International Journal of Engineering Works
https://www.ijew.io/
ISSN-p: 2521-2419
ISSN-e: 2409-2770
Vol. 11, Issue 01, PP. 07-20, January 2024
https://doi.org/10.34259/ijew.24.11010720

Smart Irrigation System Using Data Analysis

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Received: 17 December[2023], Revised: 31 December[2023], Accepted: 03 January

***Abstract*—**Random One of the significant issues the World is confronting nowadays is Water scarcity. Water scarcity includes issues of water pressure, water shortage, and other water crises. According to statistics, it has affected about 2.8 billion people worldwide and 1.2 billion people don't have access to clean drinking water. The water available for people is decreasing day by day and in today world, our earth covers only 2.5% of fresh water and the remaining water is distributed in the shape of glaciers, oceans saline seawater. Out of total water utilization, around 95% of Pakistan water is utilized in the agriculture sector, with 60% of its total population directly associated with the agriculture and livestock sector and 89i90% of its exports are dependent on these sectors. Over 60%of irrigation water is wasted because of using the traditional irrigation system. One of the solutions to overcome the problem of shortage of water is to utilize the water available efficiently and for this purpose, we have designed a Smart Irrigation System

The objective of the project is to irrigate the crops in an effective way to save water. The system is portable and compliant with the current water system. All the sensors Soil Moisture sensor, Humidity and Temperature sensor, and Smoke sensor send the measured values to the Microcontroller. Bluetooth modules are used through which two slave Microcontrollers send the values of Moisture sensors to the master Microcontroller. The master Microcontroller calculates the average of all the moisture sensors and based on the average moisture percentage and temperature and humidity, the pump will be turned on/off. Thus, crops will be receiving the required amount of water only and the field will be saved from under and over irrigation. A user-friendly webpage is developed to help users monitor and control the system. The user can select either manual control for timely irrigation or automatic control using wireless sensors.

***Keywords*—** Water Scarcity, Microcontroller, Regression Mathematical Model, Parameters of Soil.

I. INTRODUCTION

One of the significant issues the World is confronting nowadays is Water scarcity. Water scarcity includes issues of water pressure, water shortage, and other water crises. According to statistics, it has affected about 2.8 billion people worldwide and 1.2 billion people don't have access to clean drinking water [3]. The water available for people is decreasing day by day and in today's world our earth covers only 2.5% of fresh water and the remaining water is distributed in the shape of glaciers, oceans saline seawater [4]. Out of total water utilization, around 95% of Pakistan's water is utilized in the agriculture sector, with 60% of its total population directly associated with the agriculture and livestock sector and 80% of its exports are dependent on these sectors. Over 60% of irrigation water is wasted using the traditional irrigation system [5]. One of the solutions to overcome the problem of shortage of water is to utilize the water available efficiently and for this purpose, we have designed a Smart Irrigation System. The project is divided into different phases, Figure 1 shows the design and implementation flow of the project.

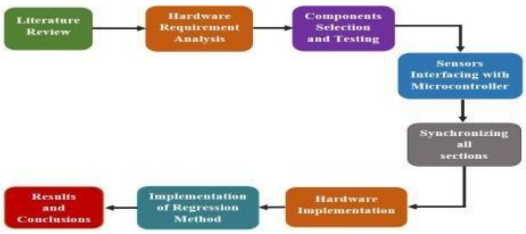


Figure 1. Design and Implementation Flow of the Project

II. RESEARCH BACKGROUND

In the agricultural sector, research has been improved in many ways to upgrade the quality and quantity of agricultural productivity. Researchers have worked on a wide range of projects to deal with characteristics and parameters of soil, and various climatic Conditions as well as exploring various crops. Farmers can evaluate this data for fertilizer necessities for the crop. It will help with smart climate solutions. We have tried to make this project fully automatic, ensure the healthy growth of the crops, and inform the farmer about the status/condition of the field through web pages so that we can check the status of the field anywhere, anytime.

III. PROBLEM STATEMENT

Out of total water utilization, around 95% of Pakistan's water is utilized in the agricultural sector, with 60% of its total population directly associated with the agriculture and livestock sector and 80% of its exports are dependent on these sectors.

Over 60% of irrigation water is wasted using the traditional irrigation system [5]. Figure 2 shows water available per capita in Pakistan is decreasing devastatingly.

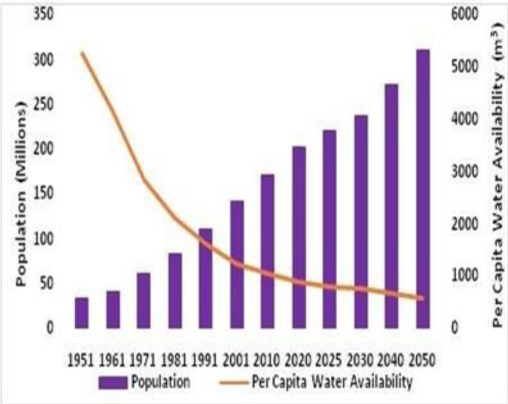


Figure 2. Water availability per person in Pakistan [1]

Problems faced in Pakistan in irrigating crops are as follows.

a. Lack of water resources and wastage of water in Pakistan.
b. Crops are not irrigated efficiently; they get over or under-irrigated.
c. Increasing Food Demand.
d. Most farmers in Pakistan are poor they can't afford labor costs.
e. The population of the World is increasing exponentially; to cope with increasing food and energy demand improved methods of agriculture are required. Figure 3 discusses the change in world population, food demand, and water availability by the year 2050.

Figure. 3

IV. Objectives of Study

This project focuses on supplying only the required amount of water to the crops and making water supply automatic. The whole process has been made automatically to minimize human error and achieve maximum output. The objectives of the project are as follows.

- Comparison of water utilization by automatic and manual irrigation systems.
- Efficient utilization of water.
- Effect of automatic and manual irrigation systems on crop growth.
- Parameters like soil moisture, temperature, pH, humidity, and air quality will be continuously monitored in the field.
- To continuously observe and analyze the parameters of the field, an IOT system will be developed.

V. Research Question

i. The research questions related to the project are discussed below.
ii. How to power the Microcontroller and water pump?
iii. How to interface different sensors and pumps with a Microcontroller?
iv. Based on which the parameters pump will be turned on/off?
v. How to send data to the cloud through a Microcontroller?
vi. How to control the t h e pump using the t h e Regression Mathematical Model?

VI. Literature Review

Smart Irrigation System has a lot of work and optimization in its performance, by using resourceful practices. Worthwhile research has been done on smart irrigation systems. Research on smart irrigation has been done from different ideas and techniques, among which a few are discussed below Table 1 shows the overview of the papers discussed.

VII. Soil Nature Comparison

Soil nature and type influence plant growth and development in many ways, sometimes in surprising ways. The most evident impacts are on root development, which is restrained by hard soil, and affects the capacity of the root to extract the required amount of nutrients and water from the soil. Soil moisture is the water content present in a specific region of the soil, it describes health and all plants should be in a particular soil moisture range. To support the growth of plants, one not only has to make sure the soil is fertile enough but should also be able to keep soil moisture in a certain range. The water present breaks down the nutrients and minerals that plants need from the dirt, allowing them to absorb these helpful particles into their systems. Table 2[12] describes at what level of moisture different soil types need to be irrigated.

TABLE I. OVERVIEW OF THE PAPERS DISCUSSED

No.	Title	Hardware and Software Used	Summary
1	IoT-Based Smart Agriculture Monitoring System [7]	PIC Microcontroller, PIR sensor, Moisture sensor, Temperature and Humidity sensor, and GSM Module	This project is developed. to provide a Smart Agriculture System for the farmer using which he can monitor his field parameters and turn on/off the sensors using a mobile application.
2	Precise Automation and Analysis of Environmental Factors Affecting the Growth of St. John's Wort [8]	Arduino, Wi-Fi Module, Temperature, Humidity, Soil Moisture, and Light sensors	A greenhouse is designed with monitoring and controlling features for optimum growth of herbs. Temperature predictions are done by the regression method.
3	Temperature extremes: Effect on plant growth and development [9]	————	The temperature of the environment affects the production and yield of crops. Each plant has its scope of temperature. for optimum growth.
4	Soil Moisture, Temperature and Humidity, Measurement Using Arduino [10]	Arduino UNO, Moisture Sensor, Temperature and Humidity Sensor	This project was designed. to make cultivation easy for farmers and help them to precisely monitor all parameters affecting crop growth.
5	An IOT-based Agriculture Monitoring System [11]	Raspberry Pi, PIR, Sensor, Relay, Moisture Sensor, Pi Camera, Temperature and Humidity Sensor	The principal reason for this paper is to analyze different parameters ofcrops and provide users with an automatic irrigation system with monitoring and controlling features.

Soil Type	No need of Irrigation	Irrigation to be Applied	Irrigation is Compulsory
Fine(Clay)	80-100%	60-80%	Below 60%
Medium(Loamy)	88-100%	70-88%	Below 70%
Coarse(Sandy)	90-100%	80-90%	Below 80%

TABLE II. SOIL NATURE COMPARISON BASED ON SOIL MOISTURE

pH	Fine (Clay)	Medium (Loamy)	Coarse (Sandy)
7.5	10 - 15	15 - 20	20 - 25
8.0	25 - 30	30 - 40	40 - 50
8.5	40 - 50	50 - 60	60 - 75

TABLE III. REQUIRED AMOUNT OF SULPHUR TO LOWER THE PH OF SOIL.

VIII. CROPS PARAMETERS COMPARISON

Moisture Comparison:

Soil Type	No Irrigation Needed	Irrigation to be Applied	Dangerously Low Soil Moisture
Fine(Clay)	80-100%	60-80%	Below 60%
Medium(Loamy)	88-100%	70-88%	Below 70%
Coarse(Sandy)	90-100%	80-90%	Below 80%

IX. CROPS PARAMETERS COMPARISON

To support the growth of plants, irrigating the field is not enough but other parameters should be kept in a certain range for good growth of crops. Table 5 describes the range of parameters like soil moisture, pH, temperature, and humidity of the field of some crops [13].

TABLE IV. CROPS PARAMETERS COMPARISON

No	Crop Name	Suitable Parameters			
		pH [20] [21] [24]	Temperature [22][24]	Relative Humidity [22] [23]	Moisture [22][23][25]
1	**Onion**	5.5 to 6.5	20° to 25°C	65 to 70%	Not less than 75 %
2	**Tomato**	6.0 to 6.8	18 to 30°C	80 to 90%	1 to 1.5 inches water per week
3	**Okara**	5.8 to 7	21 to 30°C	90 to 95%	20 to 50%(1 inches water per week)
4	**Cucumber**	6 to 7	18 to 24°C	60-70% at day 70-90% at night	1 to 2 inches per week

X. MAIN COMPONENTS

Different types of electronic devices and components are available to make agriculture systems smart. In our project, we have used the following components.

- Arduino Microcontroller
- Bluetooth Module
- Smoke sensor
- Temperature and Humidity sensor
- Soil Moisture Sensor
- Card Reader Module
- Keypad
- LCD
- Relay Module
- Water Pump
- Power Supply
- Wi-Fi Module which is an optional component.

XI. METHODOLOGY OF RESEARCH

Description:

A Smart Irrigation System is a system that reduces the intercession of farmers in the field by automatically irrigating the field when needed. In this way, it will make it easy for the farmers to get healthy growth of the crops and check the status of the field anywhere anytime through a page. This system avoids water wastage and provides stable and healthy growth of the crop.

Figure 7 describes a block diagram of the e-system which shows that there are two fields one has a smart irrigation system while the other one has a manual irrigation system. Each field is 12 x 6 feet. We will do a comparison of auto and manual irrigation concerning different parameters, after completing the project. In it three Arduino modules are used, two Arduino UNO and one Arduino Mega, and Arduino Mega is t h the central controlling unit of the system. Both Arduino UNO are acting as a slave microcontroller and Arduino Mega is working as a Master microcontroller. A Bluetooth Module is configured with each.

Arduino. Two soil moisture sensors relate to each Slave Microcontroller and related toro controller. The central controlling unit and both Slave Microcontrollers are closed in a waterproof box to save the system from any harm and make it efficient. As the power is supplied to the system, the system asks the user to enter the password. In case of entering an incorrect password, LCD will display t h the incorrect password and demand the user to provide the password again, unless the right password is provided the system will not proceed further. When the password provided is right, the title of the project is displayed on the LCD and the system will ask to select the crop. Once the crop is selected all sensors measure the corresponding parameter and all data is collected at the central controlling unit which is a master microcontroller. Both Slave Microcontrollers measure soil moisture values and send them to the master Microcontroller via Bluetooth module. After the selection of the crop, Slave 1 gets connected to the Master Microcontroller and sends. The value of soil moisture measured by soil moisture sensors 1 and 2 to the central controlling unit.

After sending data, Slave 1 disconnects, and Slave 2 gets connected to the Master Microcontroller and sends the value of soil moisture measured by soil moisture sensors 3 and 4 to the central controlling unit. A smoke sensor, pH sensor, soil moisture sensor 5, Temperature and Humidity sensor, Keypad, LCD, a Card Reader Module, and WIFI Module are interfaced with the Master Microcontroller. In the Master Microcontroller average soil dampness is calculated and based on the average soil dampness, the water pump is turned on/off. The relay is a device that works as a switch, in this system, it receives the signal from the Master Microcontroller to turn on/off the water pump. A smoke sensor is used to check the air quality of the field and for the detection of smoke in the field. The alarm is turned on if smoke is detected in the field. All the data measured by sensors is continuously displayed on a web page(optional) using a Wi-Fi module and LCD screen. Using a keyboard, the user can check the data on the LCD and change the set points of parameters. The data measured by sensors is also saved on a memory card using a card reader module. On this data mathematical modeling is applied for future predictions.

Regression Analysis is a technique used to estimate any factor by finding a relation. Between dependent and independent variables. The basic types of Regression are.

- Linear Regression
- Multiple Linear Regression
- Non-Linear Regression

Linear regression analysis helps to find a relationship between a single dependent and single independent variable, the general equation for linear regression is shown in equation 1, where y is the dependent variable, x is the independent variable, m is the slope, c is a slope and e is the error.

$$y = mx + c + \epsilon \quad \text{equation 1}$$

Multiple regression analysis helps to predict the factor dependent on more than one variable. The general equation for Multiple Linear regression is shown in equation2, where y is the dependent variable, x1, x2, an n d x3 are the independent variables, a,f, and s are the slope, c is the slope and e is the error.

$$y = ax1 + fx2 + sx3 + \epsilon \text{ equation 2}$$

In our project dependent variable is soil moisture, on the basis which of water will be turned on/off, and the humidity and temperature of the field are independent variables. So we will be using regression analysis to predict soil moisture and based on it water pump will be turned on/off. After the implementation of the t h e project in the t h e field, values of one month of temperature and humidity of the field will be utilized to find the mathematical relation between dependent and independent variables, which will help to predict average soil moisture and prediction of turning on/off of water pump.

TABLE V. COMPONENTS DETAILS

Name of component	Purpose	Input Voltage	Output	Range	Accuracy
MQ135	Gas Sensor, NH3, CO2, Smoke	DC 5V	0-5V	10ppm-1000ppm	-
DHT22	Humidity & Temperature Sensor	3 - 5V	Serial data	0 – 100% RH -40 –125°C	± 2 – 5% RH ±0.5°C
FC28	Soil Moisture	3.3-5V	0-4.2V	0 – 1023 or 0 – 100%	-
pH Sensor	pH Sensor	-	-	3.5 - 8 pH	-
TF Card Reader Module	Flash Memory Module	3.3V – 5V	3.3V	-	-
ESP8266	Wi-Fi Module	2.5 – 3.6v	-	366 meters	-
Pump	Water pump	12V	-	350 litre/hour	-
Relay Module	On/off pump	0 – 5V	30V DC or 250V AC	-	-
LCD	Display data	4.7 –		-	-

		5.3V			
Keypad	Input to MCU	5V	5V	-	-

XII. FLOW CHART

Data Collection Procedure:

Figure 4 is the flow chart of the Smart Irrigation System. When the system is powered on, the system asks the user to enter the password. In case of entering an incorrect password, LCD will display the incorrect password and demand the user to provide the password again, unless the right password is provided, the system will not proceed further. When the password provided is right, the title of the project is displayed on the LCD and the system will ask to select the crop, press 1 for Okara and 2 for Onion. Once the crop is selected, Slave 1 gets connected to the Master Microcontroller and sends the value of soil moisture measured by soil moisture sensors 1 and 2 to the central controlling unit. After sending data, Slave 1 disconnects, and Slave 2 gets connected to the Master Microcontroller and sends the value of soil moisture measured by soil moisture sensors 3 and 4 to the central controlling unit. All sensors connected to the Master Microcontroller measure the corresponding parameters and all data is collected at the master microcontroller. All the data is continuously saved in a card reader module and displayed on an LCD as well as a web page (optional). The alarm is turned on if smoke is detected in the field. In the Master Microcontroller average of soil moisture is calculatedand if the average soil moisture is less than the set point water pump is turned on and this whole process repeats.

Flow Chart:

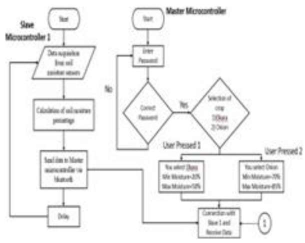


Figure. 5

Flow Chart (Add DHT Details)

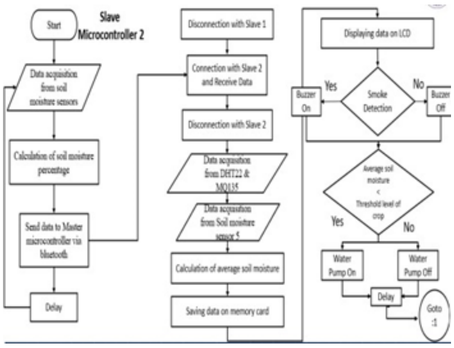


Figure. 6

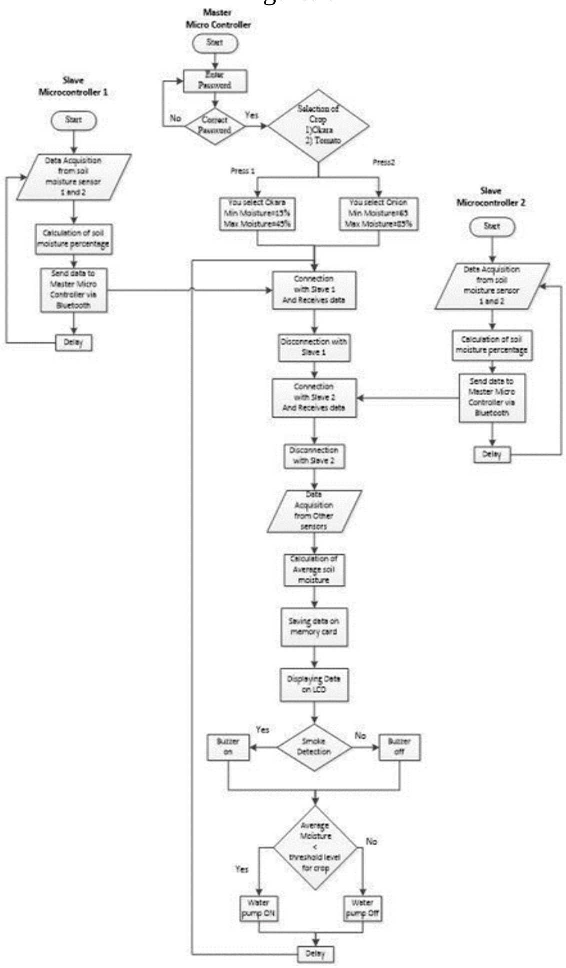


Figure 4: Flow Chart of the Smart Irrigation System

XIII. DATA COLLECTION AND ANALYSIS

The generic block diagram shows that the power supply powers the Microcontroller, DC pump, and all other components. All sensors are sending data to the microcontroller from where it is sent on the web page, which is optional and displayed on LCD.

Based on average soil moisture and field humidity the microcontroller sends the signal to the relay to turn on/off the water pump.

Generic Block Diagram:

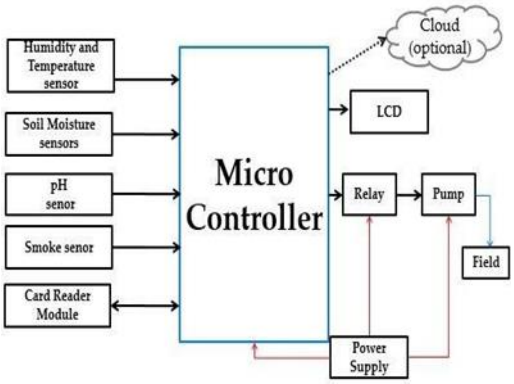


Fig 7 Generic block diagram

Figure 8 describes a block diagram of the system which shows that there are two fields one has a smart irrigation system while t h the other one has a manual irrigation system. We will do a comparison of auto and manual irrigation concerning different parameters, after completing the project. The in which the smart irrigation system is deployed shows that two moisture sensors are interfaced with each Slave Microcontroller and all other sensors and components are interfaced with the Master Microcontroller.

Slave Microcontrollers send the measured values of soil moisture to the Master Microcontroller via Bluetooth Module. In the Master Microcontroller average of soil moisture is calculated, based on soil dampness and humidity of the field relay receives the signal from the Master Microcontroller to turn on/off the water pump. A smoke sensor is used to check the air quality of the field and for the detection of smoke in the field.

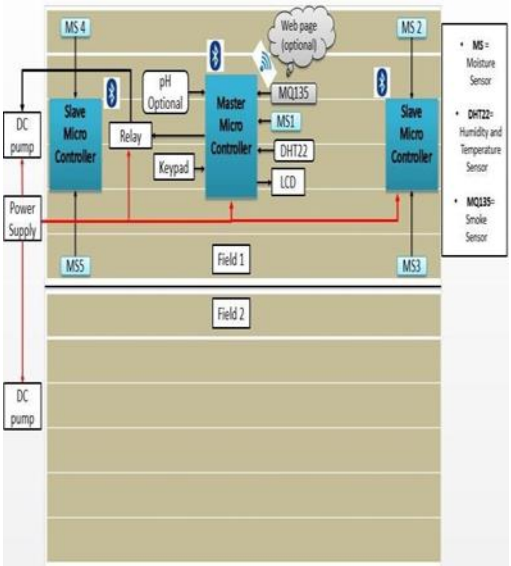


Figure. 8

All the data measured by sensors is continuously displayed on a web page(optional) using a WIFI module and LCD screen. Using a keyboard, the user can check the data on the LCD and change the set points of parameters. The data measured by sensors is also saved in memory cards using a card reader module. On this data mathematical modeling is applied for future prediction.

XIV. CAD Model/ Conceptual Model

The CAD Model of the Research Project is shown in Figures 9 and 10 which show there are two fields, each one 12 x 6 feet in size. The position of each Microcontroller, all sensors, and other components is shown in the CAD model.

Smart Irrigation System:

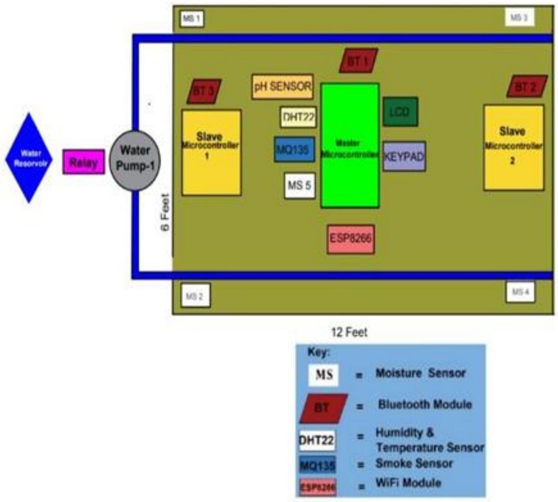


Figure 9: CAD Model of smart irrigated field

Manual Irrigation System:

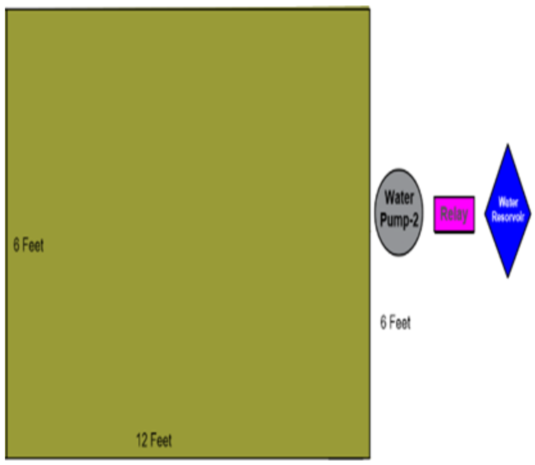


Figure 10: CAD Model of traditionally irrigated field

Four moisture sensors are placed at each corner of the field interface with the corresponding slave microcontroller and one moisture sensor is at the center of the field interfaced with the master microcontroller. All other sensors are interfaced with the master microcontroller and placed at the center of the field; however, the LCD and keypad are placed outside the field so that the user can easily access them also the pump is placed outside the field to make irrigation effective. Moisture sensors at the corner send the value of soil moisture to the master microcontroller via the slave microcontroller using a Bluetooth module while, all sensors send data to the master microcontroller directly. All this data is sent on the web page, which is optional and displayed on LCD. Based on average soil moisture and field humidity, the Microcontroller sends the signal to the relay to turn on/off the water pump.

XV. HARDWARE SCHEMATICS

Figure 11 is the schematics of the project. It describes the pin connection of each sensor and electronic with the Microcontroller. The name of each component is displayed along it. Although the circuit diagram shows that the circuit has been designed using a breadboard, the circuit was designed using a verso board to make connections stable and make the system work efficiently. The central controlling unit and both Slave Microcontrollers are closed in a waterproof box to save the system from any harm and make it efficient.

Hardware Schematics of Project:

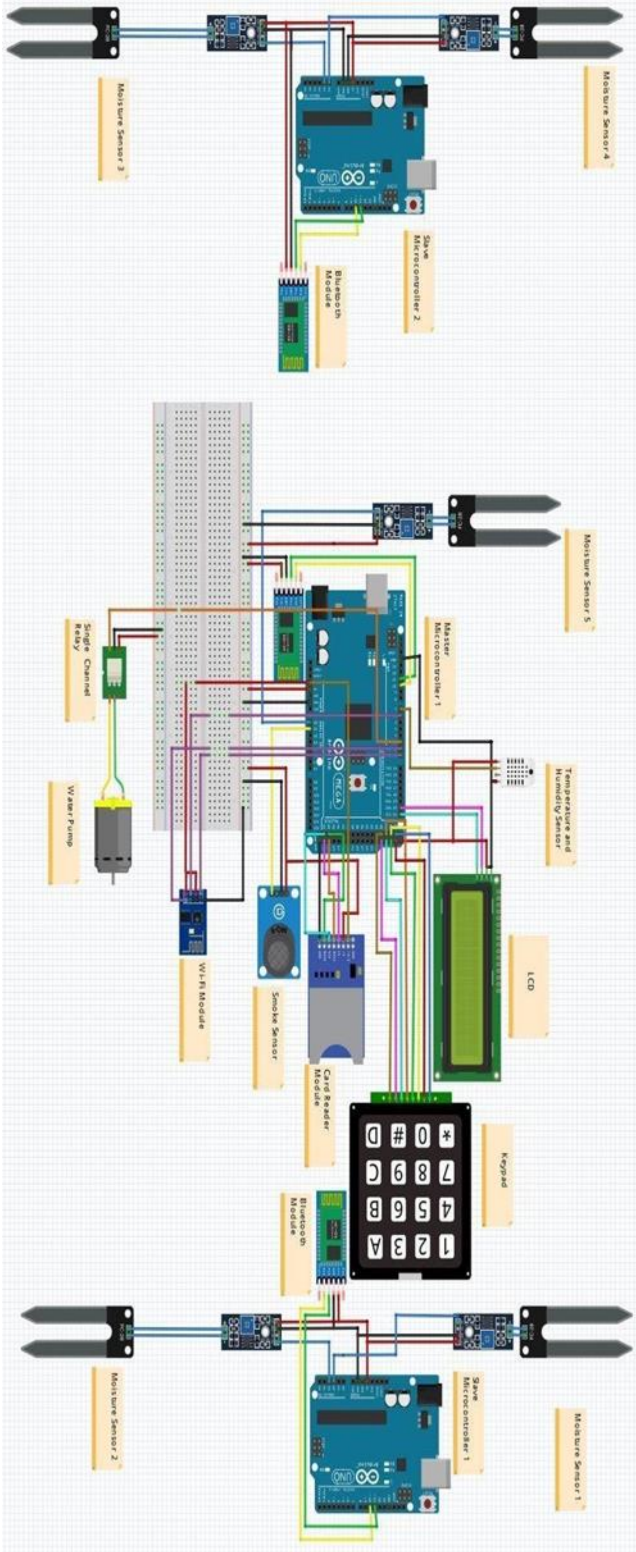


Figure 11: Hardware Schematics of Project

Hardware Schematics Master Microcontroller:

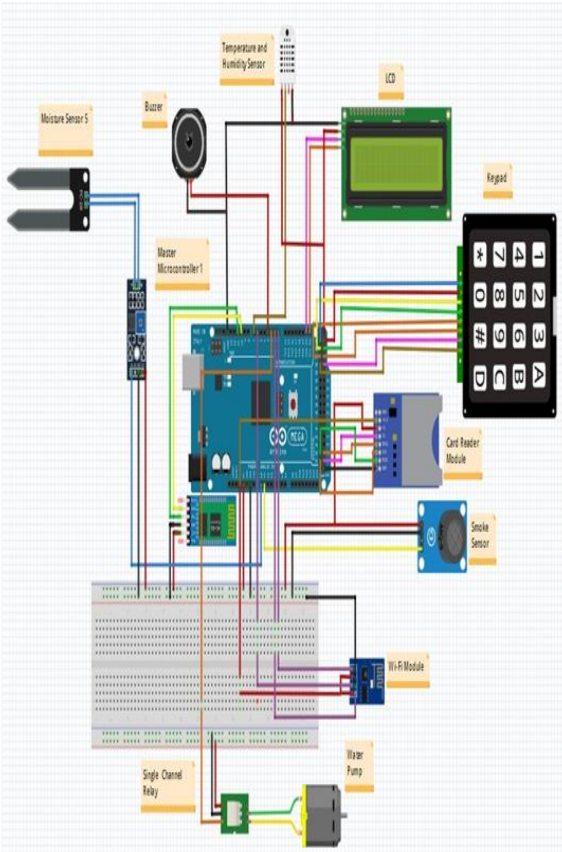


Fig 12: Hardware Schematics Master Microcontroller

Hardware Schematics Slave Microcontroller 1:

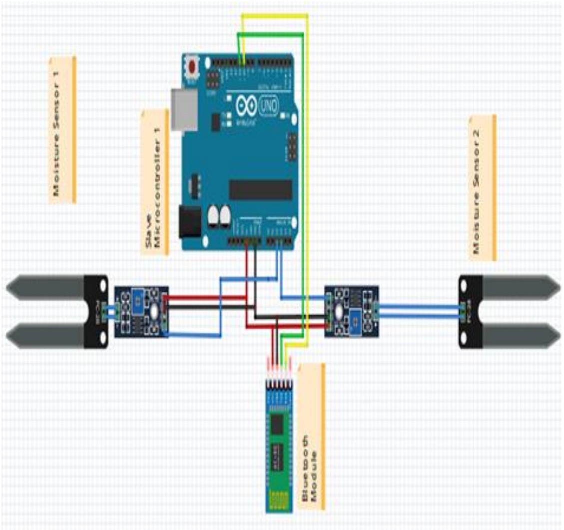


Fig 13: Hardware Schematics Slave Microcontroller 1

Hardware Schematics Slave Microcontroller 2:

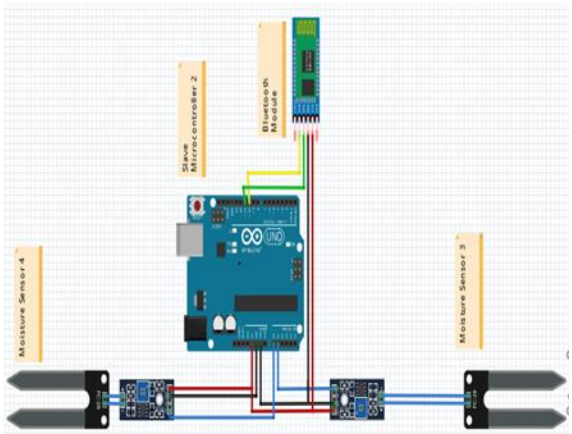


Fig 14: Hardware Schematics Slave Microcontroller 2

Bluetooth Configuration:

Master Microcontroller Configuration

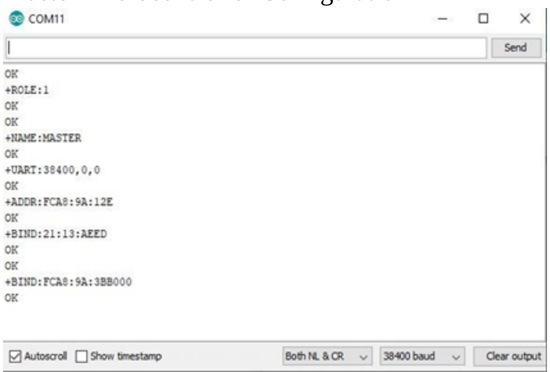


Figure. 15

Slave Microcontroller Configuration:

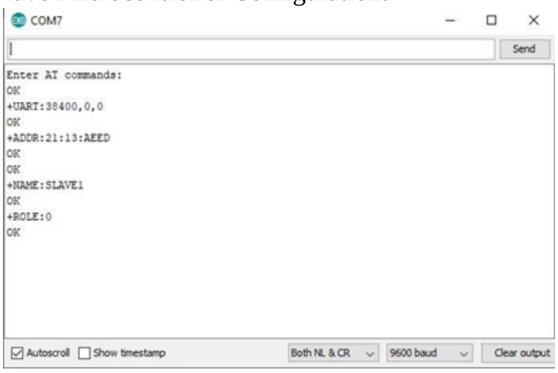
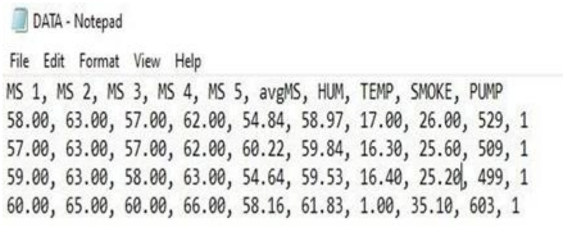


Figure. 16

XVI. RESULTS

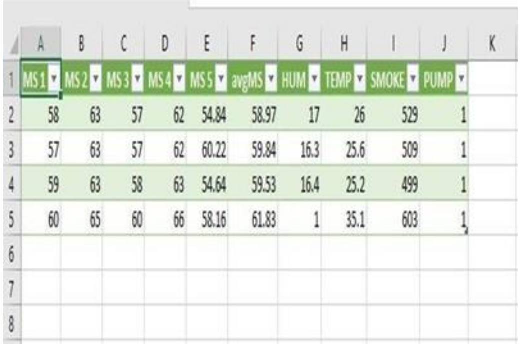
Representation of data saved in memory card. Data is saved in a memory card in a Notepad file.


DATA - Notepad

File Edit Format View Help

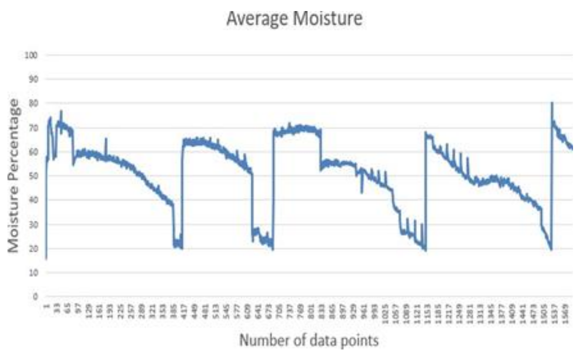
```
MS 1, MS 2, MS 3, MS 4, MS 5, avgMS, HUM, TEMP, SMOKE, PUMP
58.00, 63.00, 57.00, 62.00, 54.84, 58.97, 17.00, 26.00, 529, 1
57.00, 63.00, 57.00, 62.00, 60.22, 59.84, 16.30, 25.60, 509, 1
59.00, 63.00, 58.00, 63.00, 54.64, 59.53, 16.40, 25.20, 499, 1
60.00, 65.00, 60.00, 66.00, 58.16, 61.83, 1.00, 35.10, 603, 1
```

Figure. 17



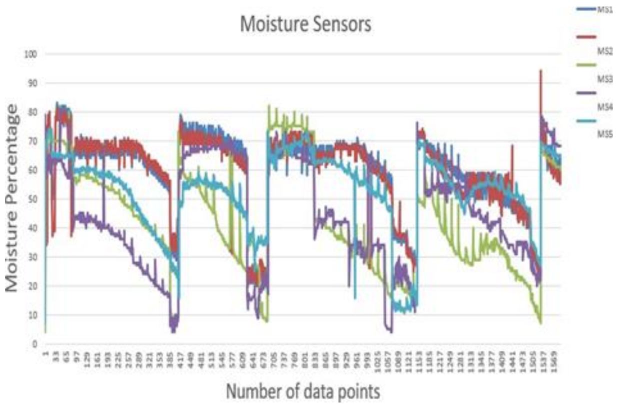
	A	B	C	D	E	F	G	H	I	J	K
1	MS1	MS2	MS3	MS4	MS5	avgMS	HUM	TEMP	SMOKE	PUMP	
2	58	63	57	62	54.84	58.97	17	26	529	1	
3	57	63	57	62	60.22	59.84	16.3	25.6	509	1	
4	59	63	58	63	54.64	59.53	16.4	25.2	499	1	
5	60	65	60	66	58.16	61.83	1	35.1	603	1	
6											
7											
8											

Figure. 18



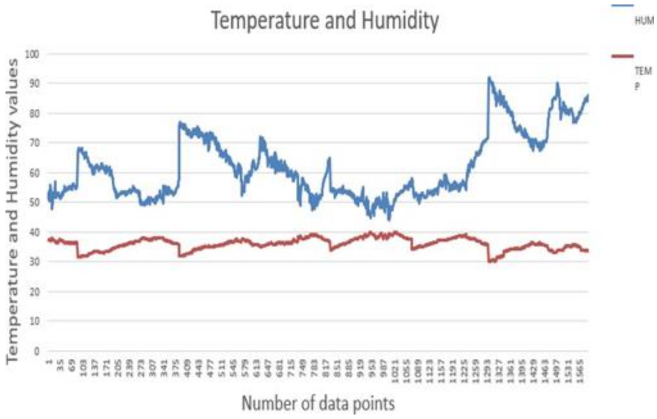
Graph 1

This graph shows the average soil moisture of the field measured by sensors in 7 days.



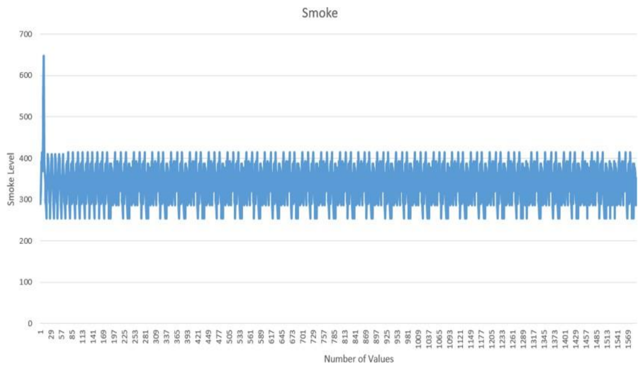
Graph 2

This graph shows soil moisture measured by each soil moisture sensor.



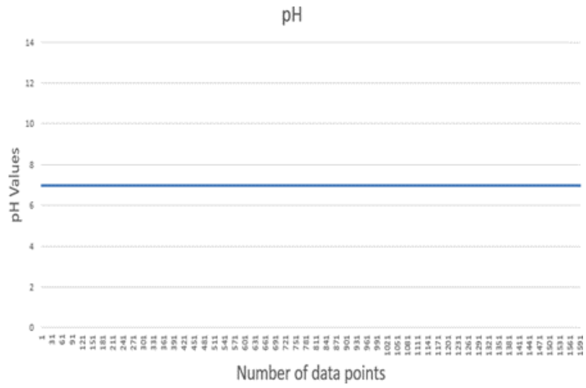
Graph 3

These graphs show the change in temperature and humidity of the environment in 7 days.



Graph 4

This graph shows a change in smoke level measured by a smoke sensor in 7 days.



Graph 5

This graph shows the pH of the soil in 7 days. pH of soil remains constant for seven days

Regression Mathematical Model:

Regression analysis is a powerful statistical method that is used to estimate any factor by finding a relation between dependent and independent variables.

- Multiple regression analysis helps to predict the factor dependent on more than one variable. The general equation for Multiple regression is shown in the equation below, where y is the dependent variable, x1, x2, and x3 are independent variables, a, f, and s are the slope, and e is the error.
- $y = ax1 + \quad fx2 + sx3 + \quad e$
- In this project soil moisture is the dependent variable, based on which water pump is turned on/ off while temperature and humidity are independent variables.
- Multiple regression analysis was done on Rapid Miner. The figure below shows the process flow diagram of the analysis.

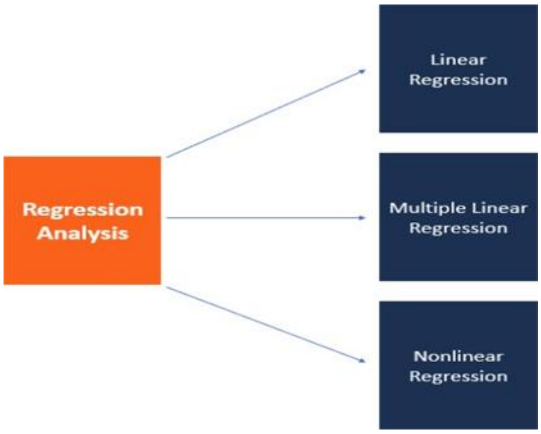
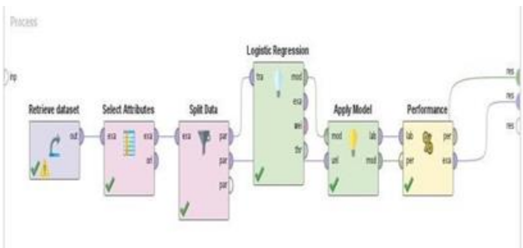


Figure. 19



Graph 6

The equation below shows the relation between predicted average soil moisture and parameters measured by sensors

Predicted Average Moisture=

0.197(MS1)+0.2(MS2)+0.201(MS3)+0.201(MS4)+0.198 (MS5)-0.004(HUMIDITY)0.00595(TEMPERATURE)+0.0374

TABLE VI.

The table shows the actual soil moisture measured by the soil moisture sensor and the predicted soil moisture using regression analysis.

avgMS	prediction(a...
50.760	50.803
57.320	57.404
57.720	57.802
58.090	58.175
71.780	71.784
69.230	69.246
67.780	67.731
66.110	66.117
58	58.089
58.560	58.637
60.120	60.188
57.980	58.060
59.560	59.639
72.080	72.087
72.020	72.021

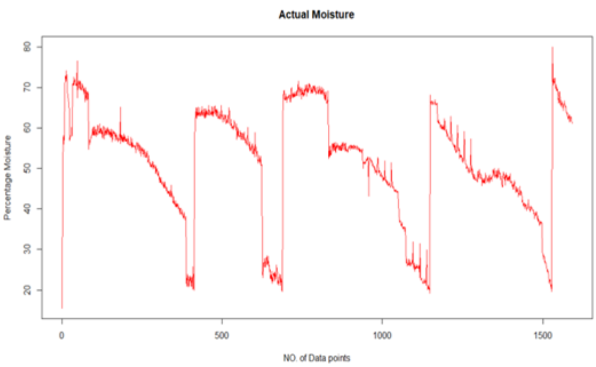
Attribute	Coefficient
MS1	0.197
MS2	0.200
MS3	0.201
MS4	0.201
MS5	0.198
HUM	-0.004
(Intercept)	0.374

Graph 7

TABLE VII.

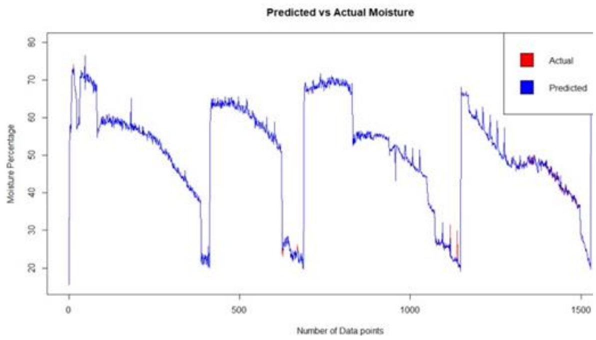
The table is the coefficient matrix; it shows the relation of parameters with each other.

Attribut...	MS1	MS2	MS3	MS4	MS5	avgMS	HUM	TEMP	PUMP
MS1	1	0.940	0.682	0.666	0.740	0.905	-0.264	0.245	0.145
MS2	0.940	1	0.666	0.573	0.701	0.868	-0.247	0.192	0.129
MS3	0.682	0.666	1	0.690	0.722	0.874	-0.153	0.098	0.116
MS4	0.666	0.573	0.690	1	0.694	0.847	0.131	0.070	0.097
MS5	0.740	0.701	0.722	0.694	1	0.874	-0.043	0.188	0.103
avgMS	0.905	0.868	0.874	0.847	0.874	1	-0.120	0.173	0.134
HUM	-0.264	-0.247	-0.153	0.131	-0.043	-0.120	1	-0.729	-0.013
TEMP	0.245	0.192	0.098	0.070	0.188	0.173	-0.729	1	0.008
PUMP	0.145	0.129	0.116	0.097	0.103	0.134	-0.013	0.008	1
pH	?	?	?	?	?	?	?	?	?

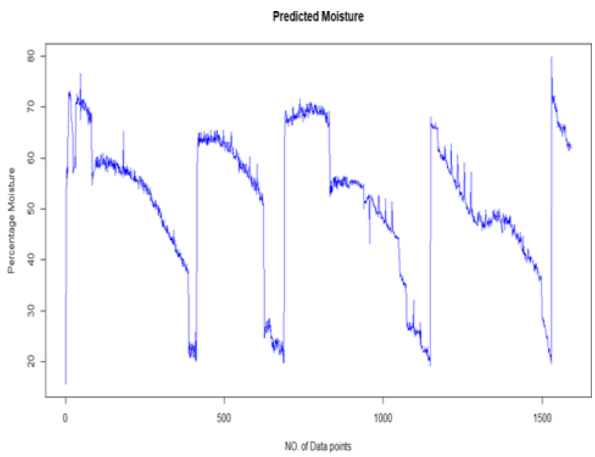


Graph 8

The graphs below show the actual soil moisture measured by the soil moisture sensor and the predicted soil moisture using regression analysis.



Graph 9



Graph 9

The graph below shows the comparison between the actual soil moisture measured by the soil moisture sensor and the predicted soil moisture using regression analysis.

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How to cite this article:
Engr. Muhammad Raees, Engr. Malik Muhammad Suleman Haider, Engr. Sundas, Engr. Syed Ijlal Haider, Engr. Syeda Lubaba Zehra, Engr. Muhammad Sajawal "Smart Irrigation System Using Data Analysis" International Journal of Engineering Works, Vol. 11, Issue 01, PP. 07-20, January 2024. https://doi.org/10.34259/ijew.24.11010720.