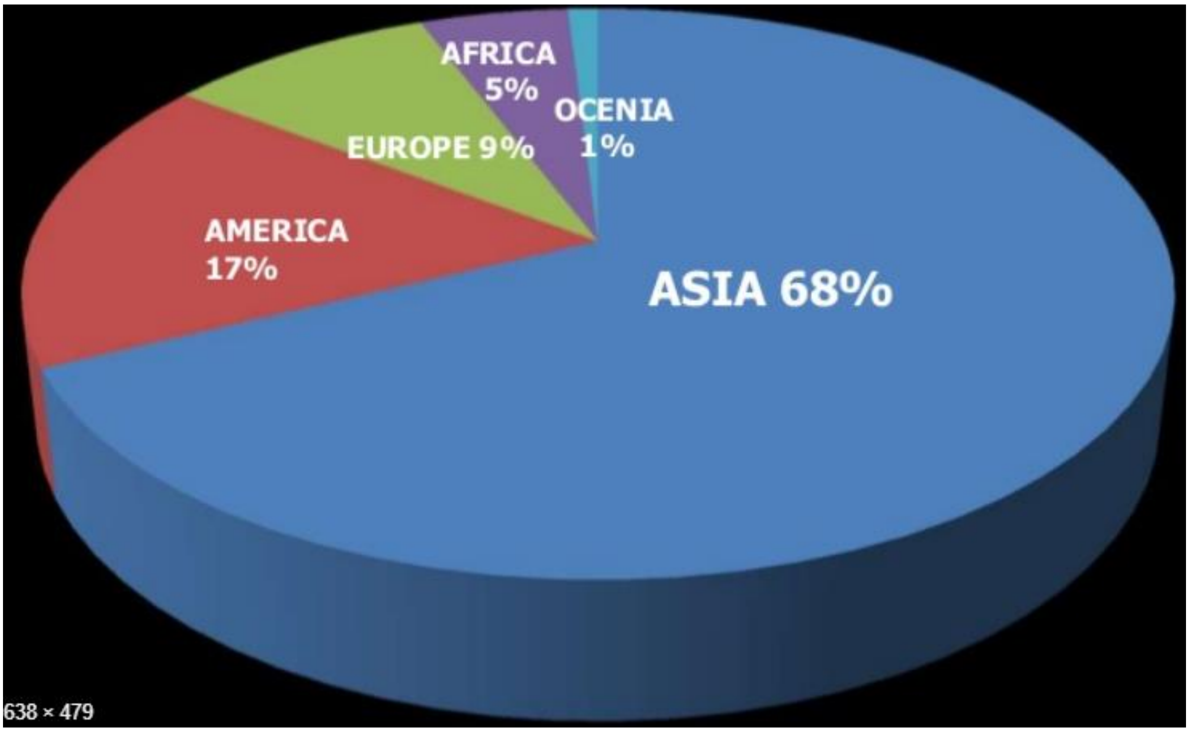

Figure 1: Percentage of irrigation in the world

Agriculture in India is mostly dependent on monsoon and Groundwater resources. Still two-thirds of the net sown area (land on which cultivation is done at least once a year) is dependent on rainwater, mostly during the four monsoon months. However, rainfall in India is notoriously capricious, causing floods and droughts alternately. Its distribution and amount are not in accordance with the needs of the crops.

India has a population as much as 15% of the world's population but has only about 4% of the world's fresh water resources. Much of these are unevenly distributed. Average annual rainfall in India is about 1,170 mm, which corresponds to an annual precipitation including snowfall of 4,000 billion cubic meters (BCM). Nearly 75% of this (3000BCM) occurs during the monsoon season, confined only to 3-4 months (June to September) a year. According to the Planning Commission, India has so far created a total of about 225BCM of surface storage capacity. However, per capita storage capacity in India is very low at 190 cubic meters. If we compare this data to other developed countries, we find the per capita storage capacity to be 5,961BCM in USA, 4,717BCM in Australia, 3,388BCM in Brazil, and 2,486BCM in China.

Though the average water availability in India remains more or less constant according to the natural hydraulic cycle, per capita availability is reducing progressively owing to the increasing population. In 1990, the average figure was around 2,200 cubic meters. In 2015, the figure was 1829 cubic meters, which may further go down to about 1340 cubic meters and 1140 cubic meters a year by 2025 and 2050 respectively. The situation in some of the river basins is worrisome. According to international agencies, any country with per capita water availability of less than 1700 cubic meters is considered 'water stressed' and those with per capita water availability less than 1000 cubic meters is considered 'water scarce'. Already six river basins of the country fall into the water scarce category, and five more basins are likely to be 'water scarce' during 2025-50. Only 3-4 basins will be 'water sufficient'. Water availability both in quality and quantity has been on the decline over the past 3-4 decades because of gross mismanagement.

1.2 Smart Irrigation Concepts

While implementing a smart irrigation system, it is necessary to take into consideration two important characteristics. They are:

- Soil Characteristics
- Plant Characteristics
- Weather Characteristics

The Soil Characteristics include four main properties of the soil, namely Field Capacity, Permanent Wilting Point, Available Moisture and Readily Available Moisture. For a given type of soil, these properties are fixed. In this project setup, we are experimenting with Red Soil.

The Plant Characteristics include properties such as crop period and different growth stages and their duration in days. The crop period for greens is generally 60 days, while for rice, wheat, and other grains it can vary from 90-120 days. Generally, most crops have crop duration between 60-120 days. There are some exceptions to this rule though, such as sugarcane, which has a crop period ranging from 12-18 months.

The weather characteristics are the different weather parameters such as Wind Speed and Direction, Temperature, Humidity, Rainfall and UV Index. The weather parameters need to be monitored continuously and can be used for weather prediction, as well as aid in the process of efficient indication.

1.2.1 SOIL CHARACTERISTICS:

As mentioned before, the four important soil characteristics are:

- Field Capacity (FC)
- Permanent Wilting Point (PWP)
- Available Moisture (AM)
- Readily Available Moisture (RAM)

The physical definition of Field Capacity is as follows: Field Capacity is the bulk water content retained in soil at −33 kPa/kg (or −0.33 bar) of hydraulic head or suction pressure. Field Capacity is the amount of soil moisture or water content held in the soil after excess water has drained away and the rate of downward movement has been decreased. This usually takes place after 2–3 days after rain or irrigation in previous soils of uniform structure and texture.

The physical definition of Permanent Wilting Point (PWP) or Wilting Point (WP) is as follows: Permanent Wilting Point is the water content at −1,500 kPa (−15 bar) of suction pressure, or negative hydraulic head. Permanent Wilting Point is the minimum amount of water in the soil that the plant requires to not to wilt. If the soil moisture decreases to this or any lower point a plant wilts and can no longer recover its turgidity when placed in a saturated atmosphere for 12 hours.

The difference in moisture content of the soil between field capacity (F.C) and permanent wilting is termed the Available Moisture (AM). Available moisture can be expressed as percentage moisture PW, as percentage PV or as depth d.

Soil moisture content near the wilting point is not readily available to the plant to absorb. Hence, the term Readily Available Moisture (RAM) has been used to refer to that portion of the available moisture that is most easily extracted by plants. Readily Available Moisture is defined at approximately 55% of the available moisture, though to make calculations easier the value is rounded off to 50%.

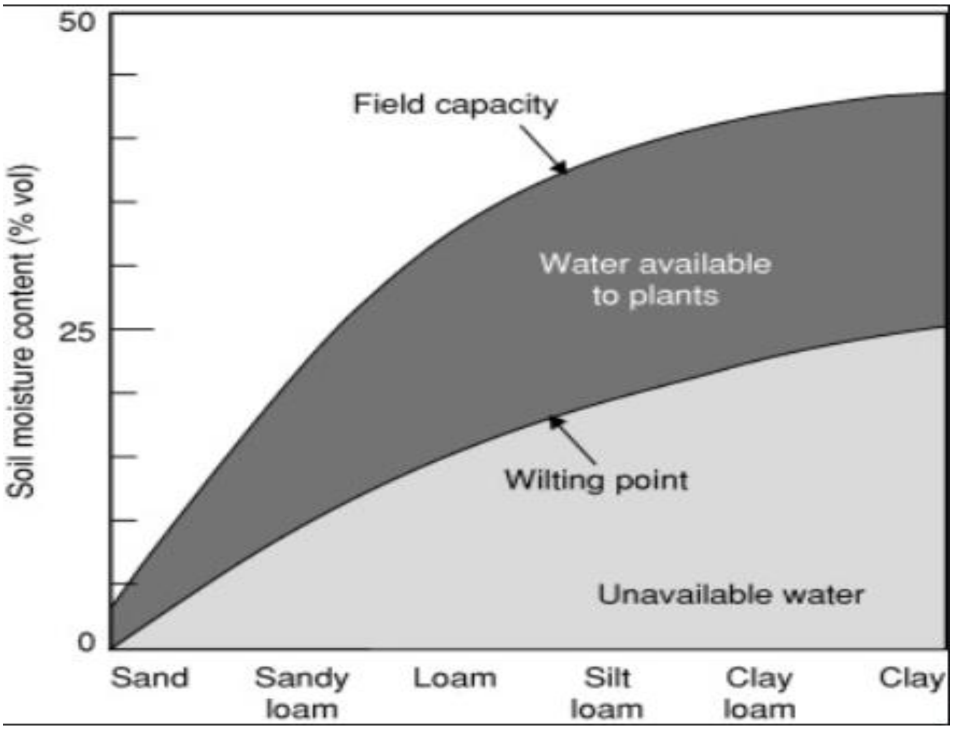

Figure 2: Field Capacity and Permanent Wilting Point for different types of soil

The importance of the Available Moisture and Readily Available Moisture parameters are seen in the types of seeds used. There are mainly two types of seeds used by farmers, local seeds and hybrid seeds. Over 90% of the farmers prefer hybrid seeds over local seeds because the yield from hybrid seeds is very high when compared to local seeds. However, Hybrid seeds have one disadvantage with them, which is, they are extremely water sensitive. What this means is if the soil moisture level falls to the Permanent Wilting Point (PWP) value of the soil, let alone below the Permanent Wilting Point value, the plant will not be able to extract water and will die out as a result. However, local seeds are able to extract moisture from the soil even if the soil moisture level falls a little below the Permanent Wilting Point level. In order to avoid this danger with hybrid seeds, a new parameter, Readily Available Moisture, is defined and its value is set at approximately 55% of the Available Moisture level.

Let us take an example to understand the relationship between the soil moisture parameters. Let the Field Capacity (FC) of the soil be 24%, and let the Permanent Wilting Point (PWP) of the soil be 10%. These two parameters are fixed for a given type of soil.

Now, to calculate Available Moisture (AM), it is given by:
AM = FC – PWP

So,
AM = 24% - 10%
AM = 14%

Now, to calculate the Readily Available Moisture (RAM), it is given by:

k = 0.55 X AM

So,
k = 0.55 X 14%
k = 7% (approx.)
Now,
RAM = FC – k

So,
RAM = 24-7
RAM = 17%

The soil characteristics are shown in the figure below.

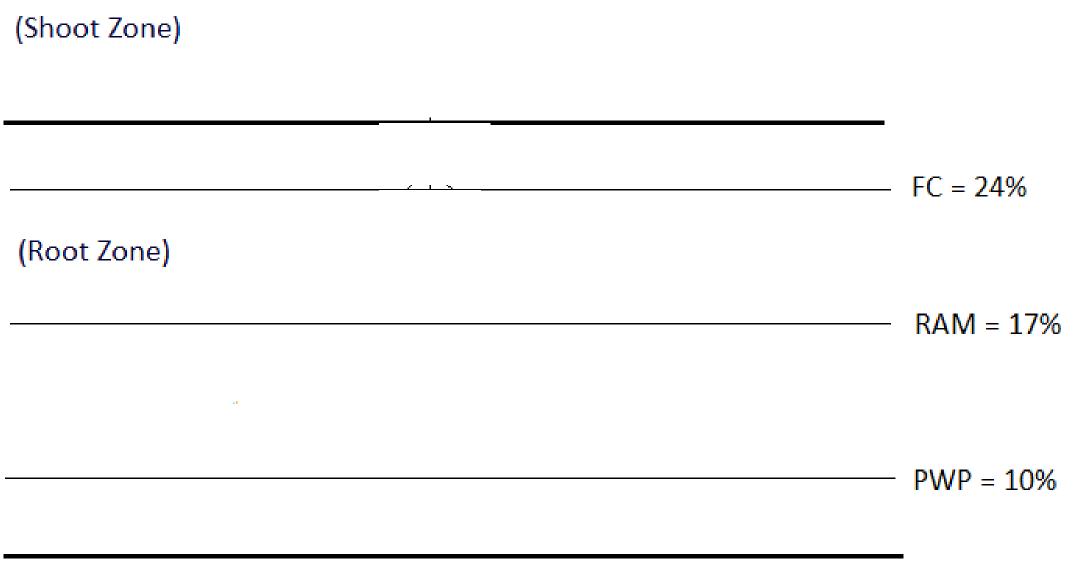

Figure 3: Soil Characteristics

WATER CYCLES:

The crops are supplied with water whenever the moisture level falls below the Readily Available Moisture limit in case of hybrid crops, or below the Permanent Wilting Point limit for local seed crops. Generally, once the crops are watered, they need not be supplied with water for some duration, which varies based on the season. For example, in summers, evaporation is more and hence the crops need to be watered more regularly, say, once every two days. However, during winters, evaporation is less; hence the crops need not be supplied with water as frequently as in summers, and once in around four days should be enough. Note that all these explanations are just rough figures to explain the watering cycle for crops. The figure below gives an example of how the watering cycle takes place in case of both hybrid seed crops as well as local seed crops.

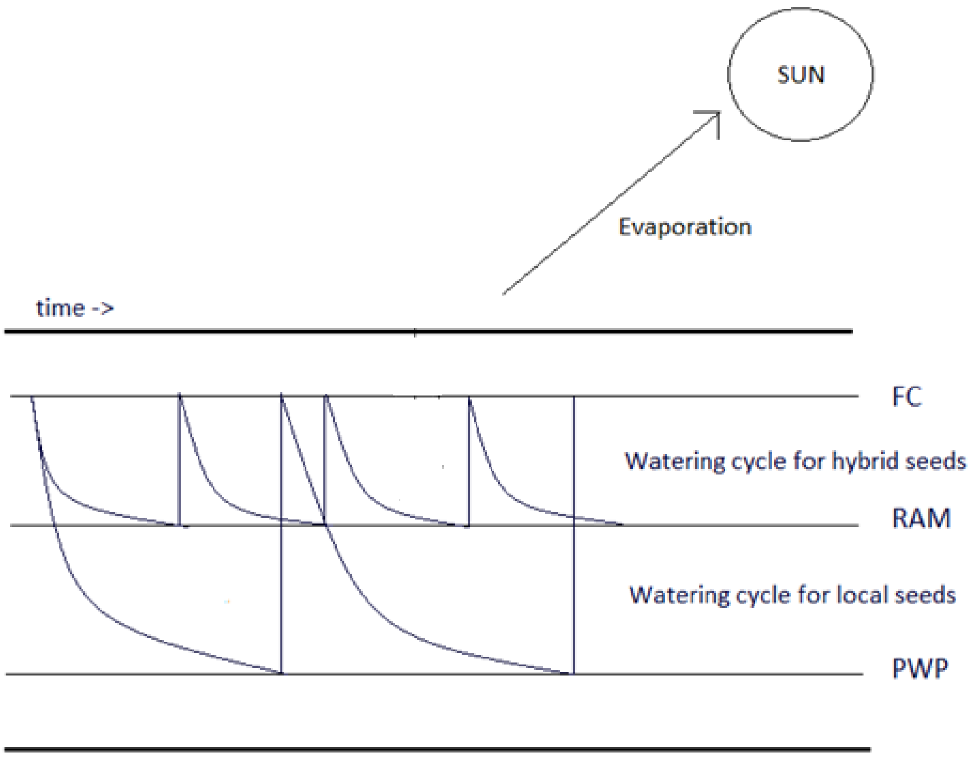

Figure 4: Watering Cycles

1.2.2 PLANT CHARACTERISTICS:

Crop cycles, as discussed earlier, generally range from 60 days for greens to 120 days for grains, with some exceptional crops such as sugarcane taking anywhere between 12-18 months between the Vegetative stages to the Harvesting stage. In this section, we talk about the five stages in a crop cycle, which are listed below as follows:

- Vegetative Stage (V)
- Flowering Stage (F)
- Yield Formation Stage (Y)
- Ripening Stage (R)
- Harvesting Stage (H)

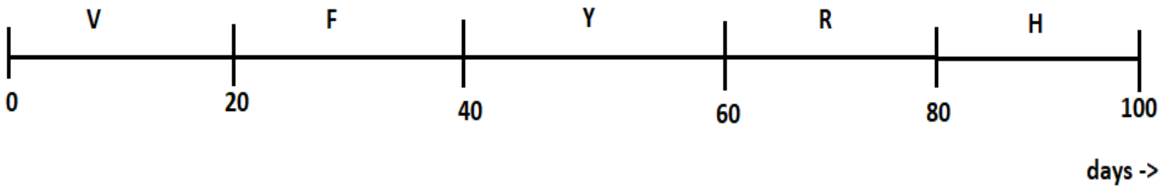

Figure 5: Different Stages of Growth of a Plant

The vegetative stage is the initial stage of plant growth. It is in this stage that the root growth takes place. The Linear Root Depth Model, which is an extremely useful theoretical method to calculate the growth of the root throughout the vegetative phase, is explained later. The vegetative stage is extremely water sensitive, which means that any problems or negative variations in watering the plant at this stage will have a drastic effect on the growth of the plant in the later stages.

The flowering stage is the second stage in the plant cycle. By this time, the root has stopped growing. The plants start flowering. This stage also is extremely water sensitive and any problems or negative variations in watering the plant at this stage will affect the growth of the plant in the later stages.

The third stage in the plant cycle is the yield formation stage. By this time the first signs of fruits are seen from plants. This stage is also water sensitive, but not as sensitive as the first two stages.

The Ripening stage is the fourth stage in the plant cycle. At this stage the plants have completely produced all the fruits and they are ripening. Finally, after the ripening stage, comes the harvesting stage where the fruits are ready to be harvested from the plants.

LINEAR ROOT DEPTH MODEL

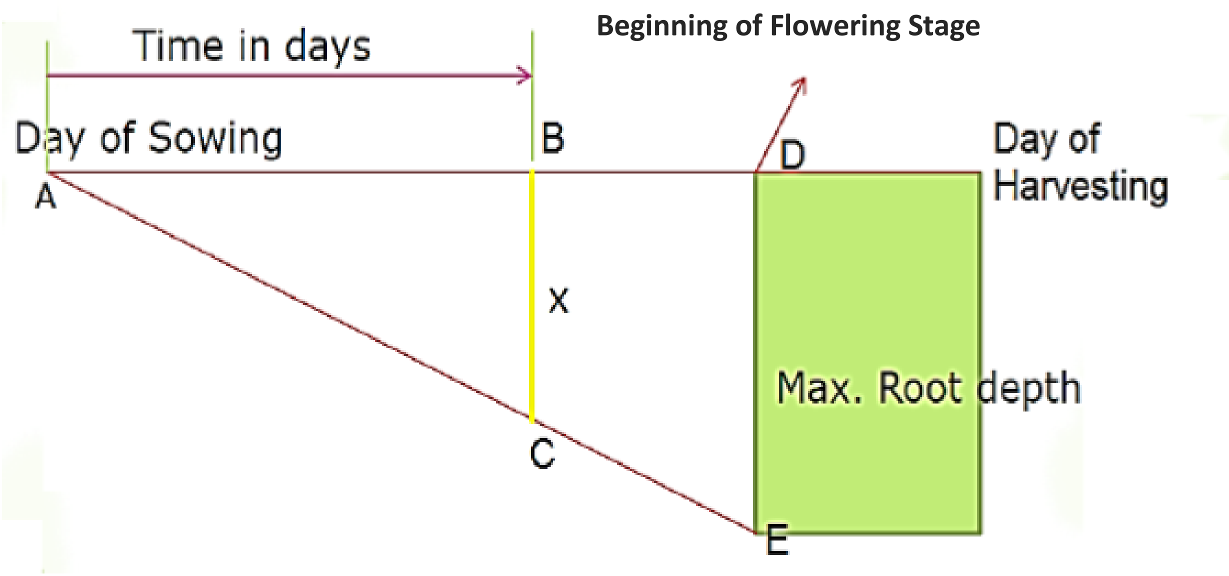

Figure 6: The Linear Root Depth Model

The above figure shows the linear root depth model. Since it is practically impossible to find out the depth of the root at any point of time during the vegetative phase of the plant cycle, scientists have developed a theoretical model to measure the depth of the root at any point of the vegetative phase of the plant cycle.

It is quite straightforward to calculate the depth of the root for a given time passed during the vegetative stage of the plant cycle. Let ‘t’ be the time in days passed, and let ‘x’ be the depth of the root in meters for time ‘t’ passed. Further, let ‘T’ be the total time duration of the vegetative phase in days, and let ‘D’ be the maximum depth of the root in meters, which is reached at the end of the vegetative phase. Using the concept of similar triangles from mathematics, we can calculate the depth of the root for any time duration passed. The formula is given by:

$t/T = d/D$ (or) $d=tD/T$

Where, d gives the depth of the root in meters for t days passed.

1.2.3 WEATHER CHARACTERISTICS

All of the weather-based products reviewed operate on the principle of scheduling irrigation based on weather conditions. Most of the products use real-time or historical weather data to schedule irrigation based on Evaporation Transpiration (ET), which is a function of weather conditions and plant type.

ET is defined as the quantity of moisture that is both transpired by a plant and evaporated from the soil and plant surfaces. The American Society of Civil Engineering’s (ASCE) standardized reference ET equation parameters are maximum and minimum air temperature, net solar radiation, average vapor pressure, and average wind speed.

Each of the weather-based irrigation scheduling systems evaluated use micro processing devices that calculate or adjust irrigation schedules based on one or more of the following parameters sets: weather conditions (temperature, humidity, rainfall, wind, and solar radiation), plant types (root depth and low versus high water use), and site conditions (latitude, soils, ground slope, and shade). Some of the systems generate watering schedules automatically. Others require the user to enter a base daily irrigation schedule, and then the device determines the frequency (which days) irrigation occurs or adjusts run times. Some of these partially automated systems provide guidelines for establishing the base schedule while others do not. Our irrigation system primarily focuses on the second set of conditions to carry out the irrigation process, and a weather station is installed to carry out the irrigation process according to the first set of parameters. On combining the first two parameters sets in our system we can aim for a high degree of accuracy in the irrigation process.

In our project, a completely functional weather station is maintained onsite. In real world conditions, since the weather generally does not vary much over a large area, we can say it is sufficient to maintain one weather station for say, a cluster of villages.

Further, to incorporate the weather characteristics, the ET Equation used, also known as the Penman-Monteith Equation, is as follows:

$$ET_o = \left[\frac{0.408\,\Delta\,(R_n - G) + \gamma \left(\frac{900}{T + 273} \right) u_2\,(VPD)}{\Delta + \gamma\,(1 + 0.34\,u_2)} \right]$$

Where,
ETo = daily reference ET [mm/day], for longer periods 900 becomes 37
T = air temperature at 2 m high [°C]
VPD = vapor pressure deficit [kPa]
u2 = wind speed at 2 m high [m/s] = 2 m/s
Rn = net radiation at the crop surface [MJ m-2 d-1]
Δ = slope vapour pressure curve [kPa °C^-1]
γ = psychometric constant [kPa °C^-1]
G = soil heat flux density [MJ m^-2 d^-1]

Each of these parameters can be further calculated as follows:

Temperature (T):
The weather station records the temperature at regular intervals, In a given day, we should take the average of the minimum and maximum temperatures to get the value of T.

Vapor Pressure Deficit (VPD):
The following 4 Equations Give the calculation of vapour pressure deficit.

1. $$VPD = (e_s - e_a)$$

2. $$e_s = \frac{e_{(T_{\max})} + e_{(T_{\min})}}{2}$$

3. $$e_{(T_{\min})} = 0.6108 \exp\left(\frac{17.27\,T_{\min}}{T_{\min} + 237.3} \right)$$
$$e_{(T_{\max})} = 0.6108 \exp\left(\frac{17.27\,T_{\max}}{T_{\max} + 237.3} \right)$$

4. $$e_a = \frac{RH_{mean}}{100} \left[\frac{e_{(T_{\max})} + e_{(T_{\min})}}{2} \right]$$

In the four equations, Tmax and Tmin are recorded directly from the weather station, so is the Relative Humidity RH. From these parameters we can calculate VPD.

Net Solar Radiation (Rn):
This parameter is directly recorded by the weather station. Take the average of the maximum and minimum recorded values.

Wind Speed (u2):
Wind speed is calculated as follows:

$$u_2 = u_y \left[\frac{4.87}{\ln(67.8\, y - 5.42)} \right]$$

Where:
y = height of instrument above ground [m]
uy = measured wind speed at y meters above ground level [m/s]
u2 = wind speed at 2 m above ground [m/s].

Slope Vapor Pressure Curve (Δ):
Slope Vapor Pressure Curve is given as:

$$\Delta = 4098 \left[\frac{0.6108 \exp\left(\frac{17.27\, T}{T + 237.3} \right)}{(T + 237.13)^2} \right]$$

T is the mean temperature.

Psychometric Constant (γ):
Psychometric constant is calculated by these two equations:

1. $$\gamma = 0.665 \times 10^{-3}\ P$$

2. $$P = 101.3 \left(\frac{293 - 0.0065\, z}{293} \right)^{5.26}$$

Here, P is the calculation of the atmospheric pressure in KPa.
Z is the elevation above the sea level in meters.

Soil Heat Flux Density (G):
Can be ignored for now, take it as 0.

CHAPTER 2: LITERATURE SURVEY

The Indian Council of Agricultural Research (ICAR) is an autonomous organisation under the Department of Agricultural Research and Education (DARE), Ministry of Agriculture and Farmers Welfare, Government of India. ICAR is the authority when it comes to all aspects of agricultural research and control in India. Most of the data presented and explained in the previous section is defined or set by the ICAR after doing extensive research and experiments as well as collaborating with international agencies and conforming to international standards.

Formerly known as Imperial Council of Agricultural Research, it was established on 16 July 1929 as a registered society under the Societies Registration Act, 1860 in pursuance of the report of the Royal Commission on Agriculture. The ICAR has its headquarters at New Delhi. The Council is the apex body for coordinating, guiding and managing research and education in agriculture including horticulture, fisheries and animal sciences in the entire country. With 101 ICAR institutes and 71 agricultural universities spread across the country this is one of the largest national agricultural systems in the world. The ICAR has played a pioneering role in ushering Green Revolution and subsequent developments in agriculture in India through its research and technology development that has enabled the country to increase the production of food grains by 5.4 times, horticultural crops by 10.1 times, fish by 15.2 times, milk 9.7 times and eggs 48.1 times since 1951 to 2017, thus making a visible impact on the national food and nutritional security. It has played a major role in promoting excellence in higher education in agriculture. It is engaged in cutting edge areas of science and technology development and its scientists are internationally acknowledged in their fields.

To note the developments in Smart Irrigation Systems throughout time, we first look at G. Vellidis, who in 2007 presented a real-time wireless smart sensor array for scheduling irrigation. A prototype real-time, smart sensor array for measuring soil moisture and soil temperature that uses off-the-shelf components was developed and evaluated for scheduling irrigation in cotton. The array consists of a centrally located receiver connected to a laptop computer and multiple sensor nodes installed in the field. The sensor nodes consist of sensors, a specially designed circuit board, and a Radio Frequency Identification (RFID) tag which transmits data to the receiver. The smart sensor array described offers real potential for reliably monitoring spatially variable soil water status in crop fields. This paper describes the smart sensor array and testing in a cotton crop. Integration of the sensors with precision irrigation technologies will provide a closed loop irrigation system where inputs from the smart sensor array will determine timing and amounts for real-time site-specific irrigation applications.

Yunseop (James) Kim, in 2008, presented Remote Sensing and Control of an Irrigation System Using a Distributed Wireless Sensor Network where it describes details of the design and instrumentation of variable rate irrigation, a wireless sensor network, and software for real-time in-field sensing irrigation system. Field conditions were site-specifically monitored by six in-field sensor stations distributed across the field based on a soil property map, and periodically sampled and wirelessly transmitted to a base station. Communication signals from the sensor network and irrigation controller to the base station were interfaced using Bluetooth wireless radio communication. While this was a great initiation in the development of Smart Irrigation, the major disadvantage was that the total cost of Bluetooth wireless modules used in this paper for the in-field WSN was approximately $1000.

Zhang Feng, in 2012, presented his research paper on water-saving irrigation automatic control system based on Internet of things. To enhance Irrigation system water utilize productivity, lessen cost of water system water, this paper talked about the outline of remote sensor system and Internet innovation of farmland programmed water system control technique. Accentuation on an examination of the directing convention of sensor system hubs to accomplish the framework equipment and programming outline, middleware, and applications, for example, cell phone or remote PDA of web of things, will constitute an assortment of sensors astute system, in this manner improving the general robotization framework and observing levels. The last investigation of the system in the Internet in light of the rural plants of farmland water-sparing water system framework coordinated approach. Client utilize cell phones or remote PDA can without much of a stretch soil dampness substance of web based checking and control to understand the water system mechanization.

Kay Smarsly, in 2013, presented Agricultural ecosystem monitoring based on autonomous sensor systems where the prototype monitoring system consists of a number of intelligent wireless sensor nodes that are distributed in the observed environment. The sensor nodes are connected to an Internet-enabled computer system, which is installed on site for disseminating relevant soil information and providing remote access to the monitoring system.

Ahmed Hussein Abbas, Maya Medhat Mohammed presented a Smart Watering System for Gardens using Wireless Sensor Network. This paper discusses the usage of wireless sensor networks in irrigation control by a smart watering system in which the irrigation process is controlled by valves. The application of wireless soil-moisture sensor networks to detect water content in the soil can utilize water resources very efficiently. Water requirements depend on the type of plants and the soil as well as the season. A study has been made on the clay soil to observe its behavior and its different characteristics. By this study the time of excitation of the sensor could be known and the period of irrigation could be detected. This will be more efficient in terms of the time in which the sensor will be excited and the quantity of water that will be used.

Nattapol Kaewmard, Saiyan Saiyod in 2014 presented Sensor Data Collection and Irrigation Control on Vegetable Crop Using Smart Phone and Wireless Sensor Networks for Smart Farm. The exploration objective is to give a long haul reasonable answer for mechanization of agribusiness. Agribusiness computerization has a few techniques to get information from vegetable products like sensors for ecological estimation. In this way, the framework built up a convenient estimation innovation including soil dampness sensor, air stickiness sensor and air temperature sensor. Also, a water system framework utilizing remote sensor arrangement has introduced these sensors, with the reason for gathering the earth information and controlling the water system framework by means of advanced cells. The reason for the examination is to discover better methods for controlling a water system framework with programmed framework and manual control by advanced mobile phone. So as to control a water system framework, a framework was created the specialized techniques of the remote sensor arrange for gathered environment information and sending control order to turn on/off water system framework.

Konstantinos X. Soulis in 2015 investigated the effects of soil moisture sensors positioning and accuracy on soil moisture based drip irrigation scheduling systems. This study investigates how soil moisture sensors positioning and accuracy may affect the performance of soil moisture based surface drip irrigation scheduling systems under various conditions. For this purpose several numerical experiments were carried out using a mathematical model, incorporating a system-dependent boundary condition in order to simulate soil moisture based irrigation scheduling systems. The results of this study provided clear evidence that soil moisture sensors positioning and accuracy may considerably affect irrigation efficiency in soil moisture based drip irrigation scheduling systems.

If we want to look at the present state of development of Smart Irrigation Systems, The KBL (Kirloskar Brothers Limited) Irrigation sector provides fluid handling solutions for Irrigation schemes and also offers best suitable pumps and valves for irrigation. KBL fluid handling solutions help many countries and states to achieve food sufficiency. The Irrigation sector closely works with National and State Irrigation Departments. The Irrigation sector has executed many projects in India and abroad. The KBL irrigation strength lies in project management from "Concept to commissioning". The irrigation sector has dedicated team of engineers and experts from Hydraulics and Project management.

CHAPTER 3: PROBLEM ANALYSIS

3.1 Problem Definition

Many of the farmers don't have knowledge about the amount of average water needed to yield the crop. This is one of the causes for variable crop yield. If distance between the home and the field is more, it is difficult to travel for just irrigating the land and monitoring its moisture content. It is not possible to continuously monitor the irrigation process; it is a waste of time.

The first and foremost common problem in irrigation is that we do not know the answer for simple questions like "When do I water?" and "How long do I water?" Starting an irrigation cycle too early and running an irrigation cycle too long is said to be over watering. This practice wastes water and money and overwatering can cause crop damage if this practice is repeated for a long time. Similarly, starting an irrigation cycle too late or not running the system for a long enough period of time is considered under watering and can cause reduced yields and poor crop quality which can affect price.

As the crop grows the root goes deeper into the soil. Monitoring the moisture content in depth is difficult. We just supply water to the field to keep it wet but if the plant is quite big its root which is in depth will not get sufficient water this causes crop damage and poor yielding. In some fields the surface soil absorbs the water quickly and always looks like a dry land. But the moisture will be there in the soil under that. In this situation it is difficult to know about the moisture content in the soil. And watering more also affects the crop.

Another problem we face with respect to irrigation is that we irrigate the fields without knowing about the climatic conditions in that area. This can also have adverse effects on the crop yield, since after some time if there is rain then the water which we used in irrigation is wasted and also this reduces the crop yield by supplying more water to the roots. So, it is also important to continuously monitor the weather conditions.

3.2 Proposed Solution

THE PROBLEM OF WATER SUPPLY:

In order to tackle the problem of when to supply water to the crops, we install soil moisture sensors in the ground in the root zone of the plants. For this purpose, we have chosen the VH400 soil moisture sensor. Since it is not reliable to depend on a single sensor's reading, we plan to use 2 sensors, one installed at a depth of d/4 in the soil and one at a depth of d/2 in the soil, where'd' is the root depth. This installation of sensors this way is shown below:

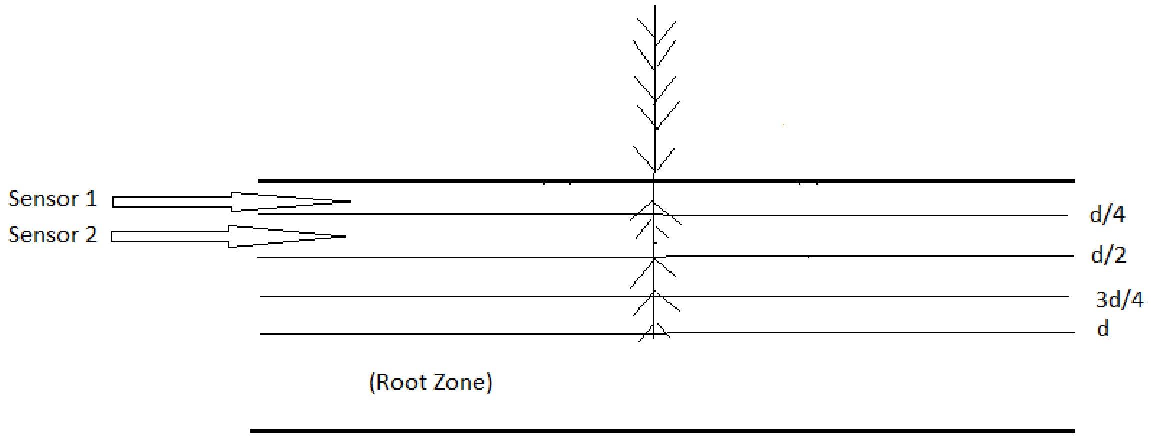

Figure 7: Sensor Placement in Soil

One more important parameter to consider while placing the soil sensors is the optimal placement of these sensors. Soil moisture sensors are very costly, ranging from Rs.4,500 when purchased individually and around Rs.3,000 when purchased in bulk. Obviously, one cannot place sensors at each plant. There has to be some way to optimally place the sensors so as to optimise the cost. So, what is the best way to place the sensors in a field so as to minimize the cost of installation?

The two important characteristics to consider while considering the optimal placement of sensors are as follows:

- The Soil Profile
- The Types Of Crops Planted

These two can be explained better from the figure below.

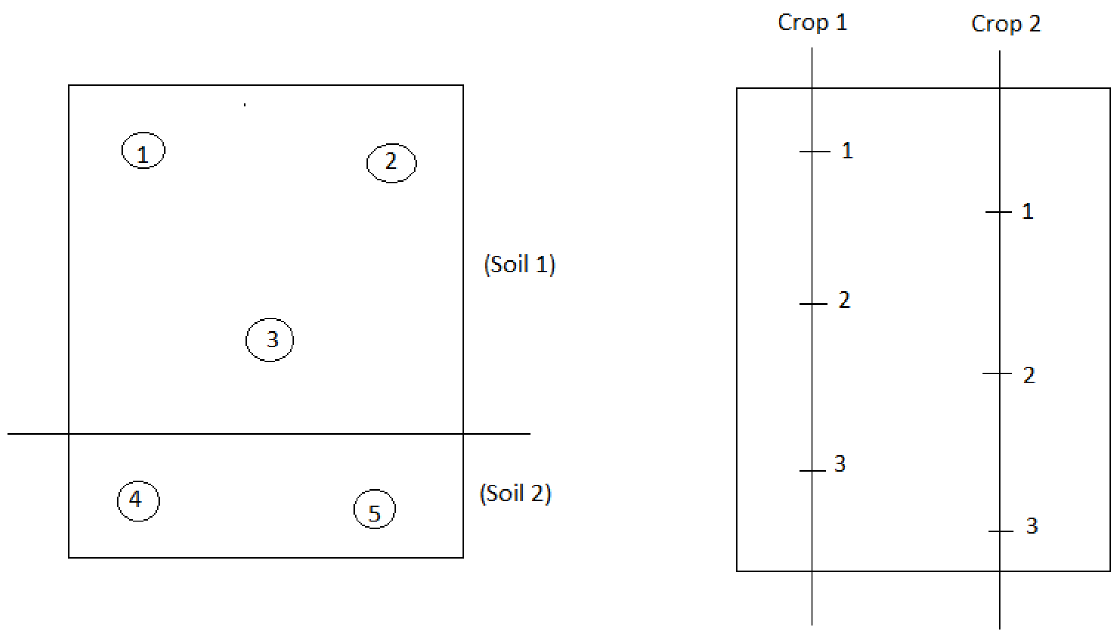

Figure 8: Optimal Sensor Placement

The scenario on the left explains the soil profile. To evaluate the soil profile of a given piece of land, we can take samples of soil at different points on the field. The figure on the left shows a scenario where five samples are taken at different points in the field. Two cases arise here, as follows:

If all the soil samples are found to be the same, then placing sensors at one or two points in the field is more than enough. However, if the soil samples are found to be different, as shown in the figure above, then we need to place one or two sensors wherever the soil profile has changed.

The second scenario is when different crops are planted on the same field. In this case, we need to place one or two sensors wherever the crop changes. However, generally, the two factors coincide and the optimal placement of sensors is interplay between the soil profile and the types of crops planted.

Further specifications and implementation details of the Soil Moisture Sensors are explained in the Methodology and implementation chapter.

THE PROBLEM OF WEATHER MONITORING:

As mentioned earlier, monitoring the weather conditions is also important to the irrigation process, if there is rain then the water which we used in irrigation is wasted and also this reduces the crop yield by supplying more water to the roots. So, it is also important to continuously monitor the weather conditions. For the purpose of this project, we plan to monitor the temperature (in degrees Celsius), humidity, UV Index, Amount of Rainfall (in millimetres/hour), Wind Speed and Wind Direction (in kilometres/hour).

For these purposes, we use Davis Weather Station, which looks like a pedestal and contains the sensors to measure the required parameters. What comes with the Weather Station is a Vantage Pro 2 Console, which is a full-featured backlit LED console which is used to display the data from the Davis Weather Station. Further information about the weather station as well as the Vantage Pro console is explained in the Methodology and Implementation Chapter.

CHAPTER 4: METHODOLOGY AND IMPLEMENTATION

In this section we discuss the overall project implementation block diagram and the complete flow of the project, as well as the implementation with respect to the soil moisture sensors, the weather station and the LPC1768 microcontroller.

4.1 Implementation Block Diagram

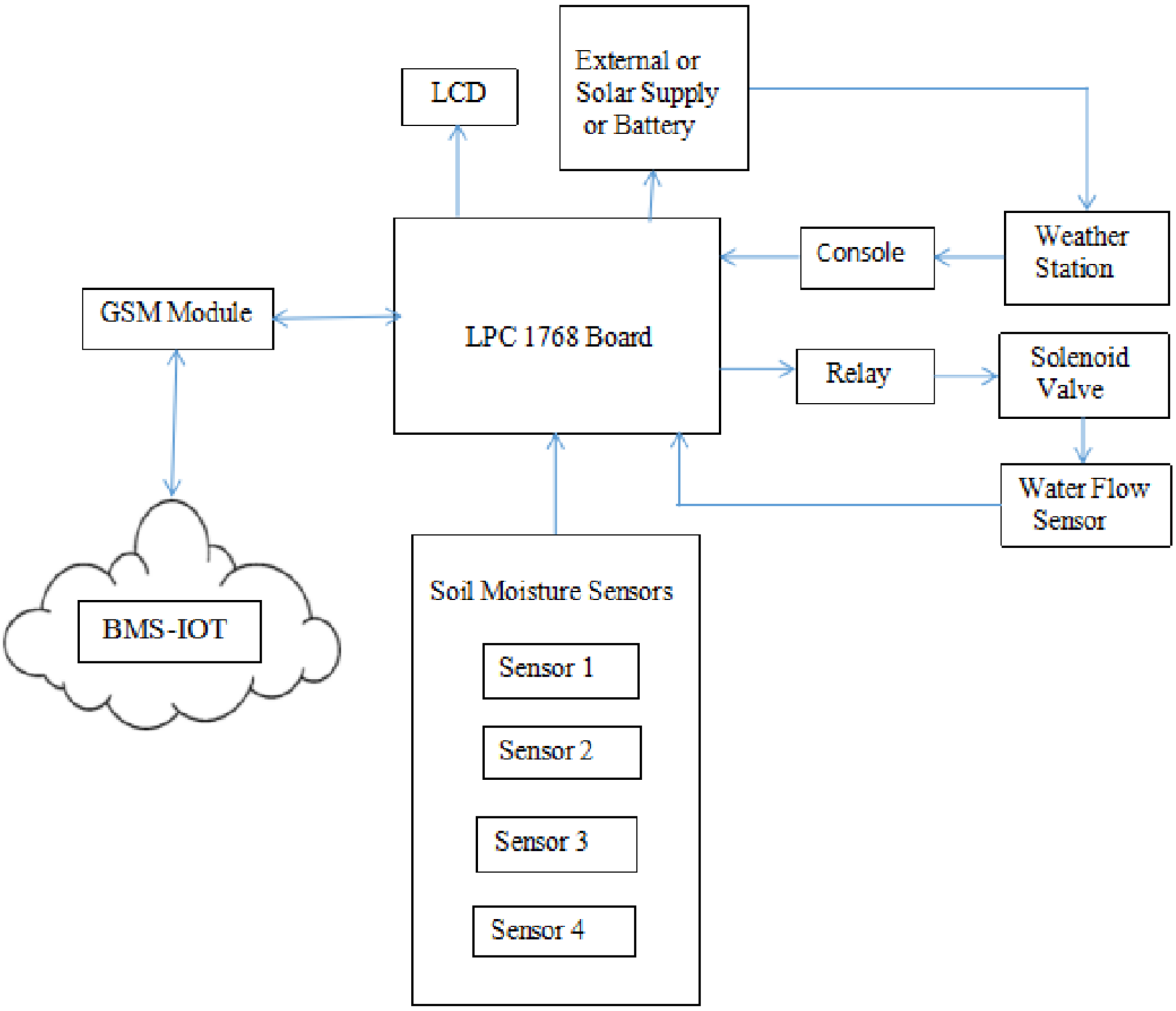

Figure 9: Implementation Block Diagram

The implementation overview is as shown as above. The LPC1768 Microcontroller is at the heart of things, and it is the one to which all the different components are interfaced. The diagram shows the interface of the soil moisture sensors on the bottom of the figure, while the right hand side of the figure shows the interface of the weather station to the microcontroller board through the display console and it also shows the interface of solenoid valve through a relay. The left hand side of the figure shows the implementation of sending the data to the IOT website, which is yet to be implemented as of now but is a future must to have feature as a part of the smart irrigation system.

4.2 Project Flow

We have completed the different stages of the project as shown in the flowchart below:

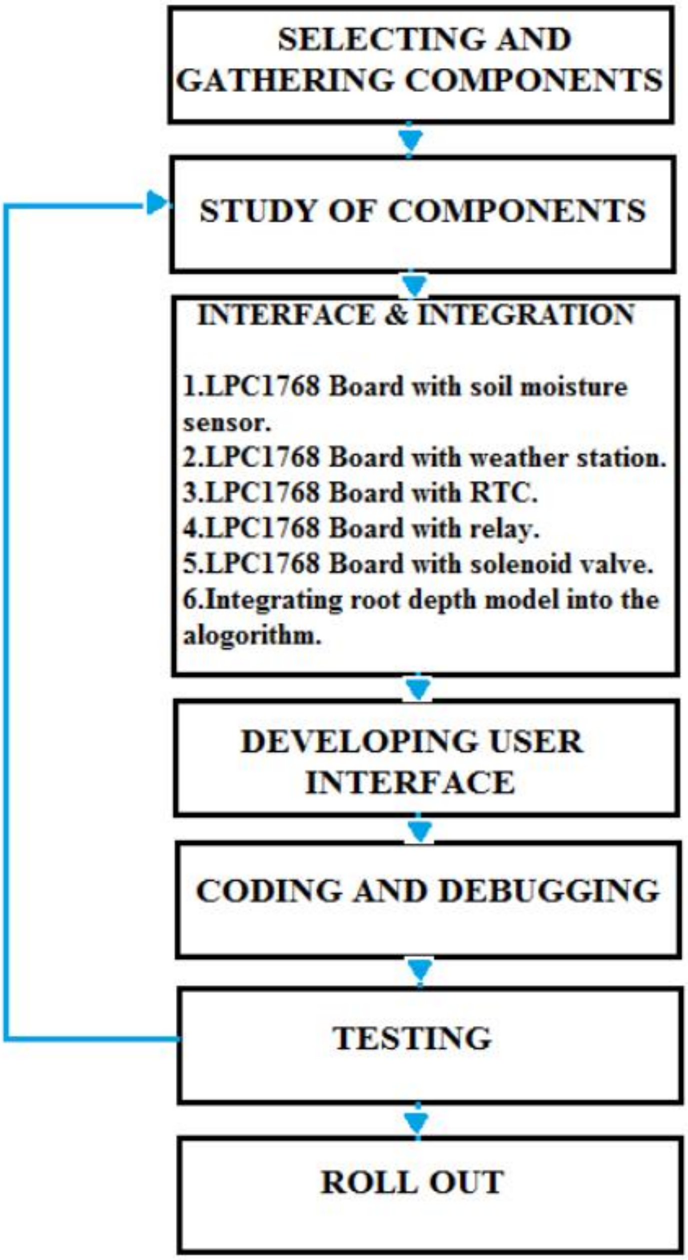

Figure 10: Project Flow

4.3 LPC1768 And BMS-IOT Box

The LPC176x/5x is an ARM Cortex-M3 based microcontroller for embedded applications requiring a high level of integration and low power dissipation. The ARM Cortex-M3 is a next generation core that offers system enhancements such as modernized debug features and a higher level of support block integration.
High speed versions (LPC1769 and LPC1759) operate at up to a 120 MHz CPU frequency. Other versions operate at up to a 100 MHz CPU frequency. The ARM Cortex-M3 CPU incorporates a 3-stage pipeline and uses Harvard architecture with separate local instruction and data buses as well as a third bus for peripherals. The ARM Cortex-M3 CPU also includes an internal prefetch unit that supports speculative branches.

The peripheral complement of the LPC176x/5x includes up to 512 kB of flash memory, up to 64 kB of data memory, Ethernet MAC, a USB interface that can be configured as either Host, Device, or OTG, 8 channel general purpose DMA controller, 4 UARTs, 2 CAN channels, 2 SSP controllers, SPI interface, 3 I2C interfaces, 2-input plus 2-output I2S interface, 8 channel 12-bit ADC, 10-bit DAC, motor control PWM, Quadrature Encoder interface, 4 general purpose timers, 6-output general purpose PWM, ultra-low power RTC with separate battery supply, and up to 70 general purpose I/O pins.

The LPC1768 has numerous features which make it the desirable choice for our project. However, we do not wish to run through the entire list of specifications for the microcontroller. Instead, we present a block diagram of the BMS-IOT Box which is built based on the LPC1768 microcontroller, and serves as the heart of our hardware, since all the components are interfaced to this IOT Box.

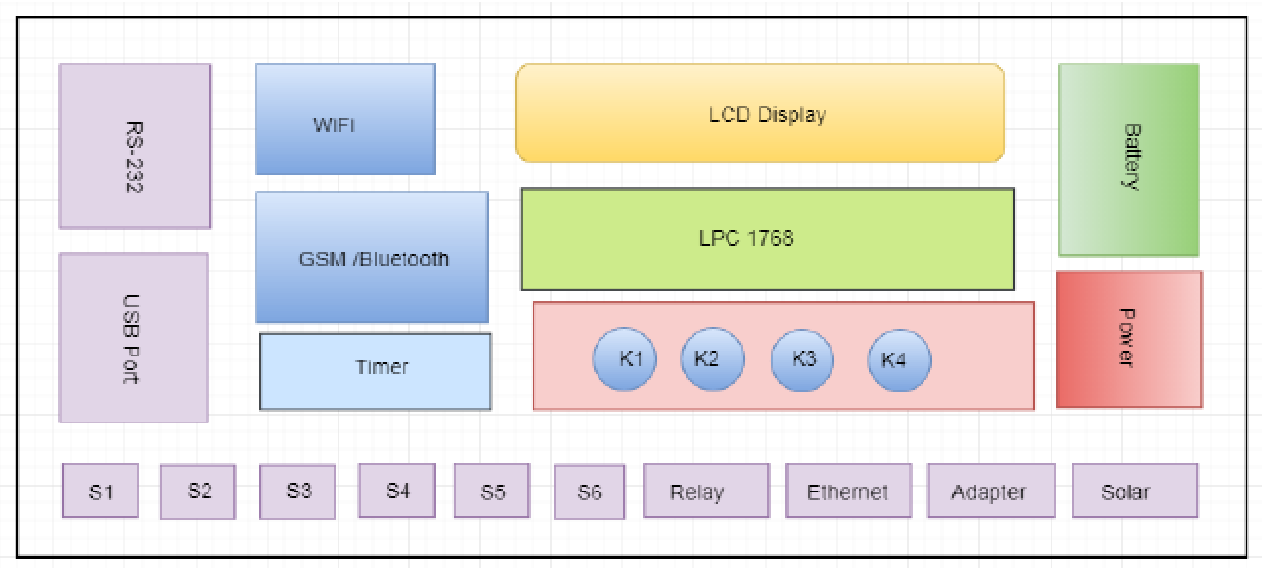

Figure 11: Block Diagram of the BMS-IOT Box

4.4 Weather Station

Vantage Pro2 is an Integrated Sensor Suite (ISS) containing rain collector, temperature and humidity sensors, anemometer, UV, and solar radiation sensors in one package. It is a customizable station with a wide range of options and sensors to help us to measure, monitor, and manage weather data. The stations are designed to withstand scorching sun, corrosion, up to 200 mph (321 kmph) winds, temperature extremes, and more. It provides the highest level of accuracy, reliability and ruggedness. Vantage Pro2 station includes a console and a versatile sensor suite that can be customized by adding consoles or special-purpose options. The anemometer can be attached separately from the rain collector. One can easily get their own local forecast, highs/lows, totals or averages and graphs for virtually all weather variables over the past 24 days, months or years all without using a PC.

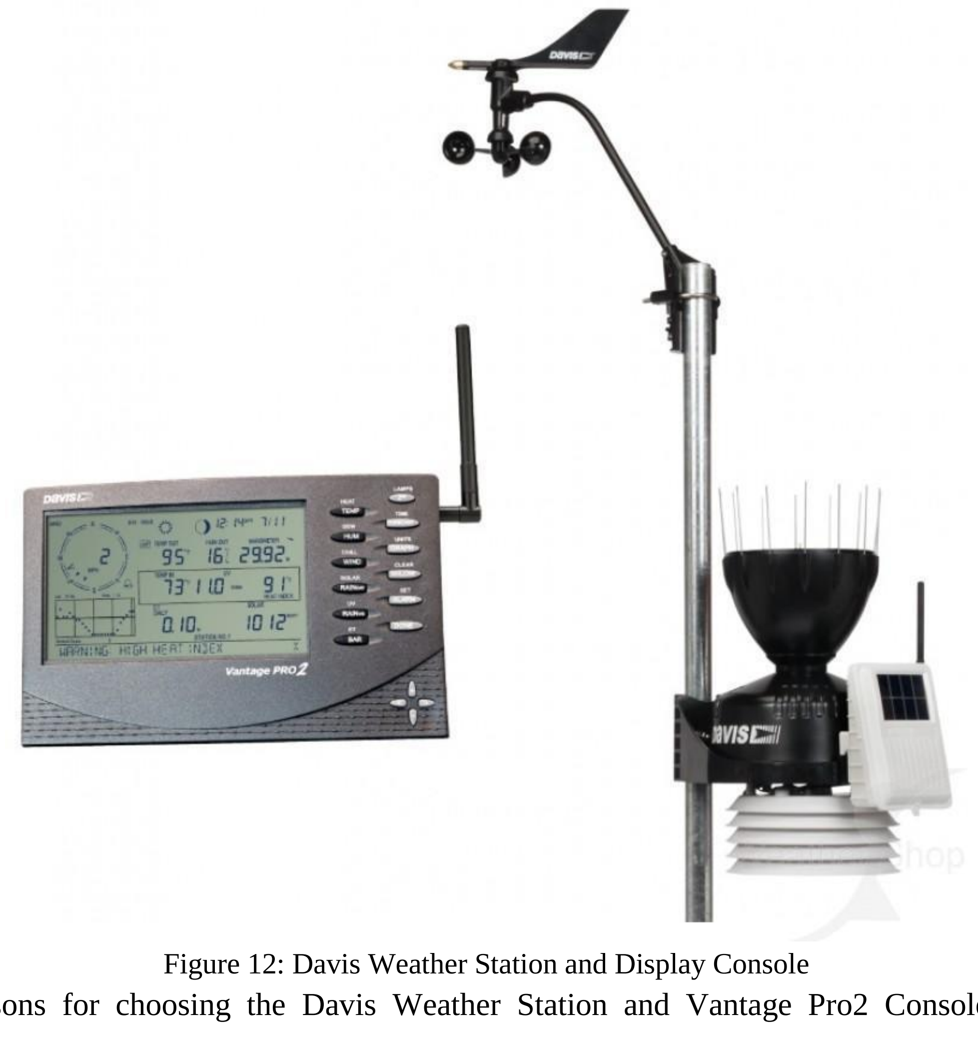

Figure 12: Davis Weather Station and Display Console

The reasons for choosing the Davis Weather Station and Vantage Pro2 Console are as follows:

- Rugged and flexible, it offers reliable weather data even under the extreme climates.
- It has a dependable data transmission. The wireless version of Vantage Pro2 solar-powered transmitter with battery backup is used to keep your data flowing. The frequency-hopping spread spectrum Vantage Pro2 radio can transmits and receives

data up to 1,000 ft. (300 m) line-of-sight. The cabled version transmits data using cable.

- It is available in both wireless and wired versions.
- Vantage Pro2 also offers 12-hour advance weather forecasts as well as 24- to 48-hour advance forecast ticker-tape.
- One can also view and store data on their computer or online.

The specifications of the VantagePro2 Console are as listed in the figure below:

VANTAGE SPECIFICATIONS

	Accuracy
Wind: Direction: 1°	±3°
Speed: 2 to 150 mph (3 to 241 km/h)	±5%
Wind Chill: -134° to 140°F, -92° to 60°C	±4°F, ±2°C
Humidity: Inside: 0% to 100%	±5%
Outside: 0% to 100%	±3%
Barometer: 8 in to 33.50 in Hg (460 to 820 mm Hg)	±0.03 in Hg, ±1.3 mm Hg
Temperature: Inside: 32° to 140°F, 0° to 60°C	±1°F, ±0.5°C
Outside: -40°F to 150°F, -40° to 65.5°C	±1°F, ±0.5°C
Rainfall: Daily: 0 to 199.99 in (0 to 6553 mm)	±4%
Accumulation: 0 to 199.99 in (0 to 6553 mm)	±4%
Time & Date: 12 or 24 Hour Clock, Time Alarm and Date	

Figure 13: VantagePro2 Console Specifications

Vantage Pro2 is an easy installation device and can be set up using the manual from Davis instruments. Vantage Pro2 Console can also be set up using their manual. Vantage Pro2 Console is a LCD display system for Vantage Pro2. Time, longitude, latitude, baud rate (For wired transmission only) and many other fields can be updated. Once the setup is complete, one should long press the DONE button. If Vantage Pro2 is connected to the console, the console starts reading data from sensors.

The console has inbuilt temperature, humidity and pressure sensors whose readings are displayed even without Vantage Pro2. The sensors can be calibrated if there is any error in the sensor data. The sensor data is updated every 2.5 seconds. The console also has an option to set alarm with respect to both time and sensor values. The data received from the weather station are stored in the WeatherLink data logger present inside the Console. We can also get the graphical representation of sensor data in order to get variation of certain parameters over time.

Figure 14: Different components in the Davis Weather Station

The console with a WeatherLink data logger has following 3 types of memory:

- 132 KB archive memory, which can store up to 2560 archive records.
- 4KB EEPROM memory, which is used for calibration numbers, station latitude/longitude/elevation/time zone values, transmitter configuration, and Console graph points
- 4KB of processor memory, which is used in storing the current sensor data, today's high/low values, and other real-time values.

Figure 15: Vantage Pro2 Console Display Details

Sample Interval	Capacity of logger in time
1 minute	1 day and 20 hours
5 minutes	8 days and 21 hours
10 minutes	17 days and 18 hours
15 minutes	26 days and 16 hours
30 minutes	53 days and 8 hours
1 hour	106 days and 16 hours
2 hours	213 days and 8 hours

Table 1: Capacity of data logger

SERIAL COMMUNICATION WITH CONSOLE:

Data from loggers can also be viewed in computer or laptop using WeatherLink software. The data logger is connected to the computer using an adapter for wired communication. The data is sent as packets through serial communication. The serial communication has 8 data bits, one start and one stop bit. There are no parity bits. Default baud rate is set to 19200. The user can choose any baud rate among 1200, 2400, 4800, 9600, 14400, and 19200. For wireless communication, WeatherLink Live has to be interfaced with vantage pro 2 console. The WeatherLink software increases the readability of graphs. The data can also be viewed in tabular format.

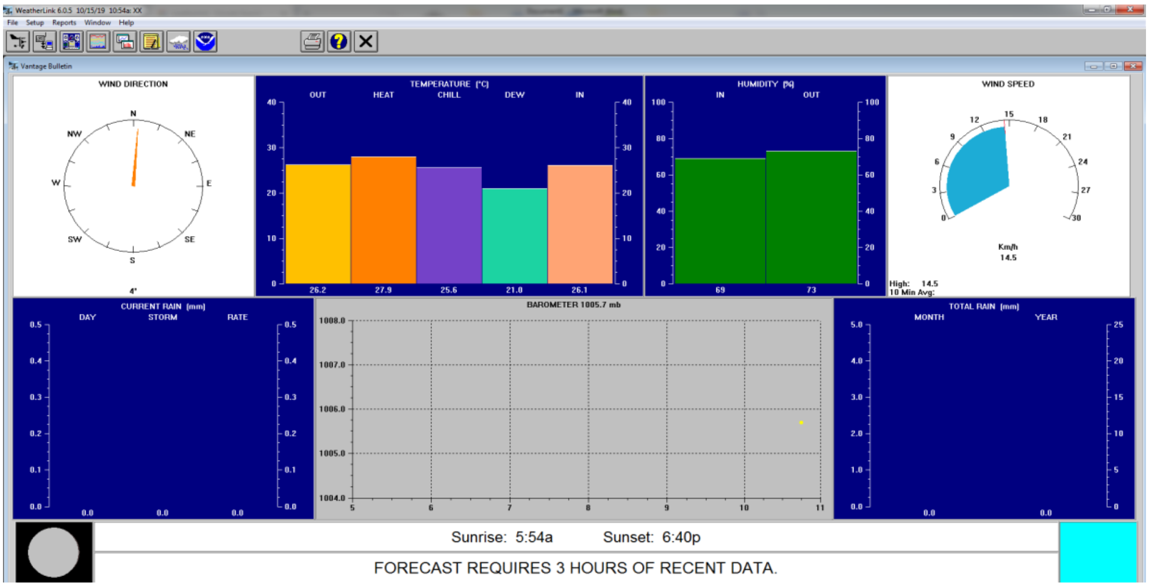

Figure 16: WeatherLink Software

We have used YAT (Engineering, testing and debugging of serial communication) to establish serial communication between computer and console. There are multiple commands to communicate with console. Commands are basically ASCII strings. In order to conserve battery power, the console will be in sleep mode, and will wake up only when required. One should always perform a wakeup procedure before sending commands to the console. Line Feed character, '\n' (decimal 10, hex 0x0A) acts as console wake up command. The console responds with Line Feed and Carriage Return characters ('\n\r'). The console also responds with 'ACK', 'NAK', 'OK', 'DONE' commands as per the commands sent. The serial communication can be tested by sending 'TEST' to the console. If the console reply with 'TEST\n', the serial communication is established, else one should recheck the connections. There are various other commands like 'RXCHECK', 'RXTEST', 'VER', 'RECEIVERS', etc. in order to test serial communication. There are various testing, downloading, current data, EEPROM, clearing, calibrating and configuring commands.

The sensor data can be seen through YAT using 'STRMON' and 'STRMOFF' commands. The console starts sending data when STRMON command is sent to the console. The data contains 8 bytes and each byte comes with least significant bit first. The data comes every 2.5 seconds and will stop only if STRMOFF command is sent.

The 8 bytes contain data and can be read as follows:

Byte 0: It is the header. The upper nibble represents the sensor the data is from. Following are the upper nibble with respect to sensor from which it has been obtained.

2 = Supercap voltage (Vue only)
4 = UV Index
5 = Rain rate
6 = Solar radiation
7 = Solar Cell output

8 = Temperature
9 = Wind gust
a = Humidity
The Transmitter ID is given by the lowest three bits in the low order nibble. Bit 3 in the low order nibble of Byte 0 becomes high if the transmitter battery is low else the bit is set to zero.

Byte 1: It gives wind speed in mph. The wind speed is updated in every transmission.

Byte 2: It gives wind direction. It is also updated in every transmission. The Vantage Pro2 uses a potentiometer with a significant dead zone around North. Therefore there are no values reported between 352 and 8 degrees inclusive. This byte can vary from 1 to 255. This can be mapped to 1 to 360 degrees as follows
If this byte is 0, wind direction is 360.
Else wind direction is found using formula, 9 + Byte2 * 342 / 255.

Byte 3-5: This depends on the type of sensor data being at that instant.

Message 2 (Supercap voltage): Bytes 3 and 4 represents the Supercap voltage. The Supercap stands for super capacitor that is used to store excess energy from the ISS solar cell during the day, which helps to power the console during night. This is very effective in extending the battery life of the non-rechargeable lithium CR2032.

Message 4 (UV Index): Bytes 3 and 4 represents UV Index. MSB is in Byte 3 and LSB is in Byte 4. If the third byte is FF, it indicates that there is no sensor present. The UV index can be calculated as follows:
UVIndex = ((Byte3 << 8) + Byte4) >> 6) / 50.0

Message 5 (Rain Rate): Byte 3 and 4 represents rain rate information. The rate is the time in seconds between rain bucket tips in the ISS. The rain rate is calculated using the bucket tip rate and the size of the bucket. The rain rate can be calculated as follows:
If Byte3 == 0xFF, there is no rain.
If (Byte4 && 0x40) == 0, it is light rain.
If (Byte4 && 0x40) == 0x40, it is strong rain
In case of light rain, rainrate [mm/h] = 720 / (((Byte4 && 0x30) / 16 * 250) + Byte3)
In case of strong rain, rainrate [mm/h] = 11520 / (((Byte4 && 0x30) / 16 * 250) + Byte3)

Message 6 (Solar Radiation): Bytes 3 and 4 represents solar radiation. MSB is in Byte 3 and LSB is in Byte 4. If third byte is FF, it indicates that there is no sensor is present. The Solar radiation can be calculated as follows:
Solar radiation = (((Byte3 << 8) + Byte4) >> 6) * 1.757936

Message 8 (Temperature): Bytes 3 and 4 represents temperature. Byte 3 is MSB and Byte 4 is LSB. The temperature in Fahrenheit can be obtained as

Temperature = ((Byte3 * 256 + Byte4) / 160

Message 9 (Wind Gust Speed): This message transmits the maximum wind speed during the previous 10 minutes. Byte 3 gives gust.

Message a (Humidity): Bytes 3 and 4 represents humidity as 10 bit value. Bits 5 and 4 in Byte 4 are the two MSB's. Humidity can be obtained as
Humidity = (((Byte4 >> 4) << 8) + Byte3) / 10.0

Byte 6-7: This represents CRC of the data.
Consider an example of data received through console:
a0 09 82 83 38 00 6a c9
Byte 0: 0a represents that bytes 3-5 contains information about humidity sensor.
Byte 1: 09 represents wind speed in mph. The wind speed is 9 mph (Hexadecimal to decimal).
Byte 2: 82 represents wind direction. Here the wind direction is 183^{o} N.
Byte 3-5: Humidity is represented as two bytes in Byte 3 and Byte 4 as a ten bit value. Bits 5 and 4 in Byte 4 are the two most significant bits. Byte 3 is the low order byte. The ten bit value is then 10x the humidity value displayed on the console. The functions of the four low order bits in Byte 3 that cause the apparent jitter are not known.
The corresponding humidity value is then
((0x38 >> 4) << 8) + 0x83 = 131 + 768 = 899 = 89.9% relative humidity.
The displayed humidity at the time was 90%.

Sensor data	Time between two transmissions
Outside temperature	10 seconds
Wind speed	2.5 seconds
Wind direction	2.5 seconds
Outside humidity	50 seconds
Rain	10 seconds
Solar radiation	50 seconds
UV	50 seconds

Table 2: Sensor data with their update time

4.5 Soil Sensors

USEFUL DEFINITIONS:

Volumetric Water Content:
To explain it in simple terms, dry soil is composed of solid material and air pockets together called as pore spaces. A typical volumetric ratio is composed of 55% solid material and 45% pore space. When water is added to the soil, the pore spaces begin to fill with water. Soil that seems damp to the touch might have 55% minerals, 35% pore space and 10% water. So this is an example of 10% volumetric water content. The maximum water content in this scenario is 45% because at this value, all the available pore spaces would have been filled with water. This soil is said to be saturated, because at 45% volumetric water content, the soil can hold no more water.

Time domain reflectometry (TDR):
It determines soil moisture by measuring the transit time of an electromagnetic pulse transmitted along a parallel metallic probe placed in the soil. The pulse travel time is proportional to the apparent dielectric constant of the soil which is the basic principle used in measuring the soil moisture.

TYPES OF SOIL MOISTURE SENSORS:

Tensiometric and volumetric are the two primary sensor types that measure soil moisture. Tensiometric sensors as the name implies measures the soil moisture tension, or the potential soil moisture. Tensiometers are responsive to soil properties by measuring how tightly a particular soil type retains water. Volumetric sensors measure the actual volume of water contained in the soil. Each technique is explained in detail in the following:

Volumetric Techniques mainly consists of two main sensors:

- Resistive Sensor
- Capacitive Sensor

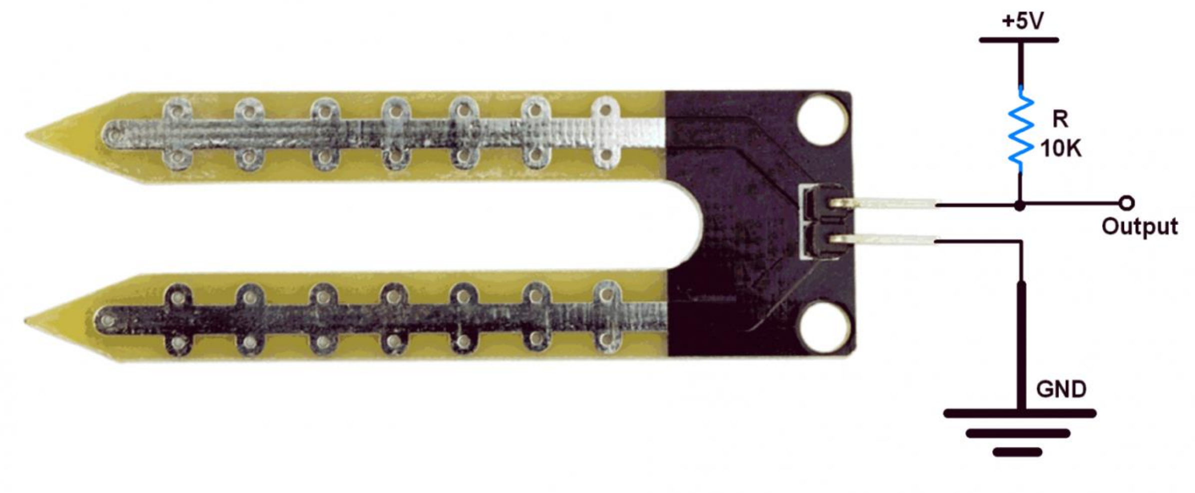

Figure 17: Resistive Sensor

Figure 18: Capacitive Sensor

Resistive Sensor:

The working of the sensor: Soil moisture sensor comprises of two conducting plates. First plate is connected to the +5Volt supply in series resistance of 10K ohm and the second plate is connected directly to the ground. It functions as a voltage divider bias network, and output is taken directly from the first terminal of the sensor pin, which is shown in the above figure. The output will change in the range of 0 – 5 Volt, in proportion with change in content of soil moisture in the soil. Ideally, when there is zero moisture in soil, the sensor acts as open circuit and will have infinite resistance. Thus we get 5V at the output.

The resistive sensor consists of two probes which are used to measure the volumetric content of water. These two probes allow the current to pass through the soil and then it uses the resistance value to measure the moisture value. When there is abundant water, the soil will conduct more electricity which means that there will be less resistance. Therefore, the moisture level will be significantly higher. Dry soil conducts electricity poorly, so when there is less water, then the soil will conduct less electricity which implies that there will be more resistance. Therefore, the moisture level will be significantly lower.

Capacitive Sensor:

The sensor measures the soil moisture levels by measuring the capacitance, rather than measuring the resistance like other types of moisture sensor. The ability to prevent corrosion is because it is made of a corrosion resistant material giving it durability and reliability.

Soil moisture content may be determined via its effect on dielectric constant by measuring the capacitance between two electrodes inserted in the soil. Where soil moisture is predominantly in the form of free water, the dielectric constant is directly proportional to the moisture content. The probe is given a frequency excitation to permit measurement of the dielectric constant. The values from the probe are not linear with water content and are influenced by soil type and soil temperature. Therefore, careful calibration is required and long-term stability of the calibration is not assured.

Tensiometric Techniques:

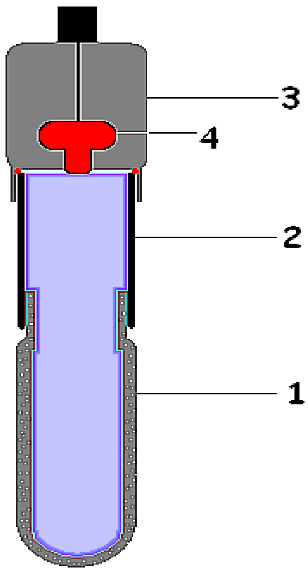

Figure 19: Electronic Tensiometer Probe

The above figure shows an Electronic tensiometer probe, which consists of the following four main parts, namely (1) porous cup; (2) water-filled tube; (3) sensor-head; and (4) pressure sensor.

A tensiometer sensor is a measuring instrument used to determine the soil moisture tension in the vadose zone. This device typically consists of a plastic tube with a porous ceramic cup, and is filled with water. The top of the tube has either a built-in rubber cap used with a portable puncture tensiometer instrument, which uses a hollow needle to measure the pressure inside the tensiometer. The tensiometer is buried in the soil, and a hand pump is used to create a partial vacuum. As water is pulled out of the soil by plants or by evaporation, the vacuum inside the tube increases. As water is added to the soil, the vacuum inside the tube pulls moisture from the soil and vacuum decreases. As the water in the tensiometer is considered to be in equilibrium with the soil water, the gauge reading of the tensiometer represents the matric potential of the soil.

The primary method for measuring capillaric tension in the soil involves the use of the tensiometer, which directly measures capillaric potential. The main disadvantage of the tensiometer is that it functions only from zero to about -0.8bar, which represents a small part of the entire range of available water. The lower moisture limit for the good growth of most crops is beyond the this range. The use of the tensiometer to schedule irrigation can cause over-irrigation.

Disadvantages: Limit range of 0 to -0.8bar not sufficient for sandy soil. Difficult to translate data to volume water content Hysteresis Requires regular maintenance, depending on range of measurements subject to breakage during installation. Further, automated systems are not cost effective and not electronically stable. Disturbs soil above measurement point and can allow infiltration of irrigation water or rainfall along its stem.

Advantages: Cost effective and easily constructed. Works well in the saturated range. Easy to install and maintain. It can operate for very long periods if properly maintained and cared.It can be used with positive or negative gauge to read water table elevation and soil water tension.

SENSORS USED IN PROJECT:

Figure 20: VH400 Sensor used in project

In this project, we have chosen the VH400 Soil Moisture Sensor developed by Vegetronix.

The characteristics and the features of the Probe are as follows:

- Cost effective.
- Saves water.
- Rugged design for long term use.
- Reliable
- Durable
- Probe does not corrode over time.
- Mechanically Robust
- Accurate and precise measurement.
- Insensitive to salinity.
- Low power for battery operation.
- Rugged design for long term use.

VH400 Soil Moisture Sensor Detail:

The VH400 is a professional electronic soil moisture sensor. It is so sensitive, that it can measure the moisture present on your hands when you touch its blade.

It is mechanically rugged, it is made up of ABS plastic, and fiberglass. VH400 moisture sensor is absolutely waterproof and mechanically strong. It can be buried at any depth in the soil.

VH400 ignores the salt content in the soil. Most other sensors, especially conductivity or resistance based sensors, are ineffective, because salts and fertilizers found in soil alter or effect their readings. The VH400 moisture sensor uses TDR to measure the water moisture in any soil regardless of soil salinity.

The metallic probe will never corrode, or need to be recalibrated.

The thin blades prevent roots from being damaged. The blade of the VH400 soil moisture sensor is designed to be as slim as possible.

4.6 Subsystems

4.6.1 SOLENOID VALVE

Solenoids are the most important components used in solenoid valves to control the flow of fluids such as liquids and gases. Solenoids are electromechanical devices that convert AC or DC electrical energy into linear motion to control fluid flow. They usually consist of a helical coil wound concentrically around an armature, made up of ferromagnetic material such as iron or steel. Most solenoid valves have a replaceable coil and can be used with coils with different voltages.

Figure 21:Solenoid Valve

When current flows through the coil, using the same basic principles as ordinary electromagnets it generates a magnetic field inside the coil which attracts the armature towards the centre of the solenoid. Since the armature is drawn towards the centre of the solenoid regardless of the polarity of the current, an opposing force is needed to return the armature into the starting position when the coil is not engaged. This is achieved by using a spring mechanism. Under ideal conditions, in order to actuate the solenoid, the force generated by the solenoid must be larger than the combined forces of the spring, and the hydraulic pressure, as well as friction.

By lifting the armature, a small port in the valve is opened that allows the flow of the media. The flow through the valve can be controlled by controlling the current flow through the coil.

4.6.2 REAL TIME CLOCK

A real-time clock (RTC) is a computer clock, usually in the form of an integrated circuit that is built for keeping time. It keeps track of time in terms of hours, minutes, seconds, months, days and even years. RTCs can be found running in personal computers, embedded systems and servers, and are present in any electronic device that may require time keeping functionality. Being able to still function even when the computer is powered down through a battery or independently from the system's main power is fundamental.

Figure 22:RTC Module

RTC ICs regulate time with the use of a crystal oscillator and do not rely on clock signals like most hardware clocks. Aside from being responsible for the timing function of the system and its clock, RTC ICs ensure that all processes occurring in the system are appropriately synchronized. Although some may argue that this is a job for the system clock, the system clock is actually dependent on the RTC, making the RTC indirectly responsible for synchronization.

4.6.3 MENU SYSTEM

In order to allow the user to set the values of various soil and plant parameters an indigenous menu system was developed. The soil parameters that can be set by the user are: field capacity, permanent wilt point. The plant parameters that can be set by the user are: crop cycle, root depth, and date of sowing. There is an option to calibrate sensors also.

Buttons assigned to set the values:

There are four buttons on the BMS IOT box. Once the controller is powered on, by pressing the fourth button on the device, the user can enter the menu.

1-SOIL DATA

2-PLANT DATA

3-SENSOR CALIBRATION

By pressing the appropriate button the user will be able to set the parameters. User can use the following buttons to set the parameters:

1-OK

2-INCREMENT

3-DECREMENT

4-BACK

The values can only be increment or decrement in terms of 5 for all the parameters. The below flow diagram shows the flow of the menu system.

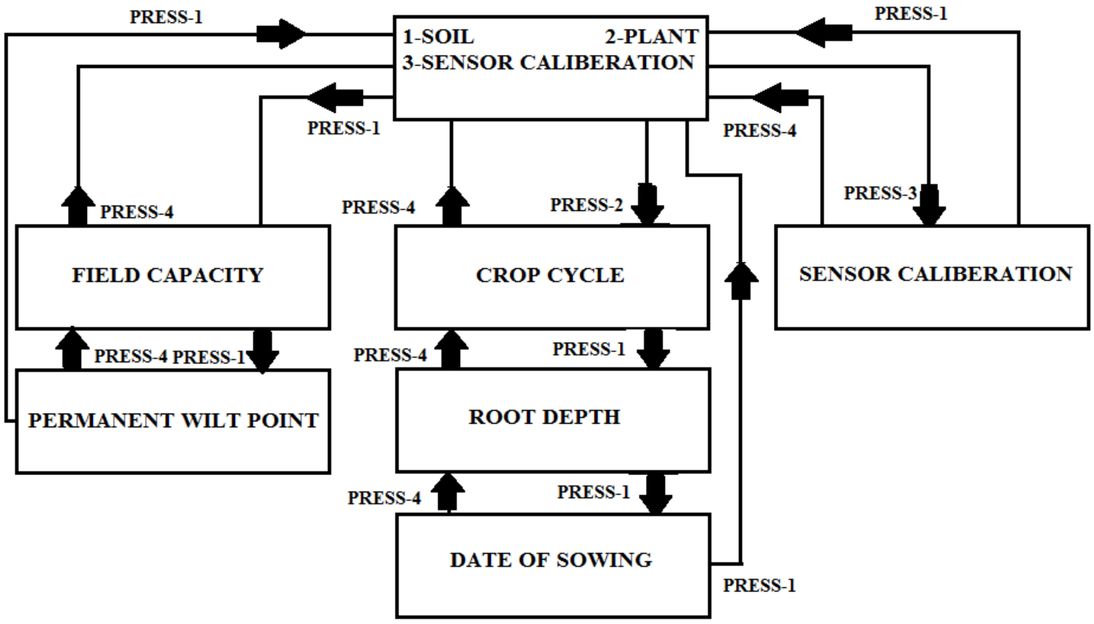

Figure 23:Flow diagram of menu system

4.7 Working

Once the device is turned on, the user should set various parameters. The soil moisture sensor wires have been crimped and have given it mechanical stability so that the sensor's values are stable. The working of major parts/ functions of the device is as follows:

Soil Moisture Sensors and RTC: The device consists of four VH400 soil moisture sensors. The four soil moisture sensors should be placed at different depths in the soil considering the root depth model of the plant. The user enters the sowing date and the crop cycle. Based on these data, the algorithm calculates the difference between present date and the date of sowing in terms of days. The root depth model which is implemented in the algorithm calculates the root depth based on the number of days past after the date of sowing. Based on the number of days, the algorithm calculates which sensors should be activated. The activated sensor's values are taken and their average is calculated. This average value is displayed and this value is also used to control the solenoid valve.
The present date, year and other time parameters are calculated using the RTC module which is built in the device itself.

Solenoid valve and relay: The outlet of water is controlled automatically by using the solenoid valve with the help of relay. The field capacity(FC) and permanent wilt point(PWP) values are set by the user. By considering the average soil moisture sensor value and comparing it with the FC and PWP values the algorithm decides whether the water has to be let out or not. The solenoid valve turns on when the average soil moisture sensor value is less than available moisture(RAM) and greater than or equal to permanent wilt point(PWP). The solenoid valve is turned on until the average soil moisture sensor value reaches the field capacity(FC) value.
The relay is used to drive the solenoid valve based on the switch signals given to it by the controller device.

Menu System: In order to make a full-fledged irrigation system, the menu system has been implemented in the device rather than fixing the values in the program. The user can set the values of various parameters which helps in the functioning of the device.

4.8 Estimated Bill

COMPONENTS	EXPECTED PRICE IN RS
Davis Vantage Pro 2+ Console	60,000
BMS IOT BOX(LPC1768)	10,000
Soil Moisture Sensors	1,000
Solenoid Valve	600
Miscellaneous	4,000
Total	75,600

Table 3: Estimated Bill

CHAPTER 5: RESULTS AND DISCUSSION

The proposed work will follow the procedure as follows:

Sensors will determine the moisture level at the Root Zone. The weather station determines Humidity, Temperature, Wind Speed and Rainfall. Micro controller should get sensor data per minute. Micro controller should analyse the data, take correct action and record the data.

Soil moisture sensor is a sensor connected to an irrigation system controller that measures soil moisture content in the active root zone based on the root depth model before each scheduled irrigation event and bypasses the cycle if soil moisture is above the user defined set point.

Once the irrigation starts, the microcontroller will request data from the corresponding sensor. When threshold moisture level is reached, it will record the data and stop the irrigation. Stored data will be sent to the central server using GSM.

With the use of this technique we can reduce water consumption. It can be set to lower and upper thresholds to maintain optimum soil moisture saturation and minimize plant wilting. It can contribute to deeper plant root growth, reduced soil runoff/leaching, less favourable conditions for insects and fungal disease. It is also possible to control the nutrition levels in their entirety thus, lower nutrition costs. No nutrition pollution is released into the environment because of the controlled system. Hence will save great amounts of irrigation water, and will have stronger and healthier plants with stable and high yields.

Below are the pictures of the different implementation phases of the Smart Irrigation System:

STAGE 1: Interfacing Weather Station and BMS-IOT Box to the Smart Irrigation System. (Done During Project for Community Service – 7th Semester)

Figure 24: Soil Moisture Sensor data displayed on the BMS-IOT Box

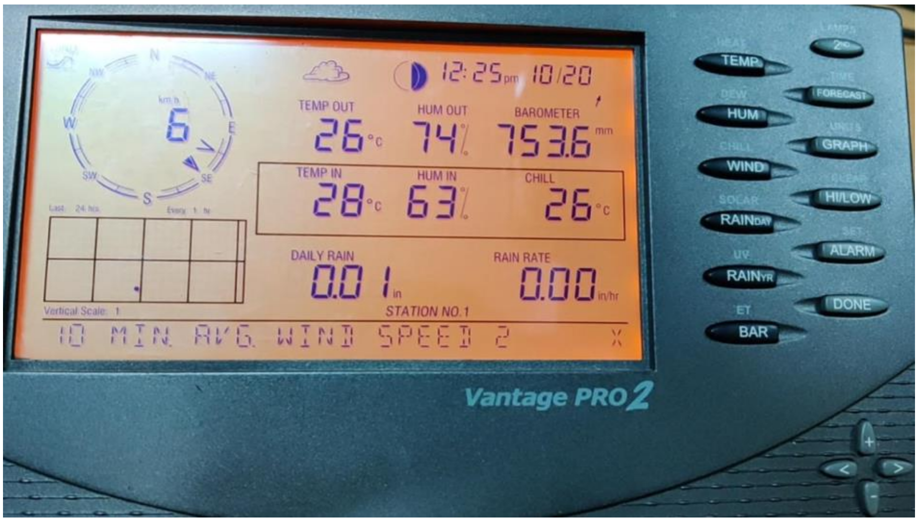

Figure 25: Weather data display on the VantagePro2 Console

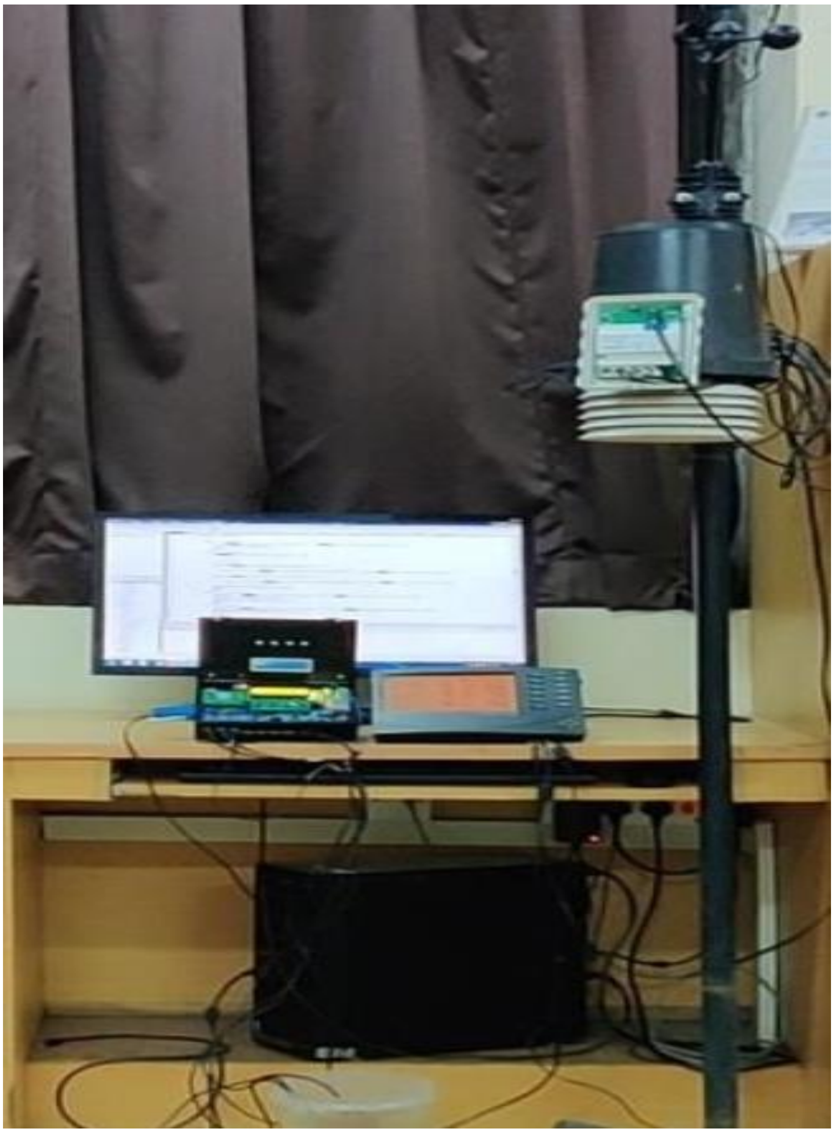

Figure 26: Complete Smart Irrigation setup with all components (Clockwise) – Weather station, Soil bucket, BMS-IOT Box, VantagePro2 Console

STAGE 2: Developing Additional Functionality to the Smart Irrigation System to make the process smoother. (Done Parallelly with Stage 3 – 8th Semester)

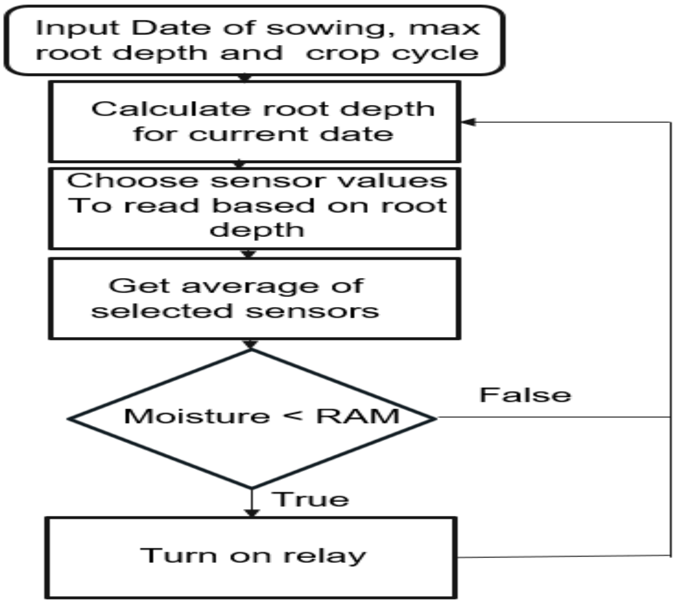

Figure 27: Implementation of Root Depth Model Algorithm

Figure 28: Solenoid Valve Implementation

Figure 29: Menu System Implementation, to set the Soil or Plant Characteristics

STAGE 3: Initial Field Plan and Setup (Done Parallelly with Stage 2 – 8th Semester)

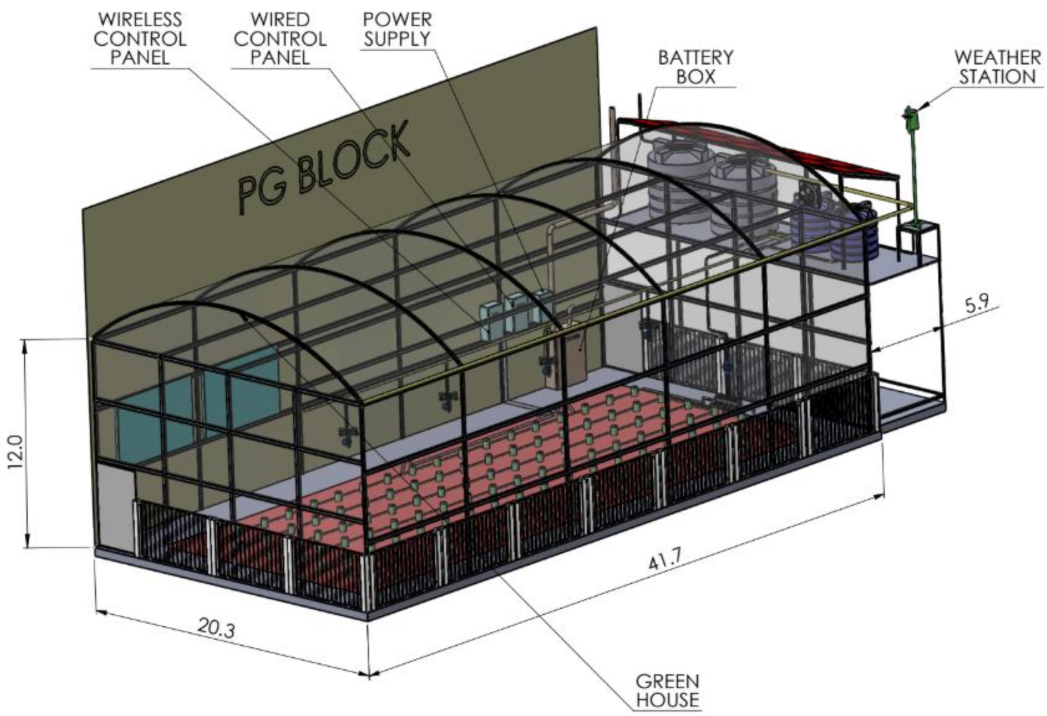

Figure 30: Field Plan for Smart Irrigation System Implementation

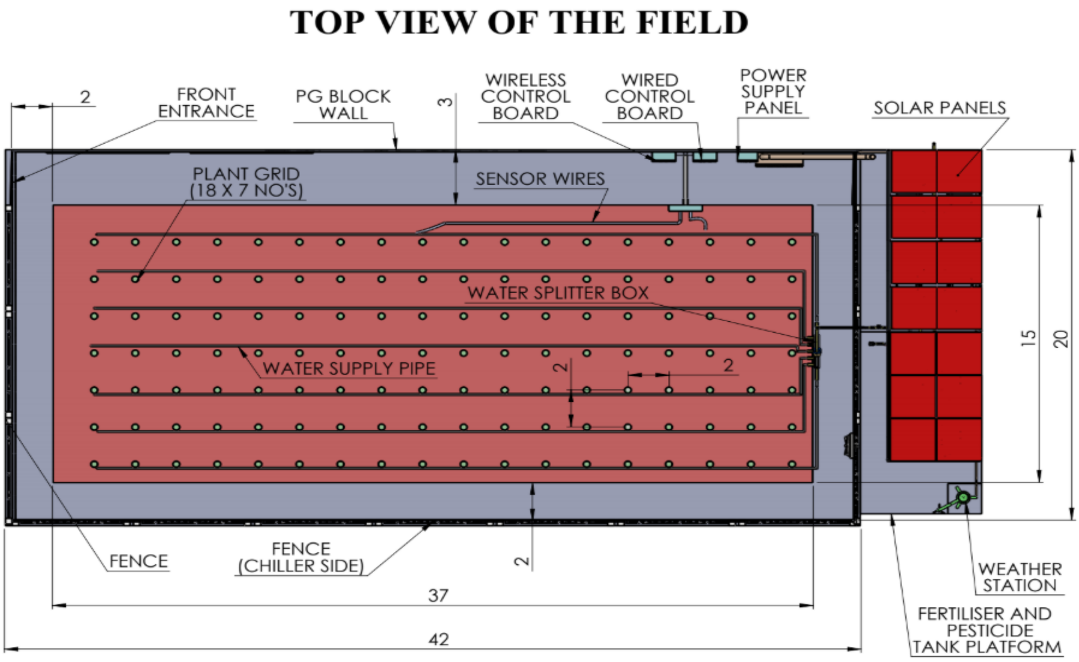

Figure 31: Top View of the Field – Plan

Figure 32: Place where implementation will be carried out

STAGE 4: Complete Smart Irrigation Setup in the Field (Final Stage)

Figure 33: Solar Panel setup in the field to power the BMS-IOT Box

Figure 34: All the components, Weather Station, Vantage-Pro Weather Console BMS-IOT Box, and Soil Sensors, placed in the field.

Figure 35: Closer view of the Vantage-Pro Weather Console and BMS-IOT Box working on the field.

CHAPTER 6: CONCLUSION AND FUTURE WORK

The system describes the design, optimization and development of a practical application to optimize water resources in irrigated agriculture by low-cost wireless system to monitor soil water status and the irrigation water and to increase the yield. The system designed is not only limited to the present functionality, but can be further can be extended for more customized functionality like smart home gardening system. It is concluded that the sensor nodes are of great help to reach the desired moisture conditions at the different depths and to maintain soil moisture level of the soil at the desired value, thus contributing to the ability to adapt the irrigation strategy developed.

The wastage of water has been reduced by adopting weather data into the system. While it was known that weather affects plants in many obvious ways, we found out that weather affects plants in ways we may not realize. While a tree snapped by a gust of wind is easy to associate with the event, large trees may not show the effects of drought until several years later. In addition to any direct effects, weather-related stress can make plants more susceptible to disease and insect problems. Weather is whatever is happening now - precipitation, temperature, wind, sun, and humidity. It is not the same as climate, which is historical weather or the average of weather conditions over a long period of time. Climate determines what will probably grow well in your area, but plants can still be damaged or killed by extreme weather.

While we have no control over the weather, in some cases we can try to design and maintain the garden to minimize the negative effects of weather on our plants. Thus, weather conditions should also be monitored to have better yield of plant and reducing water wastage problems.

6.1 Advantages Of Smart Irrigation:

- Increased Production
  Optimized crop treatment such as accurate planting, watering, pesticide application and harvesting directly affects production rates.

- Water Conservation
  Weather predictions and soil moisture sensors allow for water use only when and where needed.

- Real-Time Data and Production Insight
  Farmers can visualize production levels, soil moisture, sunlight intensity and more in real time and remotely to accelerate decision making.

- Lowered Operation Costs
  Automating processes in planting, treatment and harvesting can reduce resource consumption, human error and overall cost.

- Increased Quality of Production
  Analysing production quality and results in correlation to treatment can teach farmers to adjust processes to increase quality of the product.

- Accurate Farm and Field Evaluation
  Accurately tracking production rates by field over time allows for detailed predicting of future crop yield and value of a farm.

- Reduced Environmental Footprint
  All conservation efforts such as water usage and increased production per land unit directly affect the environmental footprint positively.

- Remote Monitoring
  Local and commercial farmers can monitor multiple fields in multiple locations around the globe from an internet connection. Decisions can be made in real-time and from anywhere.

- Equipment Monitoring
  Farming equipment can be monitored and maintained according to production rates, labour effectiveness and failure prediction.

6.2 Future Work

All the necessary components to implement a Smart Irrigation System has been successfully implemented on the field. With this, we have a functional setup to implement Smart Irrigation. Some of the future works that can be performed are as follows:

- So far, we have the weather station set up and functioning properly, recording all the necessary parameters. However, our irrigation system is still based on scheduling irrigation based on the soil moisture content. From the Penman-Monteith for Evaporation Transpiration discussed in the introduction, we can incorporate weather parameters into our irrigation system and aim for a high degree of accuracy.

- It’s now time to actually grow a crop completely using this irrigation system. Some suggestions are growing Beans, Brinjal, Tomato, etc. as they can be grown quickly, in a month or two.

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Books:

1. Integrated Sensor Suite (ISS) Manual
2. Davis Instruments Manual

CHAPTER 8: PLAGIARISM REPORT

Search operation #1

Source text
PROJECT REPORT ON "SMART IRRIGATION SYSTEM" Submitted in partial fulfilment of the requirements for the partial completion of MAJOR PROJECT [16EC8DCMPJ]IN ELECTRONICS AND COMMUNICATION ENGINEERING VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM SUBMITTED BY: Nitesh M S1BM16EC003 Nitish N1BM16EC073 Prajwal Vishwanath1BM16EC080 Varun K V Ithal 1BM16EC118 Under the Guidance of Mr. Harish V Mekali(Assistant Professor, ECE, BMSCE) January - May 2020Department of Electronics and Communication Engineering B.M.S COLLEGE OF ENGINEERING (Autonomous College Affiliated to Visvesvaraya Technological University, Belgaum)Bull Temple Road, Basavanagudi, Bangalore-560019DECLARATION We undersigned students of final semester B.E in Electronics and Communication Engineering, BMS College of Engineering, Bangalore, hereby declare that the dissertation entitled "SMART IRRIGATION SYSTEM", embodies the report of my project work carried out i ndependently by us under the guidance of Mr. Harish V. Mekali, Assistant Professor, E&C Department, BMSCE, Bangalore in partial fulfilment for the award of Bachelor of Engineering in Electronics and Communication from Visvesvaraya Technological University, Belgaum during the academic year 2019-2020.We also declare that to the best of our knowledge and belief, this project has not been submitted for the award of any other degree on earlier occasion by any student. Place: Bangalore Date: Nit esh M S 1BM16EC003Nitish N 1BM16EC073 </ Prajwal Vishwanath 1BM16EC080 B.M.S COLLEGE OF ENGINEERING (Autonomous College under VTU) Department of Elec tronics and Communication EngineeringCERTIFICATE This is to certify that the project entitled "SMART IRRIGATION SYSTEM" is a bonafide work carried out by Nitesh M S (USN:1BM16EC003), Nitish N (USN:1BM16EC073) Prajwal Vishwanath (USN:

1BM16EC080) and Varun K V Ithal (USN:1BM16EC118) in partial fulfillment for the partial completion of MAJOR PROJECT[16EC8DCMPJ] during the academic year 2019-2020.Mr.
J Dinesh Reddy </w:t
Signature with date:1.
2.
DEDICATION
This Work Is Dedicated To All The Farmers Of The NationABSTRACT
India is an agriculture based country. Ancient people were completely dependent on the agricultural harvesting. Agriculture is a source of livelihood of majority Indians and has a great impact on the economy of the country. In dry areas or in case of inade
quate rainfall, irrigation is a challenging problem. So, it needs to be automated for maximum yield and handled remotely. Increasing energy costs and decreasing water supplies demands the need for better water management. Irrigation management involves a complex decision making process to determine when and how much water to apply to a growing crop to meet specific management objectives. So, efficient water management plays a critical role in the irrigated agricultural cropping systems. A low cost alternative solution for efficient water management which is currently in use is drip irrigation system.In this project, we are going to devise a product which controls the moisture level of soil in the roots of the crop so as to supply required water to the crop
automatically based on the moisture level of the soil and also by applying the virtual water concept, which will result in maximum yield of the crop. Specifically, four moisture sensors at different root depths are used to measure the moisture content in the root of crop at different levels, and this data is sent to our website and so that we can monitor the growth of crop remotely through a data visualization platform (website) and also to keep a documentation on growth of crop. Based on the moisture content of the crop we water the crops if the moisture content drops below a defined minimum and stop watering the crops when the moisture content goes above the defined maximum values.We also interface a weather station to our product, which will monitor th
e different weather parameters such as Wind Speed and Direction, Temperature, Humidity, Rainfall and UV Index. These parameters are tracked continuously and are also updated to a website to generate datasets which can be used for weather prediction in the future. These datasets can also be fed to the Evaporation Transpiration (ET) equation to measure the quantity of moisture that is both transpired by a plant and evaporated from the soil and plant surfaces.ACKNOWLEDGEMENT
Any achievement, be it schola
stic or otherwise does not depend solely on the individual efforts but on the guidance, encouragement and cooperation of intellectuals, elders and friends. A number of personalities, in their own capacities have helped us in carrying out this project work. We would like to take this opportunity to thank them all. </w:p><w
We express profound gratitude to respected principal Dr. B. V. Ravishankar, BMS College of Engineering for providing a congenial environment to work in. Our sincere gratitude to Dr. Arathi R Shankar, Head of the Department, Electronics and Communication Engineering for encouraging and providing this opportunity to carry out the project in the department.We would like to thank our guide Mr. Harish V. Mekali, Assistant Professor, Department of ECE who helped us in all the ways to carry out the project work. He stood beside and guided us in every step.We will be incomplete, if we don't mention our heartfelt thanks to Mr. Rajath B, Research Assistant, Robotics Lab, BMSCE and Kamlesh C Muddi, B-Tech, ECE, BMSCE who helped us in all the ways to carry out the project work.We would like to share the joy completing the project to all the team members of NGX Semiconductors. We thank all our professors for providing the basic knowledge without which this project wouldn't have been possible. Last but not the least we thank our family and friends, who made their valuable support compelled us to maintain a standard throughout our endeavour.-
Nitesh
M S </wNitish
N Prajwal

VishwanathVarun K V Ithal

LIST OF FIGURES:

CHAPTER 1: INTRODUCTION
Introduction
Agriculture is one of the most basic, yet one of the most important occupations in the world. India is basically an agrarian society where around 60 percent of land area is cultivated for agriculture and about 50 per
cent of the population directly or indirectly depends on agriculture for their livelihood.Agriculture needs water in huge amounts. It is the most water consuming industry. More water will be needed to produce more food to meet the future demand. But increasing competition for water and inefficient irrigation practices constrains future food pro
duction. 70% of water is used for Agriculture while 22% for industrial use and 8% for domestic purpose. In many developing nations irrigation requires over 90% of water withdrawn from available sources for use. When we look for efficient irrigation methods, Drip Irrigation is the most efficient, followed by Sprinkler Irrigation, and the least efficient method is Surface Irrigation. However, 94% of the application methods of irrigation water at field level currently are of the category of surface irrigation, wherein the water is spread over the field by gravity.Figure 1: Percentage of irrigation in the world
Agriculture in India is mostly dependent on monsoon and Groundwater resources. Still two-thirds of the net sown area (land on which cultivation is d
one at least once a year) is dependent on rainwater, mostly during the four monsoon months. However, rainfall in India is notoriously capricious, causing floods and droughts alternately. Its distribution and amount are not in accordance with the needs of the crops. India has a population as much as 15% of the world's population but has only about 4% of the world's fresh water resources. Much of these are unevenly distributed. Average annual rainfall in India is about 1,170 mm, which corresponds to an annu
al precipitation including snowfall of 4,000 billion cubic meters (BCM). Nearly 75% of this (3000BCM) occurs during the monsoon season, confined only to 3-4 months (June to September) a year. According to the Planning Commission, India has so far created a total of about 225BCM of surface storage capacity. However, per capita storage capacity in India is very low at 190 cubic meters. If we compare this data to other developed countries, we find the per capita storage capacity to be 5,961BCM in USA, 4,717BCM in Australia, 3,388BCM in Brazil, and 2,486BCM in China. Though the average water availability in India remains more or less constant according to the natural hydraulic cycle, per capita availability is reducing progressively owing to the increasing population. In 1990, the average figure was around 2,200 cubic meters. In 2015, the figure was 1829 cubic meters, which may further go down to about 1340 cubic meters and 1140 cubic meters a year by 2025 and 2050 respectively. The situation in some of the river basins is worrisome. According to international agencies, any country with per capita water availability of less than 1700 cubic meters is considered 'water stressed' and those with per capita water availability less than 1000 cubic meters is considered 'water scarce'. Already six river basins of the country fall into the water scarce category, and five more basins are likely to be 'water scarce' during 2025-50. Only 3-4 basins will be 'water sufficient'. Water availability both in quality and quantity has been on the decline over the past 3-4 decades because of gross mismanagement.Smart Irrigation Concepts
While implementing a smart irrigation system, it is necessary to take into consideration two important characteristics. They are:

Soil Characteristics
Plant Characteristics
Weather Characteristics
The Soil Characteristics include four main properties of the soil, namely Field Capacity, Permanent Wilting Point, Available Moisture and Readily Available Moisture. For a given type of soil, these properties are fixed. In this project setup, we are experi
menting with Red Soil.The Plant Characteristics include properties such as crop period and different growth stages and their duration in days. The crop period for greens is generally 60 days, while for rice, wheat, and other grains it can vary from 90-12
0 days. Generally, most crops have crop duration between 60-120 days. There are some exceptions to this rule though, such as sugarcane, which has a crop period ranging from 12-18 months.The weather characteristics are the different weather parameters suc
h as Wind Speed and Direction, Temperature, Humidity, Rainfall and UV Index. The weather parameters need to be monitored continuously and can be used for weather prediction, as well as aid in the process of efficient indication.SOIL CHARACTERISTICS:
As
mentioned before, the four important soil characteristics are:Field Capacity (FC)
Permanent Wilting Point (PWP)Available Moisture (AM)
Readily Available Moisture (RAM)
The physical definition of Field Capacity
is as follows: Field Capacity is the bulk
https://en.wikipedia.org/wiki/Water_content
water content
retained in soil at −33 kPa/kg (or −0.33 bar) of
https://en.wikipedia.org/wiki/Hydraulic_head
hydraulic head
or
https://en.wikipedia.org/wiki/Suction_pressure
suction pressure. Field Capacity is the amount of
https://en.wikipedia.org/wiki/Soil_moisture
soil moisture
or
https://en.wikipedia.org/wiki/Water_content
water content
held in the
https://en.wikipedia.org/wiki/Soil
soil
after excess water has drained away and the rate of downward movement has been decreased. This usually takes place after 2-3 days after rain or irrigation in previous soils of uniform structure and texture.The ph
ysical definition of Permanent Wilting Point
(PWP) or
Wilting Point
(WP) is as follows: Permanent Wilting Point is the
https://en.wikipedia.org/wiki/Water_content
water content
at −1,500
kPa (−15
bar) of suction pressure, or negative
https://en.wikipedia.org/wiki/Hydraulic_head
hydraulic head. Permanent Wilting Point is the minimum amount of water in the soil that the plant

requires to not to
https://en.wikipedia.org/wiki/Wilting
wilt. If the soil moisture decreases to this or any lower point a plant wilts and can no longer recover its
https://en.wikipedia.org/wiki/Turgid
turgidity
when placed in a saturated atmosphere for 12 hours. The difference in moisture content of the soil between field capacity (F.C) and permanent wilting is termed the Available Moisture (AM). Available moisture can be expressed as percentage moisture PW, as percentage PV or as depth d.
Soil moisture content n
ear the wilting point is not readily available to the plant to absorb. Hence, the term Readily Available Moisture (RAM) has been used to refer to that portion of the available moisture that is most easily extracted by plants. Readily Available Moisture is defined at approximately 55% of the available moisture, though to make calculations easier the value is rounded off to 50%.Figure 2: Field Capacity and Permanent Wilting Point for different types of soil
The importance of the Available Moisture and Re
adily Available Moisture parameters are seen in the types of seeds used. There are mainly two types of seeds used by farmers, local seeds and hybrid seeds. Over 90% of the farmers prefer hybrid seeds over local seeds because the yield from hybrid seeds is very high when compared to local seeds. However, Hybrid seeds have one disadvantage with them, which is, they are extremely water sensitive. What this means is if the soil moisture level falls to the Permanent Wilting Point (PWP) value of the soil, let alone below the Permanent Wilting Point value, the plant will not be able to extract water and will die out as a result. However, local seeds are able to extract moisture from the soil even if the soil moisture level falls a little below the Permanent Wilting Point level. In order to avoid this danger with hybrid seeds, a new parameter, Readily Available Moisture, is defined and its value is set at approximately 55% of the Available Moisture level.Let us take an example to understand the relationship between
the soil moisture parameters. Let the Field Capacity (FC) of the soil be 24%, and let the Permanent Wilting Point (PWP) of the soil be 10%. These two parameters are fixed for a given type of soil.Now, to calculate Available Moisture (AM), it is given by
:AM = FC - PWP
So,
AM = 24% - 10%
AM = 14%
Now, to calculate the Readily Available Moisture (RAM), it is given by:
k = 0.55 X AM
So,
k = 0.55 X 14%
k = 7% (approx.)
Now,
RAM = FC - k
So,
RAM = 24-7
RAM = 17%
The soil characteristics are shown in the figure below.
Figure 3: Soil Characteristics
WATER CYCLES:
The crops are supplied with water whenever the moisture level falls below the Readily Available Moisture limit in case of hybrid crops, or below the Permanent Wilting Point limit for local seed crops. Generally, once the crops are watered, they need not be
supplied with water for some duration, which varies based on the season. For example, in summers,

evaporation is more and hence the crops need to be watered more regularly, say, once every two days. However, during winters, evaporation is less; hence the crops need not be supplied with water as frequently as in summers, and once in around four days should be enough. Note that all these explanations are just rough figures to explain the watering cycle for crops. The figure below gives an example of how the watering cycle takes place in case of both hybrid seed crops as well as local seed crops.Figure 4: Watering Cycles
PLANT CHARACTERISTICS:
Crop cycles, as discussed earlier, generally range from 60 days for greens to 120 days for grains, with some exce
ptional crops such as sugarcane taking anywhere between 12-18 months between the Vegetative stages to the Harvesting stage. In this section, we talk about the five stages in a crop cycle, which are listed below as follows:Vegetative Stage (V)
Flowering Stage (F)
Yield Formation Stage (Y)
Ripening Stage (R)
Harvesting Stage (H)
Figure 5: Different Stages of Growth of a Plant
The vegetative stage is the initial stage of plant growth. It is in this stage that the root growth takes place. The Li
near Root Depth Model, which is an extremely useful theoretical method to calculate the growth of the root throughout the vegetative phase, is explained later. The vegetative stage is extremely water sensitive, which means that any problems or negative variations in watering the plant at this stage will have a drastic effect on the growth of the plant in the later stages.The flowering stage is the second stage in the plant cycle. By this time, the root has stopped growing. The plants start flowering. This stage also is extremely water sensitive and any problems or negative variations in watering the plant at this stage wil
l affect the growth of the plant in the later stages.The third stage in the plant cycle is the yield formation stage. By this time the first signs of fruits are seen from plants. This stage is also water sensitive, but not as sensitive as the first two s
tages.The Ripening stage is the fourth stage in the plant cycle. At this stage the plants have completely produced all the fruits and they are ripening. Finally, after the ripening stage, comes the harvesting stage where the fruits are ready to be harves
ted from the plants.LINEAR ROOT DEPTH MODEL
Figure 6: The Linear Root Depth Model
The above figure shows the linear root depth model. Since it is practically impossible to find out the depth of the root at any point of time during the vegetative phase of the plant cycle, scientists have developed a theoretical model to measure the depth
of the root at any point of the vegetative phase of the plant cycle.It is quite straightforward to calculate the depth of the root for a given time passed during the vegetative stage of the plant cycle. Let 't' be the time in days passed, and let 'x' be the depth of the root in meters for time 't' passed. Further, let 'T' be the total time duration of the vegetative phase in days, and let 'D' be the maximum depth of the root in meters, which is reached at the end of the vegetative phase. Using the concept of similar triangles from mathematics, we can calculate the depth of the root for any time duration passed. The formula is given by:t/T
$= d/D$ (or) $d=tD/T$Where, d gives the depth of the root in meters for t days passed.
WEATHER CHARACTERISTICS
All o
f the weather-based products reviewed operate on the principle of scheduling irrigation based on weather conditions. Most of the products use real-time or historical weather data to schedule irrigation based on Evaporation Transpiration (ET), which is a function of weather conditions and plant type.ET is defined as the quantity of moisture that is both transpired by a plant and evaporated

from the soil and plant surfaces. The American Society of Civil Engineering's (ASCE) standardized reference ET equatio
n parameters are maximum and minimum air temperature, net solar radiation, average vapor pressure, and average wind speed.Each of the weather-based irrigation scheduling systems evaluated use micro processing devices that calculate or adjust irrigation schedules based on one or more of the following parameters sets: weather conditions (temperature, humidity, rainfall, wind, a nd solar radiation), plant types (root depth and low versus high water use), and site conditions (latitude, soils, ground slope, and shade). Some of the systems generate watering schedules automatically. Others require the user to enter a base daily irrigation schedule, and then the device determines the frequency (which days) irrigation occurs or adjusts run times. Some of these partially automated systems provide guidelines for establishing the base schedule while others do not. Our irrigation system primarily focuses on the second set of conditions to carry out the irrigation process, and a weather station is installed to carry out the irrigation process according to the first set of parameters. On combining the first two parameters sets in our system we can aim for a high degree of accuracy in the irrigation process.In our project, a completely functional weather station is maintained onsite. In real world conditions, since the weather generally does not vary much over a large area, we can say it is suf
ficient to maintain one weather station for say, a cluster of villages. Further, to incorporate the weather characteristics, the ET Equation used, also known as the Penman-
Monteith Equation, is as follows:Where, ETo
= daily reference ET [mm/day], for longer periods 900 becomes 37T = air temperature at 2 m high ['C]
VPD = vapor pressure deficit [kPa]u2 = wind speed at 2 m high [m/s] = 2 m/s
Rn
= net radiation at the crop surface [MJ m-2 d-1]Δ = slope vapour pres
sure curve [kPa 'C^-1]γ = psychometric constant [
kPa 'C^-1]G = soil heat flux density [MJ m^-2 d^-1]
Each of these parameters can be further calculated as follows:
Temperature (T):
The weather station records the temperature at regular intervals, In a given day, we should take the average of the minimum and maximum temperatures to get the value of T.Vapor
Pressure Deficit (VPD):The following 4 Equations Give the calculation of vapour pressure deficit. <
In the four equations, Tmax and Tmin are recorded directly from the weather station, so is the Relative Humidity RH. From these parameters we can calculate VPD.Net Solar Radiation (
Rn):This parameter is directly recorded by the weather station. Take the
average of the maximum and minimum recorded values.Wind Speed (u2):
Wind speed is calculated as follows:
Where:
y = height of instrument above ground [m]
uy
= measured wind speed at y meters above ground level [m/s]u2 = wind speed at 2 m above ground [m/s].Slope Vapor Pressure Curve (Δ):Slope Vapor Pressure Curve is given as:T is the mean temperature.
Psychometric Constant (γ):
Psychometric constant is calculated by these two equations:
Here, P is the calculation of the atmospheric pressure in KPa.Z is the elevation above the sea level in meters.
Soil Heat Flux Density (G):
Can be ignored for now, take it as 0.
CHAPTER 2: LITERATURE SURVEY
The Indian Council of Agricultural Research (ICAR) is an autonomous organisation under the

Department of Agricultural Research and Education (DARE), Ministry of Agriculture and Farmers Welfare, Government of India. ICAR is the authority when it comes to all aspects of agricultural research and control in India. Most of the data presented and explained in the previous section is defined or set by the ICAR after doing extensive research and experiments as well as collaborating with international agencies and conforming to international standards.Form
erly known as Imperial Council of Agricultural Research, it was
established on 16 July 1929
as a registered society under the Societies Registration Act, 1860 in pursuance of the report of the Royal Commission on Agriculture. The ICAR has its headquarters at New Delhi. The Council is the apex body for coordinating, guiding and managing research and education in agriculture including horticulture, fisheries and animal sciences in the entire country. With
https://icar.org.in/content/node/325
101 ICAR institutes
and
71 agricultural universities
spread across the country this is one of the largest national agricultural systems in the world. The ICAR has played a pioneering role in ushering Green Revolution and subsequent developments in agriculture in India through its research and technology development that has enabled the country to increase the production of
food grains by 5.4 times, horticultural crops by 10.1 times, fish by 15.2 times, milk 9.7 times and eggs 48.1 times since 1951 to 2017, thus making a visible impact on the national food and nutritional security. It has played a major role in promoting excellence in higher education in agriculture. It is engaged in cutting edge areas of science and technology development and its scientists are internationally acknowledged in their fields.To note the developments in Smart Irrigation Systems throughout time, we first look at G. Vellidis, who in 2007 presented a real-time wireless smart sensor array for scheduling irrigation. A prototype real-time, smart sensor array for measuring soil moisture and soil temperature that uses off-the-shelf components was developed and evaluated for scheduling irrigation in cotton. The array consists of a centrally located receiver connected to a laptop computer and multiple sensor nodes installed in the field. The sensor nodes consist of sensors, a specially designed circuit board, and a Radio Frequency Identification (RFID) tag which transmits data to the receiver. The smart sensor array described offers real potential for reliably monitoring spatially variable soil water status in crop fields. This paper describes the smart sensor array and testing in a cotton crop. Integration of the sensors with precision irrigation technologies will provide a closed loop irrigation system where inputs from the smart sensor array will determine timing and amounts for real-time site-specific irrigation applications.Yunseop
(James) Kim, in 2008, presented Remote Sensing and Control of an Irrigation System Using a Distributed Wireless Sensor Network where it describes details of the design and instrumentation of variable rate irrigation, a wireless sensor network, and software for real-time in-field sensing irrigation system. Field conditions were site-specifically monitored by six in-field sensor stations distributed across the field based on a soil property map, and periodically sampled and wirelessly transmitted to a base station. Communication signals from the sensor network and irrigation controller to the base station were interfaced using Bluetooth wireless radio communication. While this was a great initiation in the development of Smart Irrigation, the major disadvantage was that the total cost of Bluetooth wireless modules used in this paper for the in-field WSN was approximately $1000.Zhang Feng, in 2012, presented his research paper on water-saving irrigation automatic control system based on Internet of thi
ngs. To enhance Irrigation system water utilize productivity, lessen cost of water system water, this paper talked about the outline of remote sensor system and Internet innovation of farmland programmed water system control technique. Accentuation on an examination of the directing convention of sensor system hubs to accomplish the framework equipment and programming outline, middleware, and applications, for example, cell phone or remote PDA of web of things, will

constitute an assortment of sensors astute system, in this manner improving the general robotization framework and observing levels. The last investigation of the system in the Internet in light of the rural plants of farmland water-sparing water system framework coordinated approach. Client utilize cell phones or remote PDA can without much of a stretch soil dampness substance of web based checking and control to understand the water system mechanization.Kay Smarsly, in 2013, presented Agricultural ecosystem monitoring based on autonomous sensor systems where the prototype monitoring system consists of a number of intelligent wireless sensor nodes that are distributed in the observed environment. The sensor nodes are connected to an Internet-enabled computer system, which is installed on site for disseminating relevant soil information and providing remote access to the monitoring system.Ahmed Hussein Abbas, Maya Medhat Mohammed presented a Smart Watering System for Gardens using Wireless Sensor Network. This paper discusses the usage of wireless sensor networks in irrigation control by a smart watering system in which the irrigation process is controlled by valves. The application of wireless soil-moisture sensor networks to detect water content in the soil can utilize water resources very efficiently. Water requirements depend on the type of plants and the soil as well as the season. A study has been made on the clay soil to observe its behavior and its different characteristics. By this study the time of excitation of the sensor could be known and the period of irrigation could be detected. This will be more efficient in terms of the time in which the sensor will be excited and the quantity of water that will be used.Nattapol
Kaewmard, Saiyan Saiyod in 2014 presented Sensor Data Collection and Irrigation Control on Vegetable Crop Using Smart Phone and Wireless Sensor Networks for Smart Farm. The exploration objective is to give a long haul reasonable answer for mechanization of agribusiness. Agribusiness computerization has a few techniques to get information from vegetable products like sensors for ecological estimation. In this way, the framework built up a convenient estimation innovation including soil dampness sensor, air stickiness sensor and air temperature sensor. Also, a water system framework utilizing remote sensor arrangement has introduced these sensors, with the reason for gathering the earth information and controlling the water system framework by means of advanced cells. The reason for the examination is to discover better methods for controlling a water system framework with programmed framework and manual control by advanced mobile phone. So as to control a water system framework, a framework was created the specialized techniques of the remote sensor arrange for gathered environment information and sending control order to turn on/off water system framework.Konstantinos
X. Soulis in 2015 investigated the effects of soil moisture sensors positioning and accuracy on soil moisture based drip irrigation scheduling systems. This study investigates how soil moisture sensors positioning and accuracy may affect the performance of soil moisture based surface drip irrigation scheduling systems under various conditions. For this purpose several numerical experiments were carried out using a mathematical model, incorporating a system-dependent boundary condition in order to simulate soil moisture based irrigation scheduling systems. The results of this study provided clear evidence that soil moisture sensors positioning and accuracy may considerably affect irrigation efficiency in soil moisture based drip irrigation scheduling systems. If we want to look at the present state of development of Smart Irrigation Systems, The KBL (
Kirloskar Brothers Limited) Irrigation sector provides fluid handling solutions for Irrigation schemes and also offers best suitable pumps and valves for irrigation. KBL fluid handling solutions help many countries and states to achieve food sufficiency. The Irrigation sector closely works with National and State Irrigation Departments. The Irrigation sector has executed many projects in India and abroad. The KBL irrigation strength lies in project management from
"Concept to commissioning". The irrigation sector has dedicated team of engineers and experts from Hydraulics and Project management.CHAPTER 3: PROBLEM ANALYSIS
Problem Definition
Many of the farmers don't have knowledge about the amount of average water needed to yield the crop. This is one of the causes for variable crop yield. If distance between th

e home and the field is more, it is difficult to travel for just irrigating the land and monitoring its moisture content. It is not possible to continuously monitor the irrigation process; it is a waste of time.The first and foremost common problem in irrigation is that we do not know the answer for simple questions like "When do I water?" and "How long do I water?" Starting an irrigation cycle too early and running an irrigation cycle too long is said to be over
watering. This practice wastes water and money and overwatering can cause crop damage if this practice is repeated for a long time. Similarly, starting an irrigation cycle too late or not running the system for a long enough period of time is considered under watering and can cause reduced yields and poor crop quality which can affect price.As the crop grows the root goes deeper into the soil. Monitoring the moisture content in depth is difficult. We just supply water to the field to keep it wet but if t
he plant is quite big its root which is in depth will not get sufficient water this causes crop damage and poor yielding. In some fields the surface soil absorbs the water quickly and always looks like a dry land. But the moisture will be there in the soil under that. In this situation it is difficult to know about the moisture content in the soil. And watering more also affects the crop.Another problem we face with respect to irrigation is that we irrigate the fields without knowing about the climatic co nditions in that area. This can also have adverse effects on the crop yield, since after some time if there is rain then the water which we used in irrigation is wasted and also this reduces the crop yield by supplying more water to the roots. So, it is also important to continuously monitor the weather conditions. Proposed Solution
THE PROBLEM OF WATER SUPPLY:
In order to tackle the problem of when to supply water to the crops, we install soil moisture sensors in the ground in the root zone of the plants. For this purpose, we have chosen the VH400 soil moisture sensor. Since it is not reliable to depend on a sin
gle sensor's reading, we plan to use 2 sensors, one installed at a depth of d/4 in the soil and one at a depth of d/2 in the soil, where'd' is the root depth. This installation of sensors this way is shown below:Figure 7: Sensor Placement in Soil
One more important parameter to consider while placing the soil sensors is the optimal placement of these sensors. Soil moisture sensors are very costly, ranging from Rs.4,500 when purchased individually and around Rs.3,000 when purchased in bulk. Obviously, one cannot place sensors at each plant. There has to be some way to optimally place the sensors so as to optimise the cost. So, what is the best way to place the sensors in a field so as to minimize the cost of installation?The two important characteristi
cs to consider while considering the optimal placement of sensors are as follows:The Soil Profile
The Types Of Crops Planted
These two can be explained better from the figure below.
Figure 8: Optimal Sensor Placement
The scenario on the left explains the soil profile. To evaluate the soil profile of a given piece of land, we can take samples of soil at different points on the field. The figure on the left shows a scenario where five samples are taken at different point
s in the field. Two cases arise here, as follows:If all the soil samples are found to be the same, then placing sensors at one or two points in the field is more than enough. However, if the soil samples are found to be different, as shown in the figure above, then we need to place one or two sensors wherever the soil profile has changed.The second scenario is when different crops are planted on the same field. In this case, we need to place one or two sensors wherever the crop changes. However, general
ly, the two factors coincide and the optimal placement of sensors is interplay between the soil profile and the types of crops planted.Further specifications and implementation details of the Soil Moisture Sensors are explained in the Methodology and imp
lementation chapter.THE PROBLEM OF WEATHER MONITORING:
As mentioned earlier, monitoring the weather conditions is also important to the irrigation process,

if there is rain then the water which we used in irrigation is wasted and also this reduces the crop yield by supplying more water to the roots. So, it is also important to continuously monitor the weather conditions. For the purpose of this project, we plan to monitor the temperature (in degrees Celsius), humidity, UV Index, Amount of Rainfall (in millimetres/hour), Wind Speed and Wind Direction (in kilometres/hour).For these purposes, we use Davis Weather Station, which looks like a pedestal and contains the sensors to measure the required parameters. What comes with the Weather Station is a Vanta
ge Pro 2 Console, which is a full-featured backlit LED console which is used to display the data from the Davis Weather Station. Further information about the weather station as well as the Vantage Pro console is explained in the Methodology and Implementation Chapter.CHAPTER 4: METHODOLOGY AND IMPLEMENTATION
In this section we discuss the overall project implementation block diagram and the complete flow of the project, as well as the implementation with respect to the soil moisture sensors, the weather station and the LPC1768 microcontroller.
4.1 Implementat
ion Block DiagramFigure 9: Implementation Block Diagram
The implementation overview is as shown as above. The LPC1768 Microcontroller is at the heart of things, and it is the one to which all the different components are interfaced. The diagram shows the interface of the soil moisture sensors on the bottom of t
he figure, while the right hand side of the figure shows the interface of the weather station to the microcontroller board through the display console and it also shows the interface of solenoid valve through a relay. The left hand side of the figure shows the implementation of sending the data to the IOT website, which is yet to be implemented as of now but is a future must to have feature as a part of the smart irrigation system.4.2 Project Flow
We have completed the different stages of the project as shown in the flowchart below:Figure 10: Project Flow
4.3 LPC1768 And BMS-IOT BoxFigure 11: Block Diagram of the BMS-IOT Box
4.4
Weather StationVantage Pro2 is an Integrated Sensor Suite (ISS) containing rain collector, temperature and humidity sensors, anemometer, UV, and solar radiation sensors in one package.
It is a customizable station with a wide range of options and sensors to help us to measure, monitor, and manage weather data. The stations are designed to withstand scorching sun, corrosion, up to 200 mph (321 kmph) winds, temperature extremes, and more. It provides the highest level of accuracy, reliability and ruggedness. Vantage Pro2 station includes a console and a versatile sensor suite that can be customized by adding consoles or special-purpose options. The anemometer can be attached separately from the rain collector. One can easily get their own local forecast, highs/lows, totals or averages and graphs for virtually all weather variables over the past 24 days, months or years all without using a PC.Figure 12: Davis Weather Station and Display C
onsoleThe reasons for choosing the Davis Weather Station and Vantage Pro2 Console are as follows: Rugged and flexible, it offers reliable weather data even under the extreme climates.
It has a dependable data transmission. The wireless version of Vantage Pro2 solar-powered transmitter with battery backup is used to keep your data flowing. The frequency-hopping spread spectrum Vantage Pro2 radio can transmits and receives data up to 1,000 ft. (300 m) line-of-sight. The cabled version transmits data using cable.It is available in both wireless and wired versions.Vantage Pro2 also offers 12-hour advance weather forecasts as well as 24- to 48-hour advance forecast ticker-tape. One can also view and store data on their computer or online.
The specifications of the VantagePro2 Console are as listed in the figure below:
Figure 13: VantagePro2 Console Specifications
Vantage Pro2 is an easy installation device and can be set up using the manual from Davis instruments. Vantage Pro2 Console can also be set up using their manual. Vantage Pro2 Console is a LCD display system for Vantage Pro2. Time, longitude, latitude, ba

ud rate (For wired transmission only) and many other fields can be updated. Once the setup is complete, one should long press the DONE button. If Vantage Pro2 is connected to the console, the console starts reading data from sensors.The console has inbui
lt temperature, humidity and pressure sensors whose readings are displayed even without Vantage Pro2. The sensors can be calibrated if there is any error in the sensor data. The sensor data is updated every 2.5 seconds. The console also has an option to set alarm with respect to both time and sensor values. The data received from the weather station are stored in the WeatherLink data logger present inside the Console. We can also get the graphical representation of sensor data in order to get variation of certain parameters over time.Figure 14: Different components in the Davis Weather Station
The console with a WeatherLink data logger has following 3 types of memory: 132 KB archive memory, which can store up to 2560 archive records. 4KB EEPROM memor
y, which is used for calibration numbers, station latitude/longitude/elevation/time zone values, transmitter configuration, and Console graph points 4KB of processor memory, which is used in storing the current sensor data, today's high/low values, and ot
her real-time values.Figure 15: Vantage Pro2 Console Display Details

Sample Interval	Capacity of logger in time
1 minute	1 day and 20 hours
5 minutes	8 days and 21 hours
10 minutes	17 days and 18 hours
15 minutes	26 days and 16 hours
30 minutes	53 days and 8 hours
1 hour	106 days and 16 hours
2 hours	213 days and 8 hours

Table 1: Capacity of data logger

SERIAL COMMUNICATION WITH CONSOLE:

Data from loggers can also be viewed in computer or laptop using WeatherLink software. The data logger is connected to the computer using an adapter for wired communication. The data is sent as packets through serial communication. The serial communication has 8 data bits, one start and one stop bit. There are no parity bits. Default baud rate is set to 19200. The user can choose any baud rate among 1200, 2400, 4800, 9600, 14400, and 19200. For wireless communication, WeatherLink Live has to be interfaced with vantage pro 2 console. The WeatherLink software increases the readability of graphs. The data can also be viewed in tabular format. Figure 16: WeatherLink SoftwareWe have used YAT (Engineering, testing and debugging of serial communication) to establish serial communication between computer and console. There are multiple commands to communicate with console. Commands are basically ASCII strings. In order to conserve battery power, the console will be in sleep mode, and will wake up only when required. One should always perform a wakeup procedure before sending commands to the console. Line Feed character, '\n' (decimal 10, hex 0x0A) acts as console wake up command. The console responds with Line Feed and Carriage Return characters ('\n\r'). The console also responds with 'ACK', 'NAK', 'OK', 'DONE' commands as per the commands sent. The serial communication can be tested by sending 'TEST' to the console. If the console reply with 'TEST\n', the serial communication is established, else one should recheck the connections. There are various other commands like 'RXCHECK', 'RXTEST', 'VER', 'RECEIVERS', etc. in order to test serial communication. There are various testing, downloading, current data, EEPROM, clearing, calibrating and configuring commands.The sensor data can be seen through YAT using 'STRMON' and 'STRMOFF' commands. The console starts sending data when STRMON command is sent to the console. The data contains 8 bytes and each byte comes with least significant bit first. The data comes every 2.5 seconds and will stop only if STRMOFF command is sent. The 8 bytes contain data and can be read as follows:

Byte 0

: It is the header. The upper nibble represents the sensor the data is from. Following are the upper nibble with respect to sensor from which it has been obtained.2 = Supercap voltage (Vue only)4 = UV Index

5 = Rain rate

6 = Solar radiation

7 = Solar Cell output 8 = Temperature

9 = Wind gust

a = Humidit

yThe Transmitter ID is given by the lowest three bits in the low order nibble. Bit 3 in the low order nibble of Byte 0 becomes high if the transmitter battery is low else the bit is set to zero.

Byte 1

: It gives wind speed in mph. The wind speed is updated in every transmission. Byte 2

: It gives wind direction. It is also updated in every transmission. The Vantage Pro2 uses a potentiometer with a significant dead zone around North. Therefore there are no values reported between 352 and 8 degrees inclusive. This byte can vary from 1 to 255. This can be mapped to 1 to 360 degrees as follows If this byte is 0, wind direction is 360.

Else wind direction is found using formula, 9 + Byte2 * 342 / 255.

Byte 3-5

: This depends on the type of sensor data being at that instant.Message 2 (

Supercap voltage): Bytes 3 and 4 represents the Supercap voltage. The Supercap stands for super capacitor that is used to store excess energy from the ISS solar cell during the day, which helps to power the console during night. This is very effective in extending the battery life of the non-rechargeable lithium CR2032.Message 4 (UV Index): Bytes 3 and 4 represents UV Index. MSB is in Byte 3 and LSB is in Byte 4. If the third byte is FF, it indicates that there is no sensor present. The UV index can be calculated as follows:

UVIndex

= ((Byte3 << 8) + Byte4) >> 6) / 50.0Message 5 (Rain Rate): Byte 3 and 4 represents rain rate information. The rate is the time in seconds between rain bucket tips in the ISS. The rain rate is calculated using the bucket tip rate and the size of the bucket. The rain rate can be calculated a

s follows:If Byte3 == 0xFF, there is no rain.

If (Byte4 && 0x40) == 0, it is light rain.

If (Byte4 && 0x40) == 0x40, it is strong rain In case of light rain, rainrate [mm/h] = 720 / (((Byte4 && 0x30) / 16 * 250) + Byte3)In case of strong rain, rainrate [mm/h] = 11520 / (((Byte4 && 0x30) / 16 * 250) + Byte3)Message 6 (Solar Radiation): Bytes 3 and 4 represents solar radiation. MSB is in Byte 3 and LSB is in Byte 4. If third byte is FF, it indicates that there is no sensor is present. The Solar radiatio

n can be calculated as follows:Solar radiation = (((Byte3 << 8) + Byte4) >> 6) * 1.757936

Message 8 (Temperature): Bytes 3 and 4 represents temperature. Byte 3 is MSB and Byte 4 is LSB. The temperature in Fahrenheit can be obtained as

Temperature = ((Byt

e3 * 256 + Byte4) / 160Message 9 (Wind Gust Speed): This message transmits the maximum wind speed during the previous 10 minutes. Byte 3 gives gust. Message a (Humidity): Bytes 3 and 4 represents humidity as 10 bit value. Bits 5 and 4 in Byte 4 are the

two MSB's. Humidity can be obtained as Humidity = (((Byte4 >> 4) << 8) + Byte3) / 10.0

Byte 6-7
: This represents CRC of the data.Consider an example of data received through console:
a0
09 82 83 38 00 6a c9Byte 0: 0a represents that bytes 3-5 contains
information about humidity sensor.Byte 1: 09 represents wind speed in mph. The wind speed is 9 mph (Hexadecimal to decimal).
Byte 2: 82 represents wind direction. Here the wind direction is 18315 N.
Byte 3-5: Humidity is represented as two bytes in Byte 3
and Byte 4 as a ten bit value. Bits 5 and 4 in Byte 4 are the two most significant bits. Byte 3 is the low order byte. The ten bit value is then 10x the humidity value displayed on the console. The functions of the four low order bits in Byte 3 that cause the apparent jitter are not known.The corresponding humidity value is then
((0x38 >> 4) << 8) + 0x83 = 131 + 768 = 899 = 89.9% relative humidity.
The displayed humidity at the time was 90%.
Sensor data
Time between two transmissions
Outside temperature
10 seconds
Wind speed
2.5 seconds
Wind direction
2.5 seconds
Outside humidity
50 seconds
Rain
10 seconds
Solar radiation
50 seconds
UV
50 seconds
Table 2: Sensor data with their update time
4.5 Soil Sensors
USEFUL DEFINITIONS:
Volumetric Water Content:
To explain it in simple terms, dry soil is composed of solid material and air pockets together called as pore spaces. A typical volumetric ratio is composed of 55% solid material and 45% pore space. When water is added to the soil, the pore spaces begin to fill with water. Soil that seems damp to the touch might have 55% minerals, 35% pore space and 10% water. So this is an example of 10% volumetric water content. The maximum water content in this scenario is 45% because at this value, all the available pore spaces would have been filled with water. This soil is said to be saturated, because at 45% volumetric water content, the soil can hold no more water.Time domain reflectometry (TDR):It determine
s soil moisture by measuring the transit time of an electromagnetic pulse transmitted along a parallel metallic probe placed in the soil. The pulse travel time is proportional to the apparent dielectric constant of the soil
which is the basic principle used in measuring the soil moisture.
TYPES OF SOIL MOISTURE SENSORS:
Tensiometric
and volumetric are the two primary sensor types that measure soil moisture. Tensiometric sensors as the name implies measures the soil moisture tension, or the potential soil moisture. Tensiometers are responsive to soil properties by measuring how tightly a particular soil type retains water.

Volumetric sensors measure the actual volume of water contained in the soil. Each technique is explained in detail in the following:Volumetric Techniques mainl
y consists of two main sensors:Resistive Sensor
Capacitive Sensor

Figure 17: Resistive Sensor
Figure 18: Capacitive Sensor
Resistive Sensor:
The working of the sensor: Soil moisture sensor comprises of two conducting plates. First plate is connected to the +5Volt supply in series resistance of 10K ohm and the second plate is connected directly to the ground. It functions as a voltage divider bias network, and output is taken directly from the first terminal of the sensor pin, which is shown in the above figure. The output will change in the range of 0 - 5 Volt, in proportion with change in content of soil moisture in the soil. Ideally, when there is zero moisture in soil, the sensor acts as open circuit and will have infinite resistance. Thus we get 5V at the output.
The resistive sensor consists of two probes which are used to measure the volumetric content of water. These two probes allow the current to pass through the soil and then it uses the resistance value to measure the moisture value. When there is abundant water, the soil will conduct more electricity which means that there will be less resistance. Therefore, the moisture level will be significantly higher. Dry soil conducts electricity poorly, so when there is less water, then the soil will conduct less electricity which implies that there will be more resistance. Therefore, the moisture level will be significantly lower.Capacitive Sensor:
The sensor measures the soil moisture levels by m
easuring the capacitance, rather than measuring the resistance like other types of moisture sensor. The ability to prevent corrosion is because it is made of a corrosion resistant material giving it durability and reliability.Soil moisture content may be determined via its effect on dielectric constant by measuring the capacitance between two electrodes i
nserted in the soil. Where soil moisture is predominantly in the form of free water, the dielectric constant is directly proportional to the moisture content. The probe is given a frequency excitation to permit measurement of the dielectric constant. The values from the probe are not linear with water content and are influenced by soil type and soil temperature. Therefore, careful calibration is required and long-term stability of the calibration is not assured.Tensiometric Techniques:Figure 19: Electronic Tensiometer ProbeThe above figure shows an Electronic tensiometer probe, which consists of the following four main parts, namely (1) porous cup; (2) water-filled tube; (3) sensor-head; and (4) pressure sensor.A
tensiometer
sensor is a
https://en.wikipedia.org/wiki/Measuring_instrument
measuring instrument
used to determine the https://en.wikipedia.org/wiki/Soil_moisture
soil moisture
tension in the
vadose zone. This device typically consists of a
https://en.wikipedia.org/wiki/Plastic
plastic
tube with a porous
https://en.wikipedia.org/wiki/Ceramic
ceramic
cup, and is filled with
https://en.wikipedia.org/wiki/Water
water
water. The top of the tube has either a built-in

rubber cap used with a portable
puncture tensiometer
instrument, which uses a
hollowhttps://en.wikipedia.org/wiki/Hypodermic_needle
needle
to measure the pressure inside the tensiometer. The tensiometer is buried in the soil, and a hand pump is used to create a partial vacuum. As water is pulled out of the soil by plants or by evaporation, the vacuum inside the tube increases. As water is added to the soil, the vacuum inside the tube pulls moisture from the soil and vacuum decreases. As the water in the tensiometer is considered to be in equilibrium with the soil water, the gauge reading of the tensiometer represents the matric potential of the soil.

The primary method for measuring capillaric tension in the soil involves the use of the tensiometer, which directly measures capillaric potential. The main disadvantage of the tensiometer is that it functions only from zero to about -0.8bar, which represents a small part of the entire range of available water. The lower moisture limit for the good growth of most crops is beyond the this range. The use of the tensiometer to schedule irrigation can cause over-irrigation.

Disadvantages: Limit range of 0 to -0.8bar not sufficient for sandy soil. Difficult to translate data to volume water content Hysteresis Requires regular maintenance, depending on range of measurements subject to breakage during installation. Further, automated systems are not cost effective and not electronically stable. Disturbs soil above measurement point and can allow infiltration of irrigation water or rainfall along its stem.Advantages: Cost effective and easily constructed. Works well in the saturated range. Easy to install and maintain. It can operate for very long periods if properly maintained and cared.It can be used with positive or negative gauge to read water table elevation and soil water tension.SENSORS USED IN PROJECT:

Figure 20: VH400 Sensor used in project

In this project, we have chosen the VH400 Soil Moisture Sensor developed by Vegetronix. The characteristics and the features of the Probe are as follows:

Cost effective.
Saves water.
Rugged design for long term use.
Reliable
Durable
Probe does not corrode over time.
Mechanically Robust Accurate and precise measurement.
Insensitive to salinity.
Low power for battery operation.
Rugged design for long term use.

VH400 Soil Moisture Sensor Detail:

The VH400 is a professional electronic soil moisture sensor. It is so sensitive, that it can measure the moisture present on your hands when you touch its blade.

It is mechanically rugged, it is made up of ABS plastic, and fiberglass. VH400 moisture sensor is absolutely waterproof and mechanically strong. It can be buried at any depth in the soil.

VH400 ignores the salt content in the soil. Most other sensors, esp
ecially conductivity or resistance based sensors, are ineffective, because salts and fertilizers found in soil alter or effect their readings. The VH400 moisture sensor uses TDR to measure the water moisture in any soil regardless of soil salinity. The m
etallic probe will never corrode, or need to be recalibrated.The thin blades prevent roots from being damaged. The blade of the VH400 soil moisture sensor is designed to be as slim as possible.

4.6 Subsystems

4.6.1 SOLENOID VALVE

Solenoids are the

most important components used in solenoid valves to control the flow of fluids such as liquids and gases. Solenoids are electromechanical devices that convert AC or DC electrical energy into linear motion to control fluid flow. They usually consist of a helical coil wound concentrically around an armature, made up of ferromagnetic material such as iron or steel. Most solenoid valves have a replaceable coil and can be used with coils with different voltages. Figure 21
:Solenoid ValveWhen current flows
through the coil, using the same basic principles as ordinary electromagnets it generates a magnetic field inside the coil which attracts the armature towards the centre of the solenoid. Since the armature is drawn towards the centre of the solenoid regardless of the polarity of the current, an opposing force is needed to return the armature into the starting position when the coil is not engaged. This is achieved by using a spring mechanism. Under ideal conditions, in order to actuate the solenoid, the force generated by the solenoid must be larger than the combined forces of the spring, and the hydraulic pressure, as well as friction.By lifting the armature, a small port in the valve is opened that allows the flow of the media. The flow through the valve
can be controlled by controlling the current flow through the coil. 4.6.2 REAL TIME CLOCK
A real-time clock (RTC) is a computer clock, usually in the form of an integrated circuit that is built for keeping time. It keeps track of time in terms of hours, minutes, seconds, months, days and even years. RTCs can be found running in personal compute
rs, embedded systems and servers, and are present in any electronic device that may require time keeping functionality. Being able to still function even when the computer is powered down through a battery or independently from the system's main power is fundamental.Figure 22
:RTC ModuleRTC ICs regulate time with the use of a crystal oscillator and do not rely on clock signals like most hardware clocks. Aside from being responsible for the timing function of the system and its clock, RTC ICs ensure that all processes occurring in the syst
em are appropriately synchronized. Although some may argue that this is a job for the system clock, the system clock is actually dependent on the RTC, making the RTC indirectly responsible for synchronization.4.6.3 MENU SYSTEM In order to allow the user
to set the values of various soil and plant parameters an indigenous menu system was developed. The soil parameters that can be set by the user are: field capacity, permanent wilt point. The plant parameters that can be set by the user are: crop cycle, root depth, and date of sowing. There is an option to calibrate sensors also.Buttons assigned to set the values:
There are four buttons on the BMS IOT box. Once the controller is powered on, by pressing the fourth button on the device, the user can enter th
e menu. 1-SOIL DATA
2-PLANT DATA
3-SENSOR CALIBRATION
By pressing the appropriate button the user will be able to set the parameters. User can use the following buttons to set the parameters:
1-OK
2-INCREMENT
3-DECREMENT
4-BACK
The values can only be increment or decrement in terms of 5 for all the parameters. The below flow diagram shows the flow of the menu system.Figure 23
:Flow diagram of menu system4.7 Working
Once the device is turned on, the user should set various parameters. The soil moisture sensor wires have been crimped and have given it mechanical stability so that the sensor's values are stable. The working of major parts/ functions of the device is as follows:Soil Moisture Sensors and RTC: The device consists of four VH400 soil moisture sensors. The four soil moisture sensors should be placed at different depths in the soil considering the root depth model of the plant. The user enters the sowing dat

e and the crop cycle. Based on these data, the algorithm calculates the difference between present date and the date of sowing in terms of days. The root depth model which is implemented in the algorithm calculates the root depth based on the number of days past after the date of sowing. Based on the number of days, the algorithm calculates which sensors should be activated. The activated sensor's values are taken and their average is calculated. This average value is displayed and this value is also used to control the solenoid valve.The present date, year and other time parameters are calculated using the RTC module which is built in the device itself. Solenoid valve and relay: The outlet of water is controlled automatically by using the solenoid valve with the help of relay. The field capacity(FC) and permanent wilt point(PWP) values are set by the user. By considering the average soil moisture sensor value and comparing it with the FC and PWP values the algorithm decides whether the water has to be let out or not. The solenoid valve turns on when the average soil moisture sensor value is less than available moisture(RAM) and greater than or equal to permanent wilt point(PWP). The solenoid valve is turned on until the average soil moisture sensor value reaches the field capacity(FC) value.The relay is used to drive the solenoid valve based on the switch signals given to it by the controller device.
Menu
System: In order to make a full-fledged irrigation system, the menu system has been implemented in the device rather than fixing the values in the program. The user can set the values of various parameters which helps in the functioning of the device.4.8 Estimated Bill
COMPONENTS EXPECTED PRICE IN RS
Davis Vantage Pro 2+ Console
60,000</w:p>BMS IOT BOX(LPC1768)
10,000
Soil Moisture Sensors
1,000
Solenoid Valve
600
Miscellaneous
4,000
Total
75,600
Table 3: Estimated Bill
CHAPTER 5: RESULTS AND DISCUSSION
The proposed work will follow the procedure as follows:
Sensors will determine the moisture level at the Root Zone
. The weather station determines Humidity, Temperature, Wind Speed and Rainfall. Micro controller should get sensor data per minute. Micro controller should analyse the data, take correct action and record the data. Soil moisture sensor is a sensor connected to an irrigation system con
troller that measures soil moisture content in the active root zone based on the root depth model before each scheduled irrigation event and bypasses the cycle if soil moisture is above the user defined set point. Once the irrigation starts, the microcon
troller will request data from the corresponding sensor. When threshold moisture level is reached, it will record the data and stop the irrigation. Stored data will be sent to the central server using GSM. With the use of this technique we can reduce water consumption. It can be set to lower and upper thresholds to maintain optimum soil moisture saturation and minimize plant wilting. It can contribute to deeper plant root growth, reduced soil runoff/leaching, less favourable conditions for insects and fungal disease. It is also possible to control the nutrition levels in their entirety thus, lower nutrition costs. No nutrition pollution is released into the environment because of the controlled system. Hence will save great amounts of irrigation water, and will have stronger and healthier plants with stable and high yields.Below are the pictures of the different implementation phases of the Smart Irrigation System:

STAGE 1: Interfacing Weather Station and BMS-IOT Box to the Smart Irrigation System. (Done During Project for Community Service - 7th Semester)Figure 24: Soil Moisture Sensor data displayed on the BMS-IOT Box
Figure 25: Weather data display on the VantagePro2 Console
Figure 26: Complete Smart Irrigation setup with all components (Clockwise) - Weather station, Soil bucket, BMS-IOT Box, VantagePro2 Console
STAGE 2: Developing Additional Functionality to the Smart Irrigation System to make the process smoother. (Done Parallelly with Stage 3 - 8th Semester)Figure 27: Implementation of Root Depth Model Algorithm
Figure 28: Solenoid Valve Implementation
Figure 29: Menu System Implementation, to set the Soil or Plant Characteristics
STAGE 3: Initial Field Plan and Setup (Done Parallelly with Stage 2 - 8th Semester)Figure 30: Field Plan for Smart Irrigation System Implementation
Figure 31: Top View of the Field - Plan
Figure 32: Place where implementation will be carried out
S
TAGE 4: Complete Smart Irrigation Setup in the Field (Final Stage)Figure 33: Solar Panel setup in the field to power the BMS-IOT Box
Figure 34: All the components, Weather Station, Vantage-Pro Weather Console BMS-IOT Box, and Soil Sensors, placed in the field.
Figure 35: Closer view of the Vantage-Pro Weather Console and BMS-IOT Box working on the field.
CHAPTER 6: CONCLUSION AND F
UTURE WORKThe system describes the design, optimization and development of a practical application to optimize water resources in irrigated agriculture by low-cost wireless system to monitor soil water status and the irrigation water and to increase the yield. The s
ystem designed is not only limited to the present functionality, but can be further can be extended for more customized functionality like smart home gardening system. It is concluded that the sensor nodes are of great help to reach the desired moisture conditions at the different depths and to maintain soil moisture level of the soil at the desired value, thus contributing to the ability to adapt the irrigation strategy developed. The wastage of water has been reduced by adopting weather data into the sy
stem. While it was known that weather affects plants in many obvious ways, we found out that weather affects plants in ways we may not realize. While a tree snapped by a gust of wind is easy to associate with the event, large trees may not show the effects of drought until several years later. In addition to any direct effects, weather-related stress can make plants more susceptible to disease and insect problems. Weather is whatever is happening now - precipitation, temperature, wind, sun, and humidity. It is not the same as climate, which is historical weather or the average of weather conditions over a long period of time. Climate determines what will probably grow well in your area, but plants can still be damaged or killed by extreme weather.While we have no control over the weather, in some cases we can try to design and maintain the garden to minimize the negative effects of weather on our plants. Thus, weather conditions should also be monitored to have better yield of plant and reducing water wastage problems.6.1 Advantages Of Smart Irrigation:Increased Production Optimized crop treatment such as accurate planting, watering, pesticide application and harvesting directly affects production rates.
Water Conservation
Weather predictions and soil moisture sensors allow for water use only when and where needed. Real-Time Data and Production Insight Farmers can visualize production levels, soil moisture, sunlight intensity and more in real time and remotely to accelerat
e decision making.Lowered Operation Costs Automating processes in planting, treatment and harvesting can reduce resource consumption, human error and overall cost. Increased Quality of Production

Analysing production quality and results in correlatio
n to treatment can teach farmers to adjust processes to increase quality of the product.Accurate Farm and Field Evaluation Accurately tracking production rates by field over time allows for detailed predicting of future crop yield and value of a farm.
Reduced Environmental Footprint All conservation efforts such as water usage and increased production per land unit directly affect the environmental footprint positively.
Remote Monitoring Local and commercial farmers can monitor multiple fields in mul
tiple locations around the globe from an internet connection. Decisions can be made in real-time and from anywhere. Equipment Monitoring Farming equipment can be monitored and maintained according to production rates, labour effectiveness and failure pr
ediction.6.2 Future Work
All the necessary components to implement a Smart Irrigation System has been successfully implemented on the field. With this, we have a functional setup to implement Smart Irrigation. Some of the future works that can be perfor
med are as follows:So far, we have the weather station set up and functioning properly, recording all the necessary parameters. However, our irrigation system is still based on scheduling irrigation based on the soil moisture content. From the Penman-
Monteith for Evaporation Transpiration discussed in the introduction, we can incorporate weather parameters into our irrigation system and aim for a high degree of accuracy.It's now time to actually grow a crop completely using this irrigation system. Some suggestions are growing Beans, Brinjal, Tomato, etc. as they can be grown quickly, in a month or two.CHAPTER 7: BIBLIOGRAPHY
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