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Smart Agriculture to Restore the Vitality of the Field Using IoT Based Automatic Irrigation and Fertigation System.

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***Abstract*--** **India is predominantly an agriculture-based country, but rapid population growth combined with increasing urbanization has led to a continuous reduction in cultivable land. To meet the rising demand for food, farmers often rely heavily on fertilizers, pesticides, and fast-growth techniques, many of which are used without proper scientific knowledge. Over time, this practice has resulted in a gradual decline in soil fertility. Restoring soil health and enhancing agricultural productivity has therefore become a critical challenge. Large-scale farming systems require constant monitoring, efficient management, and informed decision-making. The Internet of Things (IoT) enables a network of interconnected devices that collect and transmit environmental and field-related data over the internet, allowing automated operations with minimal human intervention. Agriculture generates vast amounts of data that can be analyzed to improve crop yield and resource utilization. IoT-based smart farming modernizes agricultural practices through advanced information and communication technologies. Key parameters such as temperature, humidity, soil moisture, mineral content, electrical conductivity (EC), and other environmental factors can be monitored for better crop management. This review highlights these parameters and their role in data-driven analysis to support farmers in making informed decisions using IoT technologies. The adoption of IoT in agriculture not only increases crop productivity but also reduces labor costs, saves time, optimizes water usage, and helps protect crops from threats such as animals, birds, and fire [1].**

***Keywords*--Arduino, Crops, Fire detection, IoT Sensors, Moisture Sensor, Smart Fertigation, Smart Irrigation.**

I. Introduction

India is agriculture-based country. It has a long and rich history that beginning during the Indus valley civilization and developing even earlier in some regions of southern India [2]. At present, India holds the second position globally in terms of agricultural production. Although the contribution of agriculture to India's Gross Domestic Product (GDP) has gradually declined due to overall economic diversification, it remains the largest source of livelihood and continues to play a vital role in the country's socio-economic structure [2].

In 2013, India exported agricultural goods worth approximately $38 billion, as a result India ranks seventh globally in agriculture exports and sixth in net exports, with the bulk of these goods supplied to developing countries, while a smaller portion reaches developed nations. Indian agricultural produce and processed food items are supplied to over 120 countries worldwide.

Despite living in an era where automation enables precise control and operation across many sectors, agriculture in India has yet to fully adopt such advanced technologies[2]. Automated farming systems allow continuous monitoring and control of critical environmental parameters such as temperature and humidity, which directly and indirectly influence crop growth and yield. India is also facing serious challenges related to excessive groundwater usage, including aquifer depletion, declining water tables, and rising irrigation costs. If appropriate corrective measures are not implemented, these issues are expected to intensify and spread further in the coming years [3]. The present research emphasizes the need for an internet-connected system using a NodeMCU Wi-Fi module that can collect, display, and transmit real-time agricultural data, enabling farmers to monitor their fields remotely through IoT technology.

With the global population projected to grow rapidly in the coming decades, agricultural systems must evolve to produce more food while minimizing environmental impact. Smart farming addresses this challenge by integrating advanced technologies such as IoT, automation, and data-driven algorithms, particularly to improve water management efficiency [3]. Indian agriculture is largely dependent on monsoon rainfall, which is often unreliable and insufficient. Automated irrigation systems can supply water based on real-time soil moisture and temperature levels, ensuring optimal water usage. Additionally, excessive and improper use of fertilizers has led to soil degradation; automated fertigation systems help regulate fertilizer application and reduce wastage. Fire detection systems enhance crop safety, while animal and bird intrusion detection mechanisms help protect farms from damage.

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Powered by solar energy and supported by IoT technology, these automated solutions transform traditional farming into a smart and digital agricultural system.

II. Literature Review

Smart Automated Farming System using IoT and SolarEnergy. Anita Shukla, Ankit Jain, and Pranveer Singh [2]. Proposed a smart automated farming solution to address several critical challenges in agriculture, such as regulating humidity and temperature, ensuring adequate water and light availability for sensitive crops, detecting intrusions, and providing fire alerts. Their system offers a practical hardware-based approach that improves efficiency and reliability in the Indian farming context. The proposed solution is designed to be eco-friendly, cost-effective, and easy for farmers to use, making it suitable for widespread adoption.

Internet connectivity is achieved using a Node MCU Wi-Fi module which supports real-Time monitoring and remote access to farm data through IoT technology worldwide. [2] The main functionalities of the system include automatic activation of a water pump when soil moisture falls below a predefined threshold, with live data available online. Light intensity levels are continuously monitored, and artificial lighting is automatically switched on when illumination drops below the required limit, which is particularly beneficial for high-value crops. Humidity levels are tracked in real time, and water spray motors are automatically controlled if humidity exceeds set limits. Temperature monitoring ensures that cooling fans are activated when temperatures rise beyond acceptable levels, while updated readings are shared online. Additionally, the system provides security by triggering alarms and sending alerts during fire incidents or unauthorized entry by animals or humans. To ensure uninterrupted operation, solar panels are integrated as a backup power source, and all sensor data along with microcontroller decisions are displayed on a real-time monitoring interface.[2]

Solar-Powered Automated Fertigation System (I-SIRAMA. Samsudin et al. [3]. Introduced the Solar-Powered Automated Fertigation System (I-SIRAM), an IoT-based digital farming solution aimed at promoting precision agriculture. In India, digital agriculture—also referred to as smart farming or e-agriculture—represents a significant step toward modernizing the agricultural sector by incorporating advanced technologies associated with Industry 4.0. IoT has played a major role in transitioning agriculture from manual and conventional practices to intelligent and data-driven farming systems [3].

I-SIRAM is powered by solar energy and monitored through mobile applications, allowing farmers to precisely control fertilizer injection and irrigation processes. The system is built using an Arduino UNO microcontroller, along with pumps, motors, and various sensors that manage the mixing of fertilizer A, fertilizer B, and water in controlled proportions. By automating fertigation, the system helps prevent excessive use of water and fertilizers while maintaining optimal electrical conductivity (EC) and pH levels. This approach significantly reduces labor requirements and improves operational efficiency, as manual irrigation and fertigation scheduling typically demand high manpower[3]

Smart Agriculture Using IoT for Automated Irrigation and Resource Efficiency. Subir Gupta et al. [4]. Presented an IoT-based smart agriculture system designed to enhance irrigation efficiency while conserving water and energy. The proposed framework integrates IoT technologies, predictive algorithms, and automated control mechanisms to optimize irrigation practices. An Arduino-based microcontroller collects data from all soil moisture, humidity and temperature sensors to automatically control irrigation according to current environmental readings [4].

Farmers are able to monitor and manage irrigation schedules remotely using mobile devices, providing improved accuracy and ease of operation. The system analyzes real-time sensor data alongside historical records to calculate precise irrigation needs, ensuring that water is delivered only when required. Field evaluations revealed nearly a 30% decrease in water usage compared to conventional irrigation techniques, while ensuring soil moisture remains at an optimal level. It's adaptability to changing climatic conditions makes it especially suitable for arid and semi-arid regions. Initially, data transmission was implemented using the ESP8266 Wi-Fi module due to its low cost and ease of integration with cloud services. The system also supports alternative communication technologies such as NB-IoT, LoRaWAN, and 4G/5G cellular networks for enhanced scalability and reliability [4].

To address challenges such as limited or unreliable internet connectivity in rural agricultural areas where network infrastructure is often unavailable, several alternative IoT-based solutions have been proposed that rely on GSM or localized communication technologies.

IoT-Based Crop Protection System Against Birds and Wild Animal AttacksP. Navaneetha et al. [5]. Developed an IoT-based crop protection system aimed at minimizing crop damage caused by animals such as cows, buffaloes, goats, and birds.

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These animal intrusions frequently result in significant financial losses for farmers, and continuous manual surveillance of farmland is impractical. The proposed system automates crop protection by detecting animal movement and issuing timely alerts. It employs sensors such as Passive Infrared (PIR) and ultrasonic sensors to identify the presence of animals and transmit signals to a controller. Upon detection, the system generates specific sound signals to scare away animals and immediately sends alert notifications to farmers and forest officials. Communication is achieved using GSM technology, making the system effective even in areas without internet connectivity [5].

Agriculture Monitoring and Prediction Using IoT. Mohit Kumar Saini and Rakesh Kumar Saini [6]. Presented an IoT-based agricultural monitoring and prediction system designed to enhance irrigation efficiency in Indian farming practices. The system continuously monitors key environmental parameters, including soil moisture, temperature, humidity, rainfall, and water levels. Sensors such as DHT11, soil moisture sensors, and rain sensors are used for data collection, while an Arduino ATmega328 microcontroller serves as the processing unit due to its low cost and ease of programming through the Arduino IDE. The system supports crop evaluation for both Rabi and Kharif seasons by analyzing real-time sensor data. By reducing manual intervention and simplifying farming operations, the proposed solution promotes smart farming while saving time, labor, and costs. Additionally, it helps farmers access agricultural markets more efficiently through digital integration [6].

Automation and Monitoring in Farming Aboli Dhote et al[7]. Proposed an automated and solar-powered farming system to address the increasing demand for food caused by rapid population growth. The system replaces conventional farming methods with IoT-based automation to improve productivity and efficiency. It incorporates multiple sensors, including soil moisture probes, water level sensors, motion detectors, and temperature and humidity sensors. The collected data enables intelligent control of farming operations, reducing physical effort and operational expenses for farmers. GSM technology is used to allow remote monitoring and control of farm parameters, enabling farmers to manage agricultural activities from any location [7].

Internet of Things–Enabled Smart Agriculture: Current Status and Advancements. NavedNiranjan Thilakarathne et al. [8] reviewed the role of IoT-enabled smart agriculture in modern farming systems.

Agriculture continues to be a key driver of economic development in many countries, and the integration of IoT technologies in the 21st century has significantly transformed traditional farming practices. Smart agriculture combines IoT with cloud computing, artificial intelligence, and big data analytics to improve crop yield, reduce resource wastage, and support automated decision-making. Governments worldwide are increasingly promoting smart agriculture through funding and incentives. The study highlights the impact of COVID-19 on accelerating technological adoption in agriculture and provides insights into system components, advanced practices, application areas, and future research trends in smart farming [8].

Recent Technological Enhancements in the SHYPROM IoT-Based Soil Monitoring System. Alessandro Comegna et al [9]. Introduced technological upgrades to the SHYPROM (Soil HydraulicProperties Meter) system, an IoT-based solution for monitoring soil water dynamics. Efficient water resource management is critical for sustainable agriculture, environmental protection, and climate resilience. SHYPROM is designed to estimate key soil parameters such as soil moisture (θ), matric potential (h), and hydraulic conductivity (K) at variousdepths of soil. The system combines sensors like matric potential and capacitive soil moisture with wireless modules to provide continuous, high-resolution data to a cloud-based processing platform. A major enhancement includes upgrading the capacitive sensor's oscillator frequency from 600 kHz to 60 MHz, significantly improving measurement accuracy and system performance [9].

The upgraded SHYPROM system demonstrated strong robustness in estimating soil moisture (θ). Experimental results indicate that the proposed system can predict θ values with high accuracy. To further improve system performance, evaporation experiments were conducted, through which $\theta(h)$ and $K(\theta)$ relationships were successfully established for different soil types. These findings confirm the reliability of the enhanced SHYPROM system in soil water characterization and agricultural water management [9].

IoT-Based Smart Farming System. Manasa Sandeep et al [10]. Proposed an IoT-based smart farming solution built on a wireless sensor network framework to enable automated irrigation and rooftop farming management. The system monitors essential environmental parameters such as temperature, humidity, rainfall, and soil moisture using multiple sensors. Soil moisture levels are maintained using a threshold-based algorithm, where irrigation is automatically activated when moisture drops below a predefined value and turned off once sufficient moisture is restored.

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The soil moisture sensor operates by detecting impedance variations between two electrodes embedded in the soil. An Arduino Uno microcontroller is used to process sensor data, analyze analog inputs, and control actuators accordingly. The collected information is transmitted to an Android application via a Bluetooth module, allowing farmers to continuously monitor field conditions and system status in real time [10].

Precision Farming with IoT: Soil Nutrient Analysis and Fertilization Recommendation System. Ritu Raj Sandiya et al[11]. Presented an IoT-driven precision farming system focused on soil nutrient analysis and intelligent fertilizer recommendation. The system leverages IoT sensors to continuously monitor soil health parameters, including pH level, nutrient concentration, and moisture content. Using advanced data analytics and machine learning techniques, the system provides accurate fertilizer recommendations, enabling farmers to make informed decisions and optimize fertilizer usage. This approach not only improves crop yield but also minimizes environmental impact by preventing excessive chemical application. The successful implementation of this system highlights the potential of integrating IoT technologies with machine learning models to achieve sustainable and efficient agricultural practices [11].

Smart IoT-Driven Precision Agriculture: Land Mapping, Crop Prediction, and Irrigation. Gourab Saha et al[12]. Developed an IoT-based precision agriculture framework that integrates land evaluation, crop selection, and irrigation management. The system leverages machine learning, fuzzy logic, and agriculture mapping to analyze soil parameters and recommend optimal crops and fertilizer requirements. An IoT-enabled sensor network collects soil data, which is processed using machine learning algorithms for accurate crop prediction, achieving an accuracy of 97.35%. A solar-powered, fuzzy logic–based irrigation controller dynamically regulates water supply according to crop needs. Prediction of crop yield is performed using Linear Regression model with accuracy of 93.49% and Random Forest model with accuracy of 95.87% based on Root Mean Squared Error evaluation. Additionally, an LSTM-based model identifies healthy vegetation zones, helping determine land suitability for farming and supporting informed agricultural planning [12]

III. Conclusion

This review presents an overview of various IoT-enabled smart agriculture systems that utilize sensors to collect soil and environmental data, including soil moisture, soil temperature, and atmospheric conditions, to automate irrigation and fertigation processes. The adoption of IoT-based smart farming solutions significantly enhances agricultural productivity by increasing crop yield, reducing labor costs, minimizing water wastage, and preventing excessive fertilizer use. Moreover, smart agriculture plays a crucial role in restoring soil health and maintaining field vitality through data-driven and automated decision-making, ultimately promoting sustainable agricultural practices.

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