# Solar Powered Auto Irrigation Monitoring System with Plant Health Indication using Image Processing


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(2023)


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**Solar Powered Auto Irrigation Monitoring System with Plant Health Indication using Image Processing**

Submitted
in partial fulfillment of the requirements for the
Degree of

Bachelor of Science in
Electrical Engineering

Approval on ________________

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# Declaration

We hereby declare that this project report entitled "SOLAR POWERED AUTO IRRIGATION MONITORING SYSTEM WITH PLANT HEALTH INDICATION USING IMAGE PROCESSING" submitted to the "Department of Electrical Engineering (RCET)", is a record of an original work done by us under the guidance of Supervisor "ENGR. HIRA ALI JAMAL" and that no part has been plagiarized without citations. Also, this project work is submitted in the partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical Engineering.

| **Group Members** | **Signature** | **Date** |
|---|---|---|
| Maida Saleem | | |
| Khadija Nawaz | | |
| Shahroz Ali | | |

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Maida Saleem

Khadija Nawaz

Shahroz Ali

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# List of Abbreviations

| | |
|---|---|
| LCD | Liquid crystal display |
| LED | Light emitting diode |
| DC | Direct current |
| AC | Alternating current |
| GND | Ground |
| USB | Universal serial bus |
| ESP-32 | Microcontroller |
| DMM | Digital multi-meter |
| RMS | Root mean square |
| PF | Power factor |
| VAR | Volt ampere reactive |
| PCB | Printed circuit board |
| IC | Integrated circuit |
| CNN | Convolution Neural Network |
| HIS | Hue, Saturation, Intensity |
| RGB | Red, Green, Blue |

# Abstract

In our country, agriculture is one of the most important economic sectors. As it accounts for 42.3% of employment and 18.9% of GDP in Pakistan, the agriculture industry is crucial to the country's economy. Irrigation is an issue for farmers in our country. It is very difficult to evenly distribute fertilizers, minerals, and water to every area of the crop field at the right time because of the size of the crop field. The key issue in this scenario is the difficulty of manually applying fertilizers and minerals and calculating the precise duration of time that plants will need to be watered. Since manual distribution requires a lot of time. Solar Powered Auto Irrigation Control and Monitoring System is the sole effective answer to all of these issues. The productivity of important agricultural products like wheat, maize, rice, sugarcane, and cotton is crucial to the nation's economic growth. On nearly nine million hectares of land, wheat is farmed and is considered Pakistan's primary crop. However, rust disease and tan spot have a big impact on how productive it is. Given that it can lower wheat yield by up to 30% and completely wipe out a crop within a month of its initial onslaught, this disease poses a serious threat to global food security. In this project, tools for digital image processing are utilized to look for, examine, and pinpoint plant diseases. It is quite challenging to manually monitor plant diseases. In order to diagnose plant diseases, a quick, automatic, and accurate method is needed. Consequently, image processing algorithms can tell the user about the crop's health using a Raspberry Pi and Pi camera.

*Chapter 1*

# Introduction

## 1.1 Background

Agriculture plays an important role in Pakistan economy. 80 percent of farmers in Pakistan grow wheat, which accounts for around 9 million hectares (ha) or close to 40 percent of the nation's total arable area. In Pakistan, wheat is the most significant domesticated crop and is grown on 40% of the nation's agricultural area. 60% of a person's daily dietary needs are met by this main item. Furthermore, wheat accounts for 10% of the agricultural sector's value and about 3% of the nation's GDP. [1] In order to feed the growing population and improve the nation's economic status, wheat output must urgently expand. It is a big worry to attain food security in Pakistan that the rate of wheat production has decreased during the past four years (2014–2019) from 2.2% to 0.5%. [2]

Because some residents of certain communities own their own lands. But they do their jobs in cities. They consequently lack the time to regularly maintain and check their fields. It is therefore necessary to build an automatic irrigation system. It is more difficult to water and fertilize each and every portion of the crop field at the proper time because the crops are dispersed over such a big amount of land. The biggest difficulty in this situation is that it is impossible to determine the precise time at which to water the plants. The crops end up being overwatered as a result, which is bad for the farmer. The health and productivity of the crop can suffer from an unequal distribution of fertilizers and minerals when they are applied manually. Additionally, it senses the moisture content at various areas throughout the crop field to start and stop irrigating the crops at the most appropriate periods. Additionally, by dissolving fertilizers and minerals in water when necessary, growers may provide crops the nutrients and minerals they require. [3]

Our main idea is to design a cost effective system that uses solar power instead of WAPDA power. Also the system irrigates the crops at the time of need automatically and distribution of fertilizers can be controlled digitally by app. In this system by using a soil moisture sensor that detects the amount of moisture present in the soil. The moisture sensor is integrated with the ESP-32 in such a way that when moisture content decreases to a certain limit it sends command to the ESP-32 which then sends commands to turn on the motor and opening the solenoid valve. The valve is located outside the water tank in which the water coming from the pump is stored. In the water tank water level sensors are installed which provide the information about the level of water in the tank.

Pakistan is recognized for the quality of its horticulture. Horticulture is a key source of income for most people. For farmers, there are numerous field cultivation options. To ensure the best yield and highest production standards, these crops are still grown scientifically. By utilizing technology, it may be possible to increase both yield and quality. Due to ideas like industrialization and globalization, the field is facing difficulties. Additionally, the value of growth and awareness should be imparted to the younger age groups' brains. An incorrect diagnosis of a plant problem causes significant yield, time, money, and nature of the item losses. The most vulnerable component of plants, the leaves, are where disease symptoms first appear. From the very beginning of their life cycle until they are ready to be harvested, the crops must be inspected for illnesses. [4] Initially, experts had to manually check the crop fields using the time-consuming, traditional naked eye observation approach to keep a watch on the plants for illnesses. Techniques for image processing can be used to identify plant diseases. While disease signs can typically be seen on leaves, stems, blossoms, etc., we use leaves in this case to identify the disease in affected plants. The feature extraction is carried out on images that are dithered, RGB, HSV, and YIQ**.** [5]

In the suggested approach, feature extraction from RGB images is added. The major goal is to identify the defective, sick area on a wheat crop leaf. The CNN algorithm used in this research offers an efficient image segmentation technique that depends on color data from the input image. Segmenting defects is done in two stages. The clustering technique is particularly effective when the pixels are first clustered based on their spatial characteristics and color. The clustered blocks are then combined into a certain number of regions in the following phase. Even if feature extraction is not performed for each pixel in the input image of leaves, the estimating capability can be improved using different steps. [6]

## 1.2 UN Sustainable Development Goals (SDGs)

Following SDGs hit to our project:

(2)End hunger, achieve food security and improved nutrition and promote sustainable agriculture. With the help of this project productivity of the crops will able to increase.

(7)Ensure access to affordable, reliable, sustainable and modern energy for all. This project will operate on solar power which is the form of sustainable energy. It is very cheap.

(13) Take urgent action to combat climate change and its impacts. The main source of energy for this project is sun. It is the form of sustainable energy which is Ecofriendly. Emission of greenhouse gasses will reduce.

## 1.3 Problem Definition

- The human eye cannot manually detect what amount of water is required for irrigation, which leads to low production.
- The present problem faced in the field of horticulture is that the manual detection of the condition of the plant gives very inaccurate results which leads to the late detection of diseases.

## 1.4 Objectives and Goals

Our goal is to increase the comfort of these people, especially farmers who are in charge of big areas of crops, by providing them with an automatic system that monitors the ground's water demands and distributes fertilizer easily by dissolving in water and being controlled via an app. For more than half of the day in rural areas where electricity is needed to irrigate crop fields, load shedding occurs as a result of our country's long-standing energy issue.[7]Therefore, this is the main factor preventing farmers from watering plants at the most efficient periods.

Our main goals are:

- To provide an automated system, entirely powered by solar energy.
- To identify on plant health indication with help of sensors and image processing.
- To identify type of disease affecting the plant through image processing.
- Water is supplied based on temperature of the surroundings, and moisture content present in the soil.
- Find relationship between irrigation condition and plant health.
- Implementation of project under funding of PEC.
- Collaboration with Agriculture department of Gujranwala.
- For research purpose, 2 marla land (1 marla for controlled irrigation and 1 marla for manual irrigation) is assigned by Department.

## 1.5 Report Organization

After introduction (chapter 1),

- Chapter 2 presents the literature review and problem definition which include overview of publications on Solar Powered auto irrigation system and basic introduction to main elements of project.
- Chapter 3 presents the methodology adopted to complete project.
- Chapter 4 presents hardware selection.
- Chapter 5 presents environmental effects.
- Chapter 6 presents the result and discussion.
- Chapter 7 presents Conclusion and future work.
- Chapter 8 shows estimated cost of project

*Chapter 2*

# Literature Review

In the initial steps of our research work, we went through a couple of research papers which were very useful in understanding the concepts of people who had worked on this project in different parts of the world. In this chapter we will cover following topic;

## 2.1 Literature Review

Alex et al. have been focusing on the main problems of Indian farmers. The main reasons which lead to the need of solar smart auto irrigation system are discussed. Solar Panel, charge controller & battery, power supply, moisture, temperature & humidity sensor, relay, microcontroller, LCD display are the primary components used in their project. The solar panel charges the battery. As the sunlight is not always constant so it is risky to charge the battery without connecting a charge controller in between the solar panels and the battery. The charge controller regulates the voltage and currents and when it is suitable it can also stop the charging process. A 12V DC supply of battery is provided to the regulators which convert it into regulated DC supply of 5V. This 5V DC is then distributed to the microcontroller, IC's, driver and relay circuits. The moisture sensor consisting of connecting probes is installed in the crop field. It senses the how much moisture level present in the soil and sends signal to the microcontroller. Then according to the moisture percentage it acts accordingly i.e. if the percentage of water is below a certain level it conveys the message to send water to field and if the percentage of water reaches the specified limits it conveys the message to stop the flow of water. DHT 11 sensors are installed for the temperature and humidity measurement at different intervals. An LCD is being used to show these values. A relay has been used for the opening and closing mechanism of valve and the microcontroller (ATmega8). This project although not using the latest of the techniques is still very supportive and beneficial in reducing the man power, energy conservation and water wastage in irrigation process**.** [8]

Durai et al. [9] have also shared his work on project of "Solar Powered Auto Irrigation System" and it has some different components i.e. solar tracking device and LDR sensor. This Project has an additional feature of harnessing maximum solar energy by changing orientation of PV panel according to the position of sun. Another additional feature is that the farmer can switch between two options. Either he can set the system to the automatic state in which the water will start flowing automatically as soon as the moisture level in the field is low or he can choose the second option of using GSM mode. In GSM mode the farmer can send the command of "ON" or "OFF" the water pump while being away from the field. This project is using a solar tracker along with the GSM. The solar panel having LDR sensors which track maximum sunlight to produce maximum electricity are being used. To convert the analog values of LDR and moisture sensor into digital values these are sent to ADC0808. Resulting digital values are input to microcontroller 89s51 which is interfaced with 12V DC pump, GSM module and LCD**.**

Uferah Shafi have been focusing on the wheat rust disease techniques. A comprehensive review is given on different techniques i.e., Machine Learning, Deep learning and IOT which are used for wheat disease detection purposes. The most dangerous fungal disease that can significantly reduce wheat production is known as wheat rust. Wheat production must be significantly increased in order to feed the nation's expanding population and improve the economy. In this regard, they offered a thorough overview on wheat rust, its significance in Pakistan, its types and factors impacting crop health, detection methods based on remote sensing, IOT, ML, and DL, as well as hurdles to identify wheat rust disease. This article's main goal is to give a concise but comprehensive summary of wheat disease, which will aid the scientific community and agricultural users in their further investigation of wheat rust disease. ML and DL approaches are utilized in a number of systems to identify crop/plant diseases and the severity of such diseases. These models can be used to identify the many forms of wheat rust infections. The quality of the dataset (picture resolution), the method and instrument used to capture the images, and the quantity of the dataset are all factors that affect how well these models perform. High-resolution imaging is needed to detect wheat rust disease using an ML/DL model. A high-quality camera with photos taken at a specific height and angle to focus on the afflicted leaf without a cluttered background is needed for this purpose. These restrictions make it difficult to diagnose the wheat rust illness. [10]

Priyanka G.Shrinde developed automatic rice leaf detection by using K-Means Clustering Techniques. The proposed system uses K-means clustering method for segmentation of an image to segment the leaf area, disease area and background area of input image leaf in order to calculate the severity of disease in a leaf. For the detect segmentation of infected leaf, image can be achieved by the help of K-means clustering which contains three clusters for a better result. Three steps i.e., Image acquisition, image pre-processing, K-Means Image Segmentation are done to detect the infected part of the leaf. The input image is in RGB-format. It is converted into suitable color space and re-sizing of image is done. [11]

Jiale Jiang focused on the wheat disease detection using deep learning, scene labeling, convolution neural network and transfer learning. In order to identify wheat fungal diseases, this article evaluated the performance of seven cutting-edge CNNS (VGG-16, Inception-v3, ResNet-50, DenseNet-121, EfficentNet-B6, Shuffle Net-v2, and MobileNetV3). This investigation measured the effect of training methods and additional potential parameters on the detection accuracy of CNNs using the publicly available Plant Village dataset as well as our own FWDI dataset. The outcomes illustrated how crucial it is to balance recognition accuracy, processing speed, and model parameters while designing models for various tasks. In addition to the CNN model architecture, poor image quality and capture circumstances, particularly in outdoor settings (such as complicated backgrounds, erratic lighting, and image blurring), may result in incorrect categorization. A potential element contributing to confusion in crop disease diagnosis is the symptom portrayal of leaf disease. Spots on a leaf will probably be misclassified or classified with low confidence if they are too small in the image. Annotated datasets of significant size and rich variation are still essential for diagnosing agricultural diseases with CNNS, and powerful CNNs on mobile devices are sought for real-world applications. [12]

*Chapter 3*

# Methodology

## 3.1 Introduction

In this chapter whole system of irrigation and monitoring is elaborated with the help of block diagram, flow sheet diagrams and simulations. So, following headings will under concern in this chapter,

- Block Diagram and Flow sheet charts
- Design of Blynk app interface
- Simulation

Our project is divided into two phases:

### 3.1.1 Irrigation System

Experiment is done on 2 marla land i.e., 1 marla land for smart farming and 1 marla for manual farming. Different sensors and microcontroller are used for the purpose of smart farming whereas in case of manual farming, standard method of government is followed.

ESP-32 basically used to operate whole irrigation system. This Project includes controlling and monitoring system. Controlling includes different type of control elements. i.e., solenoid valve, water pump through which we can control flow of water or watering to the plants and crops. We set value of soil moisture in the form of percentage so, when the moisture value decreases to the specified value that we have set in the ESP-32, solenoid valve operate and Irrigation to crops will start. Sensor measures the volumetric water contents in the soil which determine the amount of moisture present. It is harmful for plant to over water them and it is also harmful to provide them less water. Monitoring system includes data information about all sensors i.e. soil moisture sensors, humidity and temperature sensor, rain sensor water level sensor. Firstly, we initialize all the sensors i.e. soil moisture sensors, rain sensor temperature and humidity sensor and water level sensor. If the value of the moisture sensor is greater than 30% it will again check the value of sensor and continuously check the moisture value and whenever percentage of moisture of soil decreases less than 30%; then the valves will be switched on and start watering to the plants. This current status of valve will send to the Blynk server and will be stored in database. There data will get stored in database and also shown on Blynk app and this process will end. Similarly, in case of water tank; water sensor checked either tank is empty or full if tank is full then it will again check the water sensor value. This will continuously check the sensor value until sensor sends the signal that the tank is empty tank. When the water tank is empty, Water pump turned on and start filling the empty tank. This water pump is connected with battery and also current status will be stored in database and further result will be shown on app. The humidity & temperature sensor will also show the values of humidity and temperature and stored in data base and this will show on app and this process comes to an end. It is very easy to understand whole working of project through flow chart. After taking all sensors reading or initializing all sensors rain sensor will check whether it's raining or not. If it's raining, rain sensor will send command to integrated microcontroller ESP-32 to stop all further process. Rain sensor in irrigation system has a great importance. Because by using this, we can save crops from over watering and further losses.

### 3.1.2 Block Diagram

All the process explained above can also be explained with the of block diagram which has great significance. For the purpose of ease, we used flow sheet diagram and a block diagram with components for understanding purposes.

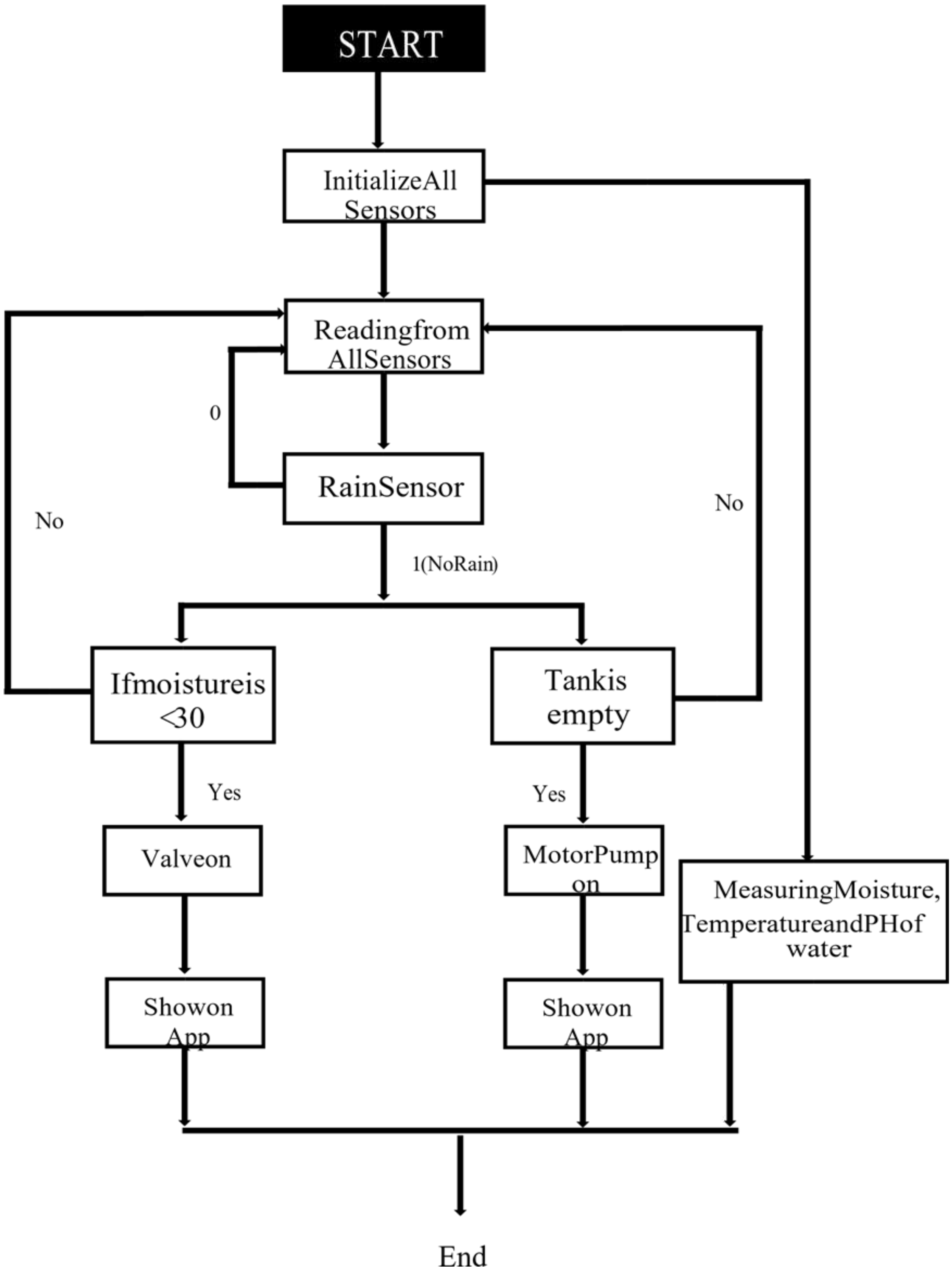


Figure 3.1.2 Flowchart of Solar Auto Irrigation

### 3.1.3 Block diagram with components

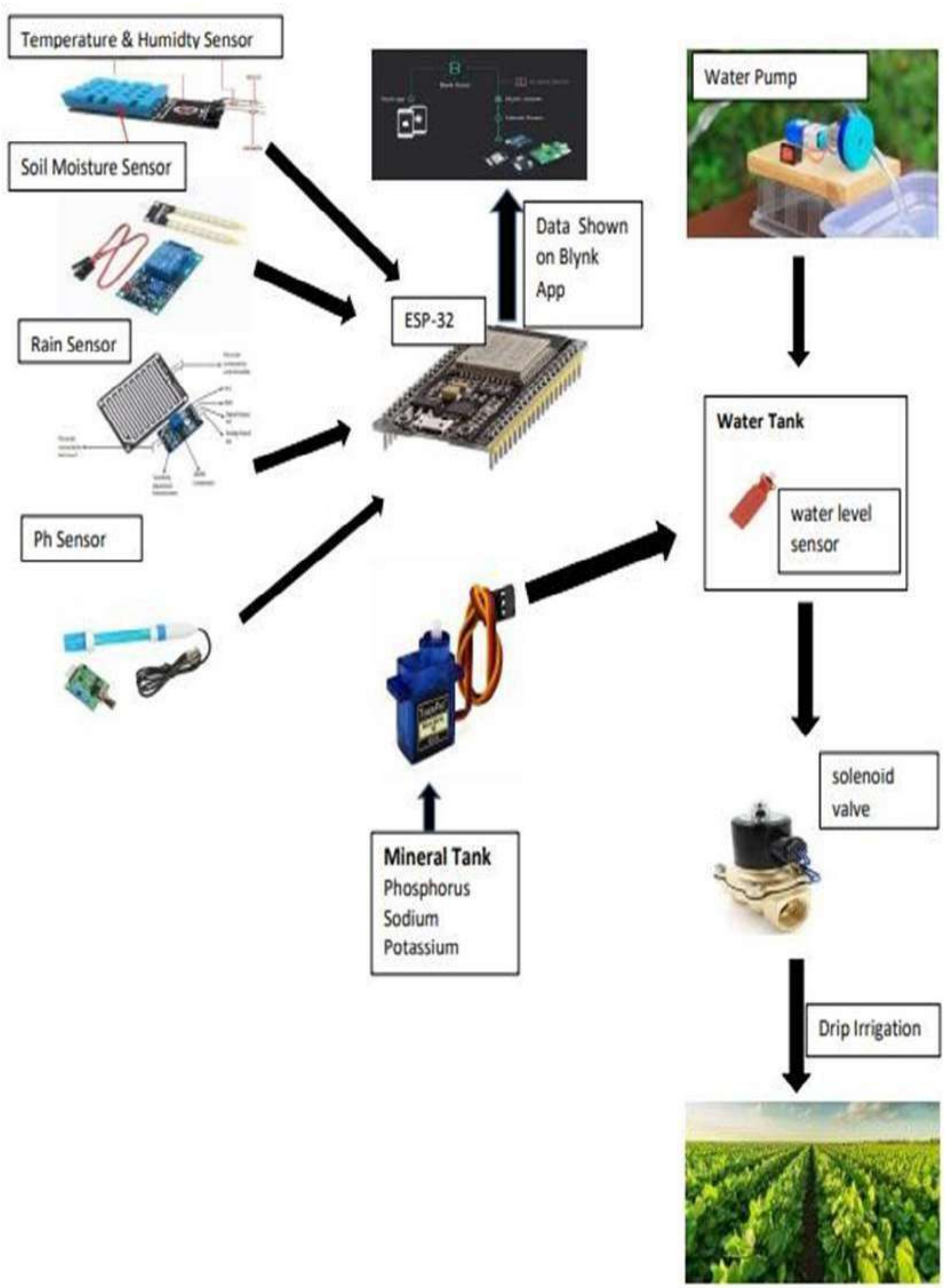


Figure 3.1.3 Block diagram with components

### 3.1.4 Simulation

First of all, to simulate the components in proteus we completed all our libraries for required sensors. All sensors integrated with microcontroller. To display results in proteus. LCD integrated with all sensor that will show the state of components. After integration of components we got following results in simulations. In first result of simulation in Figure LCD showing temperature value and soil condition and water pump condition and having the following values.

- Soil is Soggy
- Temperature $27C$
- Water pump is in off state

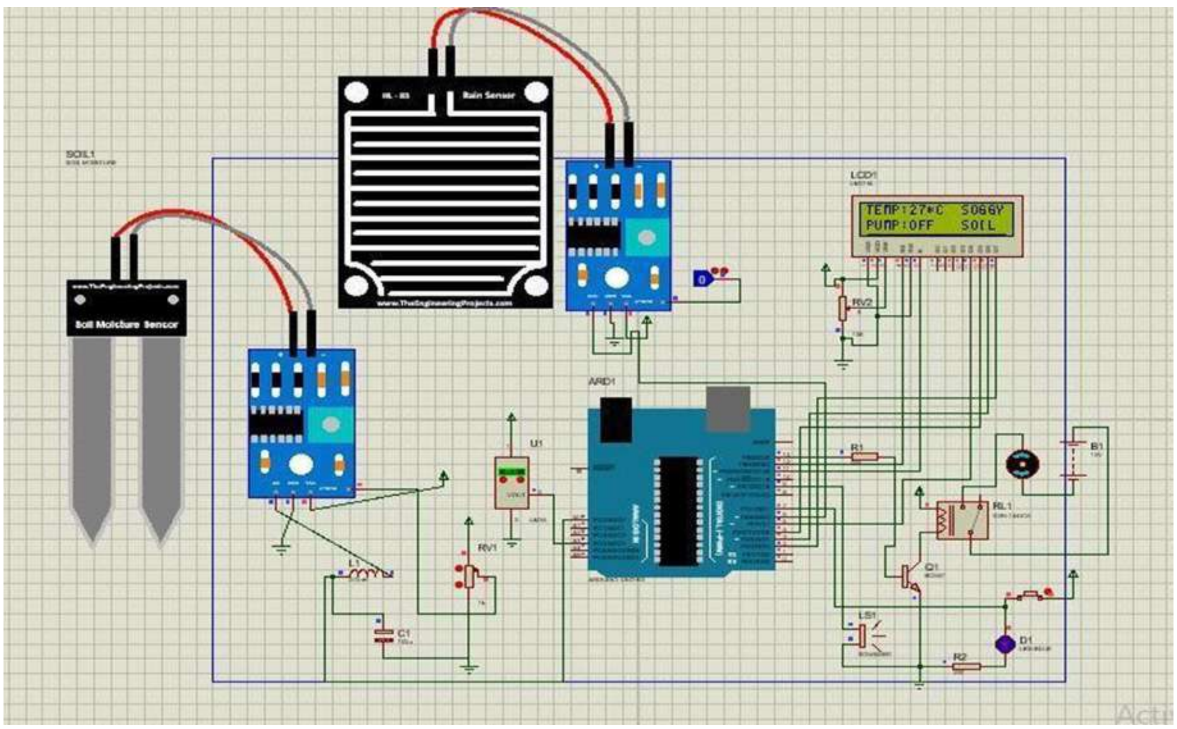


Figure 3.1.4.1 LCD shows the value of temperature and state of soil

Now again simulation performed and LCD showing temperature value and soil condition and water pump condition and having the following values.

- Soil is dry
- Temperature $27C$

- Water pump is in on state

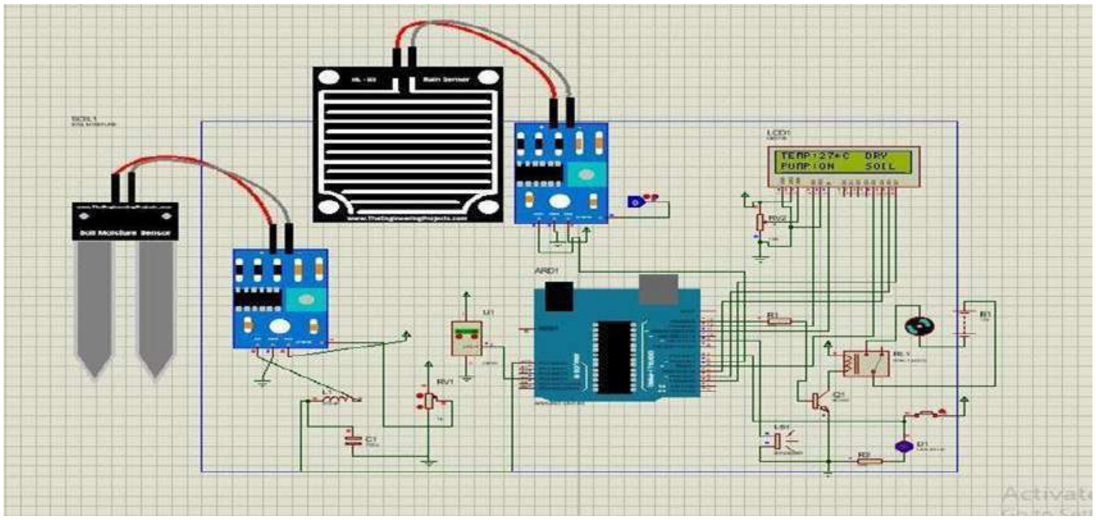

Figure 3.1.4.2 LCD shows the value of temperature and state of soil

### 3.1.5 Design on Blynk App Interface

Blynk app is built in app that is available on the paly store. It can be customized according to need and requirement

Blynk app Homepage is represented as:

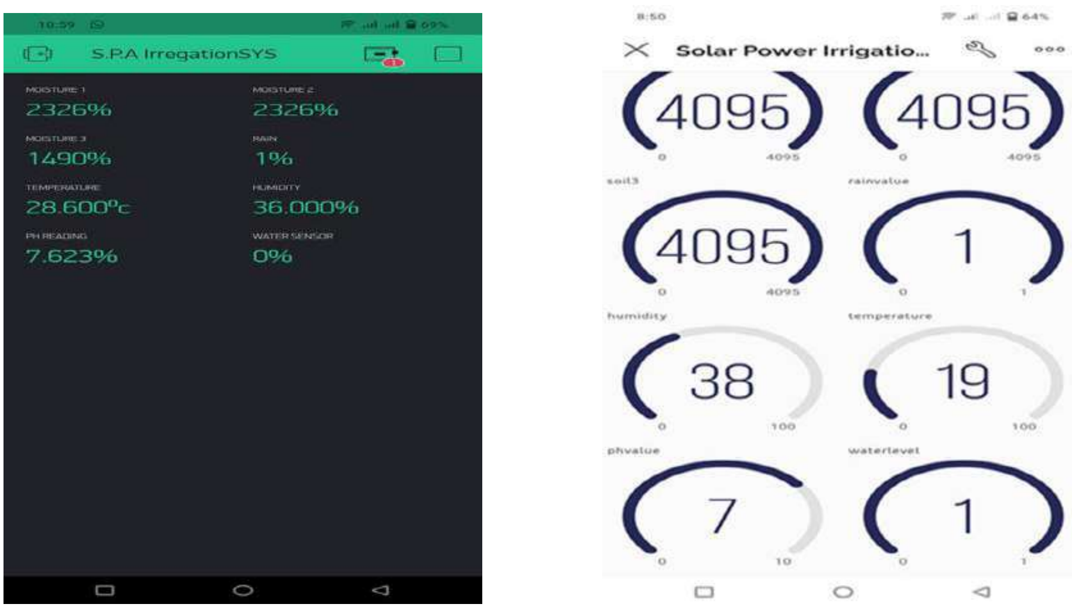


Figure 3.1.5 Blynk app Homepage

### 3.1.6 Disease Detection

In second part, whole system of wheat leaf disease detection is elaborated with the help of block diagrams, flow chart and algorithms.

The following steps represents basic parts that are involved in disease detection of wheat:

#### *3.1.6.1 Image Acquisition*

The first phase in the hypothesized process is thought to be picture acquisition. Take the camera's previously recorded image in this stage. Red, Green, and Blue (RGB) are the colors used in the input image. Following that, the RGB leaf image is transformed into the required color space in accordance with the rules. [13]

#### *3.1.6.2 Image Processing*

During this procedure, the query image is transformed into an appropriate color space, particularly the L*a*b color space, in order to be used by the algorithm. The required data from the image may be recovered more successfully by applying image pre-processing techniques like image reduction and contrast amplification. [14]

#### *3.1.6.3 Image Segmentation*

Using the K Means algorithm, a picture is segmented in this stage. It is a very useful technique for object detection that divides a set of features into K classes. The interesting area of the input image can be found by reducing the sum of the squares of the distance between the associated cluster and the item. When using K-Means clustering techniques, groups of pixels with the same value that are present in an image serve as the basis for the clusters.[15]

#### *3.1.6.4 Dataset*

Both primary and secondary sources were used to gather the data. The photos of wheat in the primary source were captured with a camera with a (516*516) pixel image size. Typically, a knowledgeable invigilator evaluates these images from original sources. Primary and secondary sources, respectively, are used to collect various images. A camera serves as the main source, and other sources, such as websites and web pages, serve as the secondary sources.

#### *3.1.6.5 CNN*

Convolution neural network is a deep neural network built for processing structured arrays. They are widely used in computer vision and are now considered state-of-the-art for many visual applications, including picture categorization. Additionally, they have had success using natural language processing to categorize texts. They are well suited for computer vision because they have a reputation for spotting patterns in input images. They don't require any preprocessing because they work directly with raw images. A feed-forward neural network with 20 or 30 layers is what it is. Convolution neural networks frequently feature numerous convolution layers piled on top of one another, each of which is capable of recognizing complex shapes. [**16]**Convolution layer use mimics the architecture of the human visual brain. The input image's pixel matrix is convolved with a kernel matrix. The matrix's input feature is larger than the convolved feature, which is smaller. Unless the crucial traits are retrieved, this stage will continue. Convolution generates a lot of data, making it challenging to train the model. Data pooling is needed to compress the data. Because convolution shrinks the size of the input matrix, padding is used to increase the input matrix by adding fictitious pixels to the border. Two different types of operations are carried out on the convolved features.

1. Dimensionally reduce valid padding

2. Maintain the same size or increase the dimension of the padding.

### 3.1.7 Block Diagram for Image processing

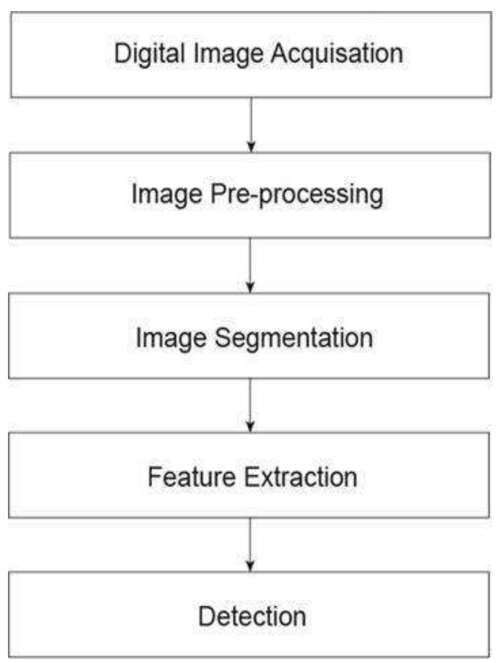


Figure 3.1.7 Block diagram for image processing

### 3.1.8 CNN Algorithm

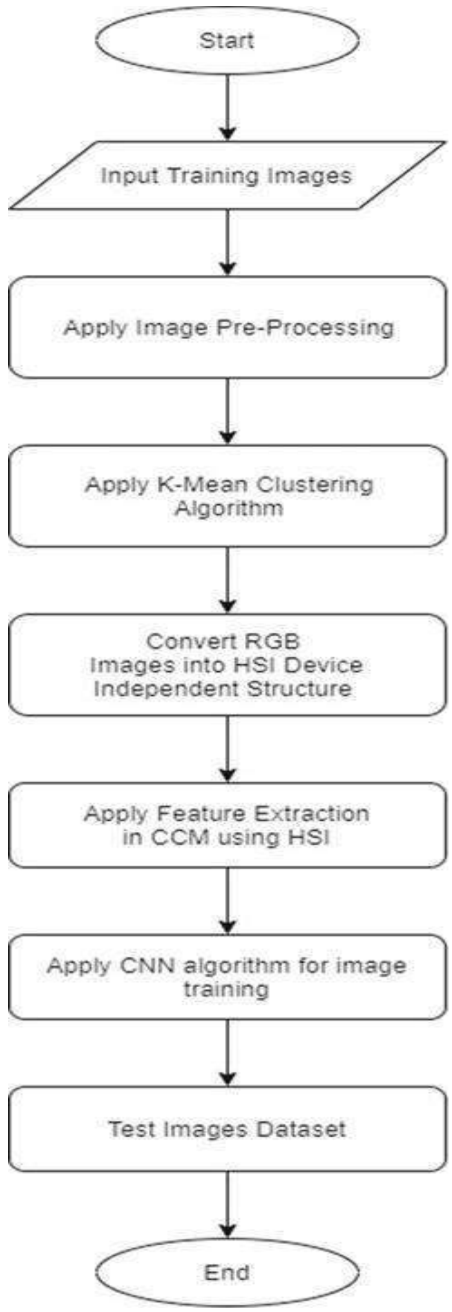


Figure 3.1.8 Flowchart of CNN

### 3.1.9 Dataset for Healthy Leaf

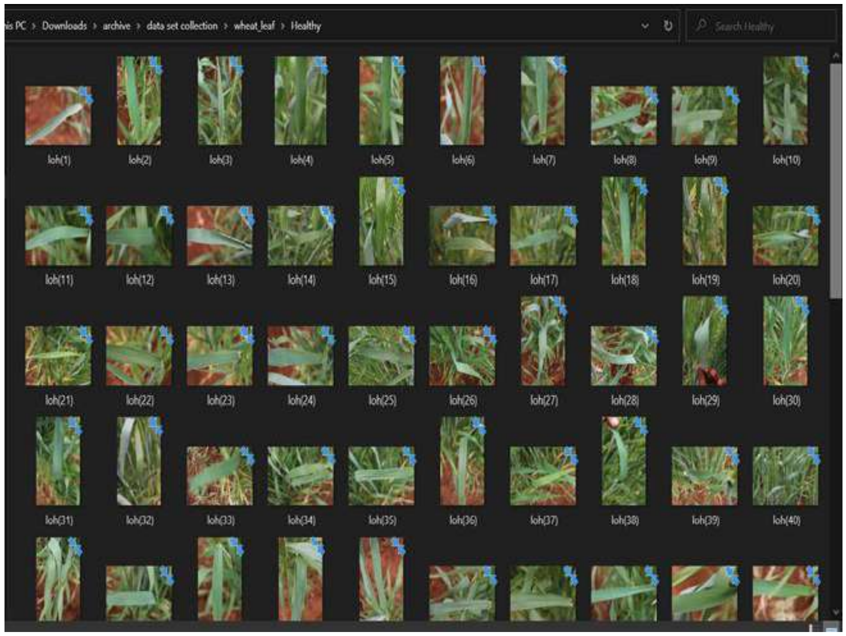


Figure 3.1.9 Dataset for Healthy leaf

### 3.1.10 Dataset for Leaf Rust

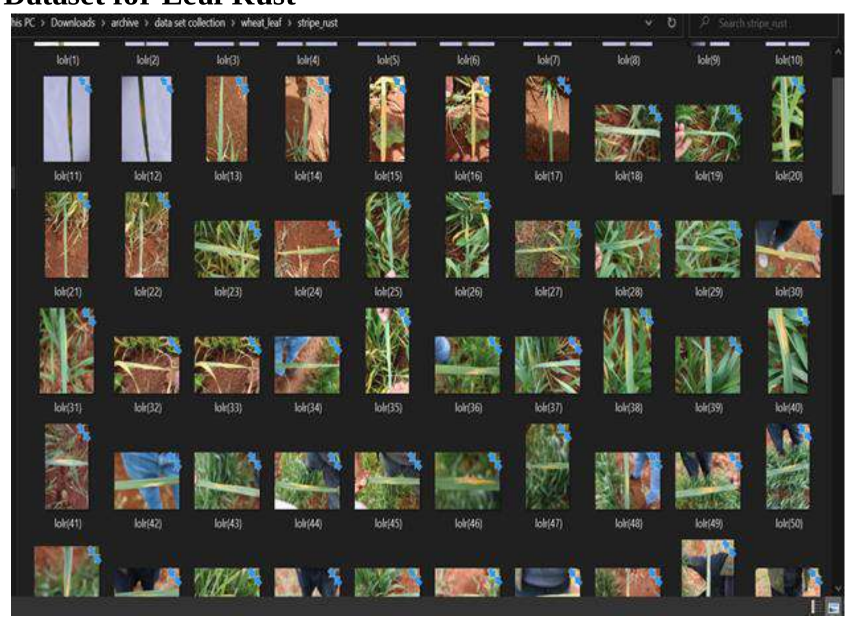


Figure 3.1.10 Dataset for Leaf Rust

### 3.1.11 Dataset for Tan Spot

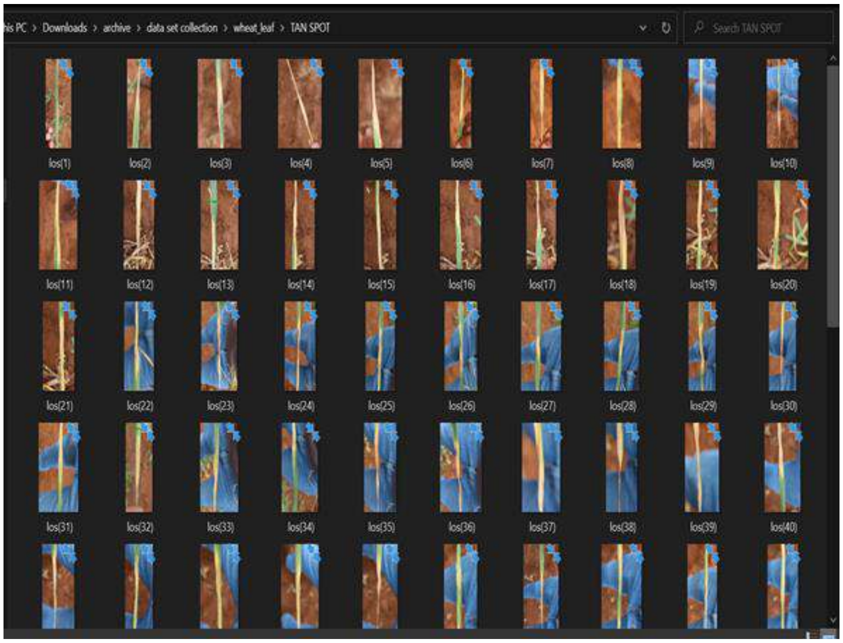


Figure 3.1.11 Dataset for Tan Spot

*Chapter 4*

# Hardware Selection and Specifications

## 4.1 Introduction

After completing methodology stage, we selected the following mentioned in Table 4-1 components to implement our project;

Table 4-1: Required Components

| **Sr. No** | **Components** |
|---|---|
| 1 | ESP-32 |
| 2 | Soil moisture sensor |
| 3 | DHT-11 Humidity and Temperature sensor |
| 4 | Battery |
| 5 | Rain sensor |
| 6 | Water level sensor |
| 7 | Servo motor |
| 8 | PH sensor |
| 9 | Charge Controller |
| 11 | Solenoid Valve |
| 12 | Pump motor |
| 13 | Water tank |
| 14 | Raspberry Pi |
| 15 | Pi Camera |

Description of hardware is specified in following table:

Table 4-2: Hardware Specifications

| **Sr. no** | **Components** | **Specifications** |
|---|---|---|
| 1 | ESP-32 Module | ○ 4 GB (32-bit) address space for both data bus and instruction bus.<br>○ 1296 KB embedded memory.<br>○ 19704 KB external memory.<br>○ 512 KB peripheral. [17] |
| 2 | Soil Moisture Sensor | ○ Operating Voltage: 3.3-5v<br>○ Adjustable sensitivity via potentiometer<br>○ Digital Output and analog<br>○ LED indicator for voltage (red)<br>○ LED indicator digital output (green) [18] |
| 3 | Humidity and Temperature sensor | ○ Power supply: 3.3-6V<br>○ Operating range: Humidity 0-100% RH; |
| 4 | Water level sensor | ○ "S" denotes input of the signal<br>○ "+" sign denotes power supply<br>○ "-" sign denotes GND |
| 5 | PH sensor | ○ Supply Voltage: 3.3~5.5V<br>○ BNC Probe Connector<br>○ High Accuracy: ±0.1@25℃<br>○ Detection Range: 0~14 |
| 6 | Solenoid Valve | ○ Voltage 12v<br>○ Orifice 16mm<br>○ Temperature -5 to 80 C<br>○ Pipe Size ½’<br>○ Operating 0 min |

## 4.2 Solar Panel

Solar panels are the most essential components of our project. This component is the main source of bringing economic benefit to our project.

### 4.2.1 Introduction

Solar panel is a panel which is manufactured in such a way that it absorbs rays coming from the sun and converts them to electricity. Solar Panel consists of solar cells which have a specific connection arrangement on the panel.

### 4.2.2 Working

The process which is used by solar panels to convert sunlight into electricity is known as photovoltaics. Atom of the silicon crystal is forming a lattice type structure. Just like other atoms the atoms of silicon have nucleus which contains the positively charged particles known as protons. Negatively charged particles i.e. electrons are revolving around the nucleus in shells.

The outer shell of the electrons has vacancies for electrons so electron sharing takes place from time to time and in this way the atoms hold each other firmly to form the crystal. When photons of light fall on the solar cells, these photons knock electrons free from the silicon atom constituting the photoelectric effect. As the photons of light strike the silicon atoms they give their energy to lose the electrons knocking them off. In order to understand a photon of light can be taken as the cue ball of snooker, when the cue ball hits the other balls on the Table it transfer its energy to them and these other balls are considered to be electrons in this example" [19].

In order to work the solar cells, need to develop an electric field. Just like the opposite poles of the magnet create the magnetic field, the electric field is created by the opposite charges. To develop this electric field, the makers of silicon have to dope it some other materials. So, positive and negative charges are formed on the sides of the cell.

In this way a large area of p-n junction of silicon is formed. If a part of p-type is silicon is placed near a part of n-type silicon, then the electrons flow from n-type side of the junction (a place of higher concentration) towards the p-type side of the junction (a place of lower concentration). This process is known as diffusion of electrons. When electrons flow through the p-n junction they recombine with holes on p-type region. However, charges build up on both sides of the junction and develop the electric field. This electric field supports the charge flow. This charge flow is known as drift current, and it opposes and eventually balances the diffusion of electrons and holes. The depletion area is where the electrons and holes have dispersed.

Silicon is a semiconductor material i.e. it has the properties of a metal as well as that of an electrical insulator. This point happens to be the key to the working of solar panel. The solar panels as stated before have solar cells on which light falls. This striking of photons on the solar cells result in the emission of electrons from the silicon material.

## 4.3 Types of Solar Panels

Some of the most commonly used solar panel types are discussed below.

- Mono-crystalline solar panels
- Polycrystalline solar panels
- Amorphous solar cells
- Hybrid solar panels

### 4.3.1 Mono-crystalline Solar Panels

These solar cells are created from thin silicon wafers cut from chemically generated crystals and given in Figure 4.10.1. These cells are made from single crystals grown in isolation, which makes them costlier than the other varieties. These solar panels are around 35% more costly than comparable polycrystalline cells. They do, however, have a substantially higher efficiency rating (i.e. 15-24 percent)".

Figure 4.3.1: Mono crystalline Solar Panel.

### 4.3.2 Polycrystalline Solar Panels

These solar panels are similarly made of thin silicon wafers cut from artificially created crystals that can be seen in Figure 4.10.2, but instead of a single crystal, these cells are made of various interlocking silicon crystals grown together. As a result, these solar panels are less expensive to produce. The efficiency of these solar panels is lower than that of monocrystalline solar cells, spanning from 13 to 18 percent".

Figure 4.3.2: Polycrystalline Solar Panel.

### 4.3.3 Amorphous Solar Cells

Amorphous solar cells are shown in Figure 4.10.3. These are the cheapest of the types of solar panels. The method of their production is also very different from the other types Silicon is coated extremely thinly on a backing substrate in the production of amorphous solar cells.

There are two main benefits of this type of solar cell. As the layer of silicon is very thin it makes the panel very flexible and also these panels are comparatively more efficient in low light levels i.e. during winters when light level is low. However, the disadvantage of this type is that their efficiency is lower as compared to the other types and it ranges between 79%.

Figure 4.3.3: Amorphous Solar Panel.

### 4.3.4 Hybrid Solar Panels

Hybrid Solar Panels are a combination of both amorphous solar cells and mono-crystalline solar cells and can be seen in Figure 4.10.4. These are known as HIT solar cells (Heterojunction with Intrinsic Thin Layer) and have higher efficiency ratings than other types of the solar panels. In addition, they are also better suited in sunnier climates, where temperatures often exceed 250C, creating up to 10% more electricity.

Figure 4.3.4: Hybrid Solar Panel.

Based upon its reliability and efficiency we have preferred to install mono crystalline solar panel in our project.

Why we selected Mono Crystalline Solar Panel over other types?

o Firstly, mono-crystalline solar panels are reliable and can be utilized for a longer timeframe.

o The efficiency of mono-crystalline solar panels is much better as compared to other types which mean they are able to transform the highest amount of solar energy into electrical energy.

- Mono-crystalline panels have greater heat resistance than other types.

## 4.4 Battery

A device which converts chemical energy into electrical energy and used as a source of power is called battery. In Figure 4.12 battery structure is shown. A battery has three main parts;

- Anode (-)
- Cathode (+) o Electrolyte

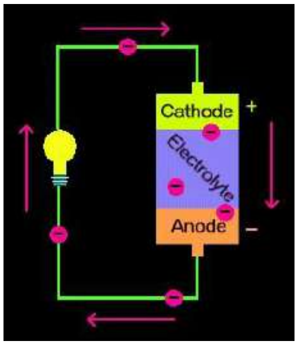


Figure 4.4: Battery structure.

When a battery is connected to any electric circuit a chemical reaction occurs inside the electrolyte making ions (the negative and positive charges starts flowing on their ways) this movement of charges makes an electric current flow through the battery and through the circuit. There are a lot of applications of battery as it is very common nowadays for example electric watches, calculators, toys, automobiles, trucks etc.

## 4.5 Types of Battery

There are basically two types of batteries/cells

- Primary cell
- Secondary cell

### 4.5.1 Primary cell

In this type of battery/cell, in which an irreversible chemical reaction occurs is called primary cell. It is also known as non-rechargeable battery and it is disposable. Examples are alkaline battery, atomic cell and shown in Figure in Figure 4.13.1.

Figure 4.5.1: Primary cell.

### 4.5.2 Secondary cell

The type of battery which is able to store electrical energy and in which a reversible chemical reaction occurs is called secondary cell and shown in Figure 4.13.2. It is also known as rechargeable battery. Examples: fuel cell, lead-acid battery, nickel iron battery etc.


Figure 4.5.2: Secondary cell.

### 4.5.3 Dry Cell Battery

A Dry cell battery is commonly used nowadays. Unlike wet cell battery dry cell battery uses paste electrolyte. As it does not contain any free liquid it provides required moisture to allow current to flow. Due to its main Advantages we are using it in our project. The type of dry cell we are using in our project as a power source is a secondary Dry Cell which is rechargeable.

Why we selected dry cell battery over other batteries?

- Dry cell batteries are way more compact as compared to wet cell batteries
- They do not contain any free liquid which prevents them from falling.

- Chemicals that are used in the battery as electrolyte are safe for human handling. o It is inexpensive.

#### *4.5.3.1 Construction*

The battery we are using is a zinc carbon battery. It is also called zinc manganese cell. Zinc act as anode while manganese dioxide and carbon paste act as cathode. Ammonium chloride/zinc chloride acts as electrolyte.

#### *4.5.3.2 Working*

The oxidation reaction takes place in anode with the zinc shell. And reduction takes place at the cathode. The working is same as a normal battery. Anode is releasing electrons and cathode is adopting the electrons both the process is simultaneous in the electrolyte.

#### *4.5.3.3 Advantages*

- Higher efficiency.
- Less leakage resistance.
- Energy density is better.

## 4.6 Submersible Water Pump

### 4.6.1 Introduction

Submersible water pump is the type of centrifugal water pumps which are designed to operate with the motor and the pump completely submerged in the water. The motor will be protected in such a way that water will not enter the motor and cause it to fail.

### 4.6.2 Working

This type of pump typically runs in a bored well and has a very thin submersible motor placed at the pump's bottom. An intake screen and a suction bell will be located directly above the motor. The fluid will be directed into the centrifugal pump stages, which include impellers and diffuser bowls.

Why we selected this?

- We can be powered directly by 12 v solar panel or battery.
- It is suitable for our Project.
- It is low cost.
- Its easily available

## 4.7 Raspberry Pi

Raspberry Pi is characterized as a minicomputer the size of a credit card that is interoperable with any input and output hardware device like a monitor, a television, a mouse, or a keyboard. You will require an SD card placed into the designated location in order to configure the Raspberry computer. The operating system should be placed on the SD card, which is necessary for the machine to boot. The Raspberry Pi can be connected to output devices such computer monitors or High-Definition Multimedia Interface (HDMI) televisions after the OS has been configured. Moreover, input devices like keyboards and mouse must be connected.

Figure 4.7 Raspberry PI

### 4.7.1 Specifications

The 2019 release of the Raspberry 4B, which has memory capacities ranging from 2GB RAM to 8GB RAM, represents a significant improvement over its forerunners. In addition, it includes a 1.5GHz processor that is quicker and a good number of 2.0 and 3.0 USB ports. The Pi 4B is the ideal Raspberry model because it works with almost every use case and has more RAM to satisfy even the most ardent programmers. Each device costs between $35 and $75, depending on memory, and it has all available connectivity choices.

## 4.8 Pi Camera

High definition video and photos can be captured using the pi Camera module. The Raspberry Pi Board has a CSI (Camera Serial Interface) interface that the Pi Camera module can be directly connected to. A 15-pin ribbon cable is required to connect this Pi Camera module to the CSI port on the Raspberry Pi.

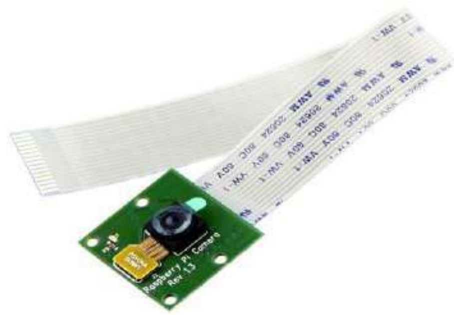

Figure 4.8 PI Camera

The Pi camera is interfaced with raspberry pi in such a way that first of all, attach the camera module's ribbon connector to the Raspberry Pi's connector. The camera's connector is the white one that is located closer to the USB and Ethernet ports. A specially created add-on module for Raspberry Pi hardware is the Raspberry Pi Camera Board. It uses a unique CSI interface to connect to the Raspberry Pi hardware. In still capture mode, the sensor has a native resolution of 5 megapixels. It supports up to 1080p at 30 frames per second for video mode capturing.

### 4.8.1 Features

- Resolution – 5 MP
- HD Video recording –1080p,30fps, 720p,60fps, 960p,45fps and so on.
- It Can capture wide, still (motionless) images of a resolution 2592x1944 pixels
- CSI Interface enabled.

*Chapter 5*

# Results and Discussions

## 5.1 Implementation, test and troubleshoot

After completing project implementation phase come. Implementation is performed with the help of drip irrigation. In Figure 6.1 implementation is shown that is in first phase:

Figure 5.1 Setting land

In Figure 6.2 after installing project at site an overview is shown with the location of moisture sensors.

Figure 5.2 Implementation and Testing

After installation and implementation reading of all sensors are shown at Blynk app. In Figure 6.3 values of all sensors can be seen that are integrated with ESP-32 and app. In Figure 6.3, Initialized all the sensors and they gave the initial readings at zero point like rain sensor shows that there is no rain.

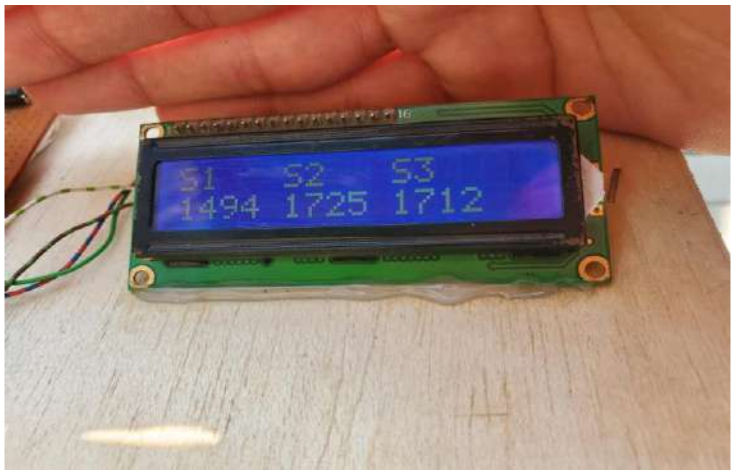


Figure 5.3 LCD reading

In Figure 6.4, Sensors gave their reading when project starts. All the moisture sensors gave the moisture level of the soil of that time.

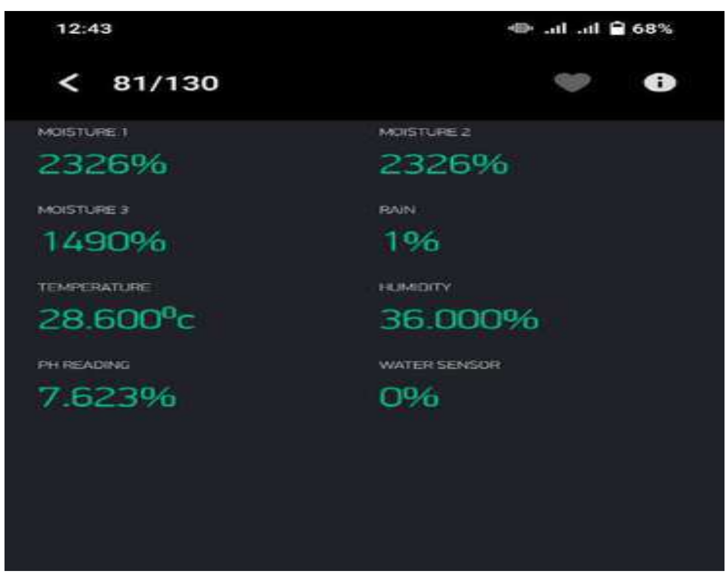


Figure 5.4 Sensor Readings on Blynk app

Then data obtained from blynk app and LCD is stored in excel sheets.

SOLAR POWERED AUTO IRRIGATION

READINGS FROM LCD

| Date | S1 | S2 | S3 | Rain | Temp | Humidity | Average |
|---|---|---|---|---|---|---|---|
| 11/12/2022 | 1502 | 1705 | 1709 | 4095 | 31C | 4017 | 1638 |
| 13-12-22 | 1494 | 1725 | 1712 | 4095 | 31C | 5017 | 1643 |
| 14-12-22 | 1490 | 1730 | 1660 | 4095 | 24C | 1042 | 1626 |
| 15-12--22 | 1440 | 1710 | 1605 | 4090 | 19C | 1029 | 1585 |
| 17-12-22 | 1495 | 1730 | 1717 | 4090 | 23C | 1019 | 1647 |
| 19-12-22 | 1505 | 1710 | 1679 | 4090 | 23C | 1020 | 1631 |
| 21-12--22 | 1495 | 1695 | 1710 | 4090 | 23C | 1030 | 1633 |
| 22-12-22 | 1490 | 1700 | 1600 | 4090 | 25C | 1040 | 1596 |
| 24-12-22 | 1509 | 1710 | 1699 | 4095 | 21C | 1590 | 1639 |
| 26-12-22 | 1494 | 1718 | 1720 | 4095 | 18C | 1090 | 1640 |
| 29-12-22 | 1690 | 1750 | 1830 | 4095 | 19C | 1010 | 1756 |
| 30-12-22 | 1440 | 1735 | 1725 | 4095 | 17C | 1070 | 1640 |
| 1/1/2023 | 1501 | 1710 | 1710 | 4090 | 17C | 1005 | 1630 |
| 2/1/2023 | 1480 | 1760 | 1714 | 4090 | 18C | 1009 | 1640 |
| 4/1/2023 | 1510 | 1640 | 1614 | 4085 | 15C | 1002 | 1588 |
| 5/1/2023 | 1559 | 1720 | 1714 | 4085 | 15C | 1050 | 1640 |

Figure 5.5 Sensor readings from LCD

SOLAR POWERED AUTO IRRIGATION SYSTEM

Readings from Blynk APP

| Date | S1 | S2 | S3 | Rain | Temp | Humidity | PH | Average |
|---|---|---|---|---|---|---|---|---|
| 12/12/2022 | 403% | 1552% | 395% | 1% | 23.7C | 38% | 8% | 783% |
| 13-12-22 | 1232% | 1365% | 1323% | 4095% | 20.006C | 11% | 7% | 1306% |
| 14-12-22 | 1111% | 1200% | 4095% | 4095% | 30.500C | 13% | 7% | 2135% |
| 15-12-22 | 1497% | 1709% | 1707% | 4095% | 40C | 17% | 7% | 1637% |
| 16-12-22 | 1490% | 640% | 1729% | 4095% | 30.5C | 25% | 7% | 1286% |
| 17-12-22 | 1056% | 1149% | 4095% | 4095% | 23.7C | 13% | 8% | 2100% |
| 19-12-22 | 156% | 1552% | 395% | 1% | 23C | 38% | 8% | 701% |
| 21-12-22 | 1330% | 1708% | 4095% | 4095% | 22C | 15% | 8% | 2380% |
| 22-12-22 | 277% | 1179% | 1322% | 4095% | 23C | 22% | 8% | 926% |
| 24-12-2 | 166% | 1465% | 4095% | 4095% | 20C | 11% | 7% | 1908% |
| 26-12-22 | 1323% | 1876% | 4095% | 4095% | 18C | 15% | 8% | 2431% |
| 29-12-22 | 1597% | 1708% | 1709% | 4090% | 18C | 15% | 6% | 1671% |
| 30-12-22 | 1099% | 770% | 1704% | 1% | 17C | 15% | 7% | 1191% |
| 1/1/2023 | 1790% | 1690% | 1750% | 4090% | 18C | 13% | 7% | 1680% |
| 2/1/2023 | 1790% | 169000% | 1690% | 4095% | 18C | 11% | 7% | 1730% |
| 3/1/2023 | 1790% | 181000% | 1737% | 4090% | 18C | 10% | 7% | 1650% |
| 4/1/2023 | 1890% | 1710% | 2250% | 4090% | 18C | 10% | 7% | 1690% |
| 5/1/2023 | 1243% | 2222% | 1710% | 1% | 17C | 9% | 7% | 1725% |
| 5/1/2023 | 1666% | 1575% | 1767% | 4095% | 17C | 9% | 7% | 1569% |

Figure 5.6 Sensor readings from Blynk app

Results for Plant leaf detection are represented as

Figure 5.7 Initializing Raspberry PI with PI Camera

### 5.1.1 Result for Healthy Wheat


Figure 5.1.1 Healthy Wheat

### 5.1.2 Result for Leaf Rust


Figure 5.1.2 Leaf Rust

### 5.1.3 Result for Tan Spot


Figure 5.1.3 Tan Spot of Wheat leaf

Experiment is done on 2 marla land i.e., 1 marla is manually irrigated and 1 marla is under control. 350 random pictures are taken in both scenarios. For manual detection i.e., 256 taken images are healthy leaves, 56 images are rusted and 38 images are defected by tan spot. Under controlled process, 280 taken images are healthy leaves, 42 images are rusted and 28 images are defected by tan spot.

Table 5-1 Amount of dataset for manual detection of wheat diseases

| Sr. no | Types of wheat leaves | Amount |
| --- | --- | --- |
| 1. | Healthy leaf | 256 |
| 2. | Leaf Rust | 56 |
| 3. | Tan Spot | 38 |

Table 5-2 Amount of dataset for controlled process

| Sr. no | Types of wheat leaves | Amount |
| --- | --- | --- |
| 1. | Healthy leaf | 280 |
| 2. | Leaf Rust | 42 |
| 3. | Tan Spot | 28 |

Following are the graphs, showing the percentage of diseases under manual and controlled process:

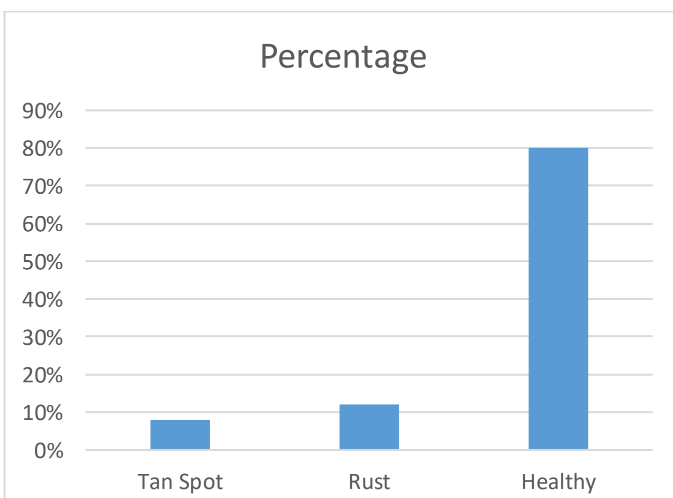


Figure 5.1.4 Percentage of diseases under control process

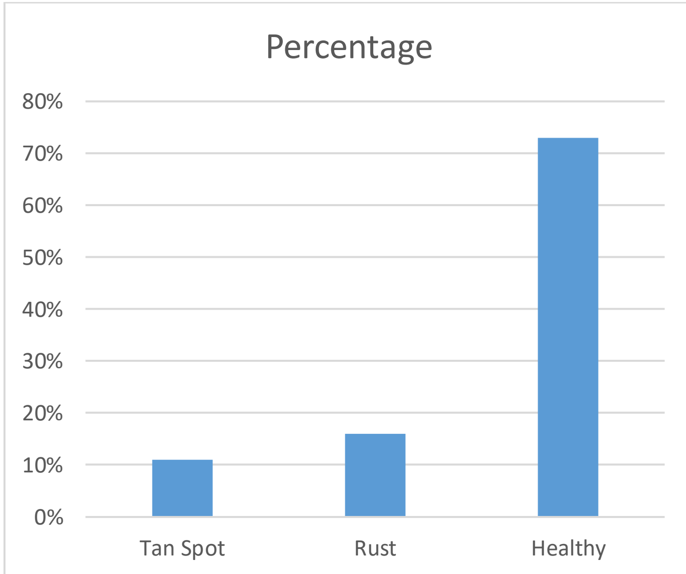


Figure 5.1.5 Percentage of Diseases manually detected

*Chapter 6*

# Environmental Effects

We have employed moisture, humidity, and temperature sensors, which are sensitive to the environment and have been functioning properly up to this point. As it is not possible to create devices that are effect-free globally, these sensors can be changed according to the conditions. Due to the fact that it enables farmers and other landowners to efficiently use their time and water, our idea is crucial from a commercial and economic standpoint. Moreover,

- The generator emits a lot of harmful greenhouse gas emissions into the atmosphere. To cut down on these greenhouse gas emissions, we employed a solar-powered system to power the water pump and the valves rather of generating the electricity through a generator. The battery, which we may use when there is no sunlight, will also be charged by the solar electricity in addition to operating the pump and valves. As a result, harnessing solar energy has helped the environment by reducing greenhouse gas emissions, which is great for the region's population's health.
- There is a significant amount of water waste when irrigating the land. The amount of water needed for the field is unknown. In contrast, there is no water wasted in our system. We have set the moisture value, and the system will now automatically provide the field with the necessary water. In the automatic system, the water that was wasted in the manually operated system can be utilized for other purposes. When there is a risk of rain during the rainy season. You can turn off the irrigation system and prevent the field from getting too much water. A DHT11 sensor that we've added to the system provides information on the temperature and humidity.
- Conservation of man force by controlling fertilizers distribution by app.
- 20% water savage by drip irrigation.
- "Plant Health indication" utilizes a creative idea to help the agricultural sector identify the afflicted crops. Using CNN Algorithm, the leaf diseased area is divided up and examined. It gives the farming community, especially in isolated villages, a good option. In terms of cutting down on clustering time and infected area size, it functions as an effective method. The process of feature extraction aids in both the extraction of the diseased leaf and the classification of plant diseases. This idea of improving accuracy by

CNN insertion produces good results. The suggested method is a useful method that can considerably aid in the precise diagnosis of leaf diseases with little computational effort.

- This project has applications in fields of study that demand a great deal of plant care. Therefore, individuals working in the field of medicinal plant research can utilize this initiative to ensure that the health of the plant is constantly being monitored, even when they are not on the fields. To stop plant diseases from spreading, this idea can also be employed in greenhouses and nurseries. This concept could also be used to agriculture, which involves massive industrial output.

***Chapter 7***

# Project Cost

Table 7-1 Project Cost

| **Sr. No** | **Component** | **Quantity** | **Price** | **Total Price** |
|---|---|---|---|---|
| 1 | ESP-32 | 1 | 3076 | 3076 |
| 2 | Soil moisture sensor | 3 | 215 | 215 |
| 3 | DHT-11 Humidity and Temperature sensor | 1 | 369 | 369 |
| 4 | Battery | 2 | 461 | 461 |
| 5 | Rain sensor | 1 | 215 | 215 |
| 6 | Water level sensor | 1 | 123 | 123 |
| 7 | Servo motor | 1 | 430 | 430 |
| 8 | PH sensor | 1 | 1076 | 1076 |
| 10 | Solar Panel | 1 | 4615 | 4615 |
| 11 | Solenoid Valve | 1 | 2153 | 2153 |
| 12 | Pump motor | 1 | 769 | 769 |
| 13 | Water storage tank | 1 | 369 | 369 |
| 14 | Mineral tank | 1 | 276 | 276 |
| 15 | Drip irrigation pipes | -- | -- | 1030 |
| 16 | wires | -- | -- | 1384 |
| 17 | Rely Module | 2 | 461 | 461 |
| 18 | Miscellaneous | -- | -- | 15000 |
| 19 | Raspberry Pi | 1 | 72,307 | 72,307 |
| 20 | Pi Camera | 1 | 10,769 | 10,769 |
| 21 | HDMI Cable | 1 | 300 | 300 |
| 22 | HDMI Port | 1 | 461 | 461 |
| 22 | Total Cost | -- | 111,244 | 111,244 |

*Chapter 8*

# Conclusion and Future Work

The implementation of Solar Powered Auto Irrigation System was done on software at first. Then the implementation was done with the hardware. After implementation of the circuit the results are compared of the software implementation measurements with the hardware implementation measurements. These software and hardware measurements were also compared with the measurements of different other projects related to auto irrigation system. An additional useful feature of monitoring system is introduced which consists of Blynk app, server". Main thing is monitoring, all the data from different part of whole system i.e. soil moisture sensors, humidity and temperature sensor, rain sensor, state of valves and water level sensor status. All data is stored in a data base and then send to server where it displays all the data to the user who is monitoring. with the help of all this data the user can estimate the flow and quantity of water which is to be supplied to the field and minerals distribution. With the Wi-Fi module connected to our system the user can access the app all the data just by entering the IP address of the local host server in the browser". The main central controlling device is ESP-32 which first collects all the data from the sensors, stores all that data in a database with the help of app and then operating the valves. Also it shows all the stored values of the database on a connected device. The majority of the time, manual identification in agricultural fields occurs at the very end, which could lead to financial losses. The project's primary goal is to automatically recognize and classify the wheat leaf diseases, which is a significant factor in crop loss in agricultural regions. The notion of CNN, which is used to zoom the image and more precisely identify the damaged portion, is utilized in image processing to identify the plant disease. [20] Later, by comparing the result with the training dataset and displaying it, the severity of the disease is determined. The suggested approach will decrease manual labor and boost yield by spotting disease at an earlier stage. As a result, the loss will be avoided.

## 8.1 Knowledge obtained from project

The knowledge that is obtained from this FYP project is as follow.

- Operational characteristics of ESP-32, moisture and temperature sensor and solenoid valves.

- Knowledge of different types of Solar panels and their working.
- Codes writing for ESP-32 module.
- Designing the circuit on PCB.
- Writing python codes.
- Knowledge of raspberry Pi and Pi Camera.

## 8.2 Experience throughout the project

Following experience gained while executing and developing FYP project:

- Learn Professionally Project Planning.
- Project Management and Implementation.
- Project Controlling.
- Time management efficiency is essential for dealing with unanticipated situations.
- There is also a need for someone to facilitate the project, someone to ensure that work begin on schedule and are completed in a suitable amount of time.

## 8.3 Future Work

- Minerals checking can be performed by using NPK sensor and it will lead to automatic minerals distribution according to requirements.
- It will be possible to accurately detect diseases if a leaf has many infections by using the 4 or 5 Means clustering technique. Also, a researcher can concentrate on automatically identifying the various clusters needed to more precisely partition the defective area. By keeping a database in the system and comparing the sensor readings with those in the database, this project can be enhanced further to produce more accurate results.
- Additionally, MATLAB simulation can be used to process photos, and the images can be shown while the robot is in action. Relays can be replaced by PLC since it performs many more tasks than a relay.

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# Appendix

## Soil Moisture Sensor FC-28

### Specifications:

Operating Voltage: 3.3-5v

Adjustable sensitivity via potentiometer

Digital Output and analog

LED indicator for voltage (red)

LED indicator digital output (green)

LM393 comparator

Dimensions PCB: 3x1, 5cm

Dimensions Probe: 6x2cm

Length Cable: 21cm

### Pin out

VDC: 3.3-5v

GND: GND

D0: Digital Output

## Technical Specification of DHT-11

The technical specifications of DHT-11 are listed in the following Table:

| | |
|---|---|
| Model | DHT-11 |
| Power Supply | 3.3-6V DC |
| Output Signal | Digital signal via single bus |
| Sensing Element | Polymer Capacitor |
| Operating Range | Humidity 0-100% RH; temperature -40~80Celsius |
| Accuracy | Humidity +-% RH(Max +-5%RH; temperature <+-0.5Celsius |
| Humidity hysteresis | +-0.3%RH |
| Long-term Stability | +-0.5% RH/year |
| Sensing period | Average: 2s |

**Datasheet of solenoid Valve**

Voltage 12v

Orifice 16mm

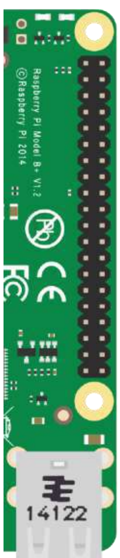
Temperature -5 to 80 C

Pipe Size ½'

Operating 0 min

Pressure MAX 10 kg/cm

# Raspberry PI Datasheet:




| Peripherals | GPIO | Particle | Pin # | | | Pin # | Particle | GPIO | Peripherals |
|---|---|---|---|---|---|---|---|---|---|
| | 3.3V | | 1 | X | X | 2 | | 5V | |
| I2C | GPIO2 | SDA | 3 | X | X | 4 | | 5V | |
| | GPIO3 | SCL | 5 | X | X | 6 | | GND | |
| Digital I/O | GPIO4 | D0 | 7 | X | X | 8 | TX | GPIO14 | UART |
| | GND | | 9 | X | X | 10 | RX | GPIO15 | Serial 1 |
| Digital I/O | GPIO17 | D1 | 11 | X | X | 12 | D9/A0 | GPIO18 | PWM 1 |
| Digital I/O | GPIO27 | D2 | 13 | X | X | 14 | | GND | |
| Digital I/O | GPIO22 | D3 | 15 | X | X | 16 | D10/A1 | GPIO23 | Digital I/O |
| | 3.3V | | 17 | X | X | 18 | D11/A2 | GPIO24 | Digital I/O |
| SPI | GPIO10 | MOSI | 19 | X | X | 20 | | GND | |
| | GPIO9 | MISO | 21 | X | X | 22 | D12/A3 | GPIO25 | Digital I/O |
| | GPIO11 | SCK | 23 | X | X | 24 | CE0 | GPIO8 | SPI (chip enable) |
| | GND | | 25 | X | X | 26 | CE1 | GPIO7 | |
| DO NOT USE | ID_SD | DO NOT USE | 27 | X | X | 28 | DO NOT USE | ID_SC | DO NOT USE |
| Digital I/O | GPIO5 | D4 | 29 | X | X | 30 | | GND | |
| Digital I/O | GPIO6 | D5 | 31 | X | X | 32 | D13/A4 | GPIO12 | Digital I/O |
| PWM 2 | GPIO13 | D6 | 33 | X | X | 34 | | GND | |
| PWM 2 | GPIO19 | D7 | 35 | X | X | 36 | D14/A5 | GPIO16 | PWM 1 |
| Digital I/O | GPIO26 | D8 | 37 | X | X | 38 | D15/A6 | GPIO20 | Digital I/O |
| | GND | | 39 | X | X | 40 | D16/A7 | GPIO21 | Digital I/O |