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DEVELOPMENT OF AN AUTOMATED IRRIGATION SYSTEM FOR SUGARCANE CROPS

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Abstract: In scientific irrigation scheduling, water is applied to a crop for the right amount of time to make sure it gets enough to suit its needs. A sugarcane crop's irrigation depth is determined by its maximum soil water deficit (MSWD) and is different for each soil. Irrigation scheduling methods that automatically control water application based on previously determined needed soil water deficit depth are effective. An auto-irrigation system that was created locally can accomplish this. The current effort focuses on designing, developing, and simulating a low-cost, fully automated, IoT-based auto-irrigation system for sugarcane crops that may considerably improve water management, increase the effectiveness of crop cultivation, and increase soil fertility. This device uses a moisture sensor to detect the depth of the soil's water deficiency and transmits actual data to an ESP-32 microcontroller. The designed circuitry can run for a long time on batteries or on dc voltages of 5 and 12 volts. This system is intended to examine the flow rate for providing sufficient water to sugarcane plantations. A key component of water management and irrigation systems is maximizing flow rates and reducing water loss. For four different types of soil—Coarse sand, Sandy loam, Silt loam, and Black cotton ploughed soil—the flow rate with the least amount of water loss has been determined using the WinSRFR 5.1.1 simulation software. The planned system has benefits for sugarcane crops, water conservation, and reducing soil deterioration.

Keywords: Sugarcane, Furrow Irrigation, Automation, Internet of Things (IoT), ESP32-Microcontroller, WinSRFR 5.1.1

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1. Introduction

Sugarcane is a water-intensive crop mostly irrigated using furrow irrigation systems. Overirrigation affects the soil's physical, chemical, and biological properties, resulting in soil erosion, chemical leaching, salinization runoff, and deep percolation occurs. Adequate moisture level is necessary for sugarcane crops to dissolve and transport nutrients from the soil particles, ensuring optimal nutrient uptake by the sugarcane crop roots. On the other hand, water-stressed soil impedes nutrient accessibility and hinders plant growth. Insufficient and over-irrigation can have adverse effects on soil moisture and soil fertility. Insufficient irrigation sugarcane crops cannot grow optimally and suffer from stunted growth, however, under irrigation weeds are drought tolerant than cultivated crops. Weeds take advantage of waterstressed conditions which leads to crops receiving inadequate amounts of water impacting decreased crop yield and affecting the soil health.

Research scholars stated that the primary limiting factor for crop growth in dryland agriculture is soil water deficit (Boyer, 1982) [1]. Water deficits affect crops differently depending on their timing, duration, and severity (Hsiao, 1990; Hsiao and Bradford, 1983) [2]. The effects of soil water deficits on the root growth of crops and on their water uptake have been investigated in several studies (Klepper, 1987; Klepper et al., 1973; Meyer et al., 1990; Taylor and Klepper, 1975; Weir and Barraclough, 1986), but only a few studies have followed crop responses after re-watering after release (e.g. Huck et al., 1983, 1987) [3,4,5]. However, Excessive irrigation can have negative impacts on soil fertility under sugarcane crops. When excessive water is applied, essential nutrients such as nitrogen, phosphorous, and potassium can be washed beyond the root zone through a process called leaching. This loss of nutrients disrupts the soil nutrient balance, Furthermore, excessive irrigation can cause soil erosion, resulting in the loss of topsoil, which is rich in nutrients and organic matter. The high volume of water applied during excessive irrigation can lead to uneven distribution of organic matter and nutrients, thereby decreasing soil fertility and impacting the growth of sugarcane crops [6,7,8].

Excessive irrigation also saturates the soil pore spaces with water, displacing air. This can lead to oxygen deprivation in the root zone of sugarcane crops, which adversely affects their growth and the overall health of the soil. Additionally, when soil is over irrigated a high concentration of salts can accumulate in the soil. As water accumulates and evaporates, salts, particularly sodium chloride, can be left behind. These salts can disrupt soil structure and create unfavourable osmotic conditions for root growth in sugarcane crops, further hindering their growth and reducing soil fertility. Insufficient and excessive irrigation have negative detrimental effects on soil moisture nutrient accessibility, crop yield, and soil fertility [9]. Proper irrigation management for sugarcane crops involves applying water to the soil within a specific range to ensure optimal plant growth and maintain soil fertility which is between the field capacity and wilting point. The field capacity is the maximum amount of water that can hold soil against the force of gravity, while the wilting point is the moisture level at which plants can no more extract water from the soil. The maximum soil water deficit (MSWD) is the difference between field capacity and the actual soil moisture content at the time of irrigation. However, it represents the amount of water needed to bring the soil moisture back to the field capacity [10]. Traditional irrigation methods often suffer from inaccuracies leading to soil degradation, and salinization, and hindering plant growth. However, with Inaccurate irrigation, plants get overwatering or insufficient watering which has detrimental effects on their health [10]. Recently, Ersin, C. Gurbuz et.al [2016] designed an Application of an automatic plant irrigation system based Arduino microcontroller using solar to control the plant's optimum water level which is very efficient compared to conventional methods [11]. Srishti Rawal [2017] and Monalisha Pramanik, Manoj Khanna, et.al [2022] a proposed microcontroller-based automatic irrigation system that monitors and maintains soil moisture conditions through automatic watering of the crops. [12,13].

Microcontroller-based automatic irrigation systems on the other hand provide precise and accurate watering based on the specific needs of the crops [14,15,16]. To ensure optimal irrigation practices for sugarcane crops often use various techniques such as monitoring soil moisture, employing irrigation scheduling based on crop, and adequate amount of water requirements for crops, and utilizing efficient irrigation methods to maintain proper growth soil fertility.

2. Experimental Work

The hardware of the system is composed of a moisture sensor, a microcontroller with an integrated Wi-Fi module (ESP-32), DC power supplies, MOSFET, and a solenoid valve as shown in Figure 1.

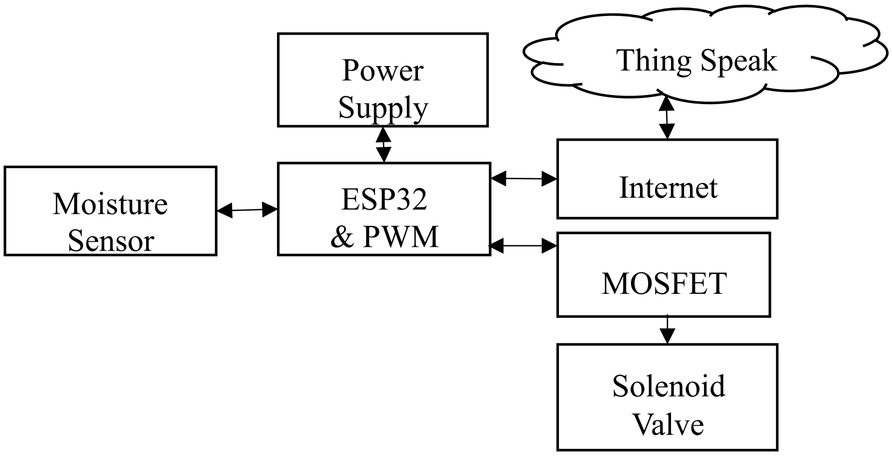

Figure 1. Block Diagram of automated irrigation

a. Initially, the moisture sensor is used to sense the moisture level in the soil. The output of the moisture sensor is then connected to ESP32 with the help of a suitable signal conditioning circuit. The microcontroller-integrated Wi-Fi module ESP-32 is synchronously connected to the solenoid valve for actuation as per the desired flow rate. The WinSRFR 5.1.1 software tool is used to estimate the adequate amount of flow rate in litres per sec. The flow rate was maintained by controlling the water solenoid valve, which is connected to the output side of the microcontroller via a MOSFET interface. The duty cycle of PWM is varied to maintain the desired flow rate. The moisture sensor is used to measure the present soil condition, whether it is dry or wet, and sends data to the microcontroller (MCU) to take necessary action. The simulations were performed for a different soil water deficit depth mm, with furrow lengths ranging from 100 to 200 meters in 50-meter steps for four common soil types in India, namely coarse sandy soil, sandy loam soil, silt loam soil, and black cotton ploughed soil. The agriculture sector is an irrigation regime within which water is irrigated at maximum water deficit depth(mm) for sugarcane crops in different types of soil. It helps to minimize the salinity of the soil. The hardware components are briefly described.
b. Microcontroller ESP32: An ESP32 microcontroller is a powerful SoC with integrated Wi-Fi 802.11 b/g/n and Bluetooth 4.2 dual mode, as well as a variety of peripherals. The main difference between it and the predecessor 8266 is that it implements two cores clocked at different speeds up to 240 MHz. In addition to these improvements, it also adds 36 GPIO pins, 16 PWM channels, 4MB RAM, 520 KB of on-chip SRAM, and more GPIO pins than its predecessor.
c. In our design, the YL69 series soil moisture sensor and probe measure the amount of water in the soil. Determining soil moisture is regarded as a crucial task in agriculture since it enables farmers to better control their irrigation systems. These probes have a quicker response time than other inexpensive sensors like gypsum block sensors. As a result, the sensors were chosen and utilized in the current design. The placement of soil moisture sensors is crucial since the value of the soil moisture sensor in a given sector determines how much irrigation is applied there. Power ranges from 3.3V to 5V for the soil moisture detector. The sensor's output value is in the range of 0 to 1000 Ω. The typical values of soil resistances are shown in Table 1.
d. Depending on the amount of moisture in the soil, the soil resistance value will vary.

Soil Type	Resistance value range
Wet	0- 300 Ω
Humid	300-700 Ω
Dry	700-1000 Ω

Table 1: Typical values of soil resistances

e. Solenoid Valve: In place of conventional valves, flow is managed by solenoid valves. A pulsewidth modulation method is used to control the flow so that the amount of flow is related to how long the valve is in the ON state. It can be controlled in either an ON or OFF mode. A relay powered by 12 volts controls the solenoid.

f.

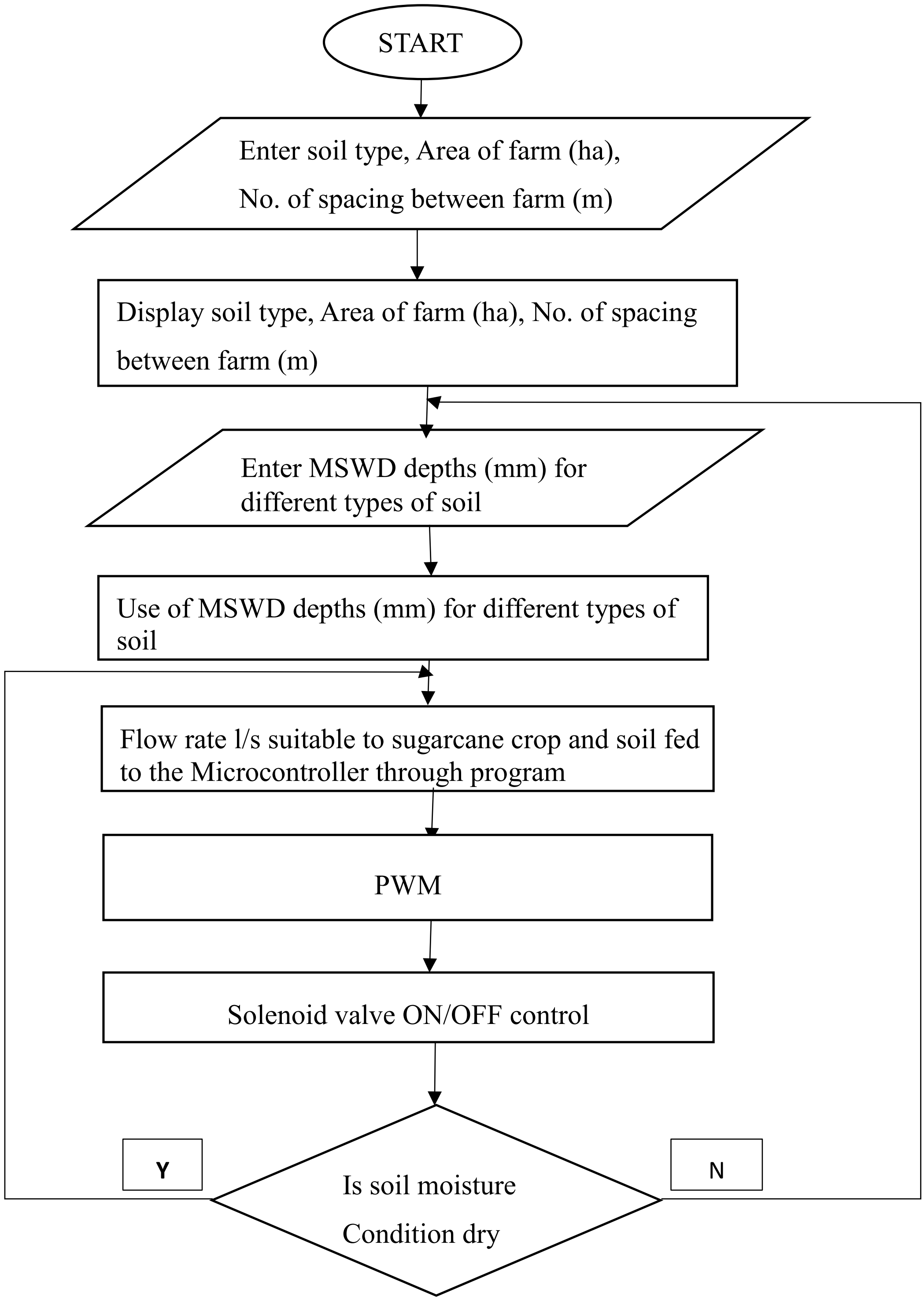

Figure 2: Flowchart of automated irrigation system

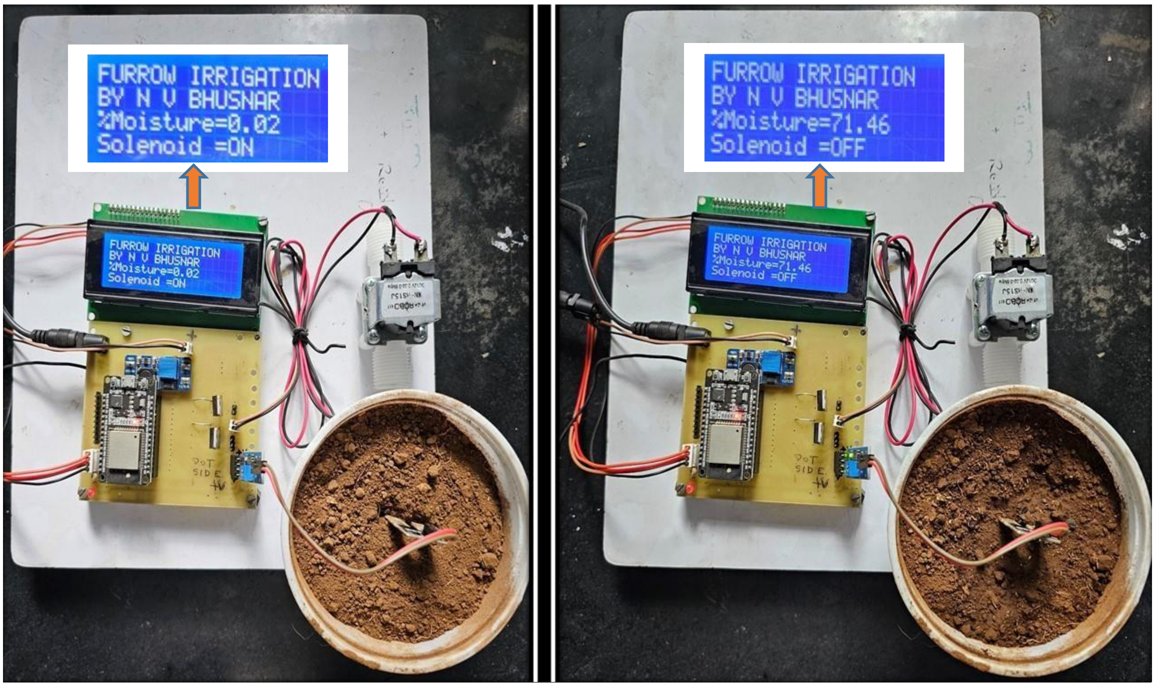

Figure 3. Developed automated irrigation system

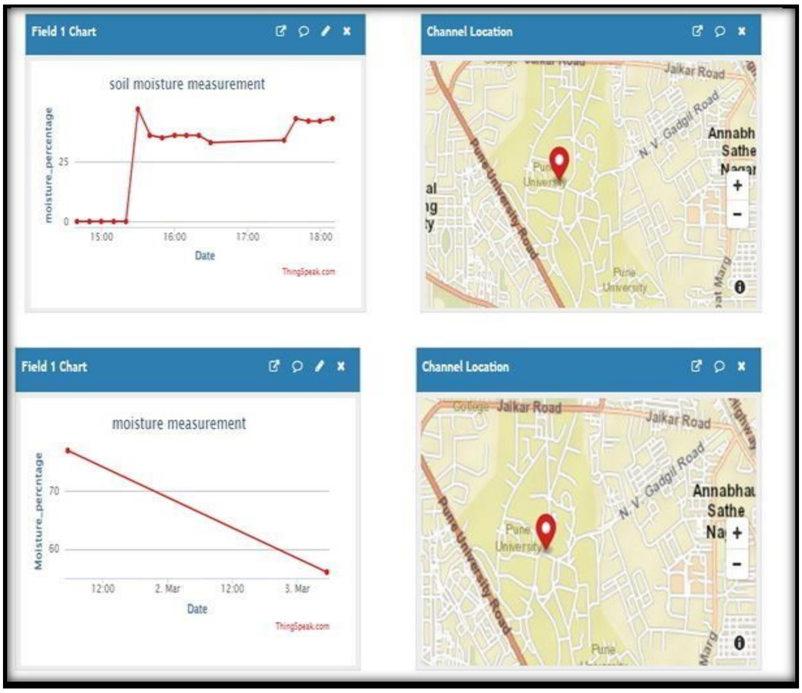

Figure 4. Real monitoring data on ThingSpeak

3. Results and Discussion

3.1. Simulation of flow rate for minimum water loss.

An open-source WinSRFR 5.1.1 software has been employed to open the desired flow rate for minimum water loss. The WinSRFR 5.1.1 regulates the following input parameters farm area (ha), Required depth (mm), and Flow rate (l/s). The following table relates MSWD (mm) for different types of soil.

Sr.no	Different types of soil	MSWD (mm)
1	Coarse sand soil	49.8
2	Sandy loam soil	75
3	Silt loam soil	120
4	Black cotton ploughed soil	124.8

Table 2. MSWD (mm) for different types of soil.

After feeding them to it, the results are obtained in the form of numerical parameters, simulation has been carried out for the type of soils, namely, coarse sandy soil, sandy loam soil, silt loam soil, and black cotton ploughed soil. The results of the simulation are depicted in Figure 4(a),(b),(c),(d). It is a review of each figure that water loss is inversely proportional to the flow rate. Table 2(a),(b),(c),(d). Shows the effect of flow rate on the water loss.

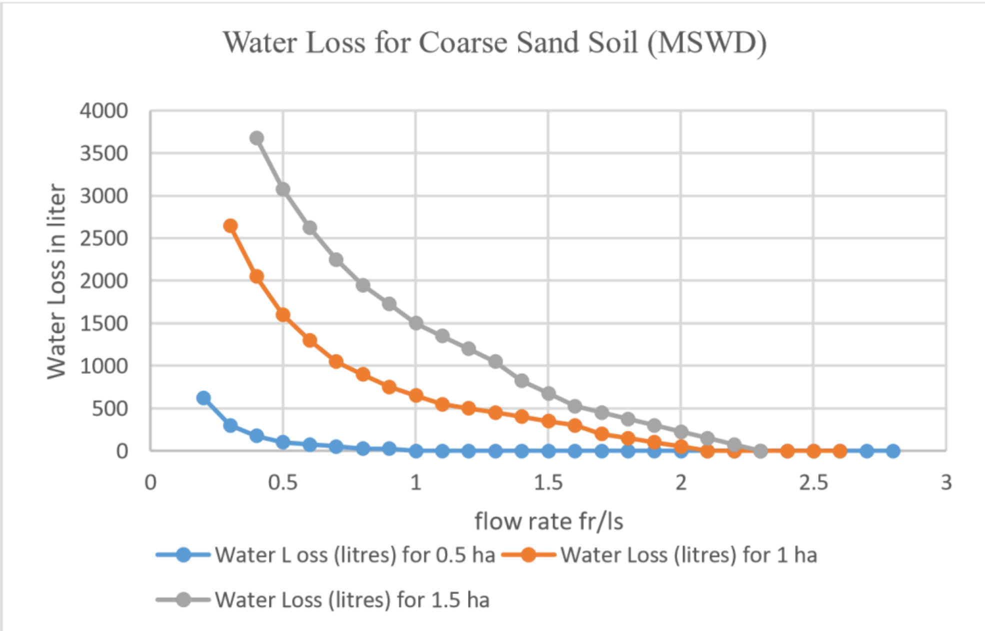

Figure 5. a. Relationship between flow rate and water loss for coarse sand soil

fr l/s	Water Loss (litres) for 0.5 ha	Water Loss (litres) for 1 ha	Water Loss (litres) for 1.5 ha
0.2	625	-	-
0.3	300	2650	-
0.4	175	2050	3675
0.5	100	1600	3075
0.6	75	1300	2625
0.7	50	1050	2250
0.8	25	900	1950
0.9	25	750	1725
1	0	650	1500
1.1	0	550	1350
1.2	0	500	1200
1.3	0	450	1050
1.4	0	400	825
1.5	0	350	675

1.6	0	300	525
1.7	0	200	450
1.8	0	150	375
1.9	0	100	300
2	0	50	225
2.1	0	0	150
2.2	0	0	75
2.3	0	0	25
2.4	0	0	25
2.5	0	0	25
2.6	0	0	25
2.7	0	0	0
2.8	0	0	0

Table 3. a. Effect of flow rate on water loss for coarse sand soil

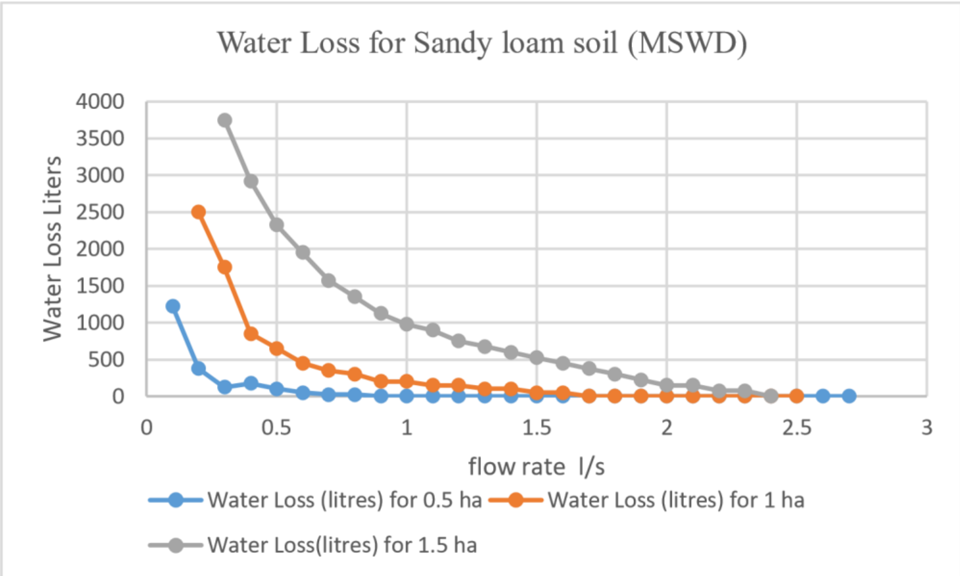

Figure 5.b. Relationship between flow rate and water loss for Sandy loam soil

fr l/s	Water Loss (litres) for 0.5 ha	Water Loss (litres) for 1 ha	Water Loss(litres) for 1.5 ha
0.1	1225	-	-
0.2	375	2500	-
0.3	125	1750	3750
0.4	175	850	2925
0.5	100	650	2325
0.6	50	450	1950
0.7	25	350	1575
0.8	25	300	1350
0.9	0	200	1125
1	0	200	975

1.1	0	150	900
1.2	0	150	750
1.3	0	100	675
1.4	0	100	600
1.5	0	50	525
1.6	0	50	450
1.7	0	0	375
1.8	0	0	300
1.9	0	0	225
2	0	0	150
2.1	0	0	150
2.2	0	0	75
2.3	0	0	75
2.4	0	0	25
2.5	0	0	25
2.6	0	0	0
2.7	0	0	0

Table 3. b. Effect of flow rate on water loss for sandy loam soil

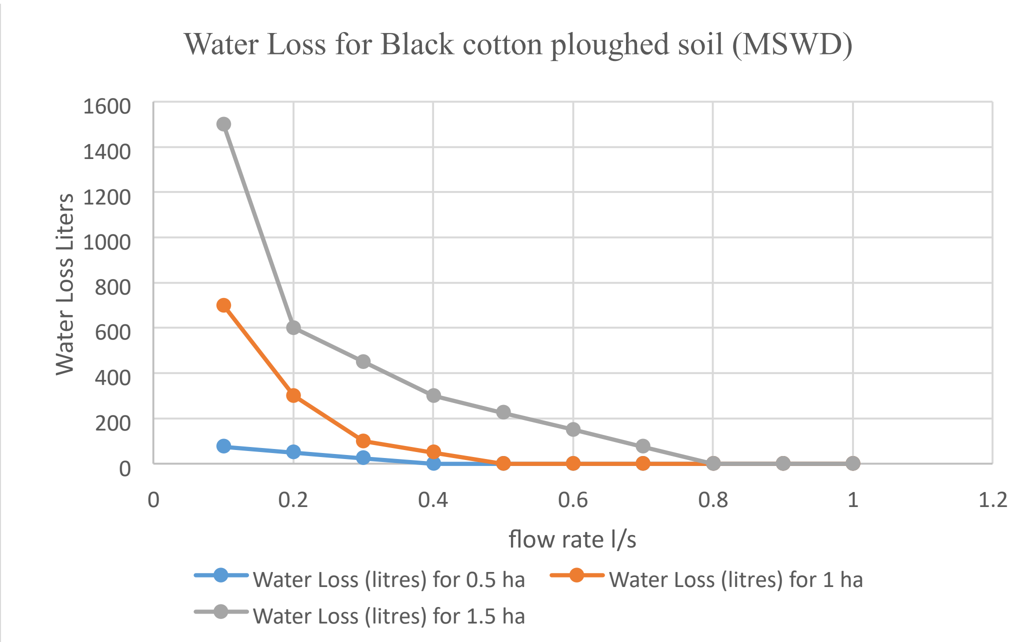

Figure 5.c. Relationship between flow rate and water loss for Black cotton ploughed soil

fr l/s	Water Loss (litres) for 0.5 ha	Water Loss (litres) for 1 ha	Water Loss (litres) for 1.5 ha
0.1	75	700	1500
0.2	50	300	600
0.3	25	100	450

0.4	0	50	300
0.5	0	0	225
0.6	0	0	150
0.7	0	0	75
0.8	0	0	25
0.9	0	0	25
1	0	0	0

Table 3.c. Effect of flow rate on water loss for Black cotton ploughed soil

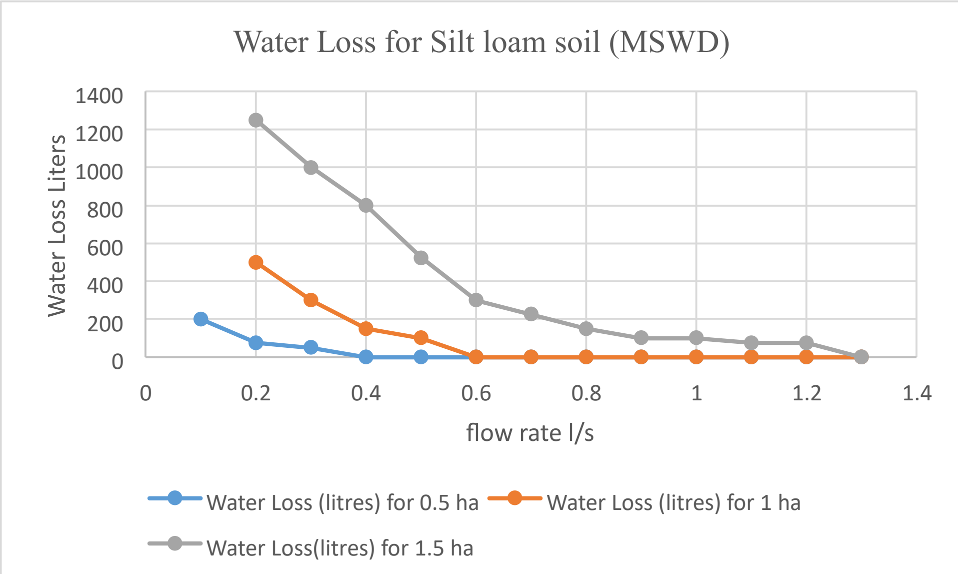

Figure 5.d. Relationship between flow rate and water loss for Silt loam soil

fr l/s	Water Loss (litres) for 0.5 ha	Water Loss (litres) for 1 ha	Water Loss(litres) for 1.5 ha
0.1	200	-	-
0.2	75	500	1250
0.3	50	300	1000
0.4	0	150	800
0.5	0	100	525
0.6	0	0	300
0.7	0	0	225
0.8	0	0	150
0.9	0	0	100
1	0	0	100
1.1	0	0	75
1.2	0	0	75
1.3	0	0	0

Table 3.d. Effect of flow rate on water loss for Silt loam soil

The values in the table shows that the water loss is also depends on the type of soil. It shows that water loss is minimum for silt loam soil. Hence this type of soil is preferred for the more water demanding crop such as sugarcane. In the present work, the calculated flow rate by simulation software has been experimentally implemented by the PWM technique. The steps in the implementation are shown in figure. Table 3 shows the calculated pulse width for different flow rates.

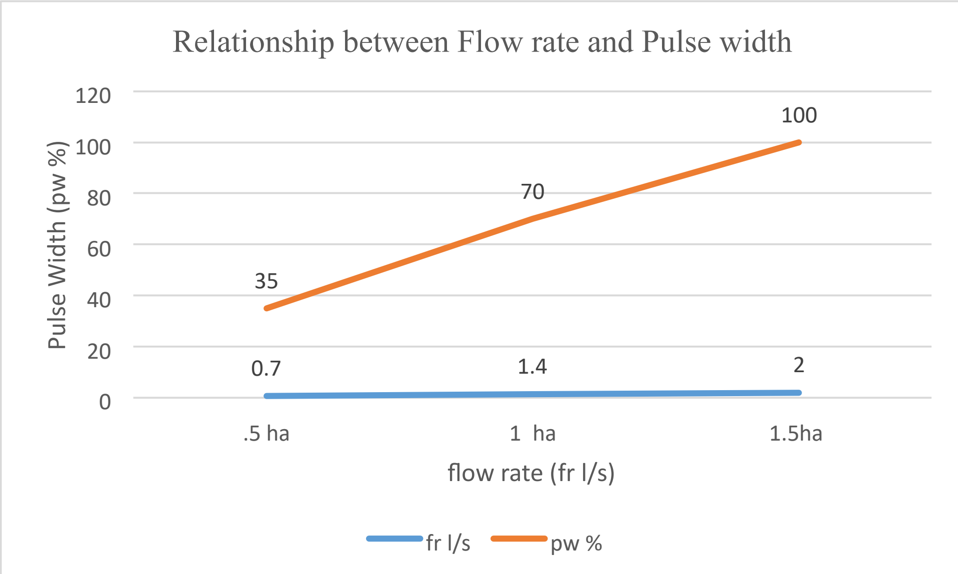

Figure 6. Pulse width (%) for different flow rates l/s.

The automated irrigation system has been successfully developed using the modern electronic devices such as microcontroller, soil sensor and solenoid. The system minimizes the water loss by employing the PWM techniques.

References:

1. Boyer J S 1982 Plant productivity and environment. Science 218, 443–448.
2. Hsiao T C 1990 Crop water requirement and productivity. In AGRITECH '90 Israel, 5th International Conference on Irrigation. pp 5–18. Proceedings.
3. Klepper B 1987 Origin, branching and distribution of root systems. In Root Development and Function. Eds. P J Gregory J V Lake and D A Rose. pp 103–123. SEB Seminar Series 30, Cambridge University Press, Cambridge.
4. Barraclough P B 1986 The growth and activity of winter wheat roots in the field. I. Nutrient uptakes of high-yielding crops. II. Nutrient inflows of high-yielding crops. J. Agric. Sci. 106, 45–59.
5. Meyer W S, Tan C S, Barrs H D and Smith R C G 1990 Root growth and water uptake by wheat during drying of undisturbed and repacked soil in drainage lysimeters. Aust. J. Agric. Res. 41, 253–265.
6. Daniel Hillel, Ademola K. Braimoh, Paul L. G. Vlek, Land Use and Soil Resources, 2008, ISBN: 978-1-4020-6777-8
7. Aadhityaa Mohanavelu, Sujay Raghavendra Naganna and Nadhir Al-Ansari, Irrigation Induced Salinity and Sodicity Hazards on Soil and Groundwater: An Overview of Its Causes, Impacts and Mitigation Strategies, Review, Agriculture 2021, 11, 983. https://doi.org/10.3390/agriculture11100983.
8. Kishor Bhosale1*, Sagar Kale2, Abhijit Limaye3, Studies on influence of AM fungi and some organic fertilizers on growth and biochemical content in Allium cepa L, International Journal of Botany Studies, Volume 5; Issue 5; 2020; Page No. 104-109
9. K. S. Grewal, G. D. Buchan & P. J. Tonkin, Estimation of field capacity and wilting point of some New Zealand soils from their saturation percentages, New Zealand Journal of Crop and Horticultural Science, ISSN: 0114-0671, 23 February 2016.
10. Soil water storage capacity and available soil moisture, water conservation fact, Ministry of Agriculture, British Columbia, Agdex: 550, June 2015.
11. Tesfaye Samuel Saguye, An Empirical Analysis of Land Degradation Risk from Local Community Knowledge Perspective: The Case of Geze Gofa District, Southern Ethiopia, Journal of Culture, Society and Development, An International Peer-reviewed Journal, ISSN 2422-8400, Vol.28, 2017.
12. Ersin Ç, Gürbüz R, Yakut AK. Application of an Automatic Plant Irrigation System Based

Arduino Microcontroller Using Solar Energy. SSP 2016; 251:237–41. https://doi.org/10.4028/www.scientific.net/ssp.251.237.

13. Srishti Rawal, IOT based Smart Irrigation System, International Journal of Computer Applications (0975 – 8887), Volume 159 – No 8, February 2017.
14. Monalisha Pramanik, Manoj Khanna, etal. Automation of soil moisture sensor based basin irrigation system. Smart Agricultural Technology, ELSEVIER, volume 2, December 2022
15. N.V. Bhusnar, P.S. Varade, P.R. Yawale, P.K. Bhadane, A.D. Shaligram, Automated crop independent furrow irrigation system, GIS SCIENCE JOURNAL, ISSN NO: 1869-9391, VOLUME 9, ISSUE 10, 2022.
16. Madhu Kumari, Anant Kumar Sah, IoT Enabled Smart Irrigation System, Monitoring and Water Harvesting in Different Soils, International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 10 Issue 03, March-2021