SMART MANGO – SMART SYSTEM FOR MANGO PLANTATION MANAGEMENT

Final Report

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IOT - BASED SMART WATERING SYSTEM

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DECLARATION

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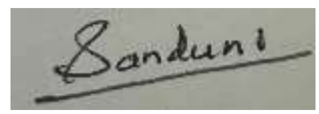
Withanaarachchi S. P.	IT20466008	

The above candidates are carrying out research for the undergraduate Dissertation under my supervision.

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Ms. Hansika Mahaadikara – Supervisor   Date

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Ms. Shashika Lokuliyana – Co-Supervisor   Date

ABSTRACT

This research introduces an innovative approach utilizing Internet of things (IoT) and machine learning to revolutionize mango cultivation practices. Since it is essential to ensure global water and food security, proper irrigation system has garnered a lot of attention. For the efficient use of water in agricultural industry and to increase crop production, a smart irrigation system is used. As a result, irrigation has less of a negative environmental impact and there is less of a strain on water supplies. This project will identify the gaps in the irrigation methods in mango cultivation in Sri Lanka and examine how they affect crop quality, productivity, and water usage. It has been demonstrated that using soil moisture sensors, temperature sensors, and humidity sensors to gain data and by analyzing them through a machine learning model, the water need to be released to the agriculture field can be determined. Therefore, it can save water while preserving crop growth and quality.

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IoT	Internet of Things
AWS	Amazon Web Services
ML	Machine Learning

1. INTRODUCTION

A country like Sri Lanka, where the economy is built primarily on agriculture and the weather conditions are isotropic, needs to quickly improve its food production technology to meet the constantly rising demand for food. Despite this, we are still unable to fully utilize our farming resources. Moreover, we constantly pollute the ecosystem and misuse a variety of farming components. The primary causes are a dearth of information and a lack of water in land reservoirs. A lot of land is steadily encroaching in the areas of unirrigated land as a result of the continual removal of water from the ground. Due to unintentional water usage, which results in substantial wastage and a reduction in the soil's fertility. To help farmers save time and money while also improving their quality of life, we are developing an automated method. For changing irrigation applications-based temperature, humidity, and soil conditions, smart irrigation systems are a developing technology. Most of the smart irrigation systems present in the market are expensive and cannot be afford by the small-scale mango farmers. This system is made using qualified sensors with reasonable prices. Therefore, this system can be provided with a reasonable price. The machine learning model used in the system can be used to accurately provide the amount of water needed to the plantation. The usage of this system will reduce many tasks that are divided among the employees, and it will help the managers to manage the farm activities efficiently and effectively.

This automated irrigation system uses IoT devices to monitor temperature, humidity, and soil moisture levels. By considering these factors, it will be easier to decide when and how much water to use in the most effective way. Water is one of the major components that affect the yield of the mango plantation. By determining the exact amount of water needed by the mango plants, it can save a lot of resources, including water, labor, and time. Water is critical factor for the sustainable development; therefore, conservation of water should be a major objective when designing an irrigation system for any purpose, like gardening or agriculture. The optimal amount of water required by each plant will then be determined using a machine learning model and delivered via automated watering pipes. The use of ML model to determine the water usage will help the farmers to increase the mango yield and the money spend on the labor can be reduced. This will help the farmers to manage the mango plantation in a more efficient and effective way.

This research explores a novel approach to revolutionize mango management, driven by the rising demand for this economically significant fruit. By harnessing machine learning and Internet of Things (IoT) technologies, this research enhanced efficiency and better decision making for both farmers and consumers.

Employing cutting-edge machine learning techniques and leveraging data from IoT sensors, our aim is to predict the optimal water requirements for mango trees at various stages of growth. Armed with this understanding, farmers can adopt sustainable irrigation practices, curbing water wastage and promoting the health of the orchard.

New scientific fields like smart irrigation utilize data-intensive ways to boost agricultural output and reduce environmental impact. Sensor data from modern agriculture improves decision-making. Smart irrigation saves water and automates irrigation systems. In IoT devices, the smart irrigation system involves data collection (sensor), irrigation control, wireless communication, data processing, and problem detection. This system regulates irrigation depending on soil and weather conditions, enabling farmers to satisfy demand using a novel water-saving strategy. IoT, smartphone apps, and sensors let farmers monitor soil, temperature, water needs, and weather. IoT automates all agricultural activities to increase productivity and efficiency.

Sensors help farmers understand crops, mitigate environmental consequences, and preserve resources. This study highlights smart irrigation utilizing IoT and sensing systems. The smart irrigation system uses well-based technology to measure soil moisture. On-demand irrigation and suspended cycle irrigation use soil moisture sensors. Water management reduces costs and boosts crop productivity in agriculture. It helps companies manage resources and complete tasks. Organizations must know soil, crop, and water basics since the external environment might affect agricultural activity.

Irrigation water management requires fundamental soil, crop, and water knowledge. In arid locations and during droughts, agricultural sectors need water management to maximize efficiency and water use. Agricultural water management strategies include measuring, metering, and managing water, water-smart landscaping and irrigation, regulating reverse osmosis, recovering rainfall, and creating reservoirs. IoT and smart irrigation systems decrease waste and enhance efficiency.

Organizations in many industries and sectors need cloud and conventional database systems. Cloud technology has helped agricultural organizations store and view data to improve their efficiency and performance. Cloud technology warnings minimize dangers and hazards. Many cloud-related applications help workers.

The irrigation system is risky, complicated, and delicate. Irrigators decrease risks and increase results using cloud technology. IoT irrigation solutions save water, money, energy and crops. IoT solutions reduce water use by automating irrigation tasks. Cost is considered, making it possible to do related tasks efficiently and cheaply. Finally, crops are only watered when required, minimizing crop waste.

1.1 Background Literature

There has been lack of research on the use of smart watering systems for Sri Lankan mango farms, despite these systems have been extensively explored for a variety of crops. Mangos are a significant fruit crop in Sri Lanka, because of the problems with water shortages and unreliable rainfall cycles, which can have a severe effect on both productivity and quality. The potential advantages of smart watering systems for mango production have been highlighted in a number of studies.

Research by Sharma et al. (2020) have demonstrated the effectiveness of IoT sensors in optimizing mango orchard water usage. Smart watering systems have the potential to increase the yield and efficiency of water use in mango plantations, more research is required to address implementation issues and limitations as well as to determine the best technologies and approaches for Sri Lanka's unique agro-ecological conditions. In locations with water scarcity and unpredictable weather, smart watering systems are a viable way to maximize water use in agricultural productivity. These systems combine multiple technologies, including sensors, controls, and communication networks, to offer real-time irrigation management monitoring and decision-making capabilities. The potential advantages of smart watering systems for crop productivity, effective water usage, and farm profitability have been shown in a number of studies. [1]

Researchers like Rahman et al. (2020) has shown that smart irrigation system for mango plantations in India found that the technology enhanced yield by 33% while reducing water use by 40%. A study by Karunarathna et al. (2021), has discovered that the water needs of mango trees in Sri Lanka varied depending on the soil type, climate, and age of the tree, demonstrating the necessity for site-specific irrigation management systems. [2]

Research by Wijeratne et al. (2019) explores the barriers to implementation in Sri Lanka Smart irrigation system adoption still faces obstacles and restrictions, despite the potential advantages. One significant obstacle for small-scale farmers is the high initial investment cost for the technology. The demand for technical competence and the intricacy of the technology might also make it difficult to adopt and maintain the systems. [3]

In a comprehensive research study, Silva et al. (2020) conducted a life cycle assessment to assess the carbon and water footprints of Brazilian mango production in the semiarid region. The study quantified greenhouse gas emissions and water consumption at various stages of mango production, considering different cultivation practices and varieties. The research revealed significant differences in environmental impact between conventional and sustainable production systems. Sustainable practices, such as efficient irrigation and reduced fertilizer use, were shown to lower carbon emissions and water consumption. The study's findings offer valuable insights for promoting eco-friendly mango cultivation and inform targeted interventions and policy measures to reduce the environmental footprint of the industry. However, the research also emphasizes the need for improved data collection and assessment methodologies to enhance the accuracy of footprint estimations and support informed decision-making in sustainable mango production. Silva et al.'s (2020) study represents a critical step towards responsible resource management and sustainable agriculture in mango cultivation [4].

Souza et al. (2017) conducted field experiments in irrigated mango orchards in northeast Brazil, using advanced measurement techniques like sap flow sensors to monitor water requirements throughout the growing season. The findings highlighted higher water demand during flowering and fruit development stages, emphasizing the importance of matching irrigation schedules to optimize water use efficiency and minimize losses. The research contributes to sustainable irrigation management strategies for mango orchards in water-scarce regions, offering valuable guidance in balancing crop productivity with responsible water resource management and potentially benefiting other regions facing water scarcity. [5] The research emphasized the importance of adjusting irrigation schedules to match tree water demand during key growth stages and conserving water during the dormant period. This offers valuable insights for sustainable irrigation management, enabling growers to optimize water use and maintain fruit quality and tree health.

Similarly, Khan et al. (2018) explored the water requirements of mature mango trees, providing guidelines for tailored irrigation management to support sustainable mango cultivation, particularly in water-scarce regions. The studies collectively contribute to responsible resource management and sustainable agriculture practices in mango orchards. [6]

Indu et al. (2013) primarily focusses on the assessment of technology utilized for remote monitoring and control as for its potential gains. The research suggests a novel remote-controlled integrated watering system that runs on GSM and Bluetooth. The system can automatically water the field while it is not being watched and determine the irrigation time based on the type of crop, temperature, and humidity. SMS on the GSM network is used to transmit data between the developed system and the remote end. When the user is within the restricted range of a few meters from the specified system, a Bluetooth module interfaced with the main microcontroller avoids the SMS charges. The system notifies the users by using the SMS or Bluetooth according to the variety of situations, including the presence of smoke, dry running motor status, elevated temperature, and the moisture content in the soil. [7]

R. Suresh et al. discussed the use of an automated microcontroller- based rain gun irrigation system in, where irrigation only occurs only when there is a significant of water hence saving lot of water. The development of Android software stack, which is utilized for devices that include an operating system, middleware, and important apps, these systems bring about a shift in the management of field resources. The android SDK offers the resources and APIs required to start developing a Java-based apps for the Android platform. The varied demands of people are almost met by mobile phone's GPRS function as a method to operate irrigation systems. These systems cover less productive area and were expensive. [8]

The integration of IoT and machine learning in smart mango watering systems aims to strike a balance between yield enhancement and resource conservation. Studies like Reddy and Kumar (2021) have shown that these technologies can lead to increased mango production while conserving water resources. [9]

The integration of IoT and machine learning technologies into mango watering systems in Sri Lanka offers a transformative approach to sustainable mango cultivation. By providing real-time data, decision support, and site-specific optimization, these systems can significantly improve water management practices, enhance mango production, and contribute to resource conservation. Addressing the challenges of technology adoption and farmer education is essential for realizing the full potential of these innovations.

1.2 Research Gap

Despite the potential benefits of smart watering systems for mango orchards in Sri Lanka, further research is still needed to determine the precise requirements and most effective ways to implement such systems. Despite studies on intelligent watering systems for other crops and in other countries, there is still a need for studies that focus on the unique characteristics of mango plantations in Sri Lanka, such as soil type, climate, and irrigation patterns. A lack of studies that could provide farmers with relevant information about the economic potential of implementing smart watering systems in Sri Lankan mango orchards is another issue. Further research is needed on the machine learning based smart watering systems, particularly for cost and availability for small-scale farms. By closing these knowledge gaps, Sri Lankan mango farming could become more efficient and productive while simultaneously promoting sustainable water use practices.

1.3 Research Problem

The dearth of research on the unique water needs of the various mango types grown in the nation represents one possible research gap in the field of smart watering systems for mango plantations in Sri Lanka. There has been research on the water demands of mango trees generally, however due to variances in climatic conditions, soil types, and other factors, different mango cultivars produced in Sri Lanka may have varying water needs. Therefore, research is required to establish the ideal water needs for the various mango varieties cultivated in Sri Lanka and to create intelligent watering systems that can adjust to these needs. This could entail running field tests to determine the water needs of various mango varieties, creating sensors that can track the moisture content of the soil in real-time, and using machine learning algorithms to optimize irrigation schedules based on the unique requirements of each mango variety.

1.4 Research Objectives

1.4.1 Main Objectives

- To implement a smart water management system that provide water to the plantation at the correct time and the correct amount.

The main objective of the system is to implement a smart water management system that provide water based on data input by different types of sensors and analyze it through a machine learning model. The amount of water analyzed through the machine learning model is distributed to the farmland through the pipelines. The real time data can be obtained through the website. This will help the users of the system to control and manage remotely. This will make the management functions easier, and the operation cost of the field will be reduced. The maximum yield can be obtained by using a smart irrigation system. The wastage of many resources such as water, energy, labor force, time, and money can be reduced.

1.4.2 Sub Objectives

- To increase the yield of the mango plantation

As the water is provided at the correct time at the correct amount, the yield of the mango plantation can be increased.

- To increase the efficiency of the workers

As the water distribution is automated lot of labor of the workers can be saved. This will help the workers to concentrate on the others works they need to do more effectively.

- To minimize the wastage of water

The water is a very limited natural resource which is very valuable to both the existence of animals and plants. The agriculture field needs lot of water. Therefore, using water more effectively by using these kind of systems helps the business to grow sustainably.

- To make the management functions easy

Before using the system, the management may need many workers to water the plantation. But after the implementation of the system, the watering process is fully automated, and the managers can control the functions of the watering system remotely.

2. METHODOLOGY

ESP32 DEV module is used as the microcontroller in this IoT device. It is used as the microcontroller because despite of having the high performance, the Bluetooth and Wi-Fi module is embedded in the microcontroller. The microcontroller is programed to take the input readings and send the data to the cloud database. DHT11 is used to measure the temperature and humidity. This sensor is selected because it has an embedded resistor in the sensor. The other equipment's used are soil moisture sensor, relay module, solenoid valve, voltage sensor, motor, and ultra-sonic sensor. The ultrasonic sensor is used to measure the level of water in the water tank. The data to the system is obtained from the temperature, humidity, and soil moisture sensor installed in the mango plantation. The data obtained from the sensors are send to the cloud server using Wi-Fi. The data obtained is analyzed through a machine learning model. The machine learning algorithm used is Linear Regression. This model will predict the irrigation data needed for the plantation. A relay module is used to automatically on and off the system. The water needed to the plantation will be released through the pipelines. The water is given to the root of the plant using sprinklers in drip irrigation method. After the water distribution the amount of water needed is recalculated. If the water is needed, the water is again distributed and if the water requirement is sufficient the solenoid valve will stay closed. Device Ids are used to identify the crops uniquely. A webpage is used to display the data obtained from the sensors and water requirement calculated by the ML model accordingly.

The system can be used in semi-automated and fully automated mode. The system can be shut down during the rainy season. The management and the authorized workers can access and control the system remotely. The data of the mango plantation can be obtained real time through the website and the mobile application. A report of the water usage will be given at the end of a specific time period according to the requirement of the management.

Linear Regression for Required Water Level Prediction: Linear regression is a straightforward and interpretable statistical method commonly used for numerical prediction tasks. We employed linear regression for both predicting mango yield and determining the required mango water level.

Required Mango Water Level Prediction: Linear regression was used to predict the required mango water level based on environmental parameters (Humidity Level, Moisture Level in the soil, Temperature). Linear regression allowed us to analyze the relationship between these environmental factors and the optimal water level required for the healthy growth of mango trees. By employing linear regression, we could make accurate predictions for the water level needed to maintain optimal growing conditions for mangoes.

2.1 Calculation

Calculation to identify the flow rate to identify maximum time the solenoid valve should be open for the water to pass.

Kv Flow factor = 28.6 L/min

Pressure Range = 0.2 - 0.8 Bar

Flow Rate (Q) = Kv x √ (Pressure Drop)

Minimum pressure differential (0.2 Bar)

Flow Rate (Q) = 28.6 x √ (0.2)

= 8.05 L/min

Maximum pressure differential

Flow rate (Q) = 28.6 x √ (0.8)

=32.01 L/min

Average pressure differential

Flow rate (Q) = 28.6 x √ (0.5)

=25.38 L/min

1 – L = 0.001m^3

1 min = 60 s

Flow rate (minimum) = 8.05 L/min x (0.001/60)

= 0.000134 m^3/s

Flow rate (average) = 25.38 L/min x (0.001/60)

= 0.000423 m^3/s

Flow rate (maximum) = 8.05 L/min x (0.001/60)

= 0.0005335 m^3/s

2.2 System Diagram

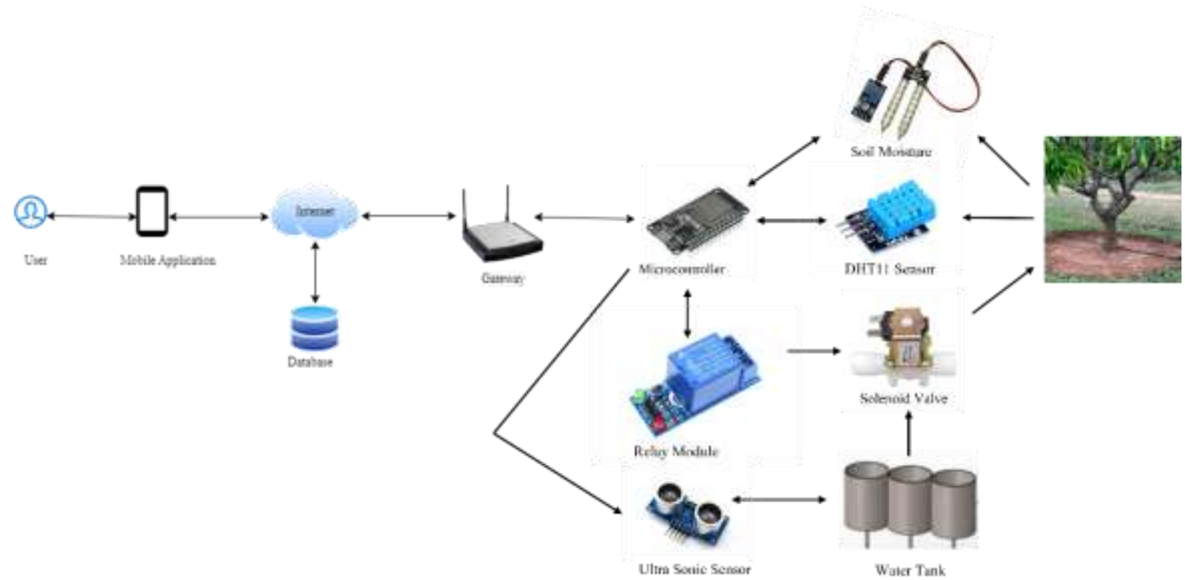

Figure 2:1 System Diagram

2.3 Commercialization of the product

2.3.1 Target Audience

The target audience of the product is mango farmers specifically in Sri Lanka. But our future plan is to make this system to be used by mango farmers worldwide.

2.3.2 Demand

The demand for this product is very high as there is a lack of smart irrigation systems for the mango plantations in Sri Lanka. As we have discussed with few mango planters in Sri Lanka, they are always willing to find a method decrease their expense and increase their income. By using a smart watering system made by using ML and IoT the water resource can be used in a more effective manner. As most of the mango plantations in Sri Lanka is located in dry areas and semi-arid areas this system will be very helpful to use the water resource sustainably. And by using this automated system it will help the mango planters to water the plantation in the correct time without any human intervention therefore it may help to avoid mistakes made by workers. Therefore, this system will have a high demand among the mango planters in Sri Lanka.

2.3.3 Marketing Strategy

We plan to sell this system through Agriculture Department in Sri Lanka. The new buyers will have a free trial period and if they are not satisfied with the product, they can return the product within the given period of time. The small-scale farmers who cannot afford the system are given a monthly based paying method. The people who cannot afford the system are given a chance to get it through NGO’s.

2.3.4 Social Media Marketing

The social media marketing is the most current trend in marketing. Even though you do not have a customer base still, you can make people aware of the product through the social media marketing like Instagram, Facebook, YouTube etc.

2.4 Testing & Implementation

This system is tested throughout the development lifecycle. All the modules were tested separately before and after the integration with the main system. The testing of the entire system was done to ensure the proper functioning of the system.

Table 2:1 Summary of testing of the system

Test ID	Test Description	Status
001	Testing of the ML model by varying the input values	Pass
002	Testing of the soil moisture sensor	Pass
003	Testing of the temperature sensor	Pass
004	Testing of the humidity sensor	Pass
005	Testing of the relay module	Pass
006	Testing of the IoT module	Pass
007	Testing of the IoT module with ML module	Pass
008	Testing of the Database	Pass
009	Testing of the mobile application	Pass

2.5 Budget and Budget Justification

Table 2:2 Budget and budget justification

Component	USD (per year)	LKR (per year)
ESP 32 Dev Module	11	3300
Soil Moisture Sensor	1	200
DHT11 Sensor	2	490
Ultra-sonic sensor	2	595
Solenoid Valve	5	1485
Relay Module	2	450
Mongo DB	10	3227
AWS	15	4840
Total	48	14,587

*Used 1 USD to LKR conversion rate of 322 Rs. on 9/10/2023

3. RESULTS AND DISCUSSION

3.1 Results

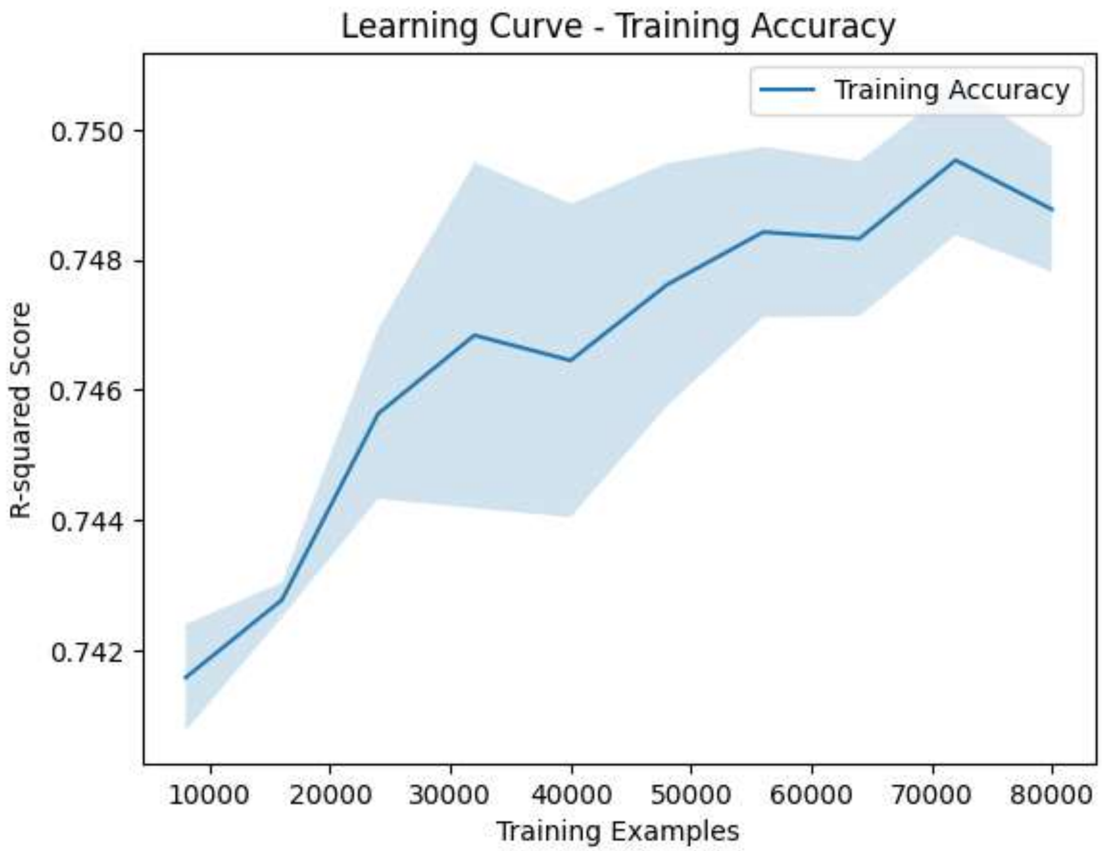

Figure 3:1 R-Scored Score

The linear regression model of the smart mango watering system is trained using a dataset of 100,000. The dataset is divided as 80% (80,000) data for training and 20% (20,000) for testing. The training accuracy of the dataset has reached its maximum value 0.7495 when the training examples are 70,000. The R-squared score of the module is 0.74621.

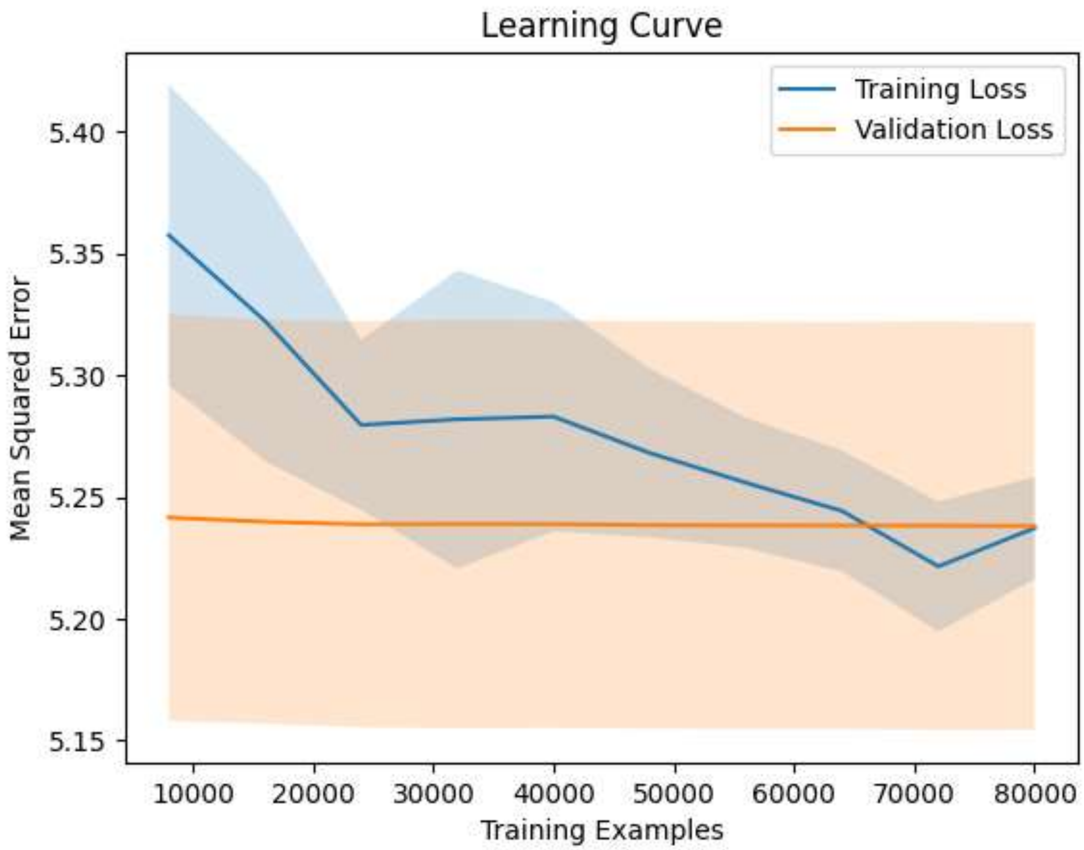

Figure 3:2 Mean Squared Error

The validation loss is nearly at a constant value of 5.24. The training loss is at minimum when it is at 75,000 training examples. The mean squared error of this machine learning model is 5.2901.

3.2 Research Findings

This research has help to identify the required level of water to the plantation by using system with the help of IoT and Machine learning models. This system has help to reduce the water wastage and use water in a more efficient way specially for the mango plantations in dry and semi-arid areas. The system also has helped to increase the yield of mango plantation by using the resources efficiently. The energy, time, cost and manpower can be saved by using this system.

3.3 Discussion

The use of IoT and machine learning for irrigation system optimization is becoming increasingly important due to the real-time monitoring of several parameters and the generation of large amounts of data. To ensure that the data is managed and controlled effectively, eliminating useless data, implementing clustering techniques, utilizing efficient algorithms, and utilizing sustainable resources are some of the recommendations. Artificial intelligence (AI) and fuzzy logic are used to evaluate the data gathered from the sensors to carry out the irrigation-related actions, and machine learning is used to make predictions. These methods enable the irrigation process to be improved by predicting any difficulties that can arise and how the risks must be addressed to guarantee maximum work efficiency. Machine learning can be used to reduce water use, more earnings, and improved agricultural yields. [10]

It can also manage irrigation-related hazards, such as crop diseases, inadequate storage management, pesticide control, weed management, inadequate irrigation, and inadequate water management. AI approaches and smart irrigation have been presented by Bannerjee et al., Chlingaryan et al., and Elavarasan et al., and precision irrigation systems can be utilized to adaptably regulate the environment's changing conditions. Sustainability is a crucial factor that is connected to irrigation systems, and a balance between the three sustainability pillars must be maintained for any system to be sustainable. Organizations engaged in the specific sector and associated operations must take these factors into account since the components of sustainability might be evaluated in various situations and media. The most important details in this text are related to irrigation and sustainability. [11]

It has been shown that irrigation activity has a variety of negative environmental effects, such as waterlogging, an increase in cases of water-borne illnesses, salinization of soils, and problems with resettlement. Additionally, water management may be included in sustainable irrigation systems, as it is important to ensure that the resource is regulated and managed properly to reduce water waste. Organizations engaged in irrigation operations must place a greater emphasis on methods that reduce pollution, illness, expenses, and other problems. [12] In terms of economic sustainability, it must be assured that the cost of irrigation does not exceed the value of irrigation's marginal production. Water depletion is another idea that might be seen as being very important in irrigation and sustainability.

The need for irrigation in agricultural cropping systems is one of the primary factors contributing to a sharp rise in water shortages. Smart irrigation is essential for water conservation and is critical to giving each crop the necessary quantity of water. The Internet of Things (IoT) is suggested as a way of integrating contemporary technology with irrigation to optimize the utilization of irrigation water in various places. [13]

Multi-agent architectures are renowned in irrigation management and its IoT solutions. The general design and layout of sensory irrigation systems based on IoT is based on multi-agent architectures. The majority of architectures are broken up into functional blocks that reflect the many tasks and activities that need to be completed. The Internet of Things (IoT) systems are made up of several gadgets that are positioned to carry out a wide range of diverse tasks, including control, monitoring, detection, and action. [14]

These gadgets also have interfaces via which connections may be made with other devices to send the necessary data. IoT architecture has traditionally been composed of three main levels: application, network, and perception. However, a new layer known as the service layer has been introduced to store and analyze data using cloud computing and fog.

Ferrández-Pastor's four-layered structures have been proposed, with the edge layer chosen to find crucial applications and carry out fundamental control operations. [15] Different tiered techniques have been developed and deployed in relation to IoT systems for irrigation, with varying degrees of success.

4. CONCLUSION

This research examines the advantages and drawbacks of the currently used methodologies in order to develop a smart water management system. Using the data provided by the sensors as input, the machine learning model will be used to predict the quantity of water needed for the plantation and to distribute it via the pipeline. One of the activities that requires the most water is agriculture. The system uses sensor data to calculate how much water should be applied to the soil, avoiding over or under-irrigation, which may be detrimental to crops. To follow the procedure, farm owners can use the website. This study has shown how the Internet of Things and automation might significantly improve agriculture. The device offers a workable solution to the problems associated with the present manual and tiresome irrigation strategy by enabling efficient utilization of water resources.

Technology developments are now crucial in the present business environment, and irrigation and its applications may be improved to deliver the maximum degree of operational efficiency while achieving the desired performance goals. Farmers have used sensory systems to get a better understanding of their crops, minimize their influence on the environment, and preserve resources, while the Internet of Things has been linked to the automation of all agricultural practices and elements to make the whole process much more effective and efficient. Businesses have been looking for strategies to protect the resource while also improving the efficiency of their operations due to the major challenge of a water shortage. In order to achieve their performance goals, smart irrigation systems are now required, and recommendations for implementing to identify the current inefficiencies in procedures and methods and develop a better strategy for improved results.

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6. APPENDICES

6.1 Interface of the mobile application

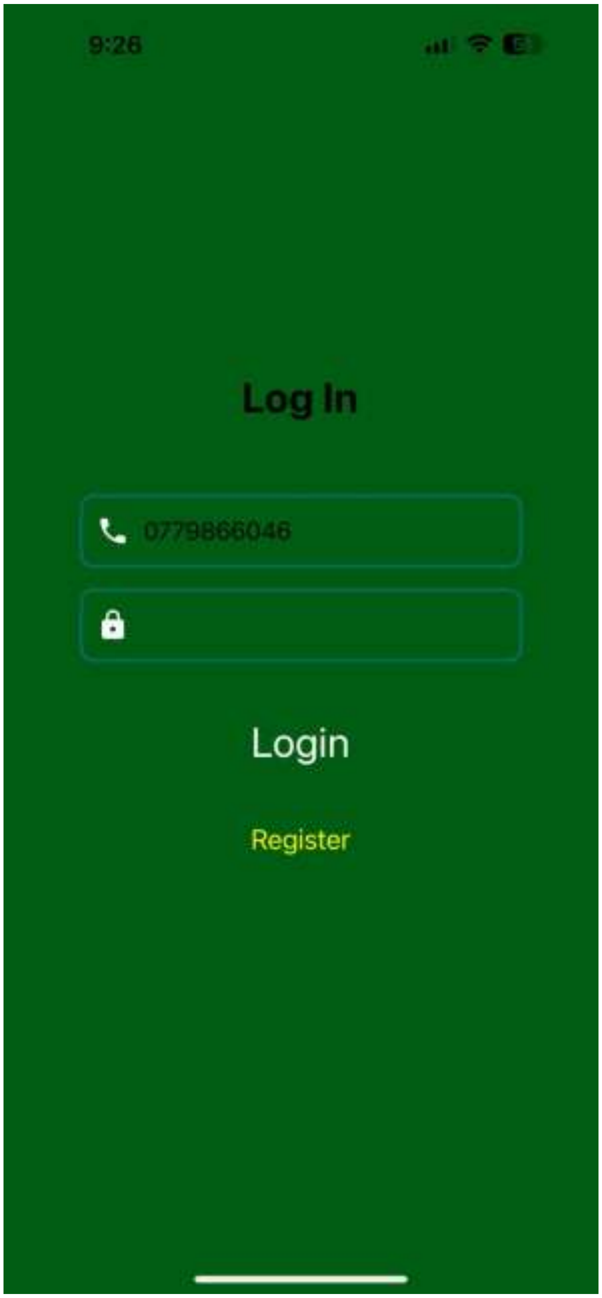

Figure 6:1Interface 1

Figure 6:2 Interface 2

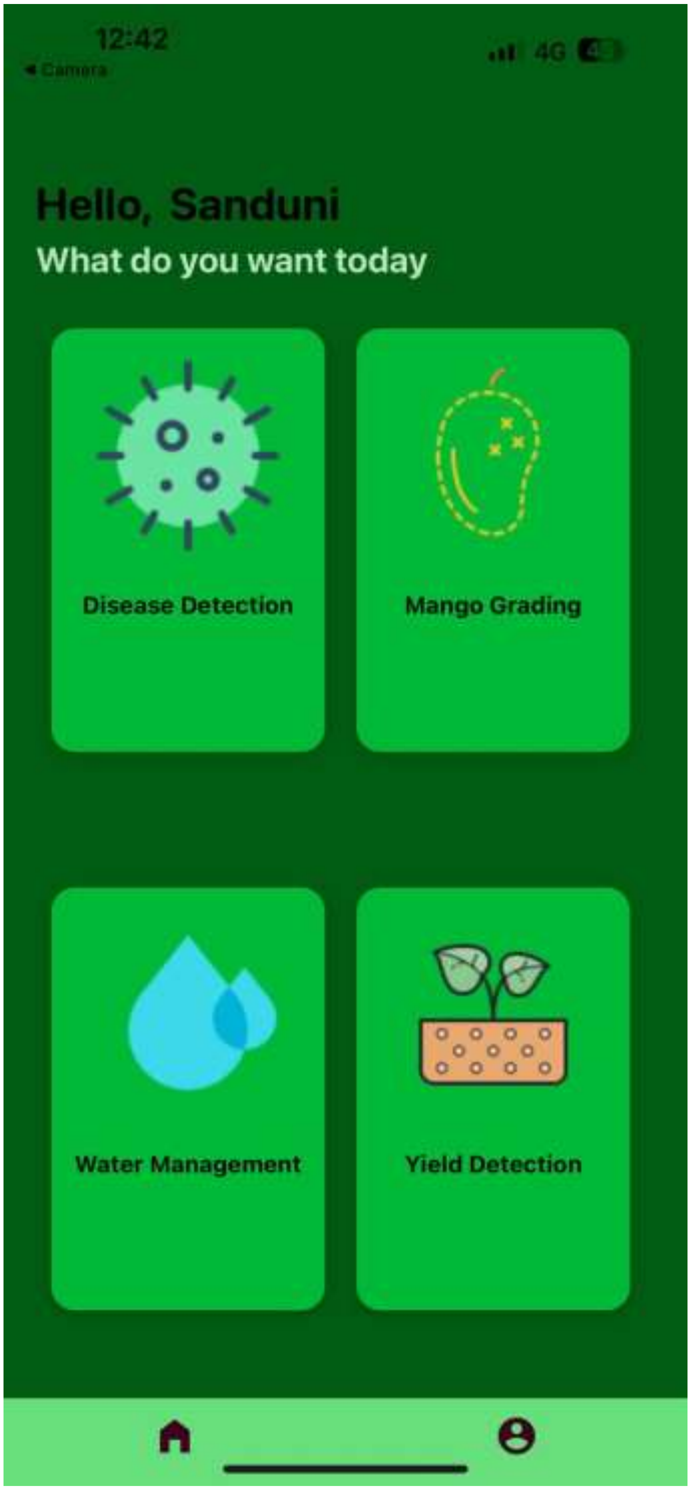

Figure 6:3 Interface 3

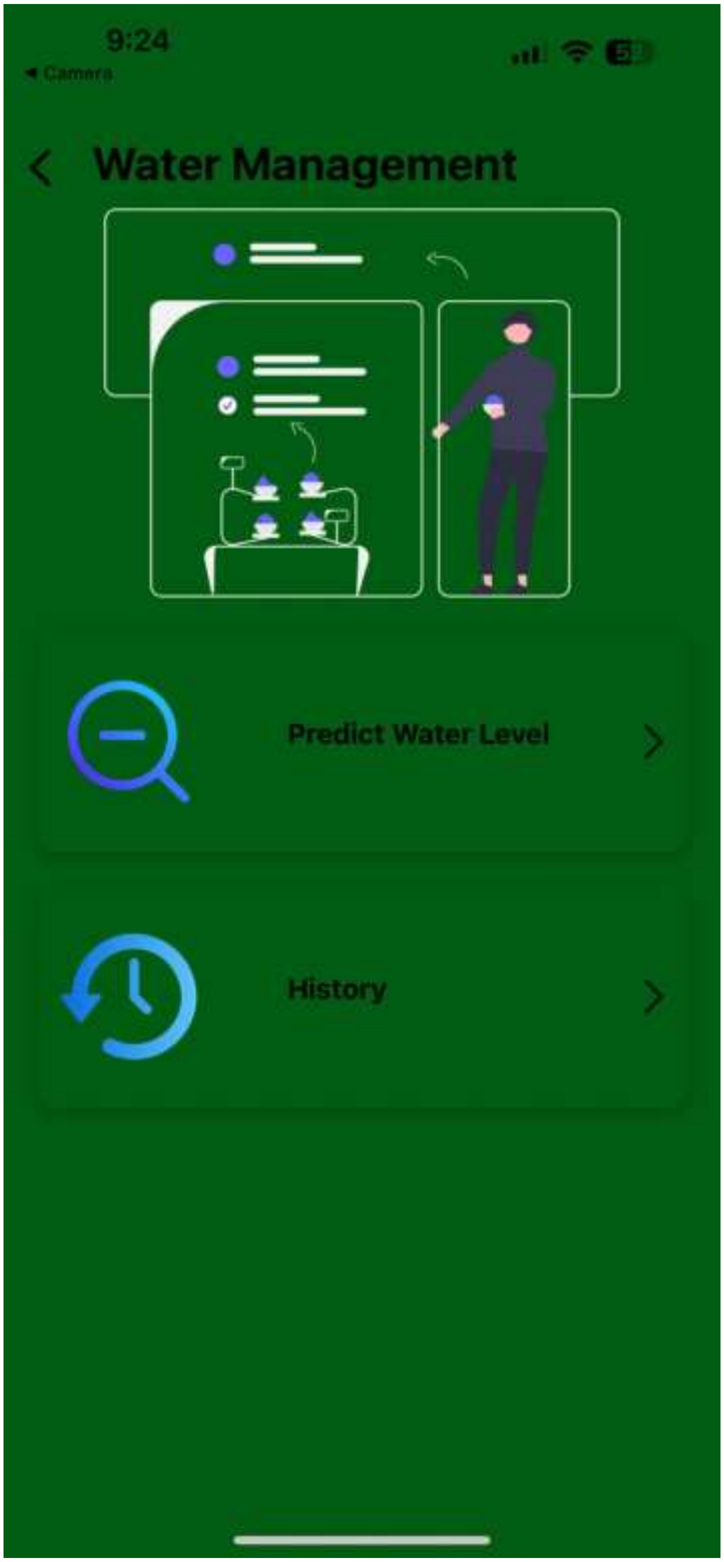

Figure 6:4 Watering System Interface

Figure 6:5 Current User Interface

6.2 Sensors used to make the IoT device.

Figure 6:6 ESP32 Dev Kit

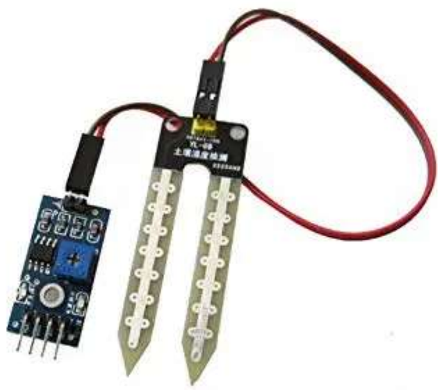

Figure 6:7 Soil Moisture Sensor

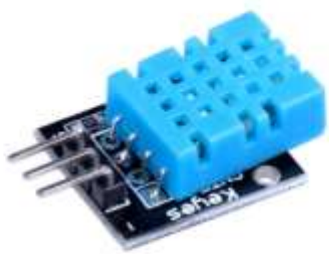

Figure 6:8 DHT11 Sensor

Figure 6:9 Relay Module

Figure 6:10 Ultrasonic Sensor

Figure 6:11 Solenoid Valve