International Journal of Advance Research in Science and Engineering
Volume No. 15, Issue No. 04, April 2026
www.ijarse.com
IJARSE
ISSN 2319 - 8354

Advanced Landslide Prediction and Alert System by IOT Sensors Machine Learning (ML) Algorithms

J.Radhika[1], Dr. R.Ramachandran[2]

[1]*Research Scholar,*

[2]*Assistant Professor Faculty of Science Annamalai University Chidambaram Tamilnadu*

drmkm1969@gmail.com

Abstract:

Landslides in mountains regions pose significant risks to human life, infrastructure and the environment, making effective monitoring and predication are essential the main root cause of it is urbanization and deforestification in mountain areas .This present paper proposes to predict landslides and provide early warnings, thereby enhancing community safety and disaster preparedness.

The System continuously monitors critical parameters such as soil moisture, rainfall intensity, and slope stability, which are vital indicators of landslide risk the unit is deployed in various land slide prone zones separated by various node equipped with GSM and all the nodes are connected with the centralized node which is analyzing the input data of various nodes and relay the abnormalities information's to local authorities and triggering the alarm in the suspected prone areas . By employing a pre-defined ML algorithm, the system analyses the real time sensor data and compared with the threshold values allowing it to predict landslide occurrences up to 24 hours in advance. This timely prediction enables authorities and local residents to take proactive measures, reducing potential casualties and damage. To effectively communicate risk levels, the system equipped with three level alarm mechanism such as Green (safe) indicates stable condition, Yellow (potential risk) signals the need for caution, and Red (imminent danger) wants of an impending landslide, promoting immediate action. The present system includes a user -friendly interface that residents to access real-time weather updates and landslide risk assessments easily. The interface is designed for ease of use, ensuring that critical information is readily available to those who need it most. Ultimately, this advanced landslide mitigation system aims to reduce the impact of landslides through timely alerts, fostering a culture of preparedness and communities.

Keywords: *Landslide mitigation, IOT sensors, Machine Learning, Early-Warning System, Soil moisture monitoring, Rainfall detection, Predictive analytics.*

1.Introduction: Landslides are natural disaster that frequently occur in mountainous regions, often triggered by heavy rainfall, soil erosion, and geological factors. Traditional landslide detection methods are reactive, providing warnings only after the event has begun. This paper introduces a proactive approach to landslide mitigation using IOT sensors and Machine Learning. By continuously monitoring environmental parameters and predicting landslides in advance, this system aims to save lives, protect infrastructure, and reduce economic losses. We taken Utrakhand and Kerla as a study.as shown in the figure 1

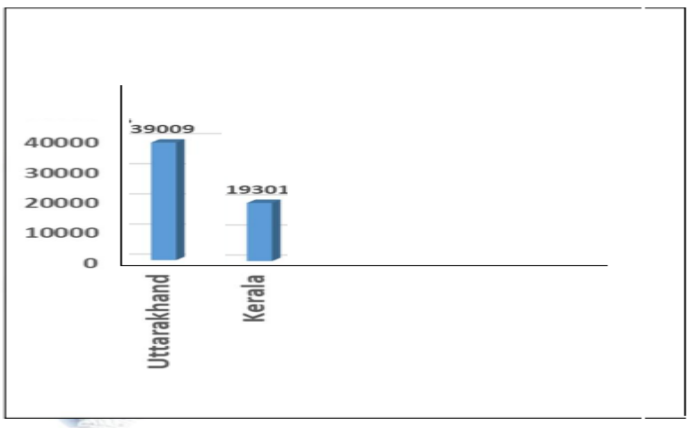

Fig 1-Land Slide Prone area in sq(km)

As per data available with GSI in the year 2015-2020 as shown in fig 2

State Name	Number of landslides
Arunachal Pradesh	33
Assam	120
Meghalaya	32
Mizoram	14
Tripura	10
Manipur	20
Nagaland	34
Sikkim	20
Himachal Pradesh	97
Jammu & Kashmir (UT)	169
Uttarakhand	27
Karnataka	194
Tamil Nadu	196
Kerala	2238
Maharashtra	78
West Bengal	374
Total	**3656**

Fig.2 Land Susceptility in India shown in the figure

International Journal of Advance Research in Science and Engineering
Volume No. 15, Issue No. 04, April 2026
www.ijarse.com
IJARSE
ISSN 2319 - 8354

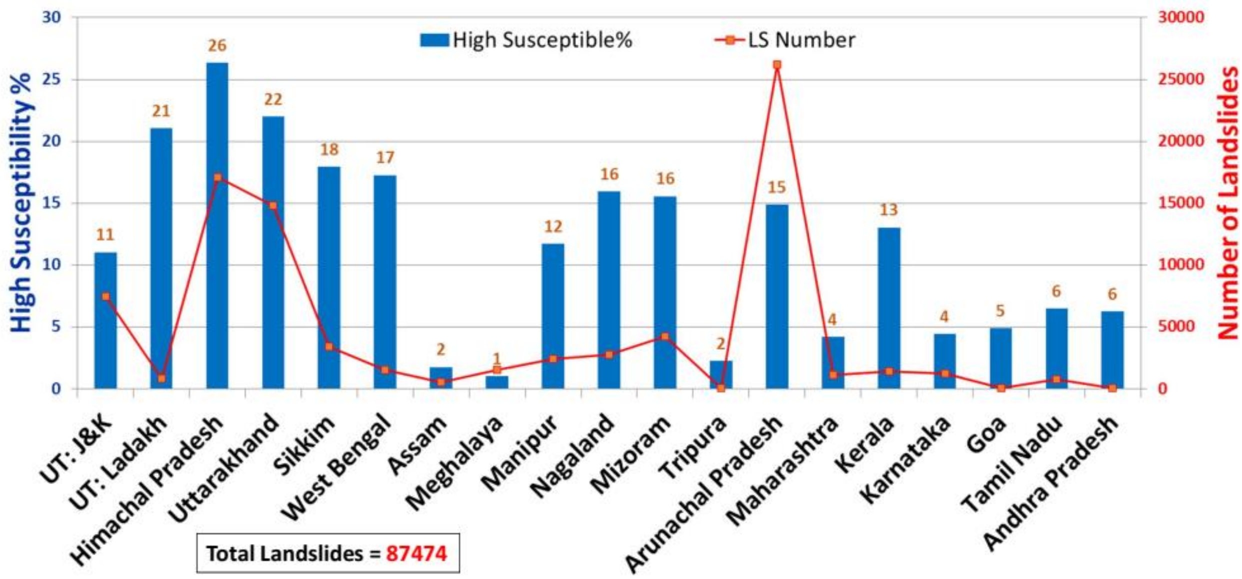

Fig3.: Land Slides Data

2.Problem Statement : Landslides cause significant damage to life, property, and infrastructure, especially in mountainous regions. Current systems rely on post-event analysis and lack the ability to provide early warnings. This paper addresses the need for a "Predictive early warning system" that can alert communities"24 hours in advance" of a potential landslide.

2.1.Objectives: Develop an IoT- based system to monitor soil moisture, Rainfall, and slope stability. Use machine learning to predict landslides based on Real- time sensor data. Implement a Three level alarm system to communicate risks effectively. Provide a user-friendly interface for real-time monitoring and alerts.

2.2Significance: This project has the potential to revolutionize disaster management by :Saving lives through timely evacuations. Reducing economic losses by protecting infrastructure. Empowering communities with real-time data and actionable insights.

3.Methodology

The research methodology involves a combination of "Desk Study", "Field Experiments" and "Data Analysis". The following steps were undertaken:

3.1Desk Study:

Reviewed existing literature on landslide prediction by IoT-based early warning system, and machine learning applications in disaster management. Analyzed government reports and policies related to disaster management and early warning systems.

3.2Field Experiments:

Used a "Random Forest Algorithm" to analyze sensor data predict landslide risks. Evaluated the model's accuracy and response time using historical landslide data.

4 System Architecture:

The proposed system consists of the following components:such as IoT Sensors,Soil Moisture Sensors use to Measure water content in the soil using capacitive or resistive sensing techniques ,Rain gauge Sensors use to Monitor precipitation levels using tipping bucket rain gauges. Accelerometers use to Detect slope movement and vibrations using MEMS-based sensors and for data Transmission Data is transmitted to a central server via "LoRaWAN" for long-range, low-power communication or "GSM" for areas with cellular coverage and also "Edge Computing" is used to process data locally, reducing latency and ensuring functionality in areas with poor connectivity.

4.1 **Machine Learning Model: The following is used**

• A **"Random Forest Algorithm**" is trained on historical landslide data to predict risks.

• The model analyses features such as soil moisture, rainfall intensity, and slope angle to classify risks into three levels : Green, Yellow, and Red

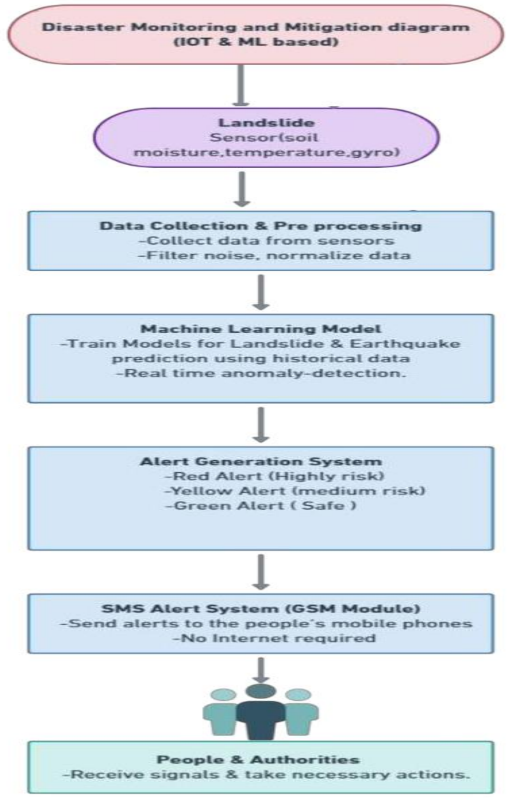

Figure 5: The above diagram illustrate the concept of Disaster monitoring & mitigation system**.**

5.User Interface:

• A **"Web-based dashboard"** and **"Mobile app" provide** real-time data visualization and alerts.

• The interface is designed to be intuitive and accessible to non-technical users

5.1. Three-Level Alarm System The System provides three levels of alerts:

Green (Safe):

• Indicates normal conditions with no immediate risk of landslides.

• Residents can continue their daily activities without concern.

Yellow (Potential Risk)

• Suggests a potential risk of landslides due to increased soil moisture or rainfall.

• Residents are advised to stay alert and prepare for possible evacuation.

Red (Imminent Danger)

• Indicates a high probability of landslides.

• Immediate evacuation is recommended, and emergency services are alerted.

International Journal of Advance Research in Science and Engineering
Volume No. 15, Issue No. 04, April 2026
www.ijarse.com
IJARSE
ISSN 2319 - 8354

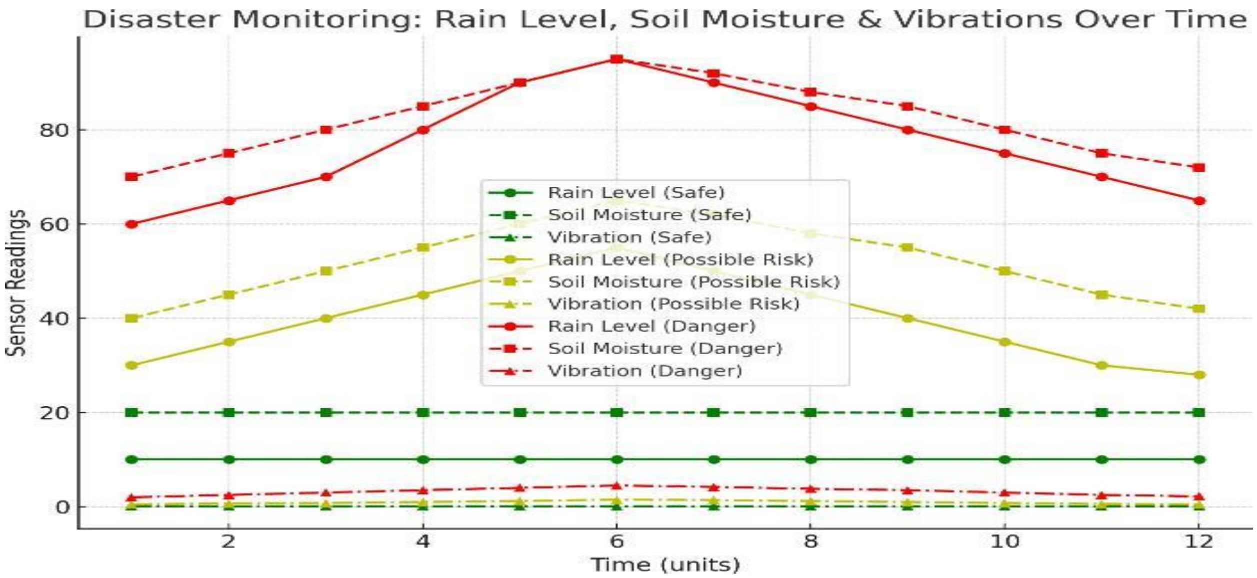

Fig 6:Sensor data input

5.2 **Sensor Placement:**

Soil Moisture Sensors:

Installed at depths of 30 cm,60 cm, and 1 meter to monitor water infiltration and saturation levels.

Rainfall Sensors: Positioned at elevated locations to avoid debris interference.

Accelerometers: Mounted on stabled rock surfaces To Detect slope movements and vibrations.

Data Collection Period: Data was collected continuously for"Six Months" Covering both monsoon season(high landslide risk) and dry periods (low risk**).**

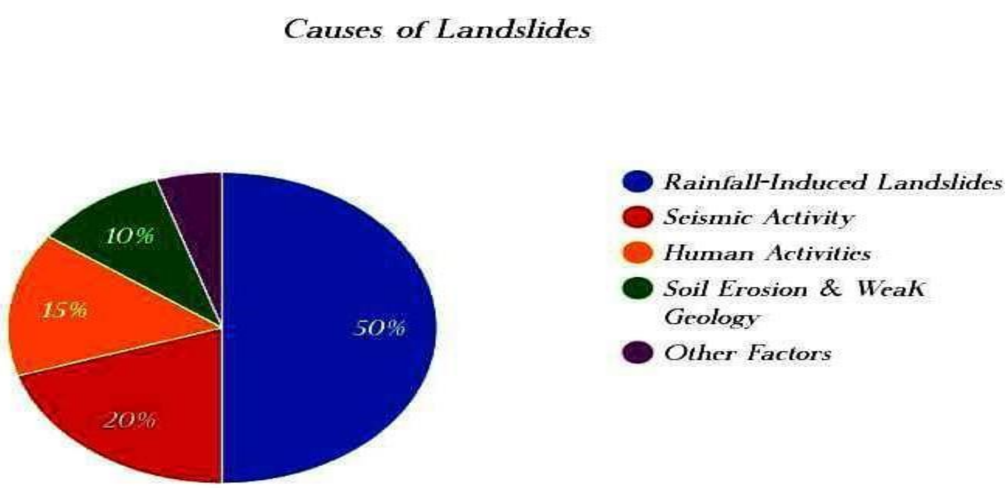

Figure:5.2 Causes of Landslides

6.**Model Training:**

-A "**Random Forest Algorithm**" was chosen for its ability to handle non-linear relationships and high-dimensional data. The model was trained on 70% of the dataset, with the remaining 30% used for validation**.**

• **Performance Metrics:**

Accuracy: Achieved 92% in predicting landslides.

-Precision and Recall: Precision of 89% and recall of 91%, indicating minimal false positives and false negatives.

-Response Time: Alerts were generated within "10 Seconds" of detecting abnormal patterns.

6.1Machine Learning Model Training and Validation:

• **Dataset Preparation:**

- Collected data was labeled based on historical landslide occurrences.

-Features included soil moisture, rainfall intensity, slope angle, and vibration frequency.

Cost effective and scalable : The use of low cost IoT sensors and open source ML algorithms makes the system affordable and scalable for deployment in other landslide-prone regions.

User Centric Design :The intuitive interface and three level alarm system ensure that even non-technical users can understand and Act on the alert.

Real – World Performance:

Landslide Events Detected:-Successfully predicted "Three landslide events" during the monsoon season, providing alerts "12-24 hours advance it "Detected" two earthquake-induced slope instabilities" with a lead time of "5-10 minutes".

False Alarms:-Only "two false alarms" were recorded, both caused by heavy machinery vibrations near the deployment site.

User Feedback:-Local authorities and residents praised the system for its accuracy and ease of use.

7.Challenges Faced:

Sensor Durability:-Some sensors malfunctioned due to prolonged exposure to heavy rain and debris.

Solution: Upgraded to ruggedized, weatherproof sensors.

Connectivity Issues: Remote locations experienced intermittent LoRaWAN and GSM connectivity**.**

Solution: Implemented edge computing to process data locally and store it temporarily until connectivity was restored.

8. Discussion:

The proposed system represents a significant advancement in landslide prediction and early warning. This section discusses the system's strengths, limitations, and potential for future improvements.

8.1.Strengths of the System:

Proactive Risk Mitigation: Unlike traditional systems that provide alerts after a landslide has begun, this system predicts events "24 hours in advance" enabling timely evacuations and preventive measures. Implement **Energy-Efficient Algorithms** to extend battery life and reduce maintenance costs. Collaborate with government agencies to integrate the system into national disaster management frameworks.

8.2.Energy Efficiency and Sustainability: Develop **Solar-Powered Sensors** to ensure continuous operations in remote areas.

8.3.Limitations:

• **Dependence on Historical Data:**

The ML model's accuracy depends on the availability of high quality historical data, which may be limited in some regions.

• **Environmental Challenges:**

Harsh weather conditions and rugged terrain can affect sensor performance and data transmission.
can interfere with landslide detection, leading to false alarms.

9.Future Work:

To address these limitations and enhance the system's capabilities, the following future work is proposed**:**

Integration with Satelite Data: Combine IoT sensor data with **Satelite imagery** and **GIS mapping** to improve risk assessment and coverage. Use **InSAR** (Interferometric Synthetic Aperture Radar) to detect ground deformations over large areas.

Advanced Machine Learning Techniques: Explore **Deep Learning Models** (e,g LSTM networks) to capture temporal patterns in sensor data. Implement **transfer learning** to adapt the model to new regions with limited historical data.

Multi -Hazard Early Warning System.: Expand the system to predict other natural disasters, such as Floods and earthquakes using the same sensor network. Develop a unified dashboard for monitoring multiple hazards.

10.Conclusion:

This paper presents a comprehensive IoT and Machine Learning-based system for landslide prediction and early warning. The system's ability to detect pre-failure signals and provide timely alerts **High Accuracy:** 92% prediction accuracy with minimal false alarms.• **Proactive Alerts:** Warnings issued up to 24 hours in advance • **User-Friendly Interface:** Intuitive design

for easy adoption by local communities it having **Broader Impact:** The System has the potential to save lives, protect infrastructure, and reduce economic losses in landslide-prone regions worldwide. By integrating advanced technologies like IoT, Machine Learning, and Satellite disaster management**.** To maximize the system's impact, collaboration between researchers, governments, and local communities is essential. Future efforts should focus on scaling the system, improving its robustness, and integrating it into national disaster management.

REFERENCE:

[1]. M.V . Ramesh, "Designm development and deployment of a wiresless sensor network for detection of landslides."**Ad Hoc Netw.. vol. 13 pp 2-18, feb 2014.**

[2]. Public EM-DAT Platform Accessed: May 5 2024. [Online]. Available: https://public.emdat.be.

[3]. M.J Froude and D. N Petley, "Global fatal landslideOccurrence from 2004 to 2016," Natural Hazards Earth Syst.,Sci.,vol 18, no 8 pp. 2161-2181, Aug 2018.

[4]. R. Bhasin, E. Grimstad. J. O. Larsen, A.K Dhawan,R. Singh, S.K Verma, and K. Venkatachalam, " LandslideHazards and mitigation measures at Gangtok, SikkimHimalaya," Eng. Geol vol 64, no 4 pp. 351-368, Jun. 2002

[5]. N. Vasudevan and K. Ramanathan, "Geological factorsContributing to landslides: Case studies of a few landslides In different regions of India," Proc. IOP Conf. Series, Earth**Environ.. Sci. vol 30, pp. 011-012, Aug 2016.**

[6]. Lee, C. H., & Choi, J. H. (2015). Landslide susceptibility mapping using a machine learning

[7]. approach. Environmental Earth Sciences, 73(12), 8017-8034.

[8]. Liu, Q., & Zhang, X. (2017). Machine learning for landslide susceptibility mapping: A review.Geomorphology, 294, 57-75.

[9]. Pradhan, B., & Lee, S. (2010). Landslide susceptibility mapping using support vector machines.Computers & Geosciences, 36(1), 48-59.

[10]. Saha, S., & O'Neill, M. (2014). Predicting landslide susceptibility using machine learning techniques. Geotechnical and Geological Engineering, 32(3), 657-675.

[11]. Carrara, A., & Guzzetti, F. (1995). GIS-based landslide hazard evaluation: A review of methodologies and applications. Natural Hazards, 11(3), 319-342.

[12]. He, Z., & Zhang, L. (2017). Landslide prediction using a machine learning algorithm: A case study from the Three Gorges Reservoir Area, China. Computers & Geosciences, 105, 88-98.

[13]. Zhang, G., & Cheng, L. (2015). Landslide hazard mapping with machine learning algorithms. Environmental Earth Sciences, 73(6), 3287-3299.

[14]. Ayalew, L., & Yamagishi, H. (2005). The application of GIS-based models to landslide susceptibility mapping in the highland area of Ethiopia. Geomorphology, 71(1-2), 125-137.

[15]. Godfrey, M. A., & Pomeroy, S. (2017). A review of machine learning methods for landslide susceptibility and hazard mapping. International Journal of Geophysics, 2017, Article 9072785.

[16]. Ahmadi, M. A., & Roudi, N. (2016). Prediction of landslide susceptibility using random forests and artificial neural networks. Computers & Geosciences, 93, 107-114.

[17]. Alvioli, M., & Catani, F. (2018). Landslide susceptibility mapping using machine learning: A review. Geophysical Research Letters, 45(21), 11- 302.

[18]. Ma, H., & Wang, Z. (2016). Machine learning algorithms for landslide susceptibility assessment: Acase study of the Baihe Area, China. Environmental Earth Sciences, 75(17), 1155.

[19]. Zhou, Y., & Li, Z. (2017). Landslide susceptibility prediction using machine learning: Acomparative analysis. Natural Hazards and Earth System Sciences, 17(9), 1391-1404.

[20]. Yang, S., & Wang, D. (2014). Landslide susceptibility mapping using a support vector machine(SVM) method: A case study in the Longmenshan region of China. Geoderma, 214, 79- 88

[21]. Wang, X., & Xu, L. (2018). Landslide hazard assessment using a hybrid model of machine learning.Natural Hazards, 91(3), 811-831.