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Remote Monitoring of Land Areas in Agriculture Based on Wireless Network Technologies

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ABSTRACT- This study presents the development and simulation of a remote environmental monitoring system for enclosed land areas using the Proteus simulation environment and the Arduino microcontroller platform. The objective was to evaluate the feasibility of real-time acquisition and monitoring of critical environmental parameters –including temperature, humidity, and ambient light intensity –through both a centralised monitoring station and a web-based interface. A comprehensive analysis was conducted on the system's operational algorithm, hardware configuration, and simulation model. Sensor data is captured and displayed via an LCD module and a virtual terminal at the monitoring centre, while simultaneously transmitted to a web server via an Internet connection. Changes in sensor readings are dynamically reflected on the web interface in real time, ensuring timely access to current environmental conditions. Experimental validation confirmed the system's accuracy, stability, and reliability under various operational scenarios. The study demonstrates the applicability of the proposed system in domains such as agricultural fields, greenhouses, and storage facilities, where continuous monitoring of environmental conditions is essential. The system offers several advantages, including low-cost implementation, scalability, and automated data reporting—thus reducing the need for manual intervention. Furthermore, the integration of simulation-based modeling with real-time data acquisition provides a robust pre-deployment testing environment. These findings suggest that the proposed architecture can serve as a reliable solution for smart monitoring applications in resource-sensitive environments.

KEYWORDS- Remote Monitoring, Wireless Sensor Network, Real-time, LCD Screen, Virtual Terminal, ZigBee/XBee, Wireless Communication.

I. INTRODUCTION

Today, although the digital transformation of industry is advancing rapidly across the globe, the application of digital technologies – particularly wireless network technology (WNT) solutions – in agriculture remains limited to a few leading countries. The development and deployment of advanced digital production technologies are primarily concentrated in specific regions, while progress in this area remains slow in many others.

Recent studies indicate that 90% of all patents registered worldwide and 70% of exports related to these technologies originate from just ten advanced countries. This highlights the low level of development and practical application of WNTs in the rest of the world, with some regions lacking such technologies entirely[1].

Wireless network technologies are becoming an integral part of modern agriculture by streamlining processes such as remote monitoring, data collection, analysis, and management decision-making. The concept of "Smart Farming" is emerging from these technological innovations [2]. In particular, systems integrated with Wireless Sensor Networks (WSNs), mobile devices, and autonomous agricultural machinery are enabling precise monitoring and management capabilities on farms.

Within the scientific community, the application of WNTs in agriculture is attracting growing interest and research. Several large international projects aimed at implementing WNTs in agriculture are currently underway within the European Union, including Smart AgriFood, SMART AKIS, and SmartAgriHubs. Meanwhile, in Australia, substantial investments are being directed toward large-scale initiatives that support the transition from the "Precision Agriculture" stage to the "Paddock to Decision" (P2D) model [3].

II. EQUIPMENT FOR THE REMOTE MONITORING

A microcontroller board based on the Arduino UNO microcontroller is a simple board that acts as an "intermediary" between the user and the microcontroller, allowing for easy connection to the pins and uploading programs to it directly from the programming environment.

Figure 1: Arduino UNO

DHT11 **-** The sensor consists of two parts: a capacitive temperature sensor and a hygrometer. The first is used to measure temperature, the second for humidity. The chip inside can perform analogue-to-digital conversion and output a digital signal that a microcontroller can read.

Figure 2: DHT11 Sensor

A soil moisture sensor consists of two probes that measure the amount of water in the soil. The two probes allow an electric current to pass through the soil and measure the soil moisture based on its resistance.

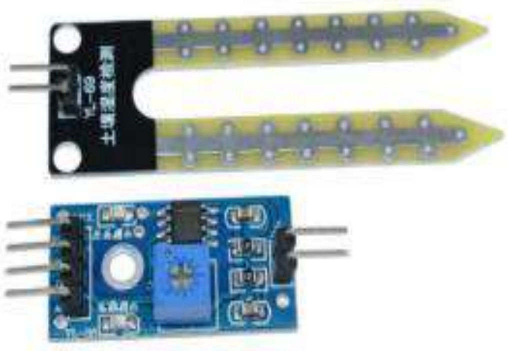

Figure 3: Soil moisture sensor

A photoresistor (light sensor) is used to measure light intensity or detect its presence or absence.

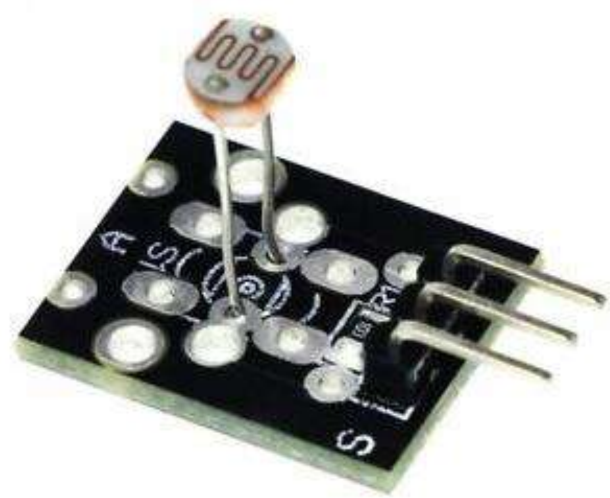

Figure 4: KY-018 – light sensor

Using the above devices it creates a single node for remote monitoring of agricultural land.

III. IMPORTANCE AND APPLICATION

In agriculture, real-time monitoring of the agro-climatic state of land areas, including soil moisture, temperature, atmospheric humidity, and weather conditions, is an important factor in increasing productivity and rational use of resources. The importance of remote monitoring systems in determining these parameters and their continuous monitoring is invaluable.

With the help of modern remote monitoring systems, climatic changes occurring in the fields, the physical condition of the soil and microclimate indicators are determined promptly, which allows farmers to make quick and effective agronomic decisions.

Almost all remote monitoring systems, according to their functional structure, consist of the following main modules:

- Sensor system (detection unit) **-** Devices that measure physical parameters such as soil moisture, air temperature, relative humidity, light level, and pressure. These modules determine the main factors affecting the agrotechnical condition.
- Data transmission and reception system – Wireless communication technologies (Wi-Fi, LoRa, Zigbee, GSM, etc.) are used to transmit data from sensors to a central control device (e.g., Arduino or other microcontroller).
- Data Processing System – This module cleans, stores, analyses, and presents the received data in a user-friendly manner. The processed data is delivered to the user via a web interface, mobile application, or SMS[4][5][6][7].

The integration of these functional components allows for real-time monitoring and optimisation of management decisions. Monitoring systems automatically provide warnings even in the event of sudden changes in climatic conditions, which allows for minimising negative impacts on crops.

Thus, the practical implementation of agro-technological monitoring systems is an important step in the digitalisation of agricultural production processes and the transition to intelligent management. These systems not only increase productivity but also create the opportunity to effectively use limited resources, such as human resources and water.

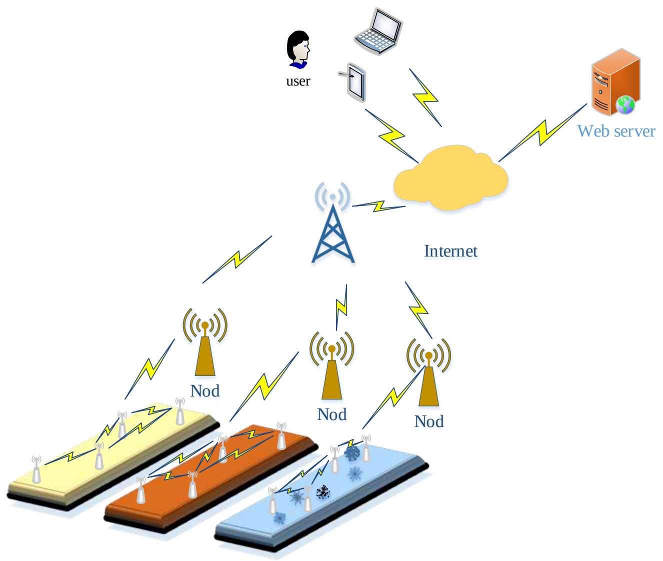

Figure 5: Remote monitoring systems

The effective operation of remote monitoring systems in agriculture directly depends on the ability to transmit data in a timely and reliable manner. In monitoring systems, data received from sensors is transmitted to a processing centre or user via various communication channels. In such systems, data transmission and reception are organised based on several technological solutions. They are divided into:

- Wired systems - The connection between sensors and control devices is made via a physical cable (often via UART, RS-485, or Ethernet). While these systems provide high accuracy and stability, they are complicated to install and have limited mobility.
- Radio channel (wireless) systems - based on technologies such as Wi-Fi, ZigBee, LoRa, GSM/GPRS, NB-IoT, data is transmitted wirelessly. Such systems have advantages in terms of coverage of large areas, energy efficiency and flexibility.
- Optical systems - Data is transmitted via fibre optic communication. Although these systems provide very high speed and reliable transmission, they are mainly used in large industrial or stationary monitoring projects. They may have poor environmental resistance.

Table 1 presents a comparative analysis of the key characteristics of various data transmission technologies, along with the factors influencing their performance [8][9][10][11].

Table 1: Comparative characteristics of factors affecting the performance of various transmission systems

Futures	**Construction methods for monitoring systems**		
	Radio communication systems	**Wired communication system**	**Fibre optic communication system**
Error Rate (BER)	1 x 10-9 BER	1 x 10- 10 BER	1 x 10- 12 BER
Liner loss (dB)	Basic breakdown	Basic breakdown	Basic breakdown
Dispersion	May deteriorate at high speeds	Not the main cause of the breakdown	May deteriorate at high speeds
Attenuation	Influence	No	No
Jitter sum	Moderate effect	High effect	Low effect
Reliability	Low	Medium	High
Channel capacity	Low/medium	Low/medium	Very high
Rain absorption loss	Loss of main frequency 10 GHz	No	No
Electromagnetic Compatibility: Sensitivity to electromagnetic radiation	Exist	Exist	No
Electromagnetic compatibility: generation of electromagnetic radiation	Exist	Certain degree	No
Vandalism resistance	Low	High	Low

Sensors, GSM, and IoT systems can prove useful in providing updates on various parameters within the ground monitoring and control system rules, as it is a complete module that can be easily optimised due to its low cost, low power operation, and therefore easy availability.

IV. PROPOSED METHODOLOGY

The main purpose of the land monitoring system is to monitor the parameters set in each area using appropriate sensors, convert the signals of the monitored parameters into digital form, and sequentially transmit them to the monitoring centre server via telecommunication channels (radio channel, wire channel). The monitoring centre in the land area is a head station, where all data on the monitored parameters of each object are collected separately, data on the parameters are processed according to a certain method, and the monitoring results are compared with established standards [11]. Based on the compared values, the system's operating status is determined. Figure 6 shows the architecture of the remote monitoring system for closed land areas.

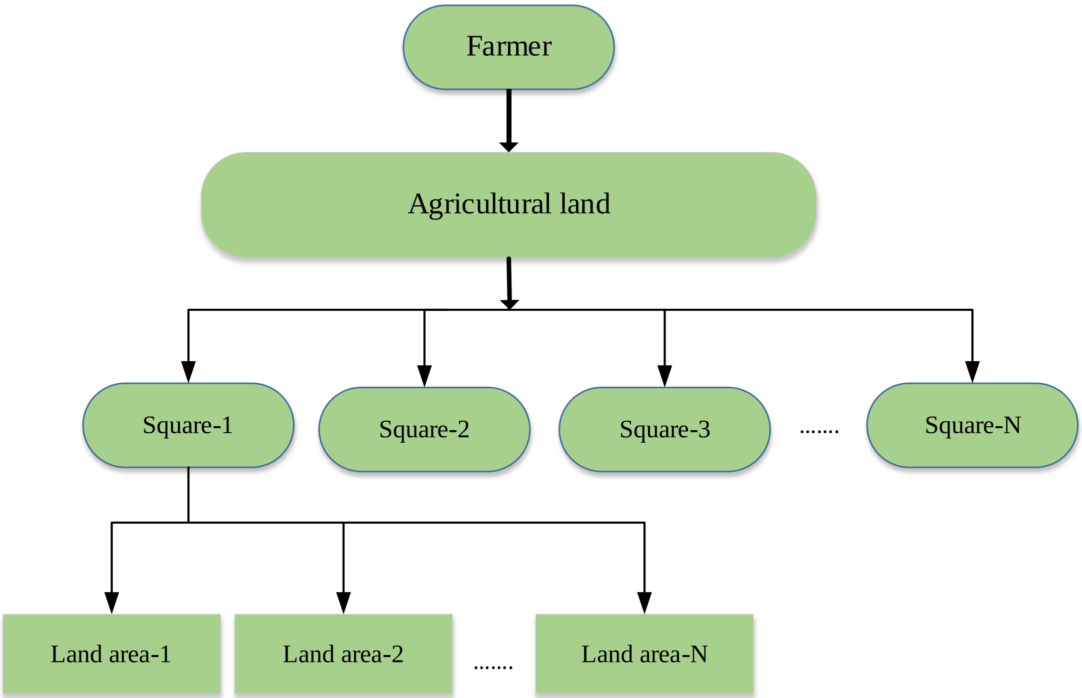

Figure 6: Architecture of the remote monitoring system for land areas

The scheme depicted in Figure 7 uses a microcontroller to convert signals received from sensors into digital data and transmit it to the monitoring centre via a ZigBee network module. The monitoring center sorts the received data by parameters and provides monitoring on the monitoring center screen. The monitoring center is also connected to the Internet and sends data to the server, and the operator has the ability to access the monitoring system using any device connected to the Internet, according to the rights granted to him[12].

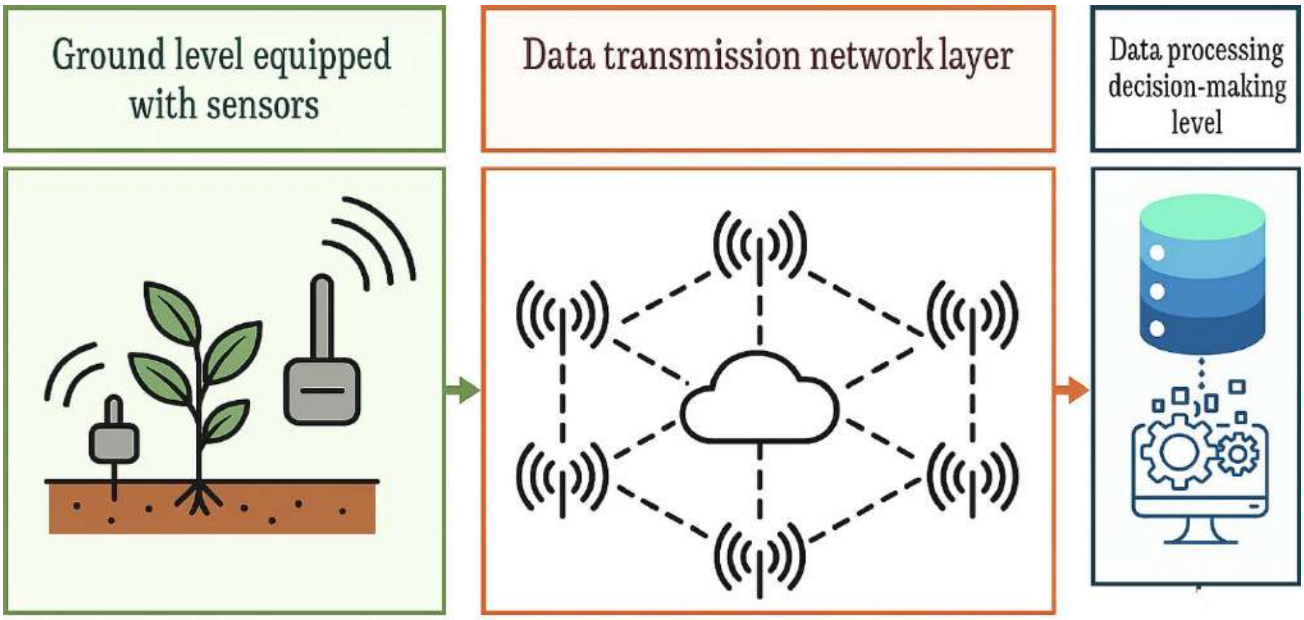

Figure 7: Structure diagram of the monitoring centre

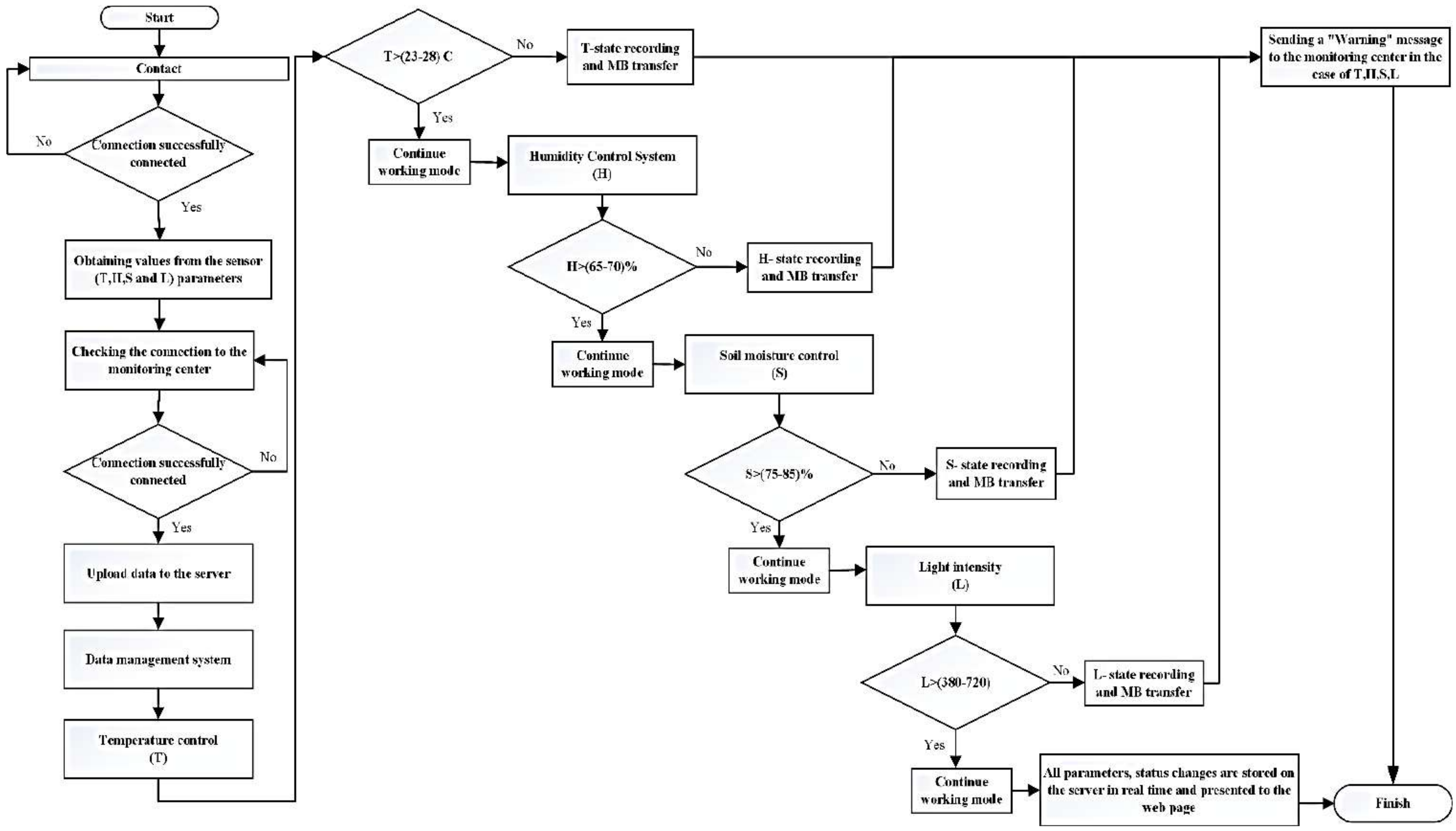

Figure 8: Algorithm for remote monitoring of land areas

The Proteus software environment allows for real-time simulation of remote land monitoring systems. This system is typically designed to remotely monitor land areas located in different regions and is used to continuously monitor their condition[13][14].
In this study, a prototype monitoring system model was developed for only one indoor area in a virtual environment. However, the main goal of the proposed system is to comprehensively implement the monitoring process in all indoor areas within a defined geographical area.
The initial design phase of this system was developed in the Proteus software environment, which is depicted in Figure 7.

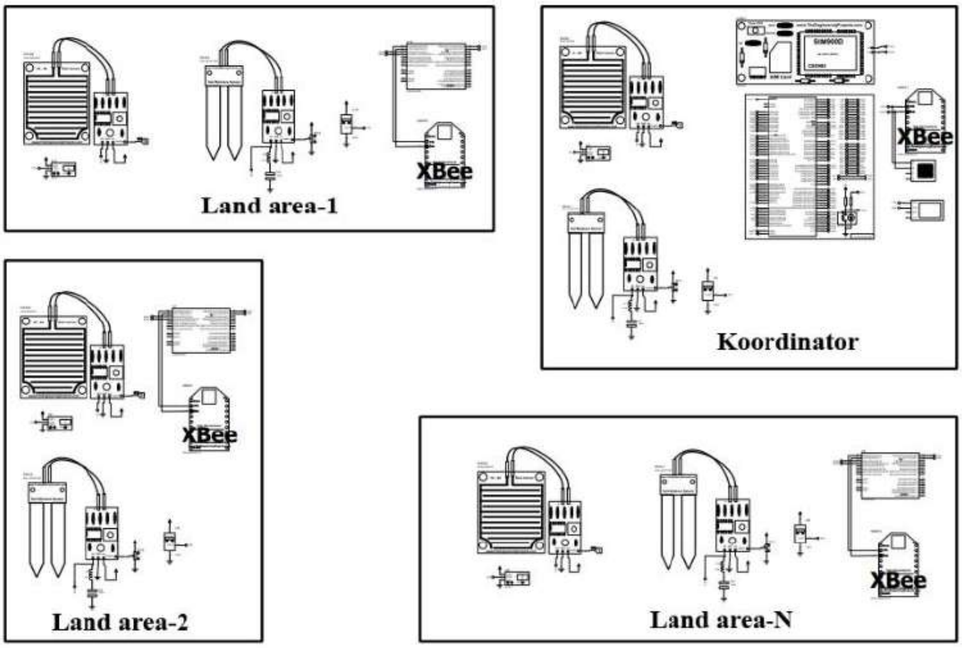

Figure 9: Land area monitoring scheme equipped with IoT technology

The monitoring system, integrated into the web interface, allows you to monitor changes in each parameter in real time, continuously [18]. This feature offers an effective solution for constant monitoring of the system's operating status, rapid detection of possible malfunctions or emergencies, and their elimination. It also creates a basis for assessing the effectiveness of the system's operation and further improving it [17].
During the simulation, the system for transmitting data from sensors located on the ground to the monitoring centre via wireless communication and the monitoring centre models are launched simultaneously. This allows you to check the simulation results in real time, change the output values of the sensors, and visually monitor these changes through the LCD screen and virtual terminal located in the monitoring centre (Figure 7) [15][16].
In addition, the parameters measured by the monitoring centre are transmitted to a web server via the Internet, allowing users to remotely monitor and analyse the system status online.

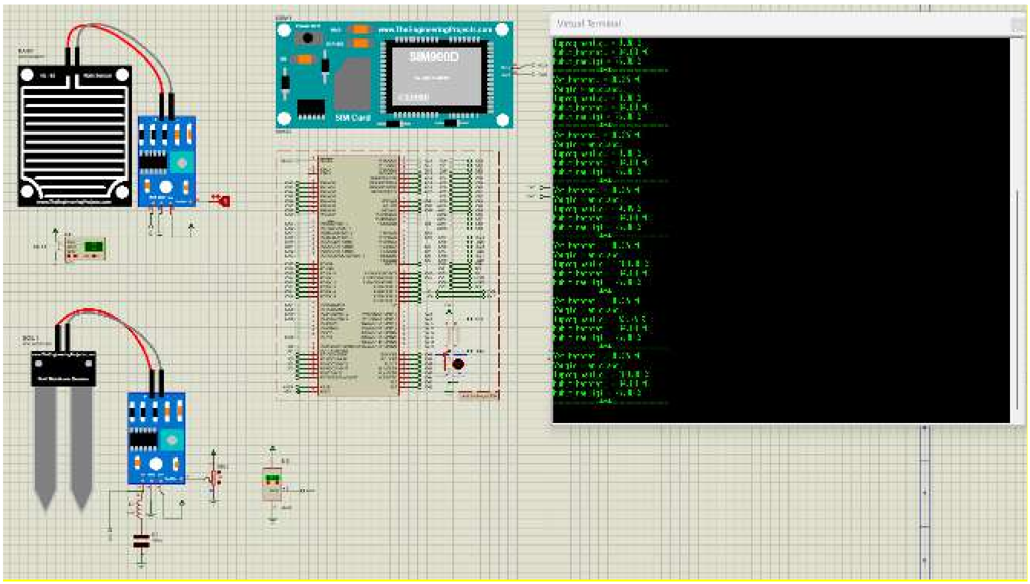

Figure 10: Simulation process and window of transmitted and received data

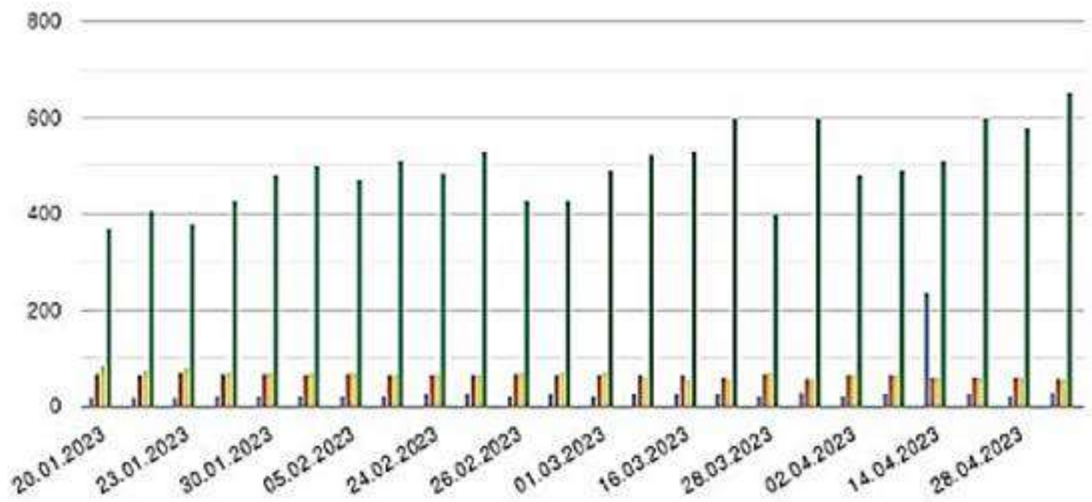

Figure 11: Graph of various parameters obtained through the monitor trace

During the experimental observations, the relative values of the parameters recorded by the sensors were depicted in a graphic form based on the results obtained by the ground monitoring system. This graphic helps to visually assess the effectiveness of the monitoring system in real-time.

The graphic displays the variable values determined at each time interval, which clearly shows the changes in physical or environmental conditions occurring in the ground. This allows the monitoring centre to make timely, appropriate decisions [18].

Analysis based on the data collected during the monitoring process shows that the parameters determined by the sensors are sensitively adapted to the changing environment, ensuring a high level of accuracy and reliability of the system. This graphic is presented in the Figure 11.

V. CONCLUSION

Today, the growing demand for agricultural products is causing the intensification of research work in the direction of creating and improving land monitoring systems. In particular, monitoring systems based on the Arduino microcontroller are widely used as an effective solution in this area.

In this study, experimental observations were conducted on all the main parameters that assess the state of the land (for example, temperature, humidity, soil moisture, light level, etc.). In cases where these parameters changed, they were reflected in real time on the interface of the monitoring centre and on the web page. This ensured the operation of the system with high accuracy and reliability. The monitoring system's quick response to parameters, convenient presentation to the user via the web interface, as well as stable operation of the system are among its main advantages. The results show the possibility of using this system in other types of facilities, including greenhouses, warehouses or agricultural land.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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