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Original Article

SDIPMIoT: Smart Drip Irrigation and Preventative Maintenance using IoT

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Abstract - *Water and Fertilizes proper use play an essential role in healthy, profitable yield. Applying the right amount of water and fertilizers to the crop root area is essential, as improper irrigation practices can create favourable conditions for fungal and bacterial diseases, pests, and weeds. The drip irrigation method most efficiently applies water at the root zone at a reasonable rate, saving valuable water resources. This helps reduce water loss due to evaporation and runoff and minimizes the spread of diseases and pests. Drip irrigation systems are increasingly used in horticultural crop production, particularly for vegetable crops. Installing and maintaining the drip irrigation system properly is essential to ensure successful crop production. This paper provides insights into the preventive maintenance of drip irrigation systems to ensure their optimal functionality with the help of IoT technologies.*

Keywords - *Drip irrigation, Plant health, Preventative maintenance, IoT, Fertigation.*

1. Introduction

The latest technology, like the Internet of Things (IoT), connects things surrounding us with the internet and influences our lives. The IoT is utilized in various domains such as offices, homes, cities, transportation, agriculture, and healthcare, making them brighter [1]. Smart devices, which can connect via different wired or wireless communication technologies, are connected and capable of making decisions based on their surroundings [2-4]. In many developed and developing countries, most farmers still rely on traditional methods at different stages of farming agriculture. Farmers can gain higher crop yields with optimal resource utilization by incorporating the latest technology into agriculture.

World’s freshwater resources are limited to 2.5%; the rest are unusable ocean water. By considering 2.5% as 100%, only 31.4% of freshwater are accessible from groundwater, surface and other place [5]. According to the 2030 Water Resources Group [6], the demand for water in 2030 is expected to be highest in agriculture. 80% of India's water, 51% of China's water, 33% of Brazil's water, and 46% of South Africa's fresh water from their country’s available fresh water will be used for agriculture. This increase in demand compared to the current supply highlights the need to reduce water usage in irrigation. If concrete action is not taken, many Countries' Rivers and groundwater may face a massive water shortage by 2030. Therefore, it is crucial to prioritize water conservation in irrigation practices [6]. Drip irrigation is a highly efficient and water-conserving method of irrigation widely used in agricultural practices worldwide.

It involves the precise water applied directly at the plant's root zone, minimizing water wastage and maximizing crop productivity. With the advent of Internet of Things (IoT) technologies, there has been a growing interest in integrating IoT into drip irrigation systems to enable real-time monitoring, control, and data-driven decision-making. This integration holds great promise for enhancing system performance, optimizing water usage, and promoting sustainable agricultural practices.

The incorporation of IoT in drip irrigation systems enables the collection and analysis of data from various sensors and devices, allowing farmers and stakeholders to gain valuable insights into the health and status of the irrigation system. Additionally, IoT facilitates remote monitoring and control, enabling farmers to make timely adjustments to irrigation schedules, nutrient delivery, and other critical parameters. Moreover, IoT-based preventative maintenance strategies can help identify potential issues or malfunctions before they lead to system failures, reducing downtime and optimizing system reliability. Drip Maintenance can be divided mainly into two categories [7]:

- preventative
- corrective

Preventative maintenance ensures a drip irrigation system's long-term performance and efficiency. Here are the critical steps of preventative maintenance for a drip irrigation system:

1.1. Regular Inspections

- Perform inspections at regular intervals of the entire system to identify any signs of wear, damage, or malfunction. This includes checking filters, valves, tubing, connectors, emitters, and other system components.
- Look for leaks, cracks, blockages, or other system performance issues.
- Address any problems promptly to prevent further damage or inefficiency.

1.2. Check and Maintain Filters

- Filters are essential for removing debris and sediments from the water supply. Regularly check and clean or replace filters to ensure unobstructed water flow.
- Inspect screens, disc filters, or other filter types for clogging or damage.
- Clean filters according to the manufacturer's recommendations or guidelines.

1.3. Maintain Pressure Regulators

- Pressure regulators help maintain optimal water pressure throughout the system. Inspect and adjust pressure regulators as needed to ensure consistent pressure.
- Verify that pressure readings are within the recommended range for your specific system.
- Repair or replace faulty pressure regulators to prevent over- or under-pressure situations.

1.4. Prevent Root Intrusion

- Roots can infiltrate the drip irrigation system, leading to blockages and damage. Take preventive measures to avoid root intrusion.
- Install root barriers or use root guards near the system components to prevent root growth towards the pipes or emitters.
- Regularly inspect for any signs of root intrusion and remove any roots that have entered the system.

1.5. Monitor and Adjust Water Distribution

- Regularly monitor and adjust the water distribution pattern to ensure even and uniform irrigation.
- Verify that all emitters or drippers are functioning correctly and delivering the intended amount of water.
- Adjust emitters' flow rate or spacing to meet the plants' changing needs.

1.6. Protect the System from Physical Damage

- Safeguard the system against physical damage, such as accidental impacts, vandalism, or extreme weather conditions.
- Ensure tubing, connectors, and other components are adequately protected and insulated.
- Repair or replace damaged components promptly to maintain system integrity.

1.7. Seasonal Adjustments

- Adapt the system settings and schedules based on seasonal changes, weather conditions, and plant requirements.
- Adjust the irrigation frequency, duration, and timing to optimize water efficiency and meet the plants' changing needs throughout the year.

1.8. Regular Cleaning

- Periodically clean system components, such as emitters, connectors, and tubing, to prevent the buildup of sediments, organic matter, or biofilm.
- Follow the recommended cleaning procedures and use appropriate cleaning solutions or detergents.
- Keep the system clean and debris-free to ensure proper water flow and prevent clogging.

By implementing these preventative maintenance steps, you can proactively address potential issues, prolong the lifespan of your drip irrigation system, and maintain its efficiency and effectiveness over time [7].

This research paper focuses on the application of IoT in drip irrigation systems, with a specific focus on preventative maintenance. By exploring the potential benefits, challenges, and key considerations associated with IoT-enabled preventative maintenance, this study seeks to contribute to the understanding and implementation of sustainable agricultural practices. The paper will delve into the various components of IoT systems, communication protocols, and data analytics techniques used in monitoring and maintenance tasks.

Furthermore, the proposed model will demonstrate the practical implementation and results of IoT-based preventative maintenance in a drip irrigation system. The study will highlight the positive impact of IoT on system performance, water efficiency, and crop yield. This research will provide valuable insights to researchers, practitioners, and stakeholders involved in drip irrigation and precision agriculture, fostering the adoption of IoT technologies and preventative maintenance practices for sustainable agricultural development.

Overall, integrating IoT in drip irrigation systems and preventative maintenance strategies can revolutionize how irrigation is managed and maintained, leading to increased efficiency, reduced water usage, and improved crop productivity. By harnessing the power of IoT, farmers can optimize their irrigation practices and contribute to sustainable agricultural practices in an era of increasing resource constraints and environmental concerns.

2. Literature Review

Researchers in the field of agriculture have been actively exploring innovative technologies to improve efficiency and optimize resource management. Irrigated agriculture produces approx—40% of total world food [8, 9]. The selection of the proper irrigation method significantly impacts plant growth and disease occurrence. It influences the dispersal of pathogens and their fruiting bodies, as well as the progression of diseases. For example, in furrow irrigation, a heavy amount of water and N fertilizer facilitates the dissemination of soil-borne pathogens [10]. Conventional irrigation methods, like flooding, result in water loss due to evaporation. However, drip irrigation systems eliminate this water loss [11]. Drip irrigation is particularly well suited for crops with broader spacing, such as vegetables, soft fruits, vines, and trees [12].In cases where climatic conditions are unfavourable for crop cultivation, options like poly houses or shade nets can be considered.

Similarly, hydroponic systems can be employed if the soil quality is poor. Nonetheless, when it comes to water scarcity, there is no alternative; water is essential [13]. The drip irrigation system allows optimal fertilizer usage due to its efficient water consumption and reduced water requirement [14, 12]. Authors in [15] gave a deep discussion of IoT, the application of IoT in different domains, possible attacks and precautions to avoid attacks while configuring IoT devices. A study [16s] by the authors addresses the world water shortage issue by designing a hardware system that utilizes real-time sensor data. The data is transmitted using RF 433MHz, and decisions are made based on pre-configured values to reduce water wastage. In [17], the authors design and deployed Bluetooth-based devices to record soil data with GPS coordinates in the field. These device works as nodes and sent data to a base station. The base station processes the data and generates site/time-specific irrigation schedules. Users can access and control the system through an internet-based GUI interface[18].

Sandeep Kumar Pandey et al. [19] discuss installing drip and different maintenance methods for achieving higher crop yield and increasing the life span of the drip system. In [20], the authors present the concept of wireless sensor nodes, relay nodes and base stations. Sensor nodes deployed under the soil to record, store and send data to the base station via relay nodes on time in a day. Sensor node equipped with permanent memory to store data and go in sleep mode in case of failure to communicate with relay or base node to save data and power. It uses IEEE 802.15.4 radio to communicate. In [21], Zhang et al. developed an artificial intelligence model. The model takes irrigation decisions for citrus trees based on real-time moisture and nutrient data. It uses ZigBee for communication. Their model decides fertilization based on soil type data and plant growth requirements. Phasinam et al. [22] utilize machine learning algorithms to anticipate the proper amount of fresh water required for cultivating a crop. Abioyeet et al. [23] deployed a weather station, Raspberry Pi, with a camera, which sends data to the cloud for processing. They use MATLAB for irrigation decision-making. In [24], Manda et al. discuss the importance of drip irrigation, its advantages and disadvantages, the impact of drip on plant health, the proper way of drip installation and the steps for maintenance of the drip system in the right for a long-lasting drip system. In [25], Akhund et al. developed a prototype to read water level, temperature, and humidity sensors and a microcontroller unit whose value decides to turn on or off the motor, and their automated system for irrigation provides notification via mobile SMS[26]. Yatnalli et al. [27] set up a small prototype model with many sensors, actuators, wifi, Zigbee, and Arduino for Solar Powered Automatic Irrigation System. Users can monitor activity on LCD and remotely on mobile applications.

3. Motivation for Proposal

Researchers in agriculture have explored various technologies, as discussed in the literature review. Many researchers discuss manual drip irrigation maintenance. However, there is a lack of integrated solutions focusing on preventative maintenance drip irrigation with IoT sensors/devices. Existing commercial solutions are often expensive due to proprietary products. Therefore, we proposed an intelligent model focusing on preventative maintenance that takes care of drip system setup, reducing maintenance costs and giving high crop yield.

4. Proposed Architecture and Solution

The proposed field deployment with different sensors and actuators is shown in Fig.1. Different sensors that check water quality are attached to the water source from where drip irrigation uses water. The motor connected to this water source pumps water toward the first filter. This filter has a wired or wireless solenoid valve, which smartly flushes sand particles from the filter. Different fertilizers, acid, and chemicals tank series are connected with the mixture tank. These tanks have an ultrasonic sensor, flow sensor and solenoid valve, which take care of calculated dose dispense commands given by the control centre as discussed in [28]. The automated injection unit injects liquid from the mixture tank to the main line between two sand filters.

The second sand filter is equipped with four solenoid valves which take care of standard filtration and back flushing to remove dirt and other particles from it based on command by the control centre. Many other sensors and actuators are deployed to intelligent irrigation in the main line, sub-main line, and farm field, as shown in Fig.1. Water used for irrigation is often impure, containing various physical (sand, silt, clay, etc.), chemical (carbonates, bicarbonates, etc.), and biological (microorganisms, algae, etc.) impurities. Several issues can arise when a drip irrigation system is not maintained correctly. If these problems are not addressed, the lifespan of the drip irrigation system will be significantly reduced, potentially failing the entire system. Therefore, it is necessary to engage in proper and regular maintenance of the drip irrigation system in order to prevent such problems. A strict maintenance program must follow for the long life span of drip and best performance. Many modifications need to perform in the basic drip irrigation setup. Different attached hardware are shown in Fig.1, some listed in Table 1. A few hardware components are discussed below:

Raspberry Pi: Raspberry Pi, as shown in Fig. 2, is like a tiny single-board computer to learn programming skills, hardware projects purpose, automation, implement cloud clusters and Edge computing, and even use in industrial applications.

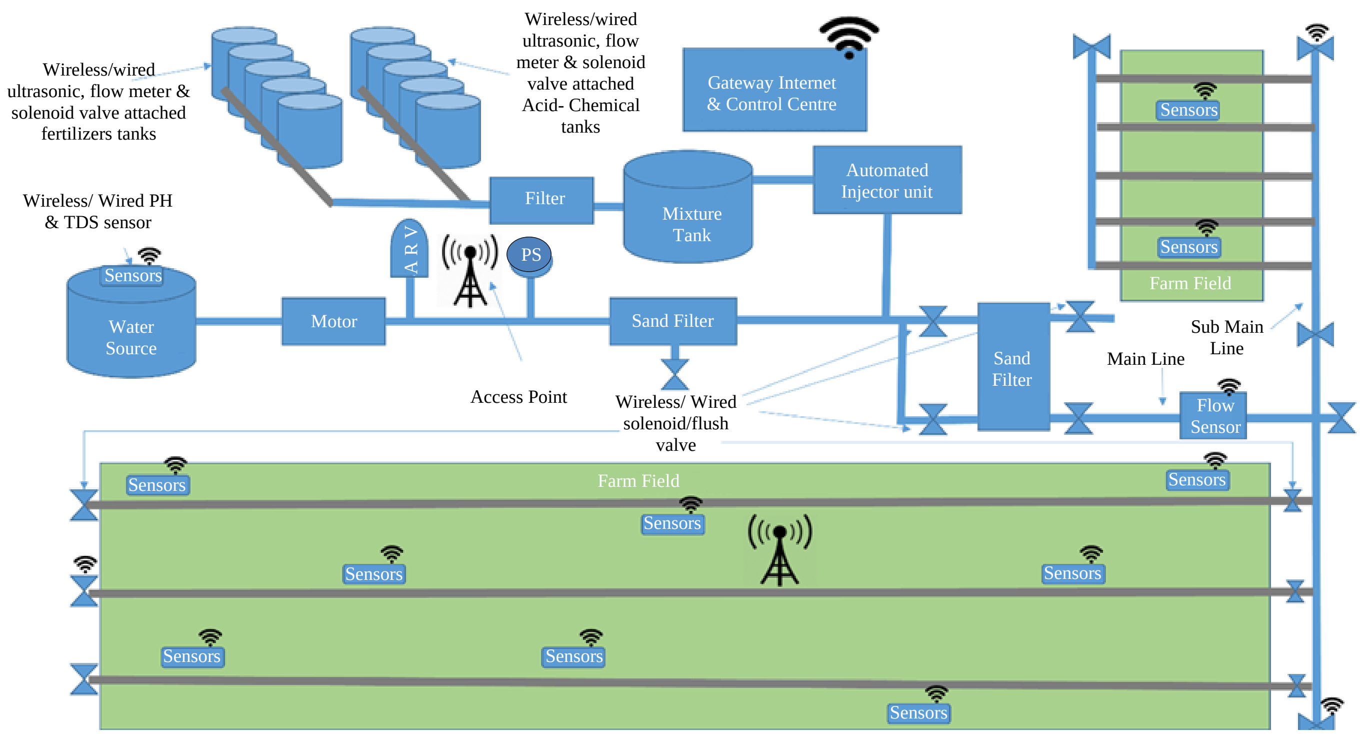

Fig. 1 Proposed deployment architecture

Table 1. Hardware components used

Basic Drip System Setup	Raspberry Pi Case	Raspberry Pi Power Supply
Pressure sensor	Solar panels	Raspberry Pi
NodeMCU	Batteries	Connecting wires
RS485 5-Pin Soil PH NPK Sensor	Battery Charge controller	Ultrasonic sensor
PH sensor	Solenoid valve	Venturi
Turbidity sensor	PCB	Flow Sensors
Arduino Uno	Pumps	Relays
Lan cable & power supplies	Soil Moisture sensors	Temperature sensors etc…

NodeMCU: NodeMCU is a cost-effective, user-friendly, open-source development board that integrates a microcontroller (ESP8266) with Wi-Fi capabilities. It has gained popularity among IoT enthusiasts and developers due to its affordability and the availability of a thriving community.

Fig. 2 Raspberry Pi

Solenoid Valve: A solenoid valve, as displayed in Fig. 3, is an electromechanical device that controls the flow of fluids or gases, commonly used in industrial automation and HVAC systems, offering remote operation and precise flow control.

Fig. 3 Solenoid valve

pH Sensor: A pH sensor, as displayed in Fig. 4, is a device that traces hydrogen ions concentration in solution for identifying acidity or alkalinity, commonly used in scientific research, water quality monitoring, and various industrial processes.

Fig. 4 pH Sensor

Famous quote - Prevention is better than cure. Therefore, as discussed above, we focus on preventative steps in this paper. According to Netafim [6], as shown in Fig.5, preventative maintenance is divided into three subcategories- Irrigation Scheduling, System Flushing and Chemical Injection. Proper irrigation scheduling based on current crop soil moisture data avoids root intrusion. In the paper [25], the authors discuss zone-wise irrigation and fertigation prediction and implementation based on sensor data. Irrigation for a short duration is also used after prolonged rain to avoid blockage of soil particles in the dripper hole.

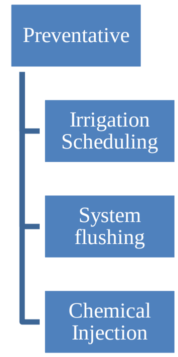

Fig. 5 Preventative maintenance methods

System flushing is divided into FilterFlush() and DripFlush(). FilterFlush() method contains an automated flush procedure of primary(first) filter and secondary(second) sand filter. As shown in Fig. 6, if the irrigation schedule is off, the water pump will start and open the drain solenoid valve for three minutes of the primary filter, which removes sand particles from the water. After 3 minutes, all valves closed, and the system started the backflushing procedure for a secondary filter by opening valves 2 and 3 to remove the organic, inorganic and salt crystal from the sand filter by flushing water from downward to upward. DripFlush() method cleans main lines, submain lines and laterals by systematically opening the solenoid valves attached. Some allowable high-pressure needs to be maintained to get the best output from this flushing. Above two methods are used with irrigation scheduling or standalone depending on sensor data or the farmer's choice. Testing lateral water based on impurity, Acid or Chlorination chemical injection treatment decided and by reading the received data/user choice chemical injection process started. This treatment required calculating the chemical amount and duration of chemicals injected in irrigation. The required amount of chemicals dispenses in a mixture tank. The irrigation process started with a switch on the pump. The automated valve of the venturi is set for chemical injection. Let it finish the irrigation schedule with a chemical injection that opens blocked pipes and drippers.

5. Results and Discussion

Live monitoring and regular interval drip system maintenance are required to achieve optimal results from drip irrigation. With the help of IoT devices deployed in the field and attached to the dashboard, as shown in Fig. 7. the Dashboard provides six options for drip maintenance: Daily, Weekly, 15 days, Monthly, Auto and Manual. Farmers can choose suitable options for maintenance.

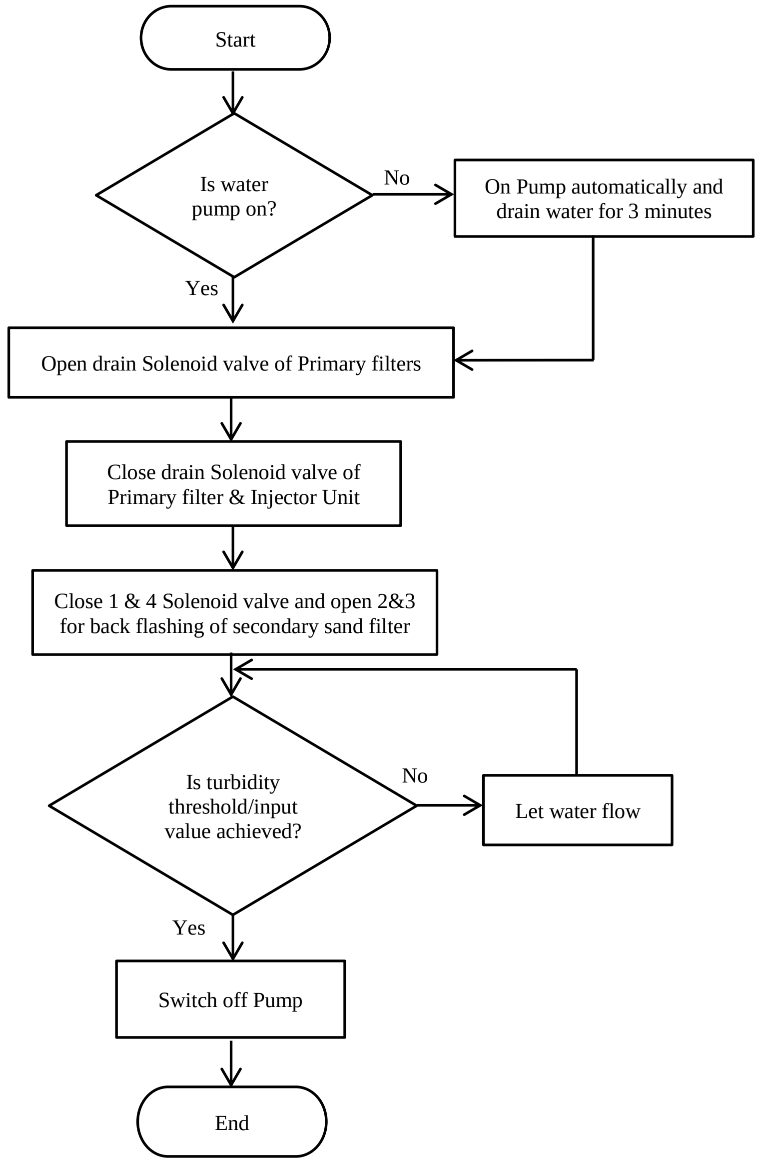

Fig. 6 FilterFlush module procedure

Based on the selection above discussed modules called irrigation scheduling. Live sensor data is displayed on the dashboard. Auto mode based on the source water's turbidity value starts system maintenance. If farmers want to manage their schedule on their own, he/she can opt manual option. From the displayed sensor value farmer can identify any issue like breakage in the drip line, filter blockage, water quality, the water level in the tank, moisture level, temperature etc. and is able to manage all remotely. Drip irrigation at installation time give approx. 95% efficiency. As years and crop cycle increase, drip system decrease performance if not properly maintain. This can be understood by simulation in the APSIM simulator. Wheat crop(Sujata cultivar) in Gandhinagar, Gujarat, India region configured with weather data from 2018 to April 2023. Five different efficiency Drip irrigation system setups are configured and run with the same initial water, soil type and fertilizers. Fig.8 shows that reaching soil threshold water fully efficient drip system takes approx. 300mm irrigation water and as efficiency decrease from full(95%) to 70%, 340mm to 470mm irrigation water required. Irrigation loss increases (15mm to 148mm approx.) as efficiency decreases. So to achieve the same yield if drip maintenance is not done regularly, we have to use more irrigation water, water loss, and electric energy for the water pump to run more times and more sensor up times use more power. Regular drip system maintenance saves these valuable resources.

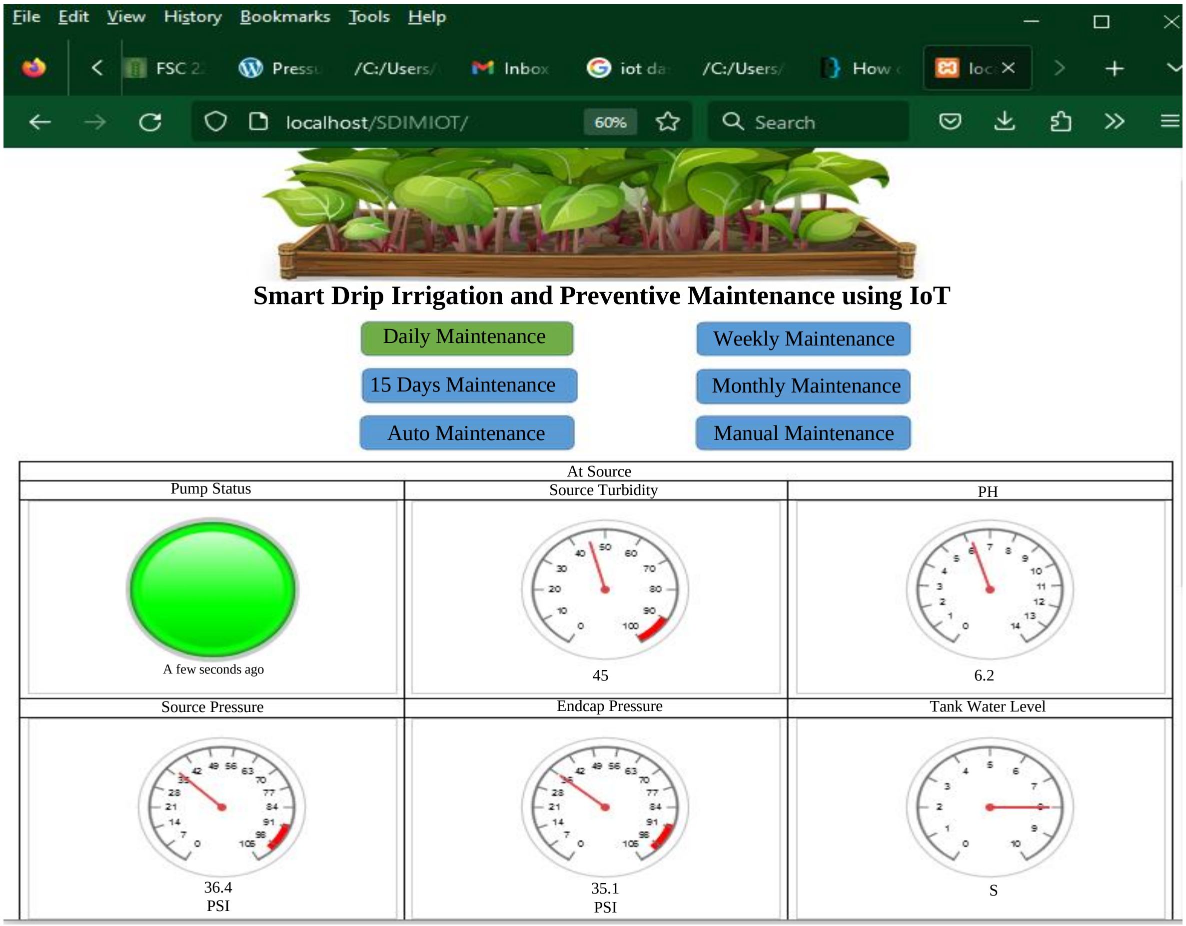

Fig. 7 The SDIMIOT dashboard

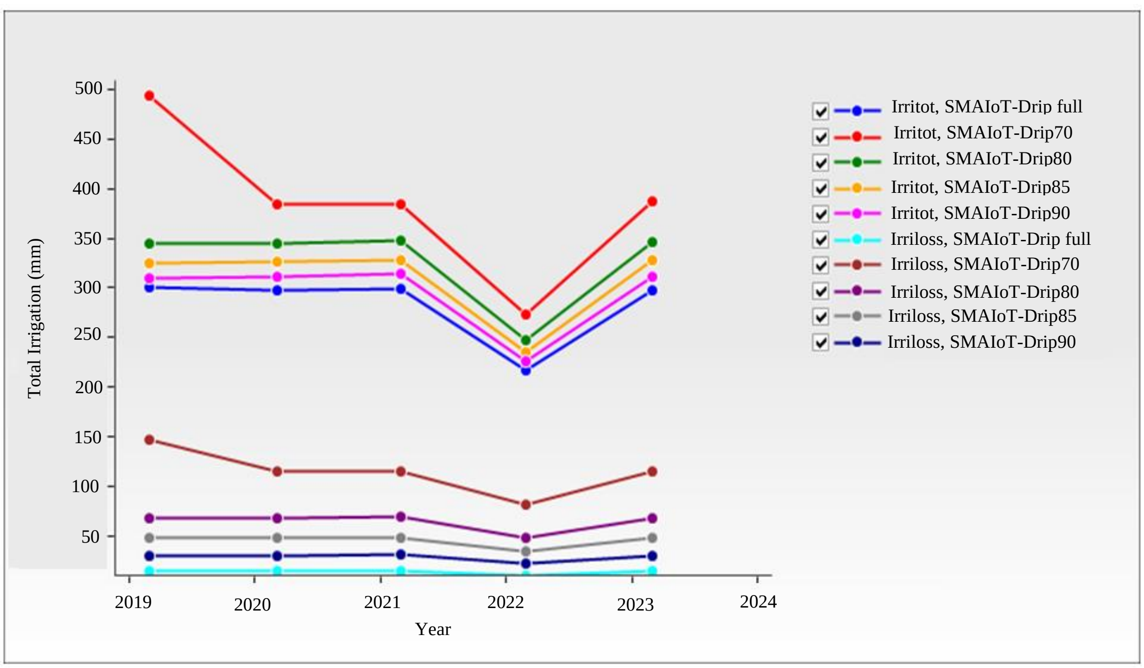

Fig. 8 Total irrigation and irrigation loss in mm during crop cycle for simulation duration

6. Conclusion

Implementing drip irrigation systems is crucial for plant health as it mitigates the spread of pests and diseases, suppresses weed growth, enhances fertilizer and water efficiency, and minimizes losses caused by pests, pathogens, and weeds. Managing Drip components, irrigation schedule, maintenance schedule, and significance of drip irrigation systems is, with the help of IoT technologies, essential for prolonging their lifespan and effectively managing plant health. Ultimately, healthy plants produce higher quality yield, increasing farmers' income and supporting FAO's goals of eradicating hunger and reducing poverty.

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