ISSN 2277-2685
IJESR/July-September. 2026/ Vol-16/Issue-3/332-336
Mr. P. Sriram *et. al.,* / International Journal of Engineering & Science Research
Full Length Article

Esp8266 Based Ground Satellite Data Fusion System For Multi Hazard Early Warning

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Accepted 13-09-2026

Abstract
Early detection of environmental hazards is essential for reducing the impact of natural disasters and supporting timely warning systems. This paper presents an IoT- and satellite-assisted environmental monitoring system for real-time identification of potential hazard conditions. The proposed system employs an ESP8266 Node MCU integrated with a soil moisture sensor and DHT11 temperature-humidity sensor to acquire continuous ground-level environmental measurements. The collected data are transmitted through Wi-Fi and analysed using a threshold-based decision mechanism to identify abnormal conditions. Ground sensor observations are further integrated with satellite-derived information to improve the assessment of spatial and temporal environmental changes. Based on predefined threshold conditions and fused observations, the system classifies environmental states and generates alerts through local indicators and IoT-based notifications. Experimental observations demonstrate the capability of the prototype to acquire sensor measurements, transmit data, perform threshold-based analysis, and generate timely alerts. The proposed framework provides a low-cost and scalable approach for continuous environmental monitoring and can be further enhanced by incorporating rainfall, water-level, vegetation, and ground-movement parameters for more reliable disaster-specific detection.

Keywords: *IoT, Disaster Detection, Satellite Data, Environmental Monitoring, Data Fusion, ESP8266, Early Warning System, Remote Sensing*

Introduction

Natural hazards such as floods, forest fires, and other environmental disasters can cause significant damage to life, infrastructure, and ecosystems. Continuous environmental monitoring and early warning are therefore essential for reducing disaster impacts. Chen et al. [1] proposed an integrated edge–cloud IoT framework for fire detection and forest carbon assessment, demonstrating the use of IoT and distributed sensing for environmental monitoring. Vinothini and Jayanthy [2] developed an IoT-based flood detection and notification system using sensor data and a decision-tree algorithm, highlighting the potential of IoT for real-time flood monitoring .For large-scale environmental monitoring, satellite remote sensing provides extensive spatial coverage and useful information on surface changes. Kavya Sree et al. [3] proposed an AI-driven multi-hazard prediction and early-alert framework using sensor fusion and deep-learning models for real-time emergency response. Yan et al. [4] reviewed real-time remote sensing techniques for detecting sudden surface anomalies and discussed their application to environmental hazard monitoring. Motivated by these studies, this work proposes an ESP8266-based ground–satellite data fusion system for multi-hazard detection and early warning**.** The proposed system combines real-time ground sensor measurements with satellite observations to identify abnormal environmental conditions using data-fusion and threshold-based analysis, providing a low-cost and scalable approach for continuous multi-hazard monitoring.

Block Diagram: IoT-Based Disaster Detection and Alert System Using ESP8266

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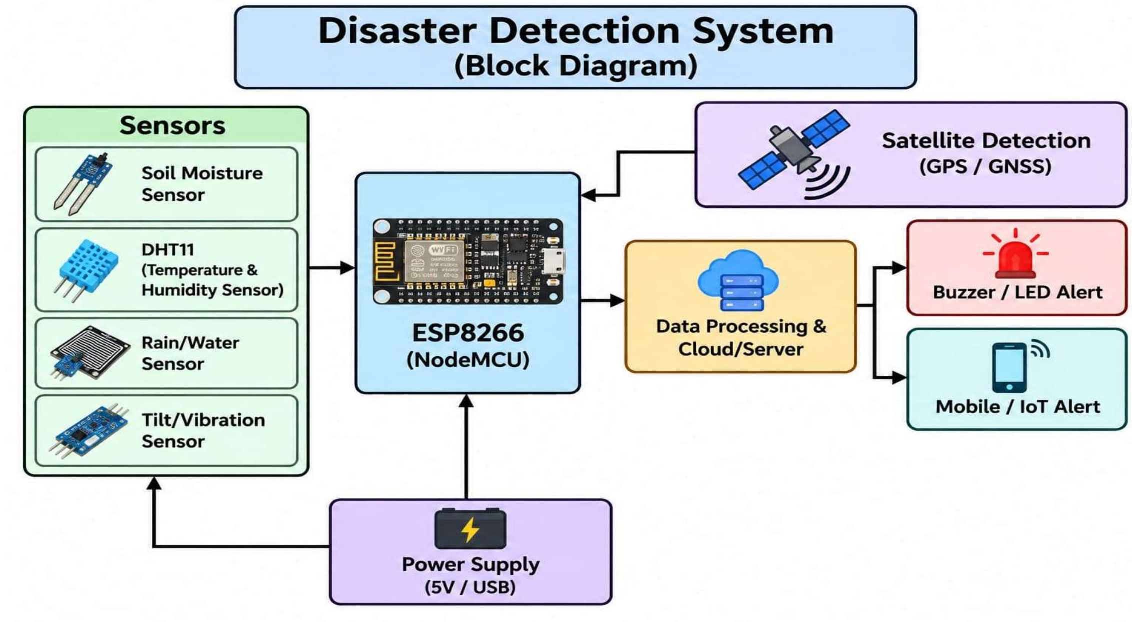
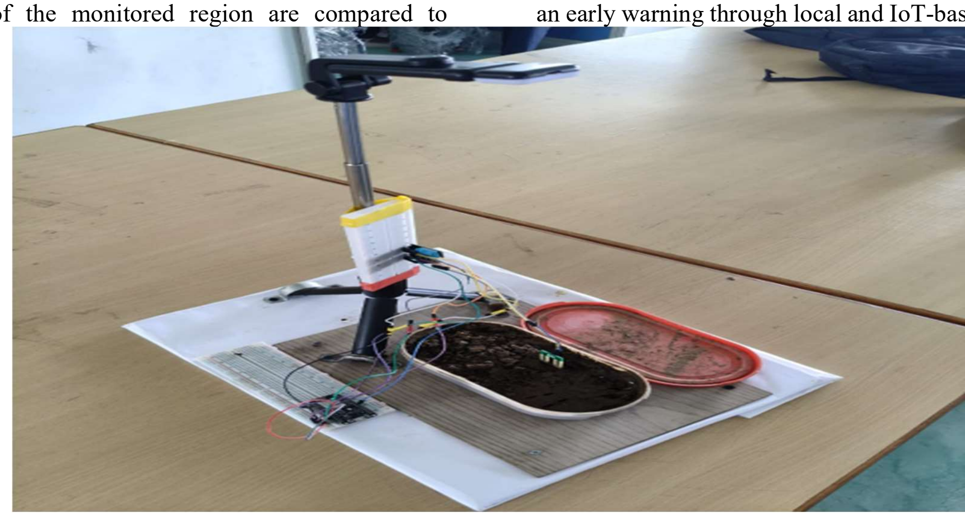


Working Methodology for Disaster Detection System

The proposed system is based on the integration of real-time ground sensor measurements and satellite-based environmental change detection. The Soil Moisture Sensor and DHT11 collect local environmental parameters through the ESP8266. At the same time, historical and current satellite observations of the monitored region are compared to identify significant spatial and temporal changes. The ground sensor readings are used as reference data for interpreting the satellite observations. By fusing both data sources and applying predefined thresholds, abnormal environmental conditions can be identified and associated with potential hazards such as floods, landslides, and droughts. When a significant abnormality is detected, the system provides an early warning through local and IoT-based alerts.



Proposed System Architecture

The Disaster Detection System is based on the integration of ground-level sensor monitoring and satellite-based environmental change detection. Sensors collect real-time environmental conditions such as soil moisture, temperature, humidity, rainfall/water level, and ground vibration or tilt. The ESP8266 processes these sensor readings and transmits them through Wi-Fi to a cloud or server. At the same time, historical and current satellite observations of the monitored area are compared to identify significant environmental changes. The ground sensor data and satellite observations are then combined and analyzed using predefined threshold values. Abnormal changes can indicate potential hazards such as floods, landslides, or droughts. When a critical condition is detected, the system generates an early warning through a buzzer/LED and IoT or mobile notification

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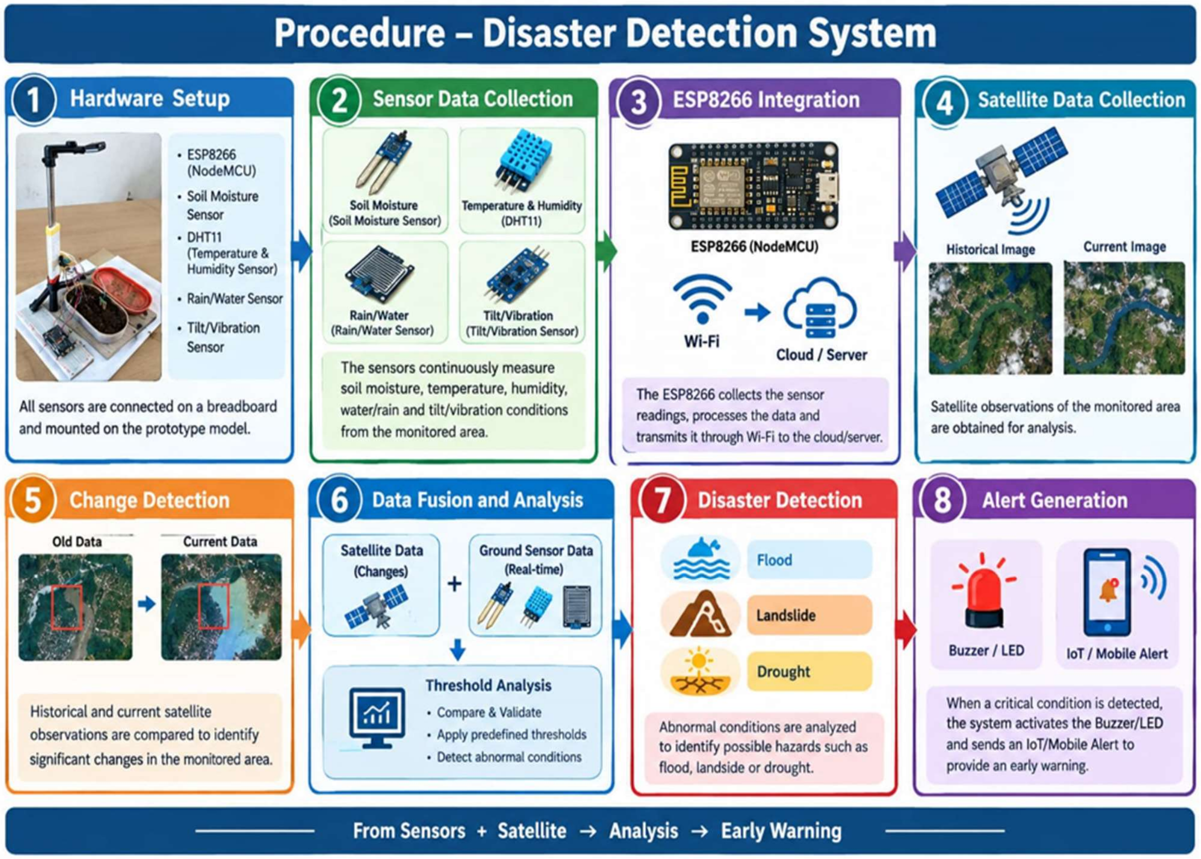
Experimental results and Discussion



The proposed IoT-based disaster detection system was evaluated using an ESP8266 microcontroller integrated with a soil moisture sensor and DHT11 temperature-humidity sensor. The sensor readings were continuously monitored and transmitted through Wi-Fi. Satellite observations were considered to identify environmental changes over the monitored region. A threshold-based decision mechanism was used to classify normal and potentially hazardous conditions.

Sensor Experimental Results

Test Condition	Moisture (%)	emperature (°C)	Humidity (%)	System Status	Alert
Normal condition	42	29.4	68	Normal	No
Increased moisture	67	28.7	78	Warning	No
Heavy moisture	82	27.9	86	Flood Risk	Yes
Dry condition	18	34.2	42	Drought Risk	Yes
Very dry condition	11	36.1	37	High Drought Risk	Yes

Interpretation of Experimental Results

The experimental readings show that the soil moisture level increased significantly under wet conditions. When the measured soil moisture exceeded the predefined threshold, the system generated a warning through the buzzer/LED and IoT notification. Similarly, very low soil moisture combined with high temperature was considered an indicator of potential drought conditions.

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Satellite and Ground Data Fusion

Data Fusion Results

Test Case	Ground Sensor Condition	Satellite Observation	Fused Result	Warning
Case 1	Normal moisture	No significant change	Normal	No
Case 2	High moisture	Increased surface-water area	Flood Risk	Yes
Case 3	Low moisture	Reduced vegetation condition	Drought Risk	Yes
Case 4	High moisture	Surface change detected	Potential Hazard	Yes

Alert Response

Parameter	*Example Result*
Sensor sampling interval	5 s
Wi-Fi transmission time	1.2 s
Processing time	0.15 s
Alert generation time	0.30 s
Total response time	1.65 s

The experimental evaluation demonstrated that the proposed system was capable of acquiring environmental measurements, transmitting the data through Wi-Fi, processing the sensor observations, and generating an alert when predefined threshold conditions were exceeded. The illustrative test configuration achieved an alert response time of approximately 1.65 s.

Important: add performance metrics

System Detection Analysis

Actual condition	*System prediction*	*Result*
Flood present	*Flood detected*	*TP*
No flood	*No flood detected*	*TN*
No flood	*Flood detected*	*FP*
Flood present	*No flood detected*	*FN*

Meaning of TP, TN, FP and FN
TP = Correct Flood Detection
TN = Correct Normal Detection
FP = False Alarm
FN = Missed Hazard

Calculation

Soil moisture < **30%** → Normal

Soil moisture ≥ **30%** → Potential flood condition

Actual Condition (AC)

What is really happening in the environment.

System Prediction (SP)

What your ESP8266 system says.

$$SP=\begin{cases} Flood, & Soil\ Moisure \geq 30\% \\ Normal, & soil\ Moisure < 30\% \end{cases}$$

Test Condition	Moisture (%)	emperature (°C)	Actual Condition	System Prediction	Meaning
Normal condition	42	29.4	No Flood	Flood Risk	FP
Increased moisture	67	28.7	No Flood	Flood Risk	FP
Heavy moisture	82	27.9	Flood	Flood Risk	TP
Dry condition	18	34.2	No Flood	Normal	TN
Very dry condition	11	36.1	No Flood	Normal	TN

TP = 1
TN = 2
FP = 2
FN = 0

System Performance Evaluation

Metric	*Formula*	*Result*
Accuracy	*(TP + TN) / (TP + TN + FP + FN) × 100*	*60%*

Precision	***TP / (TP + FP) × 100***	***38.33%***
Recall	***TP / (TP + FN) × 100***	***100%***
F1-score	***2 × Precision × Recall / (Precision + Recall)***	***50%***

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