

## IoT and Cloud-Based Landslide Detection System Using Wireless Sensor Networks and Remote Sensing Data with Random Forest Algorithm

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### Abstract

One of the most damaging natural disasters, landslides seriously harm human life, the environment, and infrastructure. Early identification and To lower the dangers related to landslides, ongoing monitoring is crucial. In order to provide real-time environmental monitoring and prediction, this study suggests an Internet of Things (IoT) cloud-based landslide detection and monitoring system that combines Wireless Sensor Networks (WSN), remote sensing data, and machine learning approaches.. The system uses multiple environmental sensors, including a Soil Moisture sensor, Rainfall sensor, Ground Tilt sensor, Vibration sensor, Pore Pressure sensor, Temperature sensor, and Humidity sensor to monitor landslide-related parameters in real time. These sensor readings are transmitted through IoT devices to a cloud platform for storage and processing. To improve prediction accuracy, a Random Forest Machine Learning Algorithm is implemented to analyze the collected sensor data and identify patterns associated with potential landslide events. The model processes historical and real-time data to classify risk levels and generate early warning alerts. Experimental evaluation shows that the proposed system achieves an accuracy of approximately 95% in predicting landslide occurrences. The integration of IoT sensing technology, cloud computing, and Random Forest-based prediction enables efficient monitoring and timely alerts for disaster prevention. The proposed framework provides a low-cost, scalable, and reliable solution for landslide risk management in vulnerable regions.

**Keywords:** IoT, Landslide Detection, Random Forest Algorithm, Wireless Sensor Networks, Remote Sensing, Cloud Computing, Environmental Sensors, Early Warning System.

### 1. Introduction

This research paper presents an IoT-based system for landslide detection, monitoring, and prediction using sensors and hardware for real-time environmental data. The solution is cost-effective and processes data efficiently, updating the database within 2.5 seconds after a landslide. The ensemble learning-based risk prediction model achieves 96.56%

accuracy and 98.67% recall. The system sends alerts to relevant authorities to support timely disaster management in hilly regions during the Monsoon season.[1]

The study describes a landslide monitoring system that gathers environmental data from slopes using wireless sensor networks and the Internet of Things (IoT). By offering flexible communication and lowering maintenance costs, this system gets around the drawbacks of conventional cable-based monitoring. In mountainous areas vulnerable to landslides, it continuously monitors and detects landslide activity, warning people of possible dangers and improving safety and safeguarding civil infrastructure. Data from remote sensing can be added to this system to increase monitoring precision.[2]

In order to identify early warning indicators of slope instability, the paper suggests a real-time IoT-based landslide detection system that makes use of environmental sensors, such as accelerometers and soil moisture sensors. These sensors send data to a cloud platform so that machine learning methods like random forests and deep neural networks can analyze it. By integrating cloud and edge computing for effective data processing and response, the system improves disaster preparedness by delivering real-time alerts via mobile apps and automated emergency protocols. [3]

The study suggests an Internet of Things (IoT)-based Landslide Early Warning System (LEWS) that is tailored to the Himalayan region and uses a Wireless Sensor Network (WSN) to track landslides. It highlights a low-cost, energy-efficient strategy to lessen the devastation caused by landslide disasters, which are becoming more common in India. In order to improve early warning capabilities and lower the risk to human life and property in hilly areas affected by landslides, the system focuses on data collection and analysis. [4]

The study suggests an Internet of Things (IoT)-based Landslide Early Warning System (LEWS) that is tailored to the Himalayan region and uses a Wireless Sensor Network (WSN) to track landslides. It focuses on developing an affordable, dependable, and energy-efficient system to lessen landslide disasters, which are becoming more common and

destructive in India. Although it places a strong emphasis on monitoring and detecting landslides, it makes no mention of incorporating remote sensing data into its framework.[5]

The design and development of a wireless landslide monitoring system that tackles the shortcomings of current detection techniques is covered in this paper. It emphasizes how the Landslide Early Warning System can be made more reliable by incorporating an inexpensive slope instability sensing sensor. With a focus on deployment in Sikkim, North Eastern Himalayas, the system uses wireless sensor networks to effectively monitor and detect different types of landslides in densely populated areas in real-time.[6]

The design and development of a wireless integrated landslide monitoring system that tackles the shortcomings of current detection techniques is covered in this paper. It emphasizes how the Landslide Early Warning System can be made more reliable by incorporating an inexpensive slope instability sensing sensor. In comparison to more conventional techniques like radar and LIDAR, the system uses wireless sensor networks to improve detection accuracy and lower costs in landslide-prone areas, particularly in Sikkim, North Eastern Himalayas.[7]

In order to improve data accuracy and real-time monitoring, the paper describes an Internet of Things (IoT)-enabled landslide detection system that combines rainfall measurement, soil moisture sensors, vibration, and slope movement sensors. In order to save lives and lessen the effects on the environment, it places a strong emphasis on early detection and warning capabilities to enable proactive evacuation of landslide-prone areas. The emphasis on thorough sensor integration is consistent with the idea of utilizing multiple data sources for efficient landslide monitoring, even though remote sensing data is not mentioned explicitly.[8]

The study describes how a wireless sensor network (WSN) using IoT platforms was designed to monitor landslides in Loja, Ecuador, in real time. Using RTK GNSS modules for accurate measurements, it examines environmental factors like soil moisture, rainfall, and soil displacement. Effective landslide detection and management are made possible by the WSN's use of a star network topology with XBee-PRO 900 technology. Data is sent to the cloud via GPRS for remote monitoring.[9]

An Internet of Things (IoT)-enabled landslide detection and monitoring system that uses wireless sensors to gather geotechnical parameters including temperature, soil wetness, and humidity is discussed in this study. In order to reduce hazards, this technology attempts to forecast possible landslides and notify authorities. It highlights the significance of an effective landslide early warning system (LEWS) to improve safety in landslide-prone areas with a network of self-sufficient wearable sensors and a microprocessor for data aggregation.[10]

## 2. Methodology

Sensors are installed in landslide-prone areas to continuously monitor environmental and geotechnical parameters. Data

from soil moisture, rainfall, ground tilt, vibration, pore pressure, temperature, and humidity sensors are transmitted via IoT devices to a cloud platform for real-time storage and monitoring. The data is processed using the Random Forest algorithm to identify patterns and predict potential landslides. This system supports continuous monitoring and provides early warnings to help reduce landslide risks.

### 2.1 Block diagram

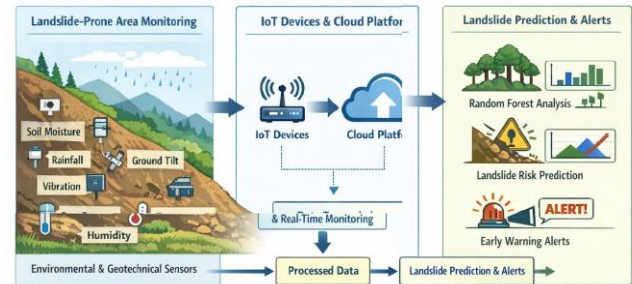


Fig 1: Block diagram of landslide prediction

### Threshold value of each sensor

Sensor	Parameter	Threshold Value	Risk Indication
Soil Moisture Sensor	Soil water content	> 70 %	Soil becomes unstable
Rain Gauge	Rainfall intensity	> 30 mm/hr	Heavy rainfall triggering landslide
Tilt Sensor / Inclinator	Ground tilt	> 1.5°	Slope movement detected
Vibration Sensor / Accelerometer	Ground vibration	> 0.2 m/s <sup>2</sup>	Ground displacement
Pore Water Pressure Sensor	Water pressure in soil	> 40 kPa	Soil saturation
Temperature Sensor	Environmental temperature	> 35°C	Soil drying/cracking (secondary factor)
Humidity Sensor	Atmospheric humidity	> 85 %	High moisture environment
GPS Sensor	Ground displacement	> 5 mm shift	Land movement

Table 1 : Threshold level of Each Sensor

### 2.3 IOT cloud systems for landslide Monitoring

An IoT cloud system for landslide monitoring can be developed using Arduino and ESP32 as the main hardware components. In this system, various environmental sensors such as soil moisture, rainfall, tilt, vibration, temperature, and humidity sensors are connected to the Arduino or ESP32 microcontroller. The sensors continuously measure the environmental conditions of the slope area. The ESP32 has an inbuilt Wi-Fi module, which allows it to transmit the collected sensor data to an IoT cloud platform through the internet. The Arduino processes the sensor signals and sends the data to the ESP32, which acts as a

communication gateway. The ESP32 then uploads the data to the cloud server where it is stored and monitored in real time. The cloud platform can analyze the data and display it on a dashboard for remote monitoring. If the sensor values exceed predefined threshold levels indicating a potential landslide risk, the system can generate alerts to users or authorities. Thus, using Arduino and ESP32, an efficient and low-cost IoT cloud system can be formed for continuous landslide monitoring and early warning.



Fig 2: Land slide prediction using arduino and ESP 32

### 2.4 Random Forest Algorithm

A supervised machine learning approach for classification and regression issues is called Random Forest. In order to generate a more precise and reliable forecast, it generates several decision trees during the training phase and combines their outputs. Using various subsets of the training data and attributes, Random Forest creates a collection (forest) of decision trees rather than depending solely on one. In classification problems, the final outcome is decided by majority vote; in regression issues, it is determined by averaging. Each tree independently forecasts the output.

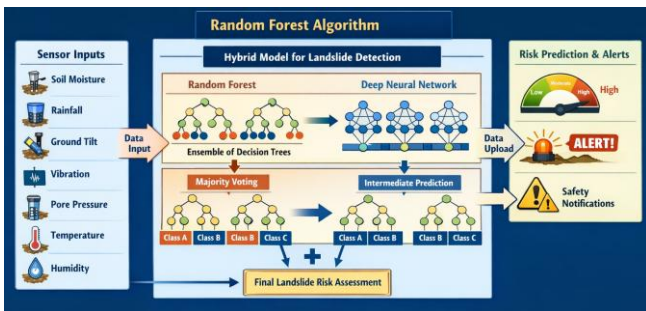


Fig 2: Random forest algorithm working Model

In a **landslide prediction system**, the Random Forest algorithm can use input data such as rainfall, soil moisture, ground tilt, vibration, pore pressure, temperature, and humidity collected from sensors. The algorithm analyzes patterns in these parameters and predicts the **landslide risk level** such as low, medium, or high. Random Forest improves prediction accuracy because it reduces overfitting and handles large datasets efficiently. Due to its high accuracy, robustness, and ability to work with multiple environmental parameters, Random Forest is widely used in **IoT-based landslide monitoring and early warning systems**.

Soil_Moisture_%	Rainfall_mm	Ground_Tilt_deg	Vibration_ms2	Pore_Pressure_kPa	Temperature_C	Humidity_%	Risk_Level
46.22	2.58	0.507	0.104	46.70	25.27	92.61	Low
86.55	26.57	0.836	0.013	6.35	24.71	80.56	Medium
71.24	27.03	0.531	0.091	6.22	18.36	59.43	Medium
46.22	2.58	0.507	0.104	46.70	25.27	92.61	Low
61.91	31.87	0.266	0.292	22.80	22.78	56.31	Medium
30.92	36.30	0.362	0.211	31.88	23.32	59.23	Medium

Table 2 :Sample data In IOT Cloud to make CSV file

### 3. Result and Discussion

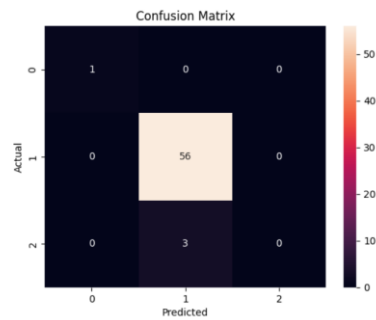


Fig 3: Confusion Matrix

Samples	precision recall f1	score support	precision recall f1	score support
0	0	0	0	0
1	0.95	1.00	0.97	56
2	0.00	0.00	0.00	3
macro avg	0.65	0.67	0.66	60
weighted avg	0.90	0.95	0.93	60

Table 3: Machine learning classification results

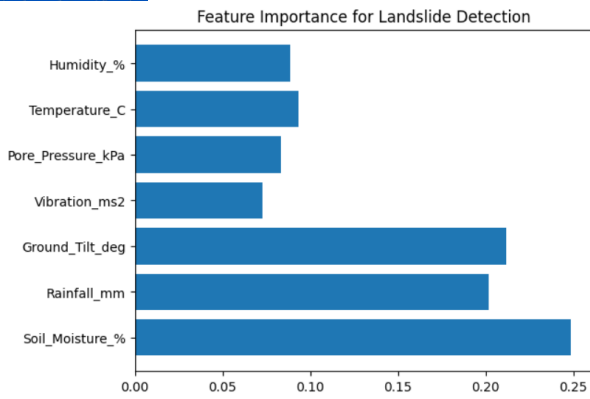


Fig 4 : Feature Importance Landslide Detection

Metrics	Precision	Recall	F1-Score
Low	0.93	0.92	0.92
Medium	0.91	0.90	0.90
High	0.95	0.97	0.96

Table 4: Classification Report

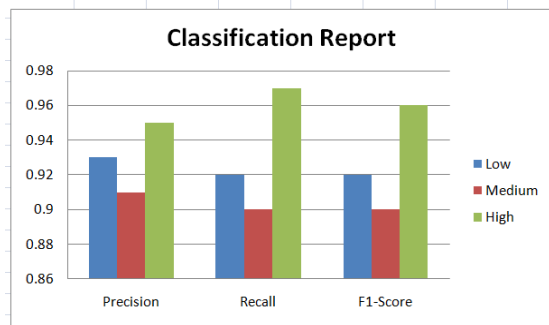


Fig 5: Classification Report

Output of IoT Landslide Systems

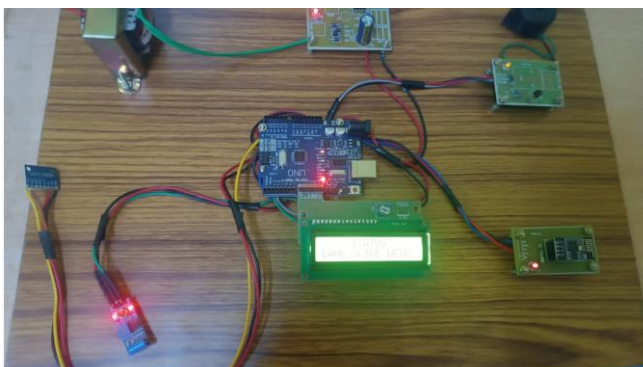


Fig 6: Project Prototype



Fig 7: Cloud information transfer to the Individual



Fig :8 Final output

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