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AGROTECH: A Smart Agricultural System Using IOT & ML

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Abstract: *Agriculture remains one of the most important sectors that support human survival which supplies basic needs, a source of income for many dependants' community. Despite these advantages, resource scarcity, adverse environmental conditions and pest infestations remain serious threats to crop products. To mitigate these concerns, we present a smart agriculture system which uses the most modern technologies like IoT (Internet of Things) machine learning (ML) and sensors with automation. The system consists of an intelligent irrigation mechanism for efficient utilization of water, an animal detection system used to trace cattle, and a Light Dependent Resistor (LDR) Sensor joined with buzzer for early detection of any global environmental changes. Additionally, the integration of plant disease detection capabilities further enhances the system's effectiveness. By employing various sensors to collect data on environmental factors, including moisture and temperature, the proposed framework enables timely decision-making for crop management. The aim is to provide farmers with actionable insights, ensuring food security while minimizing resource consumption and economic losses. This review paper discusses the potential benefits and implementation strategies of such an intelligent agricultural system, emphasizing the need for innovation in agricultural practices to meet the growing demands of an increasing population*

Keywords: Smart Agriculture System, Animal Detection, Smart Irrigation, Plant Disease, IOT, ML, Wireless communication

I. INTRODUCTION

The ecological cycle and food chain are heavily dependent on plants. Agriculture is undergoing a transformation due to the rapid growth of technology, particularly IoT and AI, which make it possible to monitor plant health and climatic factors like temperature, humidity, and soil moisture intelligently. [1] Sustainable agriculture encourages environmentally conscious farming methods that lower greenhouse gas emissions while maintaining biodiversity, conserving water, and maintaining the integrity of the soil. The number of farmers in India is declining despite rising agricultural output because of increased expenses and low productivity. Enhancing farming productivity and promoting sustainable agriculture can be accomplished through integrating digital technology such as wireless communication. [2] With population growth predicted to reach 9.7 billion by 2050, the global agriculture market is estimated to increase from USD 1.8 billion in 2018. Farmers will gain from the convergence of IoT and AI because it will save them time, yield accurate results, and make crop management, pest control, and monitoring tasks easier. The substantial potential of IoT to transform the agriculture industry is examined in this research. [3] Integrating modern technologies such as sensors, data management, and the Internet of Things, smart farming enhances resource management and agricultural productivity. By automating procedures like agricultural monitoring and irrigation, it contributes to the solution of issues like population expansion and climate change. Farmers, however, might find the technology expensive and complicated. [4]

Water scarcity affects crop yields and food production in India's agriculture. By reducing water usage and using automation and the Internet of Things, smart irrigation systems can ensure effective irrigation based on temperature,

humidity, and soil conditions. With this strategy, data will be stored in the cloud for future use and water management will be improved. [5] Having nearly fifty percent of people working for agriculture, India's economy depends largely on agriculture. Through sensors which measure temperature, humidity, and moisture in the soil, smart agriculture using Internet of Things-based systems may precisely control water usage, reducing down on waste and increasing the production of crops. [6] In India, agriculture is a major source of income and is greatly affected by the changing seasons of water availability. Using sensors to monitor soil moisture and humidity, an Internet of Things (IoT)-based smart agriculture system increases production by automating watering and delivering real-time data on crop fields. [7]
The Internet of Things (IoT) increases automation and decision-making in agriculture by allowing physical objects to communicate and share real-time data. Though the idea behind IoT has been around for a while, recent developments have made it more useful for controlling agricultural supplies and tracking crop growth. Three layers—physical, IoT, and cooperative—are included in our suggested architecture to handle different agricultural problems, such as supply chain management and animal control. [8] Since food crops are being used more and more for biofuels and other industrial purposes, crop production is becoming more and more important for sectors like cotton, rubber, and bioenergy. This raises questions about food security. Because every agricultural field is different and has factors influencing its yield, site-specific assessments are required to ensure optimal production. Farmers need creative, technologically advanced solutions to these problems in order to maximise output while reducing resource consumption. [9] The concept of precision agriculture, which combines sensors, data systems, and expert models to increase productivity and sustainability, emerged as a result of the need for exact control of resources such as light, water, and CO2 for green plants to grow to their full potential. Novel frameworks for smart plant management are made possible by recent developments in IoT and AI, which also allow for better agricultural practice decision-making and real-time data utilisation. [10] Seventy percent of Indians depend on agriculture as their main source of income. By ensuring that the appropriate amount of water is applied at the most beneficial times, changing from manual to automated irrigation systems can increase productivity, conserve resources, and improve agricultural performance. [11]

II. LITERATURE REVIEW:

Sr. No.	Title	Author Name and Publication	Abstract	Advantages	Limitations
1.	"Smart or System Plants Using IOT & AI"	T. Shastrakar, S. Dhole, A. Patle, and Mohd. IJCRT, 2023	This paper tells us about to automate irrigation by turning the motor on or off based on the health of the plants, or sensor values. Via an android app, the farm owner may keep an eye on the procedure online.	The sy automates irrigation based on plant health and sensor data, allowing remote monitoring via an Android app, which optimizes water usage and reduces manual intervention.	However, the system depends heavily on sensor accuracy, faces scalability challenges for larger farms, and requires stable internet connectivity for effective operation
2.	"Smart Farming: Internet of Things (IoT) -	M. Dhanaraju, P. Chenniappan, K. Ramalingam, S. Pazhanivelan, and R.	This paper emphasized the role of many technologies used for farming,	The system improves farming efficiency through IoT technologies	However, it faces challenges like high initial

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	Based Sustainable Agriculture”	Kaliaperumal. Agriculture, 2022, 12,	particularly the IoT, in making agriculture smarter and more effective in meeting future requirements using sustainable IoTbased sensors and communication technologies.	and promotes sustainable practices using sensors and communication tools, making it a future-ready solution for agricultural challenges.	costs, limited adoption due to a lack of technical knowledge in rural areas, and the need for reliable internet infrastructure.
3.	“IoT based Soil Nutrition and Plant Disease Detection System for Smart Agriculture”	S. Suhag, N. Singh, S. Jadaun, P. Johri, A. Shukla, and N. Parashar, 10th IEEE International Conference on Communication Systems and Network Technologies, 2021	A smart farming system includes hardware like polyhouses, sensors, to monitor crop spacing and soil moisture. The software connects to these sensors, allowing farmers to manage irrigation and automate harvesting with robotic arms. A mobile app helps them sell crops efficiently.	The system monitors crop conditions and soil moisture, enabling precise irrigation management, automates harvesting with robotic arms, and improves crop selling efficiency through a mobile app.	It requires significant hardware investment, may involve technical complexities in integration, and depends on consistent connectivity and maintenance.
4.	"A Research Paper on Smart Agriculture using IOT."	R. Srivastava, V. Sharma, V. Jaiswal, and S. Raj International Research Journal of Engineering and Technology (IRJET), 2020	The system measure moisture of soil and level of water in fields. This system works well in the ideal conditions and further improvement can be made when the conditions are not ideal like proper illumination or lightning.	The system effectively measures soil moisture and water levels in fields, helping optimize irrigation under ideal conditions.	However, its performance may degrade under non-ideal conditions, such as poor illumination or lighting, and further improvements are necessary to enhance its reliability.

5.	"Smart Irrigation system using Internet of Things,"	A. Anitha, N. Sampath, and M. A. Jerlin, International Conference on Emerging Trends in Information Technology and Engineering. IEEE, Feb. 2020	This paper proposed an IoT based smart irrigation system utilizing sensors to record the data and store it in the cloud storage.	The system utilizes sensors to record irrigation data and stores it in cloud storage, enabling easy access and analysis for optimized irrigation management.	However, it relies on internet connectivity for cloud access, and potential data security issues may arise with cloud storage solutions. Additionally, the system's effectiveness can be influenced by sensor reliability and calibration.
6.	"Smart Farming System using IoT for Efficient Crop Growth,"	M. S. D. Abhiram, J. Kuppili, and N. A. Manga, IEEE International Students' Conference on Electrical, Electronics and Computer Science, 2020	In this paper, All the values i.e. temperature, humidity level, soil moisture level and the rain condition are sent to the smart phone using Wi-Fi. Due to this system, adequate water is pumped and rain is also utilized efficiently. This system is very much helpful to farmers as they need to regularly pump water and check the status of each crop.	The system provides realtime updates on temperature, humidity, soil moisture, and rain conditions to smartphones via Wi-Fi, enabling efficient water management and optimized irrigation.	However, it relies on Wi-Fi connectivity, which may not be consistently available in rural areas, and the system's effectiveness depends on the accuracy of the sensors used.

7.	"IoT Based Smart Agriculture Monitoring System,"	H. Pendyala, G. K. Rodda, A. Mamidi, M. Vangala, S. Bonala, and K. K. Korlapati International Journal of Scientific Engineering and Research (IJSER), July 2021	Using IoT the system can predict the soil moisture level and humidity so that the irrigation system can be monitored and controlled. IoT works in different domains of farming to improve water management, crop monitoring, soil management. This system also minimizes human efforts, simplifies techniques of farming.	The system predicts soil moisture and humidity, enabling effective monitoring and control of irrigation. It enhances water management, crop monitoring, and soil management while minimizing human effort and simplifying farming techniques.	However, the system's reliance on accurate sensor data is crucial, and any inaccuracies may affect its performance. Additionally, it may require substantial initial investment in technology and infrastructure.
8.	"Smart agriculture management system using internet of things,"	K. Sekaran, M. N. Meqdad, P. Kumar, S. Rajan, and S. Kadry, TELKOMNIKA Telecommunication, Computing, Electronics and Control, June 2020	Three layers in the architecture are connected with cloud where all the data are uploaded, processed and accessed. The Architecture proposed in this paper, could provide a base for implementation of smart agriculture system using IoT.	The proposed architecture features a three-layer system connected to the cloud, facilitating data uploading, processing, and access, which supports the implementation of a smart agriculture system using IoT.	However, this reliance on cloud connectivity raises concerns about data security and privacy, and the system may require significant infrastructure investment to be effectively implemented. Additionally, the performance is dependent on consistent internet availability

9.	"Internet-ofThings (IoT)Based Smart Agriculture: Toward Making the Fields Talk,"	M. Ayaz, M. AmmadUddin, Z. Sharif, A. Mansour, and E.-H. M. Aggoune, Special Selection On New Technologies For Smart Farming 4.0: Reasearch Challenges and Opportunities. 2019	This paper considered all these aspects and highlighted the role of various technologies, especially IoT, in order to make the agriculture smarter and more efficient to meet future expectations. For this purpose, wireless sensors, Clo computing, communication technologies are discussed thoroughly.	The paper emphasizes the role of IoT and various technologies, such as wireless sensors and cloud computing, in enhancing agricultural efficiency and preparing for future demands.	However, the integration of these technologies can be complex and may require significant investment. Additionally, there are challenges related to data management, security, and the need for skilled personnel to operate and maintain such systems.
10.	"From parallel plants to smart plants: intelligent control and management for plant growth,"	M. Kang and F.-Y. Wang, IEEE/CAA Journal of Automation Sinica, 2017	In this paper, we present the three steps toward the parallel management of plant: growth description (the crop model), prediction, and prescription. This approach can update the expert system by adding learning ability and the adaption of knowledge database according to the descriptive and	The paper outlines a threestep approach for managing plant growth—growth description, prediction, and prescription—enhancing the expert system with learning capabilities and an adaptive knowledge database for	However, the approach may require substantial computational resources and sophisticated algorithms, which could pose challenges for implementatio n in resourcelimited settings.

			predictive model.	improved plant management.	Additionally, the effectiveness of the system relies on the quality and accuracy of the crop models used.
11.	"Sensor based Automated Irrigation System with IOT: A Technical Review,"	K. Kansara, Vishal Zaveri, Shreyans Shah, Sandip Delwadkar, and K. Jani, International Journal of Computer Science and Information Technologies, 2015,	This review is proposed to supports aggressive water management for the agricultural land. Microcontroller in the system promises about increase in systems life by reducing the power consumption resulting in lower power consumption. Automated irrigation system has a huge demand and future scope too. It is time saving, led to removal of human error in adjusting available soil moisture levels.	The syste promotes efficient water management in agriculture through automation, reduces power consumption with the use of microcontrollers, and minimizes human error in soil moisture adjustments, making it time-saving and reliable.	However, the reliance on technology may pose challenges in terms of initial setup costs and maintenance. Additionally, the system's effectiveness depends on the accuracy and reliability of the sensors used for monitoring soil moisture levels. 4o mini

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12.	"IoT Smart Plant Monitoring, Watering and Security System".	U. H. D. Thinura, N. Ariyaratne, V. D. Yasaswin, L. H. D. Ranul, H. M. Sumudu, and M. Herath, ResearchGate	In this paper, work. With new solution, gardeners can monitor some important factors like the plant's healthiness, soil moisture level, air humidity level, and the surrounding temperature and water their garden from anywhere in the world at any time by using our app.	The system allows gardeners to monitor key factors such as plant health, soil moisture, air humidity, and surrounding temperature, enabling remote watering via a mobile app from anywhere at any time.	However, the system's performance relies on stable internet connectivity and sensor accuracy. Additionally, initial setup and maintenance costs may be a barrier for some users.

III. METHODOLOGY

The system includes the DHT11 temperature and humidity sensor, and a soil moisture sensor, connected to a NodeMCU (ESP32), with a relay relay switching to control the turning off and on the water pump, which has valves and solenoid pumps setup by the NodeMCU, which is being powered by 5V supply. The DHT11 sensor activates a single-bus data format that sends 32-bits of data, with a checksum, in about 4ms. Sensor data was sent to the Blynk app, which was for monitoring purposes. Irrigation and nursery mixing was automated to reuse excess water and added nutrients from high moisture readings, will be allowed to recirculate by using submersible pumps.

In order to help optimize risks to plants' health, the system continuously monitors environmental and soil conditions. The NodeMCU receives a reading from the soil moisture sensor and if it reading drops to below a preset lower threshold, it turns on the water pump through the relay, when the water is sent directly to, and right beside the roots. This approach will limit overwatering, and conserve the amount of water that is required. Similarly, the DHT11 sensor gives readings about temperature and relative humidity monitor details, which will allow the user to keep an acute awareness of climatic changes, having an impact on growth. Real-time monitoring gives access to the information through the Blynk App and many of the conditions could have manual controls being executed if required, giving advantage to both automation but, also manual functions. Another significant feature of the setup is its intelligent management of nutrients mix. The plants are also given the opportunity of the soil - if there is moisture present; the automated setup will also provide nutrients when needed.

BASIC ALGORITHM FOR SMART IRRIGATION:

1. **Initialization:**
   Setup sensor inputs and actuator outputs.
   Connect to Wi-Fi (if applicable) and server/cloud.
2. **Continuous Monitoring Loop:**
   Read sensor values (e.g., soil moisture, temperature).
3. **Decision Making:**
   If soil moisture < threshold (e.g., 40%):
   Turn water pump ON.
   Else:
   Keep water pump OFF.

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4. **Data Transmission:**
   Send current sensor readings to cloud server for logging.
   Optionally, receive commands from the server (e.g., forced manual irrigation).
5. **Power Management (if battery-powered):**
   Enter low-power sleep mode between readings.
6. **Alerts/Notifications (optional):**
   If soil stays dry even after irrigation → send alert to mobile app.

IV. MATHEMATICAL MODEL

The mathematical models in the AGROTECH system optimize agricultural processes through predictive analysis and data-driven decisions. These models focus on smart irrigation, plant health monitoring, and light optimization to enhance efficiency and productivity.

1. **Smart Irrigation Model**:
Water Requirement (W) is determined by soil moisture (M), temperature (T), and humidity (H)
Equation for it is:

$$W=k\cdot(1-M)\cdot T\cdot(1-H/100)$$

2. Plant Disease Detection (ML Optimization):
Cross-Entropy Loss function for classifying healthy vs. diseased plants:
Equation for it is:

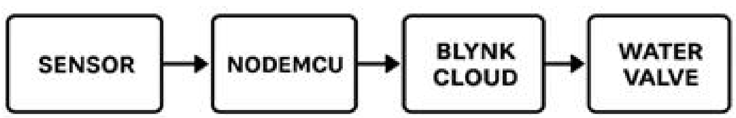
$$L = -(1/N)\ \Sigma\ [y_i \log(\hat{y}_i) + (1 - y_i) \log(1 - \hat{y}_i)], \text{ for } i=1 \text{ to } N$$

Where, y_i = True label, $\hat{y}_i$ = Predicted probability

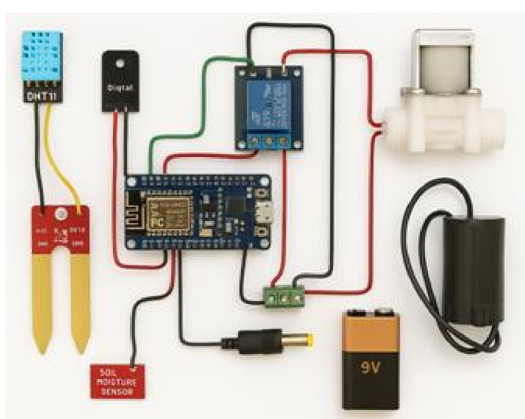
3. Light Optimization:
Adjust required artificial light (**L**) based on current sunlight intensity (**S**) and optimal PAR level (**P**):
Equation for it is**:**

$$L = \max(0, P - S)$$

BLOCK DIAGRAM:



CIRCUIT DIAGRAM:



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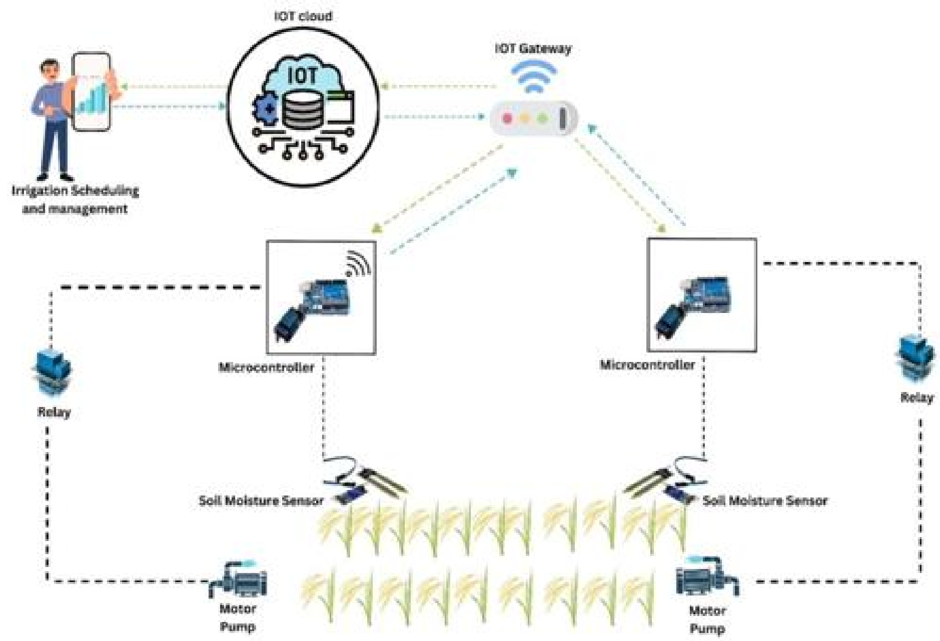
SYSTEM ARCHITECTURE:

The system architecture consists of:

- **IoT Sensors**: Sensors deployed in the field collect data on environmental parameters such as soil moisture, temperature, humidity, and light intensity.
- **Cloud Platform**: The sensor data is sent to a cloud platform where it is stored and processed. ML models analyze the data and generate insights.
- **User Application**: Farmers access the processed data and insights via mobile and web apps. They receive real-time updates and alerts about crop conditions, diseases, and resource recommendations.



OVERVIEW OF PROJECT MODULES:

The system is divided into modular components, each responsible for a specific function:

- **Sensor Module:**
  Monitors environmental conditions like soil moisture, temperature, humidity, and light intensity using DHT11, FC-28 and LDR sensors.
- **Controller Module**:
  ESP32 microcontroller reads sensor data and executes logic for irrigation.
- **Actuator Module:**
  Relay-controlled pump delivers water to the plants based on sensor data.
- **Communication Module:**
  ESP32 sends sensor data to the cloud using Wi-Fi (MQTT/HTTP).
- **Cloud/Server Module:**
  Firebase or similar platforms (MQTT) are used for data storage, analysis, and remote access.
- **Dashboard Module:**
  Mobile app (built in Flutter) displays real-time sensor data and allows manual control.
- **Power Management Module:**
  Ensures energy supply using AC power or solar panels for outdoor deployments.

TOOLS & TECHNOLOGIES USED:

HARDWARE:

- ESP32 NodeMCU
- Soil Moisture Sensor (FC-28),
- DHT11 (for temp/humidity),
- LDR (for intrusion detection)
- Relay Module,
- Water Pump,
- Solar Panel (optional)
- Battery

Fig 6.1 Arduino

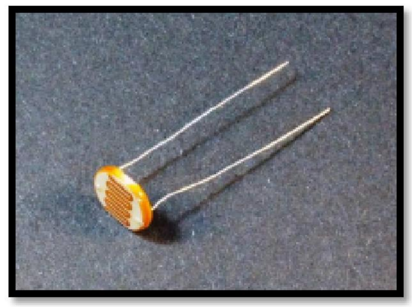


Fig 6.2 LDR Sensor

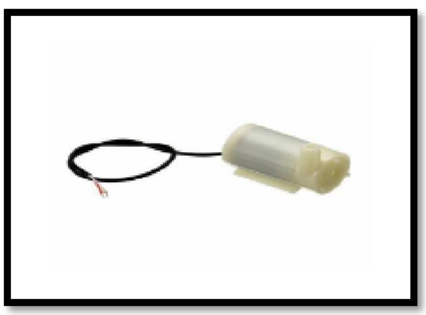


Fig 6.3 Water Motor

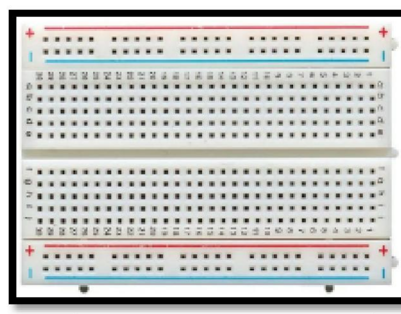


Fig 6.4 Bread board

Fig 6.5 Jumping wires

Fig 6.6 Battery

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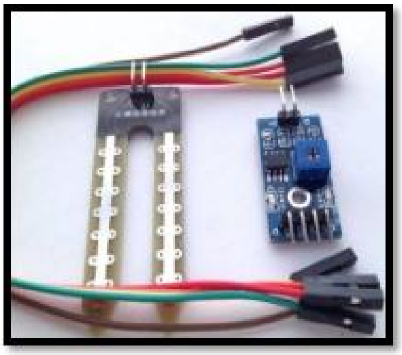

Fig 6.7 Soil Moisture and Temperature sensor

Fig 6.8 ESP32

PROGRAMMING LANGUAGES:

- C/C++ (Arduino IDE),
- Python (Raspberry Pi, if used)
- Flutter (Mobile Application development)

COMMUNICATION PROTOCOLS:

- MQTT (for lightweight IoT messaging),
- HTTP/REST API (for simple data sending),
- Wi-Fi or GSM

CLOUD PLATFORMS:

- Firebase (Real time database),
- MQTT (for lightweight IoT messaging)

MOBILE APPLICATION:

- Custom App developed with help of Flutter

DATABASE:

- Firebase Realtime Database
- MQTT

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RESULTS:

Outcomes:

Fig 8.1.1 Complete Model

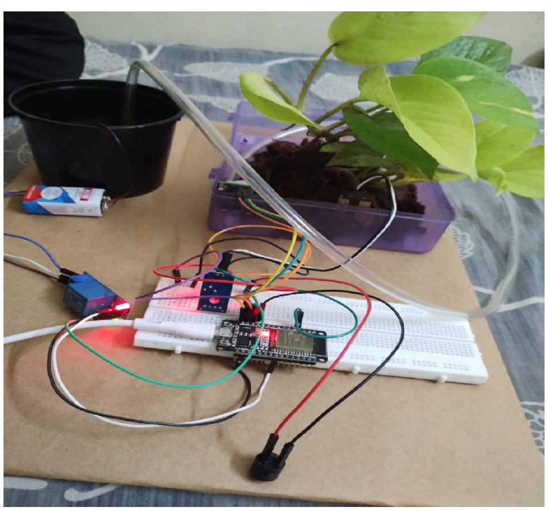

Fig 8.1.2 Complete Model

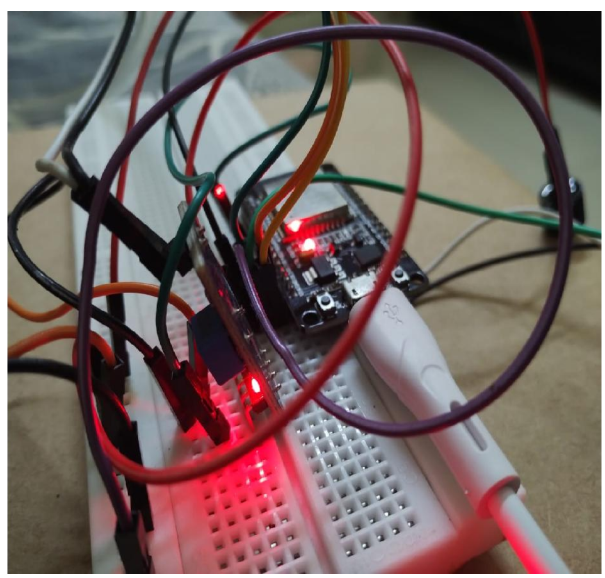

Fig 8.1.3 Bread Board & Connections

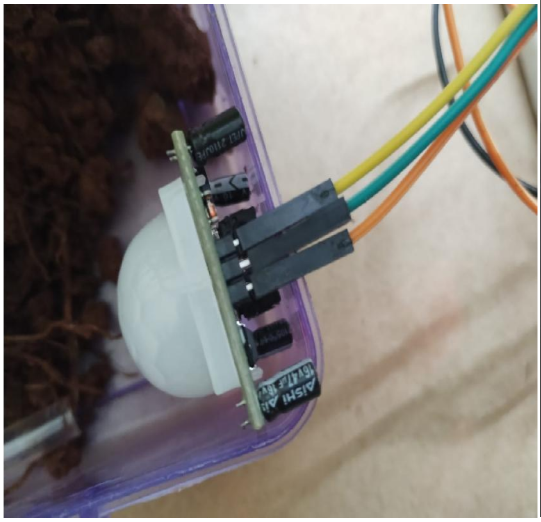

Fig 8.1.4 PIR Sensor

Fig 8.1.5 Water Pump

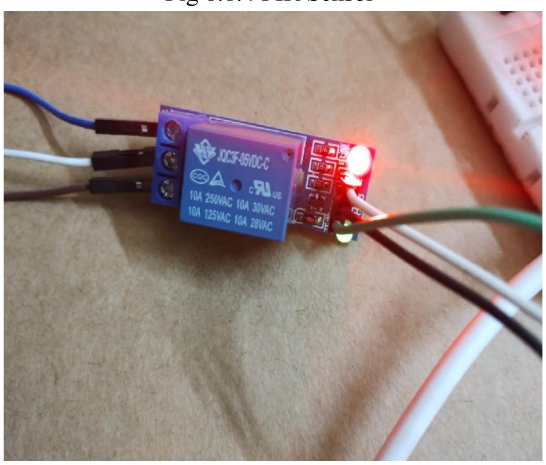

Fig 8.1.6 Relay Module

Fig 8.1.7 Soil Moisture Sensor

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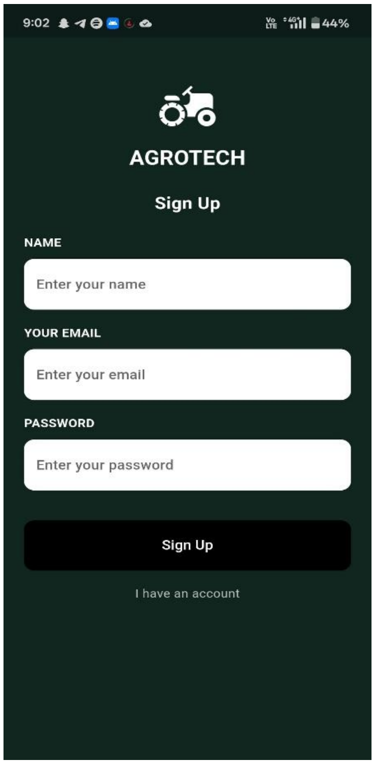

Fig 8.2.1 Sign in Page

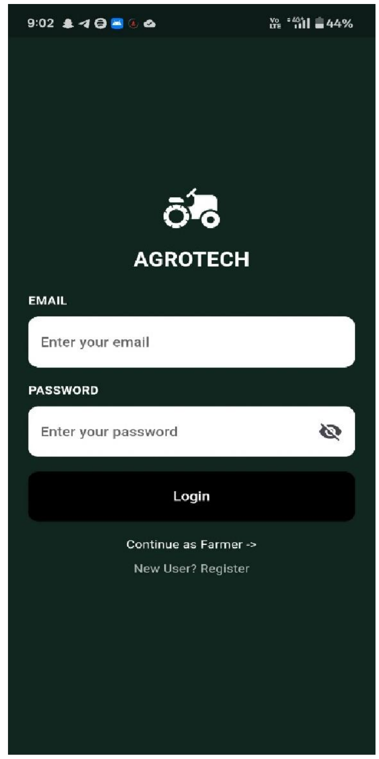

Fig 8.2.2 Login Page

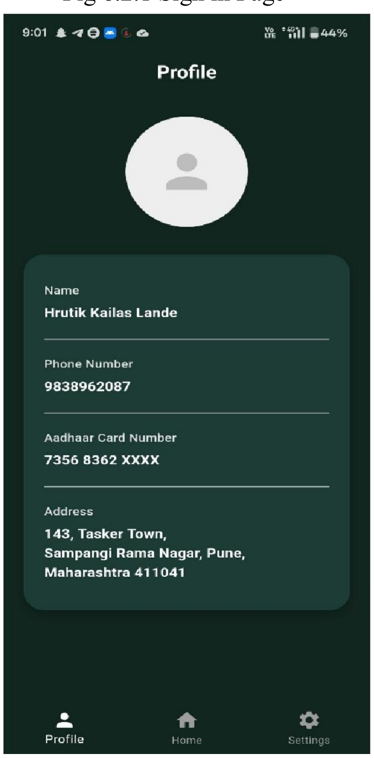

Fig 8.2.3 Profile Screen

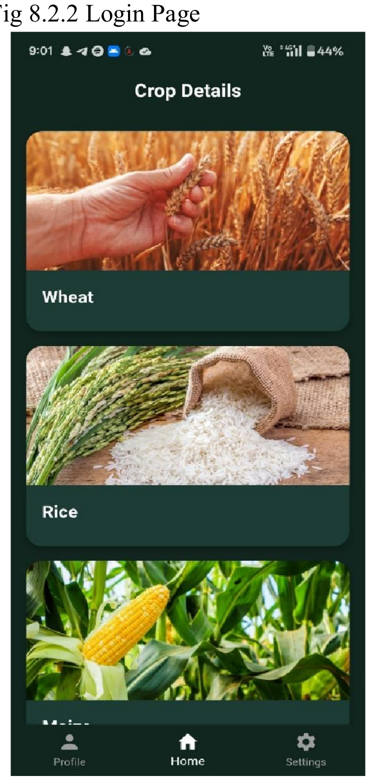

Fig 8.2.4 Home Screen

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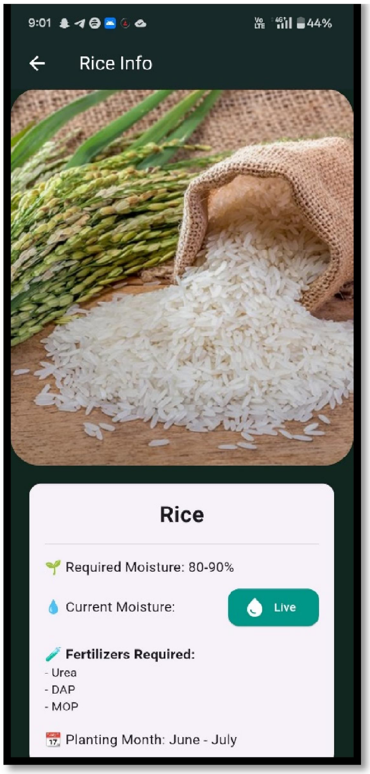

Fig 8.2.5 Crop Detail Screen

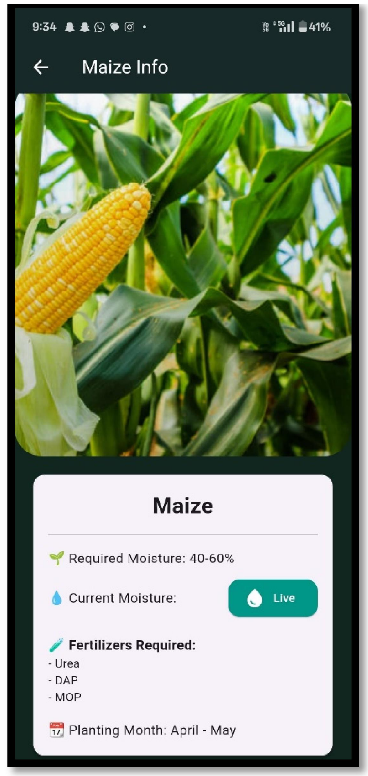

Fig 8.2.6 Crop Detail Screen

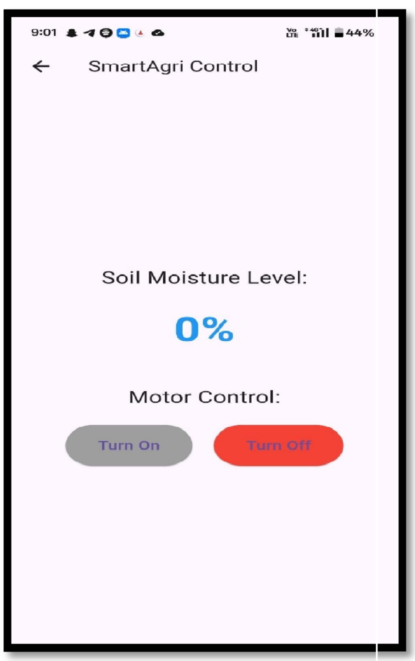

Fig 8.2.7 Soil Moisture Screen

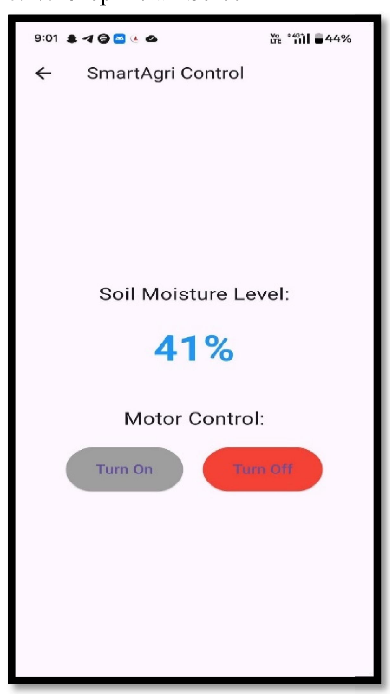

Fig 8.2.8 Soil Moisture Screen

CONCLUSION

This review highlights the potential of smart agricultural systems integrating IoT, sensors, and AI models to transform modern farming. By automating irrigation, detecting animals, and monitoring environmental conditions, these systems offer efficient, data-driven solutions for improving crop yields, resource management, and sustainability. Continued advancements in these technologies will further enhance agricultural productivity and resilience.

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