

A Review Paper on Automatic Irrigation System using Soil Moisture Sensor

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ABSTRACT

Agriculture consumes about 70% of freshwater globally, yet traditional irrigation methods result in significant water wastage. This review paper analyzes various research works on automatic irrigation systems based on soil moisture sensors. The system automates the process of watering crops by sensing the moisture content of soil in real-time and controlling the water pump via a microcontroller. This paper compares different controllers like Arduino UNO, ESP8266, ESP32, and Raspberry Pi, different sensors like capacitive vs resistive, and IoT integration. The literature shows 40-60% water saving and 20-30% increase in crop yield. This system is low-cost, efficient and essential for sustainable farming in water-scarce regions like Maharashtra.

Keywords: Automatic Irrigation system, Soil Moisture Sensor, Arduino, IoT, Water Management, Smart Agriculture, water saving

1. INTRODUCTION:

India is an agricultural country but faces severe water scarcity. Manual irrigation requires constant human monitoring and often leads to over-irrigation or under-irrigation. Overirrigation causes root rot and nutrient loss, while under-irrigation reduces yield as well as the production cost means farmer have to face this problem and also some time they are in loss to overcome on this problem and for the continues monitoring on soil moisture level with the help of automatic irrigation using soil moisture sensor When the soil becomes dry and the moisture level falls below a fixed value, the sensor sends a signal to the control unit, which automatically switches ON the water pump. When sufficient moisture is reached, the system automatically switches OFF the pump. Thus, the system supplies water only when it is required by the plants.



Figure 1: Sprinkler Irrigation System

Automatic irrigation system solves this by-

1. Measuring soil moisture continuously
2. Turning ON motor when moisture is low

3. Turning OFF motor when moisture is sufficient
4. Which reduces human effort and saves the time increases crop yield as well as profit.
5. This system supply water to crops according to requirement

2. OBJECTIVES

- To study the working of an automatic irrigation system using a soil moisture sensor.
- To review existing irrigation techniques and sensor-based technologies.
- To reduce water wastage by supplying water according to soil moisture levels.
- To minimize human effort through automatic control of water pumps.
- To improve water-use efficiency and support healthy plant growth.
- To identify the advantages, limitations, and future scope of automatic irrigation systems.

3. LITERATURE REVIEW'S

- a. **Khemnar Aniket V, More Harshal D, Shardul Prathmesh S, Gavit Siddhesh N, Mandore Sunil A (2026):** The authors have developed an automatic drip irrigation system integrated with soil moisture sensors and AI-based technology to improve crop health and water management efficiency. The system continuously monitors soil moisture levels and environmental parameters to deliver precise amounts of water directly to the root zone. According to the paper, traditional methods like flood irrigation waste 40-60% of water due to surface runoff, deep percolation losses, and uneven moisture distribution. The proposed system eliminates these issues by using real-time sensor data and AI-assisted decisionmaking to automate irrigation scheduling. Artificial Intelligence analyses both historical and real-time data to predict irrigation requirements based on crop needs and climatic conditions. This results in optimized water usage, reduced energy consumption, lower labor dependency, prevents waterlogging, and supports sustainable agriculture by improving overall crop health and yield.
- b. **Abdul Hasib, A. S. M. Ahsanul Sarkar Akib (2026)-** The authors developed a complete smart plant monitoring and automatic irrigation system using ESP32 microcontroller, which is more powerful than Arduino. The system uses multiple sensors - DHT22 for temperature and humidity, HC-SR04 ultrasonic sensor for water tank level monitoring, and soil moisture sensor for soil condition. It also has an OLED display for showing live sensor values and a buzzer for instant audio alerts when soil is dry or tank is empty. All sensor data is sent via WiFi to ThingSpeak cloud platform where farmer can see live graphs, historical data and get mobile alerts from anywhere. It saves 50-60% water, maintains optimal plant health and reduces manual effort. It is best for your IoT, Cloud Integration and Future Scope chapter to show upgradation from basic Arduino to ESP32 based smart system.
- c. **Amarappa Pagi, Srusti Madiwalar, Supriya Ghodake (2026):** Garden Watering System WITHOUT using any microcontroller like Arduino or ESP32. The whole system is implemented using only discrete analog electronic components on a breadboard. The hardware used is conductive soil moisture probes, transistor switching circuit, relay, water pump and LED indicators. Working is simple - when soil becomes dry, resistance between probes increases and transistor circuit turns ON the relay which starts the water pump automatically. Once sufficient moisture is restored, the circuit turns OFF the pump automatically, preventing overwatering and saving water. LED indicators give visual status of dry/wet soil. Advantage is very low cost, no programming needed, easy for beginners and best for understanding basic electronics. Limitation is low accuracy

compared to Arduino, no threshold setting, no IoT, no mobile app, no cloud data and probes get corroded over time. You can use this paper to compare analog vs microcontroller-based irrigation system in your report.

- d. **Delisha Gupta (2025):** The author explains that agriculture uses maximum water and traditional manual irrigation wastes a lot of water. The paper describes the history from manual flood irrigation to sprinkler systems to modern microcontroller-based systems. The main idea is to use a soil moisture sensor to check soil dryness and automatically start the water pump without human help. The author found a major research gap that commercial systems are very costly for small farmers and home users, and cheap systems are too basic and not compatible with renewable energy like solar. This paper is very useful for writing the Introduction, Problem Statement and Need of the Project in your report.
- e. **C.S. Kannapiran et al. (2025)** - The authors used a soil moisture sensor, a DHT11 humidity sensor to measure air humidity, and a rain sensor to detect rainfall, along with Arduino Uno and L298N motor driver to control the water motor. The logic is much smarter than previous papers - first it checks soil moisture, if dry then it checks air humidity, if humidity is already high then it will not water, and finally if rain is detected it will immediately stop the motor to save water. This three-level checking prevents over-watering and saves maximum water. The authors concluded that the system is fully automated, requires no manpower, reduces water loss and increases harvest, and is suitable for both home gardens and large farms.
- f. **Adarsh Tiwari et al. (2025)** - The authors reviewed 20-30 years of research on different types of sensors used for detecting soil moisture. They compared three main technologies - Dielectric based sensors like Capacitive and TDR which are highly accurate, long-lasting and corrosion free but costly, Resistive sensors like YL-69 which are very cheap and easy to use but get corroded quickly and give wrong readings due to salt and temperature, and Gravimetric and Neutron scattering methods which are very precise but only for laboratory use and very expensive. The paper also listed advantages of modern IoT sensors like realtime monitoring, resource efficiency, automation and scalability. The final conclusion is that capacitive sensors are best for future smart farming. This paper is best for your report's sensor selection justification.
- g. **Abdul Rasyid Sidik et al. (2025)-** The main focus of this review is to combine solar photovoltaic energy with soil moisture based smart irrigation for efficient water management. The authors studied many papers and found that integrating solar panels to power the water pumps saves both water and electricity, reduces carbon emissions and is ideal for remote off-grid villages where electricity is not available. The system architecture is Solar Panel -> Battery -> Controller -> Sensor -> Pump, and data can be monitored via IoT on mobile. However, the authors also found challenges like high initial cost of solar setup, limited internet connectivity in villages, and need for technical maintenance. They suggested solutions like government subsidies, using LoRa modules for long-range communication and future integration of AI for crop prediction. This paper directly solves the research gap of Paper 1 and is perfect for your Future Scope and Sustainability chapter.
- h. **Syarifah Fitrah Ramadhani et al. (2024)** - The authors used Arduino Uno as the brain,

YL-69 resistive soil moisture sensor to detect soil condition, a 5V relay module as a switch, and a small DC water pump. The working is very simple - the Arduino reads analog values from the sensor, if the soil is dry (value below threshold) it turns ON the relay and pump starts watering, and when soil becomes wet it turns OFF the pump. The system was tested practically on chili plants and results showed it works automatically and maintains optimum moisture level, which increases productivity. The limitation of this paper is it uses only one sensor which gets corroded after some months due to soil salts, and it has no protection for rainy season, so there are chances of over-watering.

- i. **Yomna Gamal et al. (2023)-** this is a complete overview of the entire field of smart irrigation. The main objective of this paper is to collaborate global efforts to make agriculture more efficient and achieve sustainable agricultural production by improving irrigation efficiency. The authors say that with increasing water scarcity, smart irrigation is mandatory. The study compared a wide range of scientific papers published during the last four years from authors all over the world to investigate scientific approaches for smart irrigation. As a result, this survey covers topics related to irrigation methods, decisionmaking techniques, and the technology used.
- j. **Dr. Geetha S et al. (2022)-** it uses a combination of two technologies - Soil Moisture Sensor + RTC (Real Time Clock) DS3231 module. Most papers only use soil moisture sensor, but this paper adds a time-based intelligence. The RTC module is used to set a specific and fixed time for irrigation, for example, only at 6 AM in the morning and 6 PM in the evening. The main logic implemented in Arduino is that even if the soil moisture sensor shows a dry condition at 2 PM in the hot afternoon, the motor will not start at that time. It will wait and only start at the fixed time set in the RTC. This is very important and scientifically proven because watering in the hot afternoon sun causes maximum water loss due to evaporation - almost 40% water is wasted - and it can also cause thermal shock to the plants. This dual condition system of moisture + time saves maximum water and protects the plants. The paper has a high Impact Factor of 6.252 and is published in a reputed journal. It is best for your Methodology, Working Principle and Advantages chapter to show time-based intelligent irrigation and to justify why you are watering in morning/evening only.
- k. **Ankit Kumar Mishra, Prof. Ashish Patra, Prof. Tarun Shrivastava (2021)-**Automatic Plant Watering System. They used a soil moisture sensor interfaced with Arduino Uno and a 5V relay module to control the water pump automatically. The main focus and motivation of this paper is to solve the major and critical problem of water scarcity in Indian agriculture, where 70% of water is used for farming but wasted due to manual methods. The authors did a practical comparison and field testing between traditional manual flood irrigation and their proposed automatic irrigation system. They proved with experimental results and data table that the automatic system saves almost 50% of water and saves 90% of labour time and human effort compared to traditional manual method. The system is very low-cost, portable and affordable for Indian small and marginal farmers. It is a very strong reference for your Chapter 1 - Introduction, Need of Project, Problem Statement and Objectives, especially to show Indian context.
- l. **Ipin Prasajo, Andino Maselena, Omar Tanane, Nishith Shahu (2020):** easy to

understand Arduino based automatic irrigation system for beginners. The working is very straightforward and well explained with flowchart - Arduino Uno continuously checks the analog moisture level from the soil moisture sensor (YL-69), and if the value goes below the pre-set dry threshold value (for example < 500), it sends a HIGH signal to the relay module which turns ON the water pump and waters the plant. When the moisture reaches a high wet level (for example > 700), the pump turns OFF automatically. The circuit diagram, block diagram and Arduino code are very simple, making it ideal for college students and for report writing. It is good for explaining your block diagram, circuit diagram, flow chart and hardware implementation in Chapter 3 and 4. It is a simple, lowcost, reliable and efficient model for small gardens, pots and small farms.

- m. **Sachin Aggarwal, Anil Kumar (2019)-** It uses IoT with Artificial Intelligence, specifically an Artificial Neural Network (ANN) for predictive irrigation. The system does not just check the current real-time moisture level like all other old papers, but it actually learns from past historical data like a human brain. It collects and stores soil moisture data, weather forecast data, temperature, humidity and soil type data for the last one month in the cloud. Then using AI and Machine Learning algorithm, it predicts and forecasts whether irrigation will be needed tomorrow or not. For example, if the weather forecast says there is a 90% chance of rain tomorrow, the system will intelligently decide not to start the motor today, thus saving a huge amount of water. This is called predictive and intelligent irrigation, which is the future of smart farming. This is the strongest and most modern point for your Future Scope, Conclusion and Research Gap chapter to show AI based smart farming and Industry 4.0.
- n. **Chawla, H. & Kumar, P. (2019)-** They used Arduino UNO with a single Soil Moisture Sensor and a relay module for automation. The logic is very simple, effective and widely used - When the soil moisture goes below the threshold value (dry soil condition), the soil moisture sensor sends a low signal to Arduino and Arduino turns ON the water pump via the relay and starts irrigation. When the moisture level goes above 70% (wet soil condition), the pump automatically turns OFF to prevent over-watering and root damage. The whole system is very low-cost, the total hardware cost is around Rs. 1500 only, which includes Arduino Uno (Rs. 500), soil moisture sensor (Rs. 150), relay (Rs. 100) and mini pump. It is best for small farmers, home gardens, balcony plants and college projects due to its affordability. You can use this as your base model for hardware implementation, working principle, and cost analysis table in your report.
- o. **Laxmikant Jayprakash Goud et al. (2019)-** s the basic automation to the next level with IoT and Mobile Application. The authors integrated a soil moisture sensor with an Android Application using ESP8266 WiFi module (NodeMCU). The ESP8266 reads the sensor data and sends all live sensor data to the cloud server and to the farmer's Android mobile phone via internet. A farmer sitting comfortably at home can monitor the live moisture status of his farm field from the mobile app in real-time and can also manually ON/OFF the motor from the app with just one click from anywhere. The paper claims with testing that it saves 40-50% water compared to manual irrigation and also reduces electricity bill and manpower. It is the first step towards modern IoT based farming and is excellent for your IoT, Cloud, Mobile Application and Results chapter to show remote monitoring.
- p. **S.P.Maniraj, Tanya Chaudhary, Akanksha Agarwal, Nandini Kishore, Vaibhavi**

Verma - (2018) In This Project, they used Arduino UNO + Soil Moisture Sensor + Relay + Pump. Very simple, basic and low-cost prototype for college level. The working is - Soil moisture sensor is inserted in the soil and it continuously reads the moisture content of the soil in analog form. If the value is less than the dry threshold (for example 400), it means soil is dry, then Arduino turns ON the water pump through the Relay module and irrigates the plant. If the soil is wet, pump remains OFF. There is No GSM, No WiFi, No IoT, No App - just pure automation to reduce human effort and save water. This is the model they made as a base prototype of automatic irrigation system for beginners and for demonstration. It is best for explaining the fundamental working principle, basic block diagram and simple code in your report for Chapter 3.

- q. **N.V. Gowtham Deekshithulu, G. Ravi Babu, R. Ganesh Babu and M. Siva Ramakrishna - (2018)** They focused mainly on the SOFTWARE part and algorithm of the irrigation system, not just hardware. They made a dedicated software program and algorithm for the microcontroller for Drip Irrigation automation. Drip irrigation is a modern method where water is given drop-by-drop directly to the roots of the plant through small pipes, which saves maximum water and prevents weed growth. Their software calculates exactly how much water in milliliters is needed for each plant based on real-time soil moisture data, soil type and crop type and controls the drip valves accordingly with precision. The paper was published in Current Microbiology journal, which means it was practically tested for real plants and also checked the microbial health of soil after automation. It is very useful for your Software Implementation, Algorithm, Flowchart and Drip Irrigation section.
- r. **Sandeep Kaur (2017)-** This is a comprehensive and detailed survey paper. The author studied and reviewed more than 30 research papers and explained in detail how Wireless Sensor Network (WSN) works in modern irrigation systems. In this WSN system, 4-5 or more soil moisture sensors are placed at different locations, depths and zones in a large agricultural field and they communicate wirelessly with the central controller via Zigbee module without any long wires. So, the controller knows exactly which part or zone of the farm is dry and which part is wet. Water is supplied only to the dry zone via solenoid valves, not to the whole farm, which saves a huge amount of water and electricity. It is excellent for large farms and commercial agriculture covering acres of land, but the main problem and research gap is battery drainage of wireless nodes which needs frequent replacement and high maintenance cost.
- s. **P. Archana and R. Priya (2016)-** This is a small, compact and simple system designed especially for home plants, balcony gardens, terrace gardens and indoor pots, not for big farms. It uses a small capacitive moisture sensor and a small 5V DC submersible pump suitable for small pots. When the soil in the flower pot becomes dry, it automatically waters the plant with a small and precise amount of water. It is very useful for people living in cities and working professionals who are away from home for 2-3 days for work or travel. The system takes care of their plants automatically like a caretaker. You can show this as a domestic, smart home and commercial application in your project to show that your project is not only for farmers but also for urban users and can be a marketable product.
- t. **R.Suresh, S.Gopinath, K.Govindaraju, N.SuthanthiraVanitha (2014) -** This is considered the base and pioneering paper for GSM based automatic irrigation in India. They used Raingun irrigation system instead of drip irrigation to cover a very large area

with one system. Raingun is like a big powerful sprinkler that throws water 50-100 meters like rain. The system has a soil moisture sensor and a GSM SIM800 module. When the soil is dry, the Raingun motor starts automatically and simultaneously sends an SMS alert to the farmer's mobile phone saying "Motor ON - Soil is Dry". When the soil becomes wet, Motor turns OFF and again sends SMS "Motor OFF - Soil is Wet". This remote alert system via SMS is very useful for large farms in Tamil Nadu and other states where farmers cannot stay in the field all day and need updates on mobile.

- u. **Pavithra D.S, M.S. Srinath - (2014)** In This System They added Android Mobile App with GSM module for better and smarter control. The farmer can not only get SMS alerts about motor ON/OFF status but can also control the motor ON/OFF from the Android app from anywhere in the world. In addition, the app also gives intelligent crop planning suggestions based on current soil moisture condition and soil type. For example, the app can suggest which crop is most suitable for the current moisture level and season. The main focus of this paper was to save two important and costly resources - water and electricity - which is critical for Indian agriculture and for reducing farmer's input cost.
- v. **Joaquin Gutierrez, Juan Francisco Villa-Medina, Alejandra Nieto-Garibay, and Miguel Angel Porta-Gandam -(2014):** This is a high-quality International Journal paper published in IEEE Transactions, one of the best in your list. They used Wireless Sensor Network (WSN) technology for large-scale precision farming. Multiple soil moisture sensors are placed in different zones of the agricultural field, all connected wirelessly via Zigbee and GPRS modules to a central server and microcontroller unit. All data from different zones is collected and stored on the server for analysis. The intelligent controller then supplies water only to the specific dry zone through automated valves, not to the whole farm, which results in maximum water saving of up to 70%. This is the most professional, scalable and research-oriented system but the initial cost is high due to multiple sensors, Zigbee modules and server setup.
- w. **Laxmishabadi, Nandini Patil, Nikita. M, Shruti. J, Smitha. P & Swati.C(2014)-**Main focus of this paper was saving both Water and Power simultaneously, which is a very practical Indian problem. They used an Android App with GSM module for monitoring and control. The system intelligently checks both soil moisture and also checks if electricity is available from the grid. If power is low or there is a power cut, which is very common in rural India, it intelligently delays the irrigation schedule until stable power comes back. This prevents motor burning due to low voltage and saves electricity. This is very important and practical for Indian villages where load-shedding and power cut is a common daily problem for 4-6 hours. It adds safety to the system.
- x. **Chaitali R. Fule and Pranjali K. Awachat (2014)-** Latest in your list for Wireless Sensor Network and one of the most cited. Real Time WSN-based irrigation system for precision agriculture. In this system, multiple soil moisture sensors placed in different parts and depths of the field send data in real time continuously to the central microcontroller via wireless communication using Zigbee. The microcontroller processes all data from all nodes and decides a smart and optimized irrigation schedule based on which zone needs how much water. They implemented it practically on a real farm and tested it for one full crop cycle. The result showed 50% water saving and 20% increase in yield compared to traditional flood irrigation. It is a proven practical model with real results.

- y. **Veena Divya & Ayush Akhouri (2013)**- In this paper, GSM technology is combined with Drip Irrigation for maximum water efficiency. In drip irrigation, water goes drop- bydrop directly to the roots of the plant through a network of pipes and emitters, so there is almost zero wastage due to evaporation or runoff. When the soil is dry, the GSM module sends an SMS to the farmer's phone "Soil is Dry, Motor Started" and when the soil becomes wet, it sends another SMS "Soil is Wet, Motor Stopped". They practically tested the system on a real farm for vegetables and found 60% water saving compared to traditional flood irrigation method. This is best for water-scarce regions like Maharashtra, Rajasthan and Gujarat where every single drop of water is important and needs to be saved.

- z. **Mansour, H.A et al. (2013)**- This is a practical agricultural field experiment paper and not just a theoretical or prototype model. They tested an Automatic Closed Circuit Raingun System on a real Yellow Corn crop in an actual farm field in Egypt. Raingun is a big sprinkler-like machine that covers a large circular area with high pressure water spray like artificial rain. The automatic system controlled the Raingun based on real-time soil moisture data from sensors. The result of this long-term experiment showed that with automatic irrigation, crop growth increased by 25%, water use efficiency increased by 30% and overall yield also increased significantly compared to manual irrigation. This paper scientifically proves with field data that automation not only saves water and labour but also increases crop production, growth and farmer's profit.

- aa. **K. Sathish kannan and G. Thilagavathi (2013)**- This is the concept of online and internet-based farming using embedded systems and Wireless Sensor Network, which was very new in 2013. All sensor data like soil moisture, temperature, humidity from different zones of the field is collected by WSN nodes and sent to a central website or web server via GPRS. The farmer can see his complete farm data live in the form of graphs and tables from any internet browser on his laptop or mobile from anywhere in the world. It was the starting point and base concept of IoT in farming in 2013, much before IoT became popular and was called "Internet of Things in Agriculture". It introduced the revolutionary idea of internet based farming and remote monitoring.

- bb. **Gautam, I., and Reddy, S. R. N. - (2012)** This Method/System is Old but very innovative and advanced for that time in 2012. They used both GSM and Bluetooth together for hybrid control. Bluetooth is used for short distance control (up to 100 meters) when the farmer is near the farm or in the field, which is free of cost, and GSM is used for long distance control when the farmer is in the city far from the farm. Embedded system means all components like controller, sensors, Bluetooth and GSM modules are integrated in one single chip or board, making the system compact, low power and low cost. It was a smart cost-saving idea.

- cc. **Purnima, S.R.N. Reddy - (2012)** Here they added Remote Monitoring feature with data logging. The farmer can not only ON/OFF the motor remotely via SMS or Bluetooth, but can also see the live soil moisture level in exact percentage on his mobile phone screen in real-time. The system automatically logs and stores all data with date and time stamp for future analysis and record keeping. It is a combination of both monitoring and controlling, which is the base of modern SCADA (Supervisory Control and Data Acquisition) systems in agriculture. It shows evolution from just control to monitoring + control.

- dd. **K.Prathyusha, M. Chaitanya Suman (2012)**- Purely focused on Drip Irrigation

Automation for precision farming and water saving. In this embedded system, the controller checks the moisture level of each individual drip line and each zone separately using multiple sensors. If one line or zone is already wet, it closes that particular solenoid valve only and supplies water only to the dry lines. This is called precision or zone-wise or selective irrigation. This saves maximum water and ensures every plant gets exactly the required amount of water, no more no less. It is the most efficient method of irrigation. Published in IJA IEM journal and is a good reference for drip automation.

- ee. K. Prema, N. S. Kumar, S. S. Dash, and S. Chowdary (2012)-** an agricultural robot that physically moves in the field on wheels. It uses a fuzzy logic controller which works like human brain thinking and decision making, not just simple ON/OFF threshold logic. Fuzzy logic can take decisions like "soil is slightly dry" or "very dry". With virtual instrumentation using LabVIEW software, the robot can be controlled online from a laptop via wireless. The robot has soil moisture sensors, camera and water tank and can move to different plants and water them as needed precisely. It is a very advanced paper for automation, robotics and AI in agriculture and is best for Future Scope.
- ff. Abhinav Rajpal, Sumit Jain, Nistha Khare and Anil Kumar Shukla (2011) -** Very basic system based on PIC microcontroller (PIC16F877A) not Arduino, because Arduino was not popular then. They made a simple automated system and proved with practical field results and yield comparison that automatic irrigation increases crop yield by 20% compared to manual irrigation. This 20% increase in yield directly increases the profit and income of the farmer. This was one of the first papers in India to scientifically link automation with profit increase and to show economic benefit to farmers.
- gg. Rajeev G Vishwakarma (2011)-** Proposed a full Wireless Solution for irrigation to solve the problem of wires in the farm. The main idea is No wires at all in the field. All soil moisture sensors are wireless sensor nodes with their own small battery or small solar panel for power. They use RF (Radio Frequency) 433 MHz communication to send data to the central controller. This reduces major problems like wire cutting by rats and animals, wire damage due to tractors and ploughing, and maintenance problems in the farm. The paper claims with implementation that this wireless method/system increases yield and profit and reduces human effort and maintenance cost significantly.
- hh. D. Baghyalakshmi et al. (2011)-** This paper is not directly about irrigation, but about temperature monitoring for a High-Performance Computing Cluster using Wireless Sensor Network (WSN). However, the concept, architecture and working of Wireless Sensor Network is explained very well in detail, including network topology like star and mesh, node communication, data aggregation and power management. The same WSN concept and architecture can be directly used for soil moisture monitoring in a large agricultural field by replacing temperature sensors with soil moisture sensors. It shows how reliable, scalable and fault-tolerant WSN technology is for large area monitoring and is a good technical reference for WSN chapter.
- ii. K. Ganesh and S. Girisha (2011)-** In this paper, the water pump is powered by renewable solar energy instead of grid electricity or diesel. During the day time, the solar panel charges a 12V battery through a solar charge controller and the battery runs the DC water pump for irrigation. The electricity bill becomes completely zero and the major problem of load-shedding and power cuts in villages is completely solved. The system works independently without any need for external power. The system is eco-friendly,

sustainable and green. Best for your Future Scope, Renewable Energy and Sustainability chapter to add solar power integration and to show zero electricity cost.

- jj. E. Pradeep, R.Ganeshmurthy, K. Sekar, and E. Arun (2011)-** PV (Photo Voltaic) solar pump automation and is an improvement and next version over the previous solar paper. It explains in detail how to increase the efficiency and power output of the PV solar panel using an automatic solar tracking system where the panel automatically rotates and tracks the sun from east to west throughout the day using LDR sensors and a motor to get maximum sunlight at all times. This dual-axis tracking increases power generation by 3040% compared to a fixed panel. Similar to previous reference but more focused on improving solar efficiency and energy optimization, which is important for running pumps.
- kk. Mahesh M. Galgalikar and Gayatri S. Deshmukh - (2010)** This paper Social Modernization and socio-economic impact through technology. Means how this automatic irrigation system will help Indian farmers not only technically but also socially and economically to improve their lifestyle. Real-time means instant action based on sensor data without delay. They used timer-based method for irrigation scheduling. They argued in the paper that automation will reduce the heavy physical labour and drudgery of farmers, save time, and will attract educated youth and next generation towards modern farming as it looks more technical, smart and profitable rather than traditional hard labour farming
- ll. V. Ahmed and S. A. Ladhake (2010)-** This paper presents a very low-cost and innovative system using a simple basic cell phone and missed call concept. The farmer just gives a missed call from his own mobile to the GSM module SIM card number connected to the motor to turn the motor ON and gives another missed call to turn it OFF. The GSM module detects the caller ID and controls the relay. In 2010, this idea was very innovative and low-cost because smartphones, Android and internet were not common in villages. The total operating cost is only the mobile recharge and one cheap GSM module. It is useful for remote control without any need for internet, WiFi or smartphone and is still practical for poor farmers
- mm. Ma Yuquan, Han Shufen, and Wang Qingzhu (2010)-** This is for advanced greenhouse, polyhouse and protected farming. It uses a master-slave distributed control architecture for large greenhouses. The master controller is the main brain and central unit which monitors temperature, humidity, light intensity and soil moisture inside the greenhouse using multiple sensors and sends commands to multiple slave nodes placed in different corners and zones of the greenhouse. Each slave node controls its own pump, fan, light or valve locally. It is a good reference for automatic environmental control in a closed greenhouse and for showing
- nn. Belgin Cakmak, I.H. Olcay Unver, Turhan Akuzum (2004) -.** It discusses a global and alarming problem that 70% of the total fresh water globally is used in agriculture alone and most of it is wasted due to inefficient flood irrigation. It explains the water scarcity problem, drought conditions and water management issues in Turkey which is very similar to the water scarcity problem in Maharashtra, India. The paper emphasizes the urgent need for efficient and automatic irrigation methods to save water. You can use this paper in your Chapter 1 - Introduction to justify why an automatic irrigation system is needed, because agriculture uses maximum water and water saving is critical for future

food security.

oo. Choukr-Allah, R. (2000) It talks about Protected Culture, meaning modern Polyhouse and Greenhouse farming technology for water saving. Although it is not directly about sensors or automation or Arduino, it gives the base knowledge of modern farming techniques and evolution of agriculture. It explains in detail how more crops can be grown with less water and less land in a controlled environment like a polyhouse with controlled temperature and humidity. Including this reference in your report shows that you studied the evolution of farming from old traditional open farming to new protected farming.

pp. M. Rosinski (1996)- This is the oldest and first paper from 1996 in your entire list of 43 papers. It is about an unattended automatic flower watering system which is purely timer based using a simple timer IC (like 555 timer). It waters the plant automatically once every 12 hours using a timer circuit, without any soil moisture sensor or microcontroller. There was no soil moisture sensor used at that time as sensors were costly. Including this paper as the last reference in your literature review shows the complete timeline and history that people have been working on the concept of automatic plant watering since 1996 for almost 30 years, and now with Arduino, IoT, GSM and sensors we have made it much more intelligent, efficient, low-cost and practical for Indian farmers.

4. CONCLUSION

After study above review paper, we concluded that, Traditional manual flood irrigation wastes 40-60% of water due to surface runoff, percolation and evaporation. The reviewed systems evolved from simple timer-based watering (1996) to Arduino UNO based single sensor systems, then to multi-sensor systems (soil moisture + DHT11 + rain sensor), GSM/SMS alert-based systems, WSN/Zigbee based zone-wise irrigation for large farms, solar powered systems for off-grid villages, RTC based time-controlled intelligent irrigation, and latest ESP32/ThingSpeak cloud based IoT and AI/ANN predictive irrigation. Automatic irrigation automatically monitors moisture level in real-time, switches the water pump ON when soil is dry and OFF when sufficient moisture is present. This reduces water wastage by 50-70%, saves 90% labour time, prevents over-watering and under-watering, reduces electricity bill, and increases crop yield by 20-30%.

Therefore, the study of previous research provides a useful base for developing our lowcost, portable and affordable Automatic Irrigation System Using Soil Moisture Sensor.

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