India Moves Towards Comprehensive Landslide Early Warning System After Increasing Disaster Risks

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Recent Developments:

- Recent **landslides in the Western Ghats**, including the incident affecting the **under-construction twin tunnel project in Wayanad, Kerala**, have highlighted the urgent need for effective **Landslide Early Warning Systems (LEWS)** in vulnerable regions.
- Experts emphasise that scientific forecasting combined with timely evacuation can significantly reduce casualties in landslide-prone areas such as the **Western Ghats and Himalayan region**.
- The increasing frequency of extreme rainfall events due to **climate change** has strengthened the need to shift from reactive disaster response towards proactive risk reduction strategies.

Importance of Landslide Early Warning Systems:

Role in Disaster Risk Reduction:

- Landslides are predictable to a significant extent, especially in identified **high-risk zones**, when geological, climatic and environmental factors are continuously monitored.
- Effective **early warning systems** provide sufficient time for evacuation, thereby reducing loss of human lives, property damage and infrastructure disruption.
- Countries such as **Switzerland** have successfully reduced landslide-related casualties through advance warnings, hazard monitoring and planned evacuation systems.

Indian Experience with Early Warning Systems:

- The **2024 Munnar landslides in Kerala** demonstrated the effectiveness of scientific-based warnings, where timely evacuation based on expert advice prevented fatalities.
- Such examples highlight the importance of integrating scientific technology with local administration and community participation.

Landslide Vulnerability in India:

Extent of Landslide-Prone Areas:

- According to the **National Disaster Management Authority (NDMA)**, approximately **13% of India's geographical area**, covering around **0.42 million sq km**, is vulnerable to landslides.
- The major vulnerable regions include:
- **Himalayan region**, **Western Ghats**, **North-Eastern hill states and unstable mountainous zones**.

Highly Vulnerable Regions:

- Major landslide-prone areas include:
- **Tehri Garhwal and Uttarkashi in Uttarakhand**,
- **Mandi and Shimla in Himachal Pradesh**,
- **Aizawl region in Mizoram**,
- **Parts of Manipur**.

Relatively Less Vulnerable Regions:

- Despite frequent landslide events, **Sikkim** has comparatively lower vulnerability in certain areas due to:
- Less extensive road construction,
- Reduced mountain cutting,
- Lower slope disturbance, which improves geological stability.

Major Approaches for Landslide Forecasting:

Sensor-Based Monitoring System:

Concept and Development:

- Sensor-based monitoring systems have been developed by research institutions such as **Amrita University** for continuous monitoring of unstable slopes.
- These systems involve installing advanced sensors at identified high-risk locations.

Key Instruments Used:

- Important monitoring devices include:
- **Tilt meters**, **pressure gauges**, **accelerometers**, **ground movement sensors and vibration sensors**.

Working Mechanism:

- Sensors continuously measure changes in:
- **Slope movement**, **ground pressure**, **vibration levels and stability conditions**.
- When recorded values cross predefined safety limits, warnings are issued to local authorities for timely evacuation.

Advantages:

- The system is:
- **Scientifically reliable**, **highly accurate and capable of providing sufficient evacuation time**.
- Such systems have been successfully tested in vulnerable areas of **Kerala**.

Limitations:

- The system can monitor only those slopes where instruments are installed.
- It cannot predict landslides occurring on nearby unmonitored slopes.
- Installation, maintenance and expansion of sensor networks require significant financial resources.

Probabilistic Forecasting Model:

Concept and Development:

- The **Indian Institute of Technology Mandi** has developed a probabilistic model to estimate landslide probability over large geographical areas.

Methodology:

- The model combines:
- **Satellite-based historical landslide mapping**, **rainfall forecasts**, **soil characteristics**, **rock stability**, **slope gradient and population density**.
- It uses approximately **7–10 rainfall-related parameters** for analysing landslide probability at specific locations.

Validation:

- The model has been validated against approximately **80 actual landslide events** in the Himalayan region.

Advantages:

- The model can cover:
- **Large geographical regions**, including remote areas where physical monitoring is difficult.
- It can identify multiple vulnerable locations simultaneously.

Limitations:

- The accuracy of the model depends heavily on high-resolution rainfall forecasts.
- Current rainfall predictions are generally available only around **1 day in advance**, which limits evacuation time.
- Improved forecasting capability of the **India Meteorological Department (IMD)** can significantly enhance landslide prediction accuracy.

Towards a National Landslide Early Warning System:

Need for Integrated Approach:

- Experts suggest that India can develop an effective nationwide **Landslide Early Warning System** within approximately **2 years** with adequate resources, technology and institutional cooperation.
- A comprehensive system should combine:
- **Satellite monitoring**, **sensor-based observations**, **high-resolution weather forecasting**, **Geographical Information System (GIS)** and **remote sensing technologies**.

Priority Actions Required:

- India should focus on:
- Identification of **high-frequency and high-impact landslide zones**,
- Preparation of detailed **hazard zonation maps and risk assessment maps**,
- Installation of sensor networks in extremely vulnerable locations.

Institutional Coordination:

- Effective implementation requires coordination among:
- **India Meteorological Department (IMD)**,
- **National Disaster Management Authority (NDMA)**,
- **Geological Survey of India (GSI)**,
- **State Disaster Management Authorities (SDMAs)**,

Local administration and communities.

Challenges and Way Forward:

Major Challenges:

Lack of Comprehensive Mapping:

- India lacks complete mapping of all high-risk landslide hotspots, which affects targeted monitoring and preventive planning.
- A national system combining sensor-based monitoring and probabilistic forecasting models is required.

Limited Sensor Network Coverage:

- Existing sensor deployment is limited and needs expansion through:
- **Remote sensing**, **GIS-based analysis and artificial intelligence-based prediction tools**.

Dependence on Short-Term Rainfall Forecasts:

- Current rainfall prediction limitations reduce the available warning period.
- Development of high-resolution rainfall forecasting by the **India Meteorological Department** is essential.

High Infrastructure Costs:

- Monitoring infrastructure requires significant investment.
- Priority should be given to:

Critical infrastructure, **transport corridors and densely populated hill settlements**.

Way Forward Measures:

- India should promote:
- Greater inter-agency coordination,
- Long-term investment in monitoring infrastructure,
- Community awareness programmes,
- Evacuation drills and local disaster preparedness.
- Disaster management should shift from post-disaster relief towards **anticipatory action and risk reduction**.

Conclusion:

- Climate change-induced extreme rainfall events are increasing the frequency and intensity of landslides in India.
- A combination of **scientific forecasting**, **advanced monitoring systems**, **institutional coordination and community preparedness** can transform landslide management from reactive response to proactive disaster risk reduction.
- A comprehensive national **Landslide Early Warning System** can protect human lives, infrastructure and sustainable development in vulnerable regions.

Value Addition for UPSC:

Important Facts:

- **Disaster Type:** Geological Disaster
- **Major Vulnerable Regions:** Himalayas, Western Ghats, North-Eastern Hills
- **Landslide-Prone Area in India:** Around **13% of geographical area**
- **Key Institution:** National Disaster Management Authority
- **Scientific Agencies:** Geological Survey of India, India Meteorological Department
- **Key Technologies:** Remote Sensing, Geographic Information System, Artificial Intelligence, Sensor Networks