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Original Article

Towards Sustainable Farming in Somalia: Integrating IoT for Improved Resource Management

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***Abstract** - This research paper presents an IoT-based greenhouse monitoring and controlling system designed to enhance agricultural practices in Somalia. Somalia's economy relies heavily on agriculture, making it vital to address challenges and improve productivity. The proposed method employs a network of sensors and actuators, led by the Arduino Uno microcontroller, to monitor and optimize critical environmental parameters such as temperature, humidity, soil moisture, and light intensity within greenhouses. The system automates irrigation, lighting, and cooling through real-time data collection and analysis, reducing human intervention while promoting resource efficiency. The system's remote monitoring capabilities empower farmers to make informed decisions from anywhere, ensuring optimal greenhouse conditions. The system's adaptability to varying climate conditions in Somalia renders it a versatile tool for enhancing crop growth and productivity. Results demonstrate that the IoT-based system has the potential to revolutionize greenhouse farming, contributing to improved food security and economic development in Somalia.*

***Keywords** - Greenhouse, Internet of Things, Arduino Uno, Agriculture, Sensors.*

1. Introduction

Somalia's economy is heavily dependent on agriculture, which accounts for about 60% of the country's GDP and employs approximately 70% of the population [1]. Agriculture is essential for Somalia's economic growth and poverty reduction [2]. Crops and livestock production positively correlate with Somali exports, indicating that increased agricultural productivity can lead to increased exports and economic growth [3]. The opportunities for the Somali agriculture sector include increased income generation, higher employment levels, poverty reduction, improved food security, and development opportunities for all Somalis [4]. However, the country's agricultural sector faces many challenges, including droughts, floods, pests, and conflicts [5].

Farmers in Somalia face challenges in accessing quality seeds, fertilizers, and agricultural machinery. Additionally, a lack of government extension services and veterinary support limits farmers' ability to improve their farming practices and address livestock health issues [6]. Limited infrastructure, including roads, irrigation systems, and storage facilities, hampers the development of the agriculture sector. Poor infrastructure makes it difficult for farmers to transport their produce to markets and store their harvest effectively [7]. Somalia is highly vulnerable to climate change, with recurrent droughts affecting agricultural productivity.

Deficiencies lead to water scarcity, livestock deaths, and crop failures, exacerbating food insecurity and poverty [8]. Farming practices in Somalia are often constrained by a lack of technical skills and knowledge [9]. There is a need for improved training, capacity-building programs, and technology solutions to enhance farmers' skills and promote sustainable agricultural practices [10].

Greenhouses have revolutionized agriculture, boosting productivity compared to traditional methods. These controlled environments allow precise climate control, extending growing seasons and enabling year-round cultivation [11]. Protection from pests and diseases reduces reliance on pesticides and enhances crop health [12].

Water use can be optimized through controlled irrigation, and nutrient management is fine-tuned for better growth and quality [13]. Greenhouses often yield higher outputs per unit area while conserving land. They also diversify crop options, enhance quality control, and support local food production, reducing carbon emissions from transportation [14]. Greenhouse farming has become essential for combating drought and climate risks in Somalia. The introduction of greenhouse farming to drought-ridden areas of Somalia has allowed people to benefit from an alternative source of food production [15]. Greenhouse farming is promising in Somalia and aims to produce better crops [16]. Farmers in Mogadishu have switched to greenhouse technologies to boost sustainable food production, reduce water consumption, and protect their crops from drought [17]. Early in the 1990s, Somalia's central government fell apart, harming farming as exports of agricultural products and extension services ceased. Local farmers have adapted contemporary food production techniques to battle famine and malnutrition [18].

Technological advancements have significantly impacted the agricultural sector, increasing productivity, efficiency, and sustainability [19, 20]. These technologies have enabled farmers to monitor and manage their crops more effectively, optimize resource usage, and improve overall yields [21]. IoT in greenhouse monitoring and controlling systems offers numerous advantages over traditional methods [22]. By providing real-time data on environmental conditions, IoT can enable farmers to make informed decisions about when to water, fertilize, and harvest crops [23, 24]. Additionally, IoT can be used to automate specific tasks, such as adjusting temperature and humidity levels, reducing the need for manual intervention and improving efficiency [25, 26]. In Somalia, where access to resources and infrastructure can be limited, IoT in greenhouse monitoring and control systems can be particularly beneficial [27]. By leveraging existing mobile networks and low-cost sensors, IoT can provide a cost-effective and scalable solution to enhance agricultural productivity and sustainability. Moreover, IoT can enable remote monitoring and control of greenhouse systems, allowing farmers to manage their crops from anywhere at any time [28].

The next-generation greenhouse design practices must address various issues, ranging from energy and land use efficiency to providing plant-optimized growth techniques. Efforts toward automating these environments have been carried out by applying different technologies, including IoT and cloud computing [29]. Keeping that in mind, we propose a method for monitoring and controlling greenhouse systems in Somalia involving Internet of Things (IoT) technologies. The proposed IoT method is an interconnection of physical devices, sensors, and software, enabling them to collect and exchange data over the Internet. IoT can collect real-time data on key environmental parameters in greenhouse monitoring and control systems, such as temperature, humidity, and light levels. This data can then be analyzed to make informed decisions about optimizing crop growth conditions to activate the actuators.

2. Related Work

Greenhouse monitoring systems are designed to collect and analyze data related to the environment inside a greenhouse to optimize crop growth and yield [30]. Researchers around the world are actively investigating greenhouse monitoring and control systems. In the context of our project, we have reviewed related works in this area. The following studies and projects provide valuable insights and knowledge that can guide and support developing our greenhouse monitoring and controlling system.

Tian et al. proposed an agricultural greenhouse environmental monitoring system that uses an ARM processor and Linux operating system to collect and transmit temperature and humidity data in real time; they used a series of sensors. The system also operates related electromechanical equipment and uses a cloud platform for data collection and distribution [31].

Subhapriya and Santhosh proposed a greenhouse monitoring system. Their work presents a structure that can automatically accumulate information related to nursery climate and yield status and control the framework, considering the assembled data. Using different sensors and a microcontroller, the system monitors other parameters such as light, temperature, humidity, and soil moisture. A closed-loop system executes control action to change temperature, humidity, light power, and soil moisture if undesirable errors occur [32].

Hou and Wang propose a system based on GPRS and a single-chip microcomputer that collects greenhouse-related parameters data using digital temperature sensors, humidity sensors, and carbon dioxide concentration sensors. The data is then sent to farmers' mobile phones and remote expert systems for analysis [33].

Ruiz et al. present that an IoT system and edge computing can monitor crop conditions by gathering data on variables relevant to crop weather conditions. IoT protocols and procedures transmit the data to the server for processing before being forwarded to the user. Remote users can engage with the system and get particular notifications and situations [34].

The research gap addressed by our study is particularly pronounced in the context of Somalia's agricultural landscape. Despite the growing importance of greenhouse agriculture in the region for crop cultivation and food security, a notable void exists regarding technological monitoring and control systems for greenhouses. Unlike some more technologically advanced agricultural areas, where greenhouse automation and remote monitoring are increasingly prevalent, Somalia's greenhouses often lack such advanced technologies. This lack of technological infrastructure leaves greenhouse operators in Somalia heavily reliant on manual methods, which can be labour-intensive, inefficient, and less responsive to the dynamic environmental conditions within greenhouses. Our research seeks to bridge this significant technological gap by introducing an innovative approach to the Internet of Things for greenhouse monitoring and controlling, tailored to the unique needs of

Somalia's agricultural sector. By doing so, we aim to revolutionize greenhouse management practices in the region, improving crop yields, resource efficiency, and overall agricultural sustainability.

3. Methods

In this study, we propose and build an Internet of Things-based greenhouse monitoring and controlling system. The proposed system consists of sensors and actuators that monitor the greenhouse environment and act upon the data from the greenhouse to make controlled decisions. The sensors in the greenhouse measure the environmental parameters important for plant growth, such as temperature, humidity, soil moisture, and light intensity. The sensors collect data regularly and transmit it to a central server. The server stores the data and analyzes it to identify any problems with the greenhouse environment. Then, the server sends commands to the actuators in the greenhouse to control the setting.

If the temperature is high, the server commands a fan to turn on, and if the soil moisture is low, the system turns on the water pump to maintain the required moisture for the crops without human involvement. The farmers can remotely monitor the system. It allows them to check the greenhouse conditions from anywhere in the world and make informed decisions to increase crop productivity. Figure 1 shows the proposed system architecture.

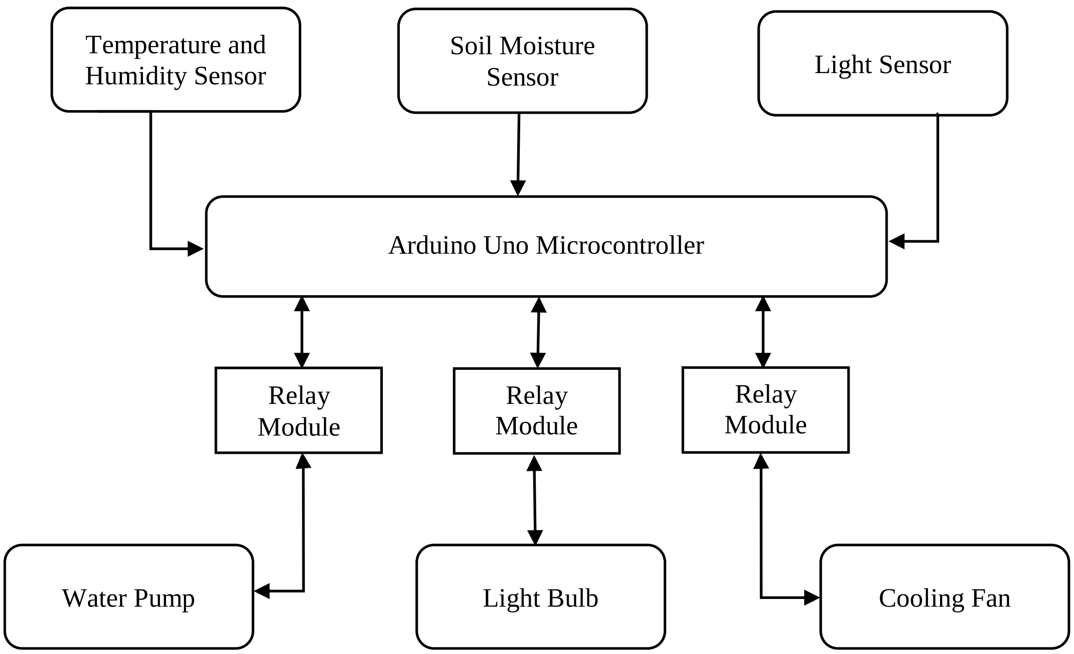

Fig. 1 Proposed system architecture

The proposed system comprises several essential components, each serving a distinct function. These components include the Arduino Uno microcontroller, temperature sensor, humidity sensor, soil moisture sensor, light sensor, water pump, bulb, cooling fan, relay module, and GSM/GPRS Module. Below, we will discuss these components and their specific roles in the system.

3.1. Arduino Uno

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P Microcontroller (MCU). It has 14 digital input/output pins (6 can be used as PWM outputs), six analogue inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. This microcontroller is selected for this greenhouse monitoring and controlling system to connect all the sensors and actuators and to preprocess the data collected by those sensors.

3.2. Temperature and Humidity Sensor

The DHT11 is a digital temperature and humidity sensor. It is a low-cost, easy-to-use sensor that can be used with various microcontrollers, including Arduino. The DHT11 uses a capacitive humidity sensor and a thermistor to measure the surrounding air and spits a digital signal on the data pin. DHT11 was selected for this project to monitor the greenhouse's humidity and temperature. Then, the data read by this will be communicated with the Arduino Uno board.

3.3. Soil Moisture Sensor

The HiLetgo Soil Moisture Sensor Module is a simple, easy-to-use sensor that measures soil moisture level. The sensor is a capacitive sensor, which means that it measures the dielectric constant of soil. The soil's dielectric constant measures how well the earth can store electrical charge. The dielectric consistently increases as the ground becomes more moist. This sensor will monitor the moisture in the greenhouse, and the data will be communicated to the Arduino Uno for further processing.

3.4. Light Sensor

The light sensor is an analogue component that measures ambient light intensity. It uses a photoresistor to change its resistance based on light levels. It consists of a semiconductor material whose resistance decreases as the intensity of light increases. The sensor's resistance increases significantly when exposed to darkness or low light [35]. This sensor is selected for this project to detect light changes and share the data back to the microcontroller.

3.5. Relay

The relay acts as a switch that lets Arduino Uno control high-power devices like motors and appliances. It ensures safety by isolating low and high-voltage circuits [36]. This project uses this relay module to control the water pump, Light bulb, and cooling. It is between the board and these devices by switching on/off based on instructions received from the board.

3.6. Water Pump

The water pump on Arduino Uno is controlled using a relay module, which acts as an electronic switch. By connecting the relay module to the Arduino board, specific digital output pins can control the pump's power supply [37]. Depending on the soil's moisture, the water pump will turn on/off.

3.7. Light Bulb

The Arduino light bulb control system allows you to use an Arduino microcontroller to switch a light bulb on or off using a relay module. It Prioritizes safety and ensures proper electrical connections when working on a project [38]. This light bulb is used to control the light intensity of the greenhouse depending on the output from the light sensor and the crop requirement.

3.8. Cooling Fan

A cooling fan for Arduino Uno is a fan that dissipates heat to prevent overheating during resource-intensive tasks or when using power-hungry components with the Arduino Uno microcontroller. It is connected to the Arduino's 5V or 12V pin for power and can be controlled programmatically using a transistor/MOSFET [39]. In this project, we integrated a temperature sensor to automatically activate the fan based on predefined temperature thresholds based on the crop requirement, ensuring optimal cooling and stable operation of the greenhouse.

3.9. GSM/GPRS Module

SIM800L is a GSM/GPRS module designed by SIMCom Wireless Solutions. It operates on 2G GSM and GPRS networks, allowing voice calls, SMS communication, and internet data connectivity. With quad-band support, it works globally and communicates via a serial interface using AT commands. The module requires a standard SIM card, operates on 3.4V to 4.4V D.C., and includes GPIO pins for external interfacing. It is commonly used in embedded systems and IoT projects for mobile communication and primary internet access [40]. This module is selected as a communication protocol.

The GPRS functionality of this system will transfer the data collected by the sensors to the central server and the commands sent back to the microcontroller. The GSM part of this module sends an SMS Message to the farmer to give updated information about the greenhouse.

4. Results and Discussion

This research paper presents the successful implementation of an Internet of Things (IoT) based greenhouse monitoring and controlling system for agricultural applications in Somalia.

The proposed method was designed to continuously monitor critical environmental parameters essential for plant growth, including temperature, humidity, soil moisture, and light intensity. Through a network of sensors and actuators, the system collected data from the greenhouse and utilized it to make informed decisions, optimizing the greenhouse environment for crop productivity. The central microcontroller, Arduino Uno, played a pivotal role in seamlessly integrating and managing all sensors and actuators. It efficiently processed data and made decisions to maintain an optimal environment for crop growth.

The temperature and humidity sensors continuously monitored the greenhouse's internal conditions, providing valuable insights into temperature and humidity. The soil moisture sensor ensured that crops received the appropriate irrigation, as the water pump was automated based on soil moisture readings. The light sensor controlled the light bulb's output to deliver the required illumination for different crop growth stages.

The cooling fan, integrated with a temperature sensor, is automatically activated to prevent overheating, maintaining a stable environment. The GSM/GPRS Module facilitated communication with a central server. It enabled remote monitoring, allowing farmers to access real-time greenhouse conditions and make informed decisions from anywhere using the mobile application.

The system demonstrated increased crop productivity, resource efficiency, remote monitoring capabilities, and adaptability to regional climate conditions. The IoT-based greenhouse monitoring and controlling system shows great potential for transforming agriculture in Somalia, contributing to improved food security and economic growth. Figure 2 shows the mobile application interface for the greenhouse monitoring and Controlling system. Implementing the IoT-based greenhouse monitoring and controlling system has shown promising results for agricultural practices in Somalia. The system's continuous monitoring of temperature, humidity, soil moisture, and light intensity contributes to optimal environmental conditions for plant growth, leading to increased crop productivity.

Automating critical processes such as irrigation and lighting reduces the need for human intervention, thereby enhancing resource efficiency and minimizing labour requirements. The water pump's automation ensures that crops receive an appropriate water supply, preventing overwatering and underwatering, which can negatively impact crop health.

The remote monitoring feature offers farmers the flexibility to manage greenhouse conditions and make informed decisions from anywhere, providing them with real-time insights into the state of their crops. This accessibility is particularly valuable for farmers with multiple greenhouses, as it streamlines the management and optimization of resources across different locations. The system's adaptability to regional climate conditions allows it to be tailored to suit the specific requirements of crops grown in Somalia's diverse geographical regions. This adaptability ensures that the system can be effectively utilized across various agricultural contexts, promoting sustainable and efficient crop production.

Distinguishing our approach from existing greenhouse monitoring and control methodologies is the core premise of our research. In contrast to prior studies that predominantly concentrate on data collection and environmental parameter monitoring, our proposed Internet of Things (IoT) based greenhouse monitoring and controlling system extends its functionality by amassing data and actively intervening to optimize the greenhouse environment. Our system can autonomously respond to fluctuating conditions by employing sensors and actuators with a central server for real-time data analysis. This significantly differs from earlier works focusing on data acquisition without immediate, on-the-ground corrective actions.

Furthermore, our approach emphasizes remote monitoring and control by integrating a mobile application, allowing farmers to access and manage greenhouse conditions remotely, regardless of geographic location. The synergy of data-driven control and remote accessibility positions our solution as a comprehensive, responsive, and user-friendly framework for greenhouse management, ultimately poised to enhance crop productivity and sustainability. Our contribution is bridging the gap between data collection and actionable control, thereby advancing greenhouse technology.

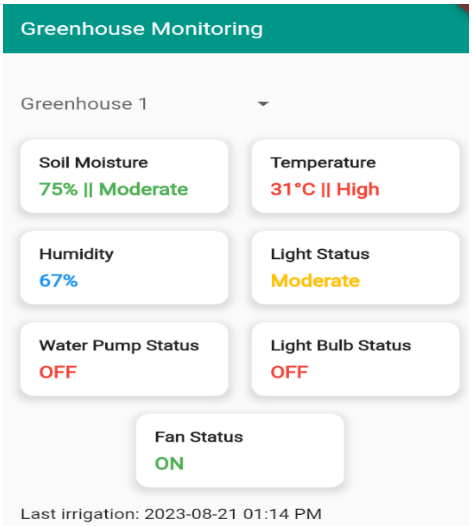

Fig. 2 Mobile application interface

Therefore, the IoT-based greenhouse monitoring and controlling system has demonstrated its potential to revolutionize greenhouse agriculture in Somalia. Integrating sensors and actuators with remote monitoring capabilities offers significant benefits, including increased crop productivity, resource efficiency, and data-driven decision-making. Further research and development and feedback from farmers and agricultural experts will be essential for optimizing the system's performance and maximizing its impact on regional farming practices.

5. Conclusion

The research paper showcases the successful implementation of an Internet of Things (IoT) based greenhouse monitoring and controlling system for Somalia's agricultural sector.

The system continuously tracks crucial environmental factors, including temperature, humidity, soil moisture, and light intensity, to optimize greenhouse conditions for enhanced crop growth. Using a network of sensors and actuators, the system collects data from the greenhouse and makes intelligent decisions to ensure maximum crop productivity.The central microcontroller, Arduino Uno, serves as the system's core, efficiently managing all components. The results indicate that the system offers multiple benefits, including increased crop yields, efficient resource utilization, and remote monitoring capabilities. Its adaptability to different climatic conditions makes it a versatile solution for various agricultural settings in Somalia. The study emphasizes the potential of this IoT-based system to revolutionize greenhouse farming, ultimately leading to improved food security and economic prosperity. For continued success, ongoing research and continuous feedback from farmers are crucial in refining and tailoring the system to suit the specific needs of the local agricultural community.

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