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TERRAWATCH CONNECT: A Unified Framework for Environmental Security

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Abstract: The expansion of extractive industries near sensitive ecological zones requires robust real-time monitoring to ensure operational safety and mitigate environmental impact. This study introduces TerraWatch Connect, an Internet of Things (IoT) framework designed for the simultaneous monitoring of active mining environments and contiguous forest areas. Utilizing a distributed network of low-power wireless sensors and long-range wide area network communication, the system continuously captures critical environmental and safety parameters, such as toxic gas levels, soil subsidence, and acoustic anomalies, across remote terrains.
Keywords: Internet of Things (IoT), Wireless Sensor Networks (WSN), Environmental Monitoring, Mine Safety, Smart Forestry, Real-Time Hazard Detection, Predictive Risk Assessment.

I. INTRODUCTION

The expansion of mining operations near sensitive forests creates a critical need for integrated safety and environmental monitoring systems. Traditional manual surveillance methods lack the speed and connectivity required to detect rapid hazards in complex terrains. To address this, this study presents *TerraWatch Connect*, an Internet of Things (IoT) framework designed for the real-time, simultaneous monitoring of active mines and adjacent forestry. By deploying a network of low-power wireless sensors and utilizing long-range communication protocols, the system continuously tracks critical parameters, such as toxic gas levels and soil subsidence. *TerraWatch Connect* provides a unified, automated solution for early hazard detection, seamlessly bridging industrial safety and proactive ecological conservation.

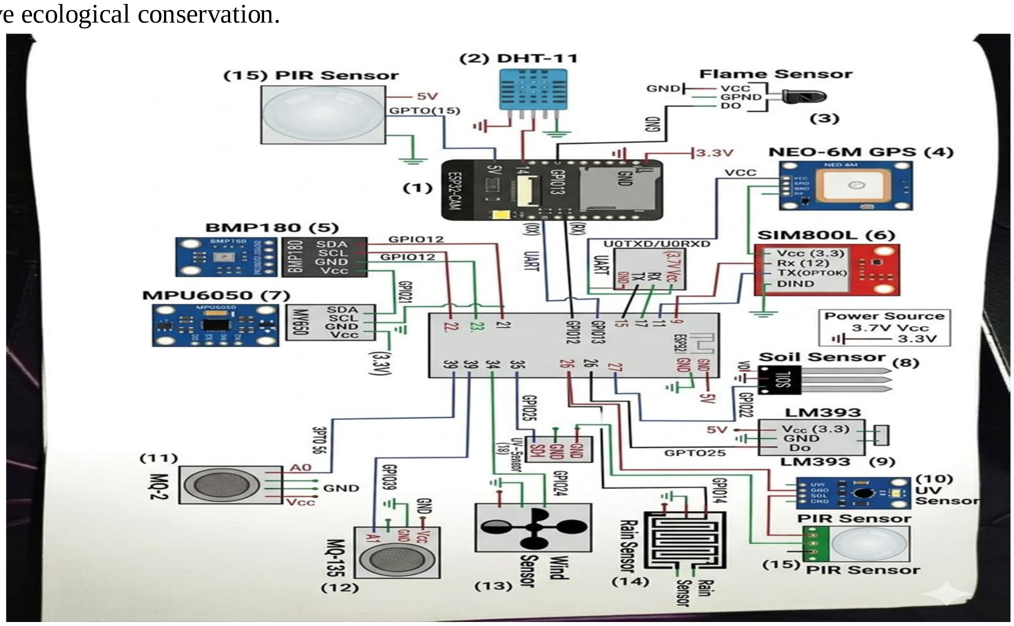

Fig:1.1 Circuit Diagram.

II. LITERATURE REVIEW

The integration of Internet of Things (IoT) technologies in deforestation prevention and wildlife protection has gained significant attention in recent years. Many researchers have focused on using embedded systems, sensors, and wireless communication protocols to develop smart and real-time monitoring systems for forest ecosystems. These systems help in detecting environmental changes, illegal human activities, and forest fires, which are major threats to wildlife and forest resources.

Sharma et al. (2020) proposed a forest fire detection system using temperature and gas sensors to identify abnormal environmental conditions in forest regions. Their system successfully detected fire risks but lacked real-time location tracking and visual monitoring capabilities. Similarly, Basha and Sree (2019) developed an IoT-based forest surveillance system that used motion sensors and RF communication to detect movement of humans and animals. However, their model required a centralized monitoring platform for better data visualization and system management.

Chen et al. (2022) introduced a biodiversity monitoring system using ESP32 and long-range communication technology for environmental data transmission. Although the system was energy efficient and suitable for large forest areas, it mainly focused on wildlife observation rather than detecting illegal activities or fire hazards. Rao et al. (2021) proposed a hybrid model combining IoT data with machine learning algorithms to predict forest fires using parameters such as temperature, humidity, wind speed, and gas concentration. Their research demonstrated improved prediction accuracy but highlighted the need for faster real-time processing.

The literature indicates that while several sensor-based monitoring systems have been developed, most of them focus on specific tasks such as fire detection, wildlife tracking, or environmental monitoring. Few systems provide a fully integrated platform that combines multi-sensor monitoring, camera-based surveillance, real-time alert mechanisms, and centralized data management. Therefore, the proposed TerraWatch Connect system aims to develop a comprehensive and intelligent monitoring framework for effective deforestation detection and wildlife protection.

III. METHODOLOGY

A. *Hardware Components*

The TerraWatch Connect system uses several hardware components to monitor forest environments and detect threats such as fire, illegal entry, and wildlife movement. The main components are:

- ESP-WROOM-32 : Acts as the core microcontroller responsible for collecting sensor data and enabling wireless communication.
- Sensors:
- DHT11 Sensor : Measures the temperature and humidity of the environment.
- PIR Sensor : Detects motion of humans or animals in the monitored area.
- Sound Sensor : Dentifies unusual noises, such as chainsaws or gunshots.
- MQ-2 Gas Sensor : Detects smoke and harmful gases to identify possible fire hazards.
- GPS6MU2 Module : Provides real-time location tracking of the monitoring system.
- Ultrasonic Sensor : Measures distance to detect nearby objects or movement.
- RC522 RFID Module : Used for identification and tracking through RFID tags.
- ESP32-CAM : Captures real-time images and supports video streaming for visual monitoring.
- Buzzer : Provides a local alarm when abnormal activity is detected.
- I2C LCD Display : Shows sensor readings and system status directly at the monitoring unit.

B. *Software Components*

- Development Environment : Arduino IDE
- Programming Language : C / C++
- Backend Server : Python.

C. *Data Flow*

- Data collection: Sensors such as DHT11, MQ-2, PIR, sound , ultrasonic , and GPS modules continuously collect envoirnmental and movement data from the forest area.
- Data Processing: The ESP32 microcontroller receives the sensor data and processes it to identify abnormal conditions such as fire, smoke, or unauthorized movement.
- Data transmission: The processed data are transmitted through a Wi-Fi network to the central server or web application.
- Data storage: The received data were stored in a MySQL database for logging, monitoring, and future analysis.
- Visual interface:The PHP-based dashboard displays sensor readings, alerts, and real-time locations on the monitoring interface.
- Alert generation: If abnormal activity is detected, the system triggers buzzer alerts and sends notifications (SMS/email) to the authorities for immediate action.

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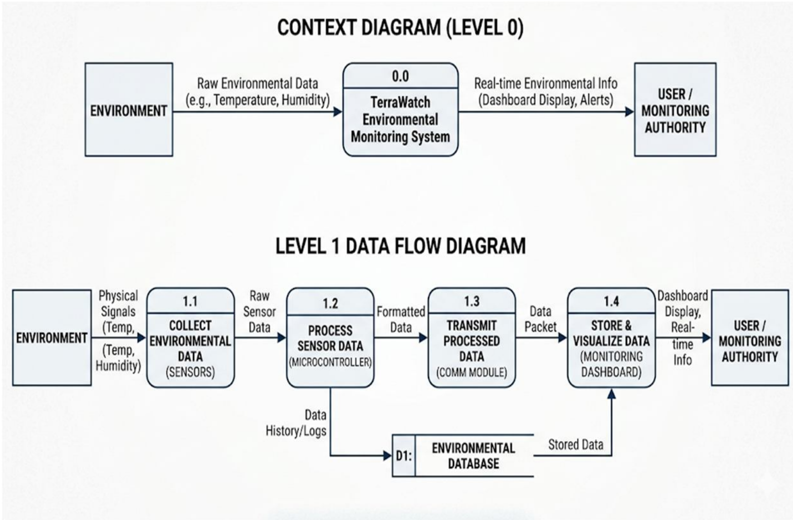

Fig:2.1.Literature Review

IV. RESULTS

The TerraWatch Connect system was tested in a controlled environment to evaluate its performance in monitoring environmental conditions and detecting potential threats. The system successfully demonstrated efficient sensor integration, real-time data processing, and alert generation.

A. *Key Outcomes*

- Accurate data acquisition from all integrated sensors including temperature, humidity, motion, sound, gas, and distance sensors.
- Reliable transmission of sensor data to the server with minimal latency.
- The monitoring dashboard updates every 10 seconds, providing real-time environmental information.
- Instant alerts via email and SMS are generated when abnormal conditions such as gas detection or unexpected motion during nighttime are detected.
- Successful integration of ESP32-CAM enabling live image capture for visual verification.
- Real-time location tracking displayed on the dashboard using OpenStreetMap for better monitoring and navigation.

Fig:4.1 TerraWatch Connect Device.

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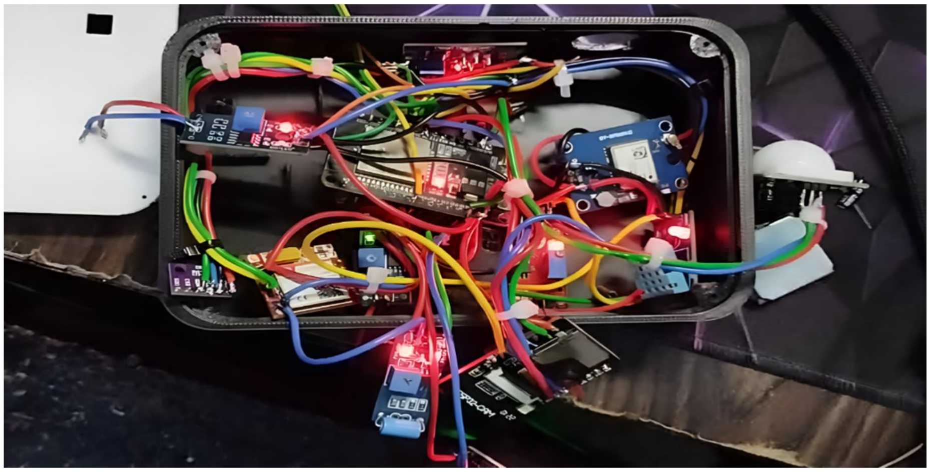

Fig:4.2 Internal Wiring.

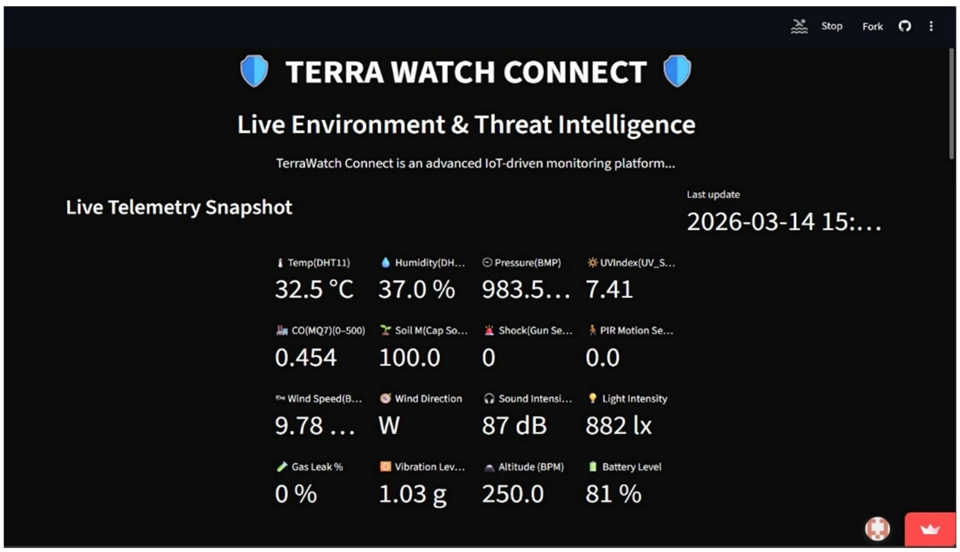

Fig:4.3 Dashboard.

V. DISCUSSION

The integration of multiple sensors in TerraWatch Connect enables effective multi-parameter monitoring of forest environments. The use of the ESP32 microcontroller makes the system low-cost, scalable, and suitable for remote deployment. The modular design allows easy addition of new sensors and features. In the future, the system can be improved with machine learning for anomaly detection, drone-based monitoring, and solar power integration for sustainable operation..

VI. CONCLUSIONS

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