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Smart Agriculture for Renewable energy Integration Using Cloud and Big Data Analysis

[1]G. Shaheen Firdous, [2]Dr. M. SriRaghavendra,[3]Ms. N. Vasavi, [4]Ms.Reshma Dudekula, [5]Ms.K. Rekha, [6]Ms.M. Mohsina Kousar

[1]sr.meeniga@gmail.com, [2]shaheencse@recw.ac.in, [3]vasavi@ashokacollege.in,
[4]reshma@ashokacollege.in, [5]kamarthirekha@ashokacollege.in, [6]mkousar003@gmail.com

[1] Assistant professor Department of CSE, Ravindra college of Engineering for Women, Kurnool,

[2] Associate Professor Department of CSE (DS), RGM College of Engineering and Technology (Autonomous)

[3] Assistant Professor Department of CSE (AI), Ashoka Women's Engineering College,

[4] Assistant Professor Department of CSE, Ashoka Women's Engineering College,

[5] Assistant Professor Department of CSE, Ashoka Women's Engineering College,

[6] Assistant Professor Department of CSE, Ashoka Women's Engineering College.

ARTICLE INFO	ABSTRACT
	Smart agriculture, often known as precision farming, is a fast-expanding multidisciplinary topic that combines expertise from agriculture, technology, data science, and environmental research. As the population grows and food demand rises, sustainable agriculture requires efficient use of water and energy resources. An integrated and cost-effective Smart Agriculture solution. Small and medium farmers struggle to accept commercial solutions due to their high cost. Renewable Energy Consolidation helps for Advance energy cost-effective agriculture by reducing reliance on fossil fuels for water table pumping. The proposed solution revolves around the cloud as it is crucial in smart farming as it stores key characteristics that are compared to field data. Wireless sensors linked to the cloud collect data from the ground. Machine learning algorithms study the data in real time. This analysis helps farmers understand the status of their crops. Big data provides complete information on rainfall patterns, water cycles, and fertilizer levels. Farmers can use this content to make informed conclusion about crop selection, soil fertility, and harvest regulation. Smart farming uses IoT, cloud computing, and big data analysis to optimize agricultural yields. This helps in enhancing sensors to be more affordable and versatile in data collection, along with advancing computer capabilities for better data analysis and predictions. **Keywords:** Cloud computing, Smart Agriculture, Machine learing, Bigdata, Wireless sensors.

I.   INTRODUCTION

As Water is becoming scarce. Unmonitored control and the use of fossil fuels in water table pumping for irrigation contribute to world warming while also damaging the ecosystem. Water is the foundation and primary motor of life on Globe. Human race utilize water for commercial enterprise reasons, sanitation, and irrigation. In recent decennium, yearly water withdrawals have fluctuated from 11 to 15 billion cubic meters, with agriculture accounting for 69% [1]. Inadequate irrigation control systems lead to significant water waste. Morocco, like many other dry and sub-Saharan countries, relies heavily on agriculture for fresh water use. The Green Plan program, implemented in April 2008, has further increased consumption. This initiative promotes agriculture as an efficient industry that can advance the economic system, combat impoverishment, and sustain many citizenries.

Agricultural regions can be managed efficiently and sustainably. The government supported farmers and capitalist in irrigation area through various facilities and initiatives, ensuring sufficient food for local intake and export development. Nevertheless, Smart Agribusiness penetration in few areas remains limited. Investors in irrigated agricultural projects have raised concerns about groundwater depletion and the need for cost-efficient real data aggregation in provision systems to benefit from advanced technologies. For sustainable, cost-efficient, and smart agribusiness in sub-Saharan Africa, a cost-effective and property data collecting instrumentation is required. The

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instrumentation should utilize inexhaustible energy and cutting-edge ICT to sustain the aridity of agricultural environments. A well-managed data collecting system can enhance agricultural output and crop quality. This technology differs from typical irrigated agriculture, which relies on subterranean water reservoirs and fossil fuels (particularly gas) for energy. Smart agriculture (SA) uses current management methods to reduce water consumption and switch to renewable energy sources, making the agricultural sector more environmentally friendly. The paper introduces an integrated and cost-efficient Smart Agriculture results. The conceptualization from a The Cyber-Natural Scheme (CNS) view shows that probable result depends on four primary IC Techniqs. A Wireless Sensors Networks (WSN) track plant environmental conditions in real-time which includes weather patterns and soil status.2. The Wireless Actuators Network (WAN) controls electrical devices like water pumps and light bulbs. The electrical systems of water pumps and light bulbs operate through wireless commands. The platform uses cloud-based storage and processing capabilities for real-time IoT data management and visualization; The Fuzzy Logic Control module establishes observations durations for irrigation processes based on the real-time noninheritable variations among expected and close soil wet. The open-source computer software system handles information collection along with propulsion and control tasks. It helps in building cost-efficient sensors devices and mechanism using off-the-shelf inexpensive nano Arduinos. Eventually, it mechanical phenomenon an active costless Cloud oriented IoT platform, like NodeRED.

The three primary development modes of SA (facility, precision, and order agriculture) are covered, including significant technology, applications, and security measures. The security challenges linked with SA are addressed through the lens of information technology and agricultural productivity. It discusses the problems and potential of SA in terms of environmental sustainability, economic viability, social acceptability, and technological breakthroughs such as AI, cloud computing, big data analytics, blockchain, and IoT. It provides an overview of upcoming agricultural IoT technologies, such as unmanned aerial vehicles, cloud/fog computing, software defined networking, open-source IoT platforms, wireless technologies, and middleware platforms. Research gaps and future directions. Drones and robotics are now widely used to automate farming activities and improve precision. The transition from traditional farming to technology-driven operations has significant benefits for efficiency, sustainability, and productivity. SA is continuously incorporating advanced technologies to optimize farming processes. Emerging approaches attempt to improve farming systems to meet global food demand while reducing environmental impact. Figure 1 depicts an overview of SA.

- Learn the way the open-source software program and cloud engineering to store and handle wireless sensor data are used. The cost-efficient wireless sensors and mechanism integrate with off-the-shelf physical parts in a real time scenario.
- By Integration inexhaustible energy with Advanced farming enables acceptation of the application in off-grid places such as dry and deccan regions.

The order of the paper is organized as follows. background information in Section 2 presents, while an overview of relevant studies covered in Section 3. Section 4 describes the overall system architecture and design. In Section 5 results and discussion is provided. In Section 6, conclusion is mentioned.

II.   LITERATURE SURVEY`

It is the strategic use of data, cutting-edge technologies, and real-time information in agricultural management to boost crop yields, minimize waste, and enhance efficiency. GPS technology, satellite images, and sensors are crucial for collecting detailed data on crop health, weather patterns, and soil conditions. Data is analyzed using machine learning and analytics algorithms to gain valuable insights. Automated machinery and robotic systems are used for precise tasks such as planting, harvesting, monitoring, and maintenance. The primary goal is to tailor inputs such as water, fertilizers, and pesticides to each field section's specific needs, reducing waste and optimizing resource utilization. PA promotes sustainable resource management while increasing productivity. Adopting PA methods can help farmers address climate change, unpredictable soil conditions, and increased food production in a more sustainable manner.

A. SMART AGRICULTURE AS A CYBER-NATURAL SYSTEM

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In recent years, rapid technical breakthroughs in the Internet of Things (IoT), Wireless Sensor Networks (WSN), and Embedded Systems have enabled the development of new systems and Applications that have drastically changed our life. CNSs, including Smart Agriculture, are among the most powerful modern systems. CNS refers to systems that ideally mix software and hardware components to execute specific functions. A formal description states: "A cyber-physical system is described as revolutionary technologies for managing interconnected systems between its natural possession and computational capableness. Figure 1 displays the Natural architecture, which uses integrated computing, wireless sensors, and actuator framework to monitoring device and control the natural environment.
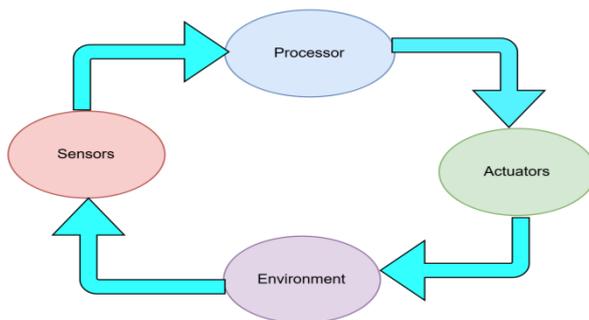
PhysiFigure 1: Architecture of the Physical system

METHODS

And allow it to adjust to fresh circonstance in real time using natural process loops. CNS's capacity to harvester and integrate several technologies has made it a critical scientific revolution, bringing invention to various industries by replacing outdated methods in many applications with new and modern ones. Smart agriculture is among the most promising CNS. applications for enhancing human living. SA can save a lot of body of water and energy due of its potential to monitoring device a variety of renewable sources, such as provision and solar systems.
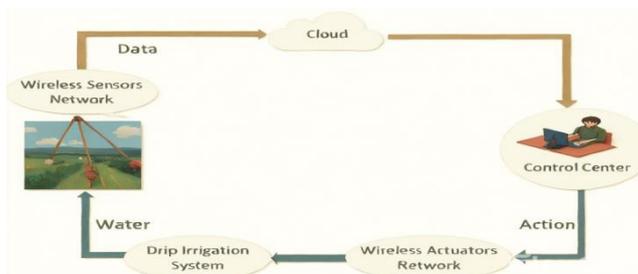

Figure 2: components used in the smart agriculture

Since the CPS, it has changed from the traditional agricultural scheme to an advanced and contemporary one that provides close agricultural administration by obtaining and analyzing plant, soil, and weather data in real-time and utilizing fine control mechanisms. Figure 2 depicts the interaction of SA's primary components as a closed-loop control CPS. The figure depicts the field, the control center, the Wireless Sensors and Actuators Network (WSAN), and the drip watering system.

B. INTERNET OF THINGS(IoT)

As the rapid increase of ICT, the time period has left the conception of the internet far behind, giving way to a fresh concept: the Internet of Things. various organizations working globally have established various definitions of the Internet of Things. ITU-T (International Telecommunication Union Telecommunication Standardization Sector) defines IoT as "a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving, interoperable information and communication technologies." [1] defines the Internet of Things (IoT) as a technology that uses the internet and existing resources to control devices.

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C. SMART AGRICULTURE APPLICATIONS USES IoT

The Internet of items and linked items changed the daily activitiess in every aspect, from smart Television to automated cars: these new tools simplify all of the activities while significantly boosting the comfort zones. Major studies indicate that the latent of linking goods is enormous. For better understanding, Phenomenon Business Organization Perception estimates that the worldwide IoT market will be valued $1,84.76 trillion by 2038. It is predicted to expand at a Compound Annual Growths Rate (CAGSR) of 29.4% between 2021 and 2028 [2]. IoT has a wide variety of uses. The most popular IoT applications for agricultural are examined further.

D) SMART IRRIGATION ANAGEMENT

The present irrigation technologies are quite advanced, relying on watering at particular times with minimal human interaction. However, it requires a significant amount of guessing andit might be quite uneconomical with respect to energy and water used. Even with modern irrigation systems, certain field areas remain under or overirrigated. Furthermore, while farmers normally switch off irrigation systems when it is predicted to rain, they may not always check the weather to properly adjust their plans. The modern-day irrigation administration system may take all the account by utlizing exactness farmings techniques. IoT based sensors track humidity, soil moisture, fundamental measure across the land. It also distributes its optimum measure of water as needed to create optimal circumstances for the plant to produce a good yielding without much wastage of water and energy.

E) BIG DATA ANALYTICS PLATFORMSUSING CLOUD

Function nodes enable JavaScript code execution on messages delivered through them. In this project, It aquiline up input, output, and physical process nodes to construct the necessary flows for data pretreatment, physical process, storing, operating the waters pumping and illumination system, and issuing alarms. The implemented Node-Red flowing construction of the irrigation system control is shown. Reference [3] discusses the current breakthroughs in IoT and sensor technology for agricultural, along with their various applications. The principal uses are crop disease detection, irrigation monitoring, fertilizer administration, processing, logistics, forecasting, harvesting, climate monitoring, and fire safety. It provides sensors for detecting plant ailments, animals, water level, temperature, humidity, light, electrical conductivity, CO_2, moisture, nitrate, pH, and flexible wearables. Debnath and Saha [4] suggest a novel method for SA that combines machine learning and IoT networks. This study is the first to employ Convolutional Neural Networks (CNN) to detect brown-spot sickness in rice paddies at an early stage. In this project, Deep Learning replaces traditional techniques. It uses real-time data for preprocessing and picture recognition. A specialized image-processing tool improves data pre-processing and feature extraction processes.

III.   RESEARCH PURPOSE

Smart Agriculture (SA) has been the topic of substantial research, with various studies investigating novel technology and approaches for improving farming practices. In [5], researchers presented a complete analysis of SA systems from a big data perspective, with the goal of integrating modern big data processing techniques into agriculture. Their research highlighted how modern Information and Communication Technology (ICT) may be fully leveraged by combining data sources such as satellite imaging, weather data, and soil sensors. They also recounted the growth of agricultural systems over time, emphasizing how SA may fully utilize technology by combining real-time data analytics, predictive modeling, and automation. The authors D. Glaroudis et al[6], conducted a thorough survey of messaging protocols commonly used in IoT applications, analyzing and comparing six key protocols: Advanced Message Queuing Protocol (AMQP), Message Queuing Telemetry Transport (MQTT), Constrained Application Protocol (CoAP), XMPP (Extensible Messaging and Presence Protocol), WebSocket, and Data Distribution Service (DDS). The performance comparison focused on critical metrics such as output, bandwidth efficiency, power utlization, latency, security and dependability. As authors also addressed difficulties raised by SA applications, including as scalability, interoperability, and energy efficiency, and offered practical solutions for implementing these protocols in real-world agricultural scenarios. The significance of IoT and Wireless Sensor Networks (WSN) in precision agriculture was highlighted in [7]. The authors created a low-cost monitoring, control, and decision-making system that dramatically increased resource efficiency and agricultural yields. By deploying low-cost sensors and actuators, the system allowed farmers to monitor environmental

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conditions in real time, optimize irrigation schedules, and save waste. The findings revealed significant gains in both resource usage and overall agricultural productivity. Another novel solution was described in [8], in which a low-cost watering system with wireless sensors was built to boost cotton yield. These sensors accurately monitored soil water tension, allowing for exact irrigation scheduling.

By guarantee that crops received the proper measure of water at the proper time, the system enhanced yield quality while simultaneously reducing water waste, making it an environmentally sustainable option. In [09], researchers used small, low-cost WSN nodes to increase potato production through field monitoring. They developed a mathematical model for irrigation management that increased crop quality even under adverse climatic conditions like drought or severe temperatures. The study found that smart technology can improve irrigation efficiency by up to 10%, highlighting their potential for agricultural resilience. The authors of [10] emphasized the essential need of monitoring environmental variables to increase agricultural output. They built a smart system with Arduino-based sensors to monitoring deviceto check soil moisture, temperature, humidity, and animal activity in the land. They also created an Android mobile application that enabled farmers to schedule irrigation, view real-time data, and receive notifications in the event of anomalies. This farmer-friendly technology enabled users to make informed decisions and react rapidly to changing circumstances. [11] described an Internet of Things-based system for monitoring nitrate levels in groundwater without human intervention. This system used Wireless Sensor Networks (WSN) with Wi-Fi and LoRa for data exchange, demonstrating its scalability and adaptability for widespread adoption by farmers. The consequence showed that the prototypel is both aspirant and feasible, providing a dependable method for monitoring water quality and preventing contamination.

In [12], researchers conducted an experimental evaluation of solar-powered IoT devices with three distinct communication technologies: ZigBee, LoRaWAN, and Wi-Fi. Their studies revealed that LoRaWAN is the foremost result for agricultural monitoring in terms of networks longevity and coverage area. The study gave useful information for picking the best technology for specific agricultural needs, particularly in distant or off-grid areas. The study in [13] described Smart Agriculture as the incorporation of current ICT into farming methods, demonstrating practical IoT hardware and software solutions customized to agricultural applications. [14] offered a realistic approach for sustainable irrigation in hyper-arid locations, combining fuzzy logic with WSN to save considerable quantities of water and physical phenomenon through efficient agriculture control.

The system's capacity to adapt to changing environmental conditions made it extremely efficient at conserving resources while maintaining crop health. To promote environmental sustainability, the authors of [15] formulated a method that uses real-time data to most correctly calculate irrigation demands, resulting in water savings of 28% to 39%. The results differed depending on whether the system merely employed temperature sensors or also took humidity and soil moisture into account. This flexibility allowed farmers to tailor the system to their specific needs and available resources. Like Industry 4.0, 'Agris-Foods 4.0' was presented in [16]. It is encouraged by the conception of 'Agriculture 4.0' and strives for improve agricultural supply chain performance through efficient and creative approaches.

A contemporary irrigation execution that uses Wireless Sensor and Actuator Networks (WSAN) to conserve resources. This mesh network is made up of nodes that function as both sensors and actuators, monitoring soil moisture, temperature, and humidity while managing drip irrigation valves. The consequence demonstrated that Agrinex offers a likely start for WSAN utilizations in agriculture, providing a scalable and effective resource management system. A GSM-based advanced irrigation system was described [17]. Environmental data was communicated using GSM technology, including soil moisture, field temperature, solar power levels, and water pump status.

IV.   SYSTEM DESIGN AND ARCHITECTURE

The projected architecture provides the design of smart grid and farming as shown in the figure.3 as shown below.It consitsof 7 processes
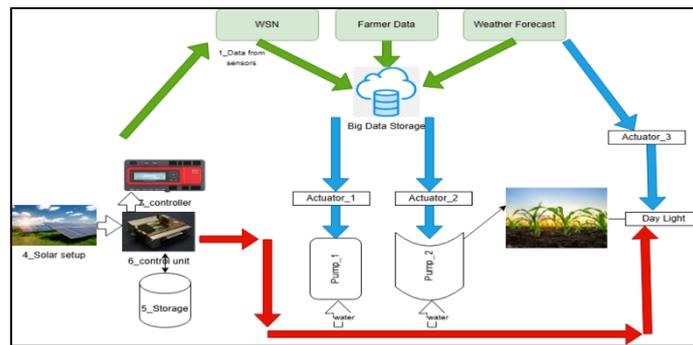
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Figure 3: projected architecture of smart agriculture with grid and farming

1) Acquisition of Data: TheWSN collects and transmits environmental data to a gateway [18]. 2) The Big Data Analytics Platform (BDAP) is the unit in charge of data storage, visualization, and processing. In addition, this platform manages the farm's drip irrigation and lighting. It installed this component on a Raspberry Pi using Node Red. 3) Wireless Actuators Networks (WANs): Actuators switch on and off water pumps and lighting bulbs based on BDAP choices.4) The Renewable Energy: The solar panels serve as the farm's renewable energy source and storage. 5) Storingdevice: Stores excess solar energy and reuses it to power water pumping and lights, which contains a lithium's battery. 6) The Controlling Unit selects to send the generated electric power to the Smart Farmimg or stores it in battery for further use. 7) ControllerCluster: Collects and filters smart grid data before transfering to cloud oriented IoT platform in real-time [19]. The system addresses the increasing demand for water by controlling pumps, integrating renewable energy, and encouraging water efficiency through drip irrigation.

a)   **DATA ACQUISTION**

It is the combined of wireless sensors and mechanism, uses a sensing element node and combined of 3 atmospheric conditions:

1. Sensors models include a soil moisture sensor, a temperature and humidity sensor (DHT11), a PIR sensor for motion detection, a fire sensor for fire detection, an Ultrasonic HC-SR04 sensor for water level, and an AC sensor for pump power utilization.

2. Microcontrollers: This study utilized an Arduino Nano board to connect all parts. 3. Communication module: It transmits data among sensor device and the BDAPs. It helps in using a Zigbee modules (Xbee series 2 S2C).

To prepare for power outages during periods of low sunlight, all connection is equipped with IoT solar method consisting of a 30W solar panel, a 25Ah battery, and a charger. The WSNs data collecting system is useful for irrigation because to its ability to be deployed anywhere without requiring power. The energy collecting system provides up to 6 days of independence for each sensors node.

b) **BIG DATA ANALYSIS PLATFORM.**

The suggested solution is built around the Big Data Analytics Platform (BDAP). The created BDAP is built on Node-RED and tested locally on a Raspberry Pi 3 board running Raspbian. In addition, we added Eclipse-Mosquitto, a message broker that supports the IoT publish-subscribe messaging protocol (MQTT). The following are the BDAP's key functionalities.

c) **DATA ACQUATION AND SAVING IN REAL-TIME**

 The BDAPS acquires real time information through the 3 sources.

1. The Digi Mesh sensor network is scattered through the field, collecting and delivering information to a gateway. The inf ormati0n is sent to the BDAP's via the USB's.

2. Wireless sensing and actuation nodes are installed in groundwater sources and basins. The ESP8266 module connects them to Wi-Fi and enables communication. The Open Weather Map online forecasting service provides up to a 5-day forecast for temperature, humidity, wind speed, pressure, and precipitation.

Debnath and Saha [20] suggest a novel method for SA that combines machine learning and IoT networks. This study is the first to employ Convolutional Neural Networks (CNN) to detect brown-spot sickness in rice paddies at an early stage. In this project, Deep Learning replaces traditional techniques. It uses real-time data for preprocessing and picture recognition. A specialized image-processing tool improves data pre-processing and feature extraction processes.

To provide farmers with access to this technology, a companion smartphone application has been built. Sarpal et al. [21] highlight the challenges that agriculture suffers due to limited infrastructure and resources, particularly for low-yield crops. The report proposes an innovative Internet of Things-based solution to address these concerns. This paper introduces a sensor-based irrigation system for real-time observation and data physical process in the cloud. The data is then integrated into an Android application, providing farmers with an easy-to-use interface. Farmers can use the app to manually manage their fields and set watering timers. Additionally, a machine learning algorithm predicts ideal crops based on changing weather conditions. The scheme includes a classified gateway that allows farmers and customers to buy and sell directly, eliminating the need for middlemen. This project introduces the use of a locally mounted LCD panel and keypad in farmers' homes for crop forecasting, monitoring, and control of agricultural equipment. The proposed framework aims to boost agricultural productivity, improve farmers' living standards, and promote national economic growth while remaining user-friendly and energy-efficient. The using a CNN-based image compression approach at the Edge layer to send data from several sensor nodes inside the gateway's range in a single message. Advanced compression algorithms reduce data size by up to 67% while maintaining a low decompression error rate of 5%. This innovative approach optimizes IoT data management. Figure 4 depicts the mechanism in question. Avcsar and Mowla [22] provide comprehensive coverage of five wireless communication technologies used in six SA applications. They highlight four barriers to SA adoption, notably in cellular communications.

The flow of the algorithm used for the smart Agriculture is as follows: Algorithm for crop yielding and accuracy

```
Start
{
Declare
model, X_data acquation from sensors
data_analysis (based on the standared information)
Comparing the accuracy (with data acquation),
X_ crop_prediction,
test_data_accuracy
Call model. predict(X_data) and store it in
X_train_prediction
Call accuracy_indication (X_data_prediction,
Y_train) and store it acutator
crop_training_data_accuracy
crop_training_data_accuracy<-"{:.2c}".
format(data_training_data_accuracy*100)
provide Accuracy on yielding data
}
End
```

The key challenges that need to be addressed are 1) cost, which is primarily dictated by hardware and maintenance, 2) system security, 3) communication quality, and 4) optimal system design.

The authors predict that communication efficacy and quality will have a significant impact on future SA application

trends. Mowla et al. reviewed recent studies on the role of wireless sensor networks and the Internet of Things in SA applications.AI and machine learning are transforming South Africa by empowering farmers to make better decisions and increase yield. AI and ML algorithms in SA systems utilize large amounts of data from sensors, drones, and other IoT devices [23]. AI systems in precision farming analyze historical and current data to predict agricultural output, improve irrigation schedules, and detect potential pest or disease outbreaks [24]. Machine learning algorithms can detect patterns in crop pictures to help farmers assess plant health and identify stressors [25].

V.   RESULTS

In July 2020, the settled WSN was used to capture real-time data remotely for five days. Temperature Soil moisture, cultivation duration, levelof the water, solar panel energy generation, and the power intake of waterpumps were all measured. And key information discrepancies are displayed. The graph shows temperature and soil moisture variations, with daytime temperatures reaching 40Centegrade and nighttime temperatures ranging from 15 to 20 Centegrade In contrast to traditional irrigation systems this system maintains soil moisture levels between 57% and 65%, which are closer to the targeted 60%.

In traditional irrigation systems, soil moisture levels range from 0% to 100%. Traditional irrigation systems can measure soil moisture in real time within 5 days. The strategy involves cultivating the field for two to three hours each day. The output highlights the following drawbacks.

Implementation of smart agriculture in practice. When soil moisture levels drop, the FICU calculates the appropriate irrigation duration and activates the wireless actuations connected to waterpumps.

High temperatures lead to longer irrigation durations. Increasing irrigation times reduces evapotranspiration losses, ensuring consistent soil moisture levels. Improved plant conditions lead to higher quality and quantity of yields. Monitoring and adjusting the water level in the basin is essential for managing the drip irrigation system. In this experiment, we continually track basin water, which varies with irrigation times calculated by the FICU. Waterpump#1 is turned off when the water level surpasses the given commencement. Otherwise, it turns on until the basin is completely filled. The results align with the previously reported water level control using a water pump with a flow rate of 260 L/hour in our experiment. Id lasted 189 minutes and used 686 liters. This rate is similar to 147.2 Ls/days consumed over the same 28 m2 area. the smart agricultural technology provides an average of 54 m3/hectors every day. The usage of electrical pumps reduces water consumption and energy intake by 4.55 times compared to traditional irrigation systems. Therefore, we conclude that standard irrigation systems are unsuccessful in maintaining soil moisture at required levels. Additionally, it wastes water and energy resources. It exhibits the real-time power intake of waterpump using an AC sensor and the energy production of solar panes using a smart energy meter over a five-day period. Solar energy can be integrated into smart agriculture without the need for large storage systems (batteries).

Table1. Price per unit of various components.

S.No	Component	Price per Unit
1	Solar Panel(20W) with battery(25Ah)	80
2	Wireless Sensor Node	60
3	Raspberry Pi	50
4	Smart Relay	15
5	ZigBee Gateway (sink node)	40

The proposed prototype is designed to be cost-effective and often adopted for smaller and medium farms. Table 1 shows the unit prices for each component. In which includes a RaspberryPi, sixty wireless sensor nodes, 80 IoT

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solar panels and batteries, two smart relays, and a Zigbees gateways. This is significantly lower than the cost of competing market options.

The proposed SA system is a promising approach for

- Improving production quality and quantity,

- Consuming less energy and water.

- Cost-effectiveness Open-source

- Environmentally friendly
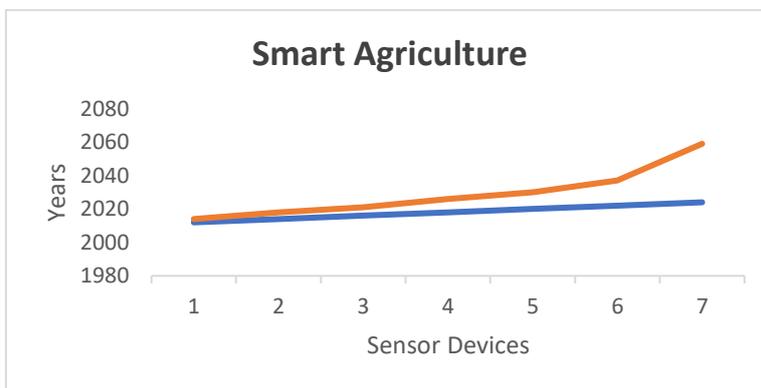
- Simple monitoring Designed to facilitate scaling

Figure 4: projected architecture of smart agriculture with grid and farming

In figure4 it shows the number of sensore devieces used in the smart agriculture from past years from 2010 to 2024 which helped in improving the yielding of the crops.
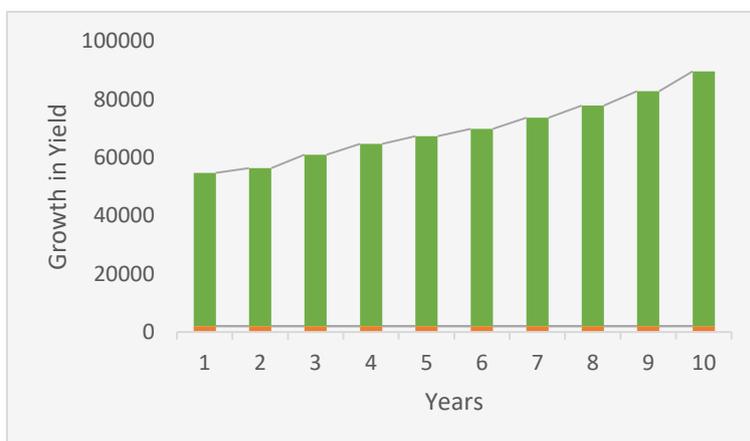

Figure 5: projected increase of the yield using smart agriculture

VI.   CONCLUSION

This study presents an open-source, user-friendly smart agriculture system that prioritizes expenditure effectuality, water utlization improvement, and renewable power integration. Since installed SA system takes advantage of cutting-edge ICT. The used IoT devices for data collecting and control, including sensors and actuators. We also utilized Cloud Computing for data processing, visualization, and storage. We used fuzzy logic to create a control unit that uses real-time data to determine the optimal irrigation duration. This strategy optimizes crop yield by conserving water and energy while also providing optimal plant conditions. This approach improves water level monitoring and aligns with sustainable agriculture principles by relying solely on solar energy. The proposed method is cost effective and can reduce water/energy use by 79.7%, making it a promising alternative to traditional

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irrigation systems, according to case study data. Cutting-edge technologies, such as sensors and drones for real-time monitoring of soil, weather, and crop conditions, AI and machine learning for predictive analytics, disease detection, and yield prediction, and blockchain for supply chain transparency and traceability, significantly improve smart farming practices. Farmers can therefore utilize resources and make good decisions as a result.In the future.

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