Progress in Landslide Science: From Unseen Forces to a More Resilient Future

Key Insights from Progress in Landslide Research and Technology, Volume 4

International Ceosertiom on Landslides | Springer

NotebookLM

A Complex and Growing Global Threat

11,500 fatalities per year

globally from landslides (2004-2016).

Landslides are a multifaceted global hazard, driven by an **intricate mix of natural forces and intensifying human activity.** They cause extensive damage to infrastructure, with economic impacts in the US alone averaging **$1–2 billion annually.**

To protect lives, we must move beyond simple observation to a deeper, more integrated understanding of their triggers, behaviour, and the frameworks needed for effective risk reduction.

"The disturbance they cause to communities can lead to the displacement of residents, loss of livelihoods, and social and economic instability." — *Binod Tiwari*

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The Unseen Forces

Revealing the Complex Interplay of Landslide Triggers

Beyond Magnitude: The Critical Role of Season in Seismic Landslides

A comparative analysis of major earthquakes reveals that pre-existing ground moisture is a critical differentiating factor in the number of landslides triggered.

DRY SEASON

Hyogoken Nanbu (Kobe), 1995

- Mw 6.8
- Occurred in January
- Monthly Rainfall: **37.5 mm**
- Result: **Few** deep-seated landslides

Tōhoku, 2011

- Mw 9.0
- Occurred in March
- Monthly Rainfall: **38.0 mm**
- Result: **<100** deep-seated landslides (far fewer than expected for its magnitude)

RAINY SEASON

Niigata, 2004

- Mw 6.8
- Occurred in October (after a typhoon)
- Monthly Rainfall: **237.5 mm**
- Result: **>1000** deep-seated landslides

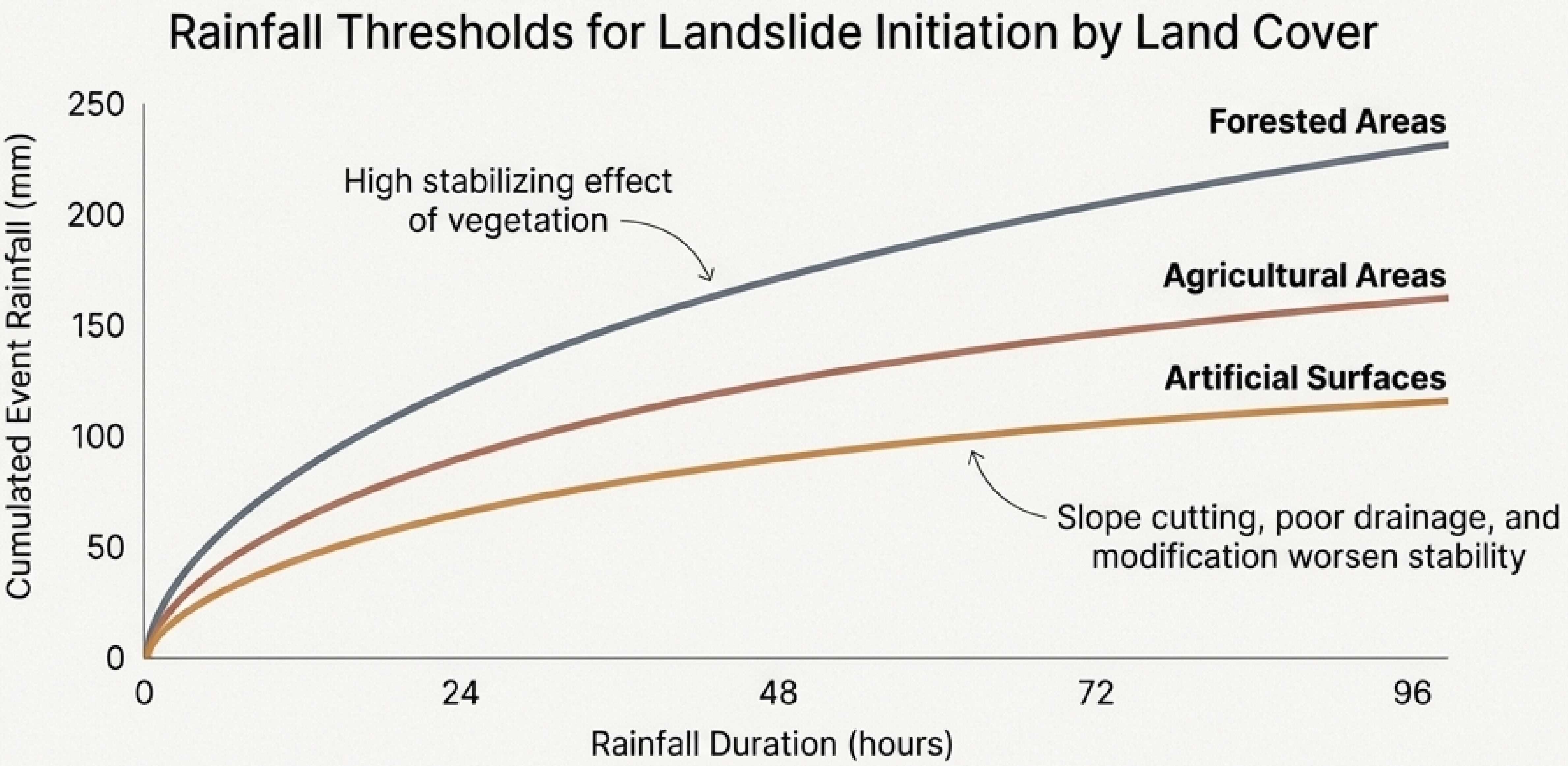
Iwate-Miyagi, 2008

- Mw 6.9
- Occurred in June
- Result: **>4100** deep-seated landslides

The occurrence of the [Tōhoku] earthquake during or after the rainy season could be significantly devastating. This underscores that seismic risk assessments must integrate climatic and hydrological data.

Human Activity Lowers the Bar for Disaster

A study of shallow landslides in central Italy demonstrates that different land covers require dramatically different amounts of rainfall to trigger a slope failure.

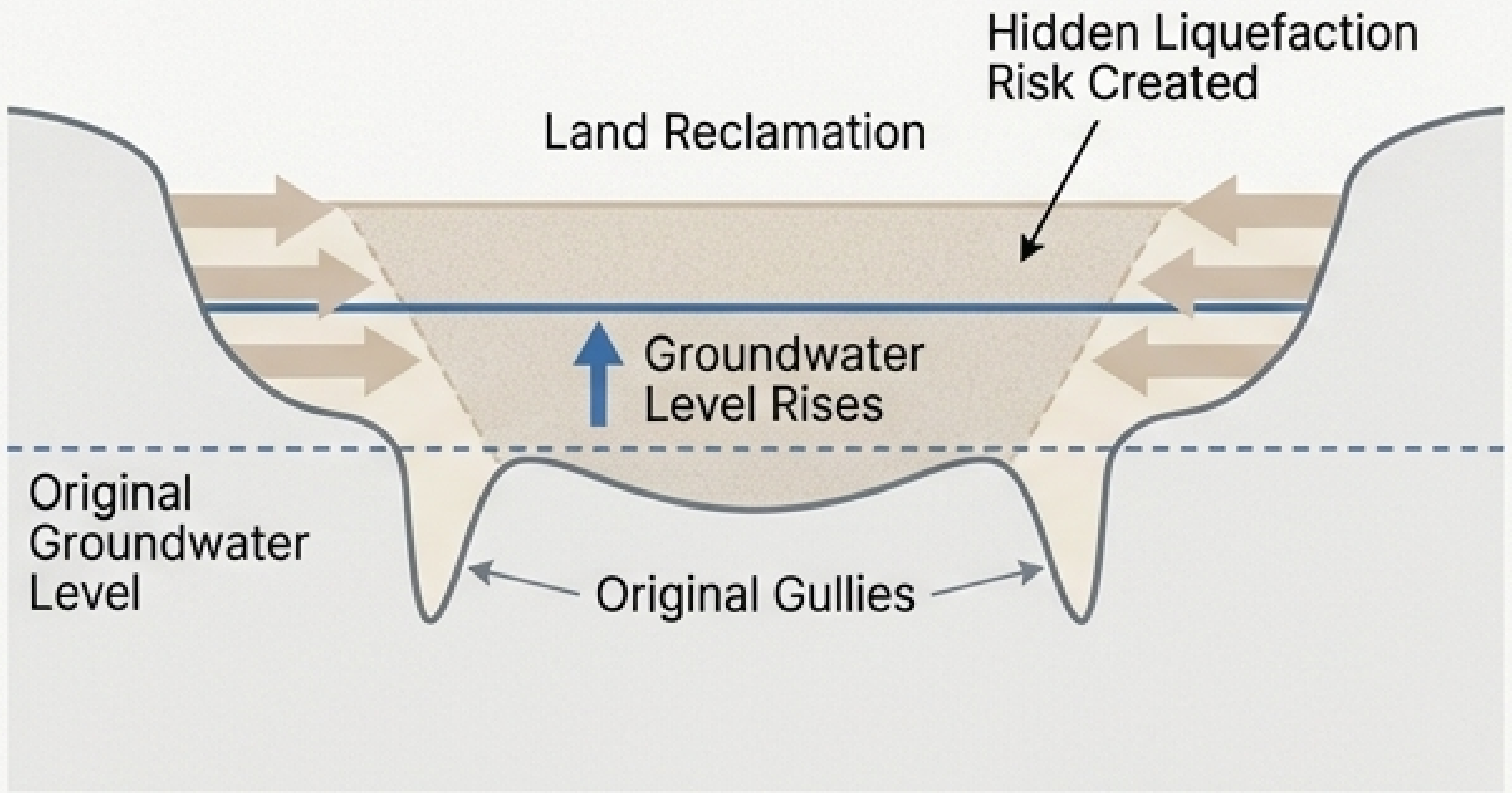


Urbanization and artificial surfaces significantly increase landslide hazard, as slopes can fail eail under less extreme rainfall conditions compared to natural or agricultural landscapes.

A Chain Reaction: How Terrain Modification Amplified a Seismic Hazard

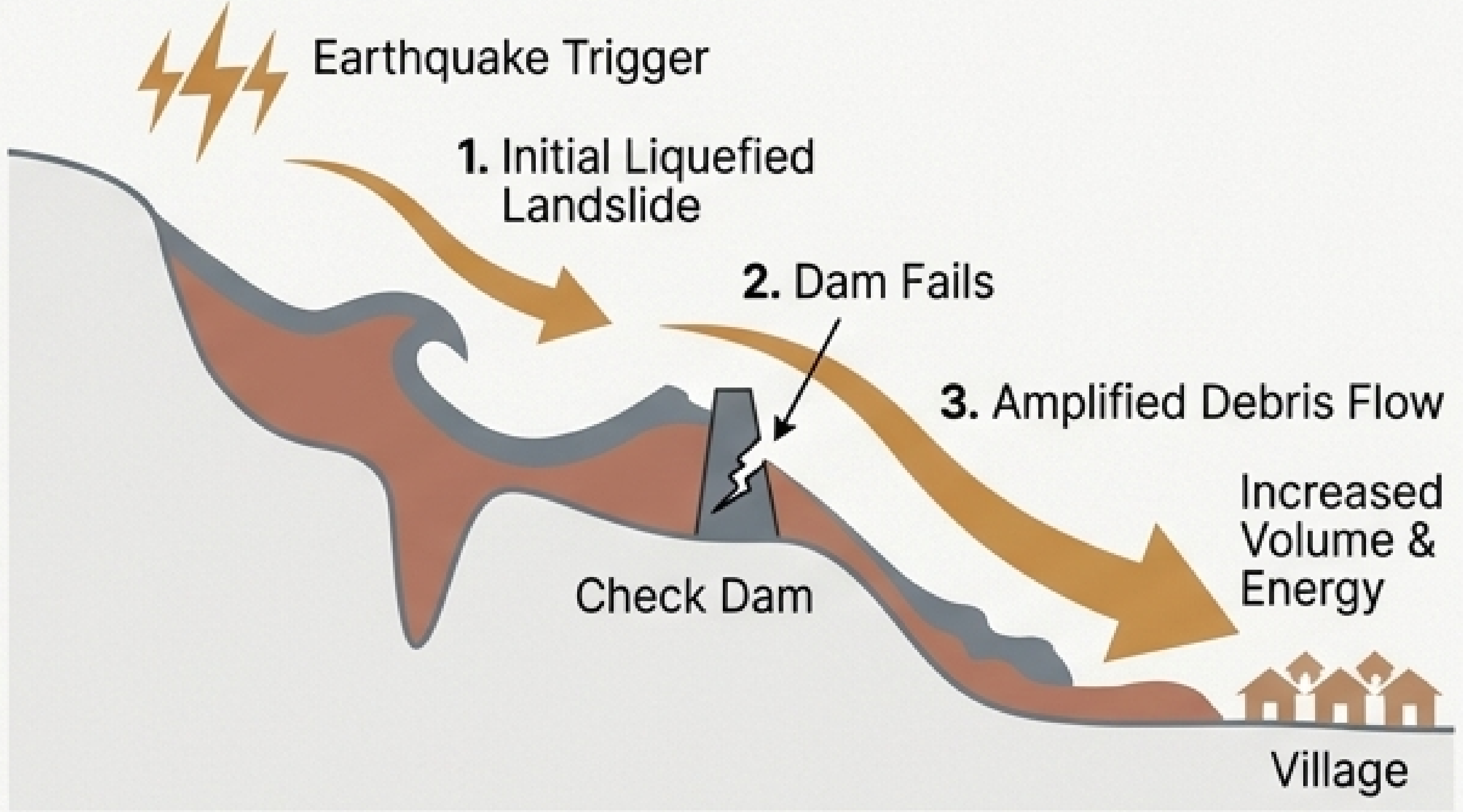
Case Study: Jintian Village, Ms 6.2 Jishishan Earthquake (Dec 18, 2023)

PART 1: THE UNSEEN RISK



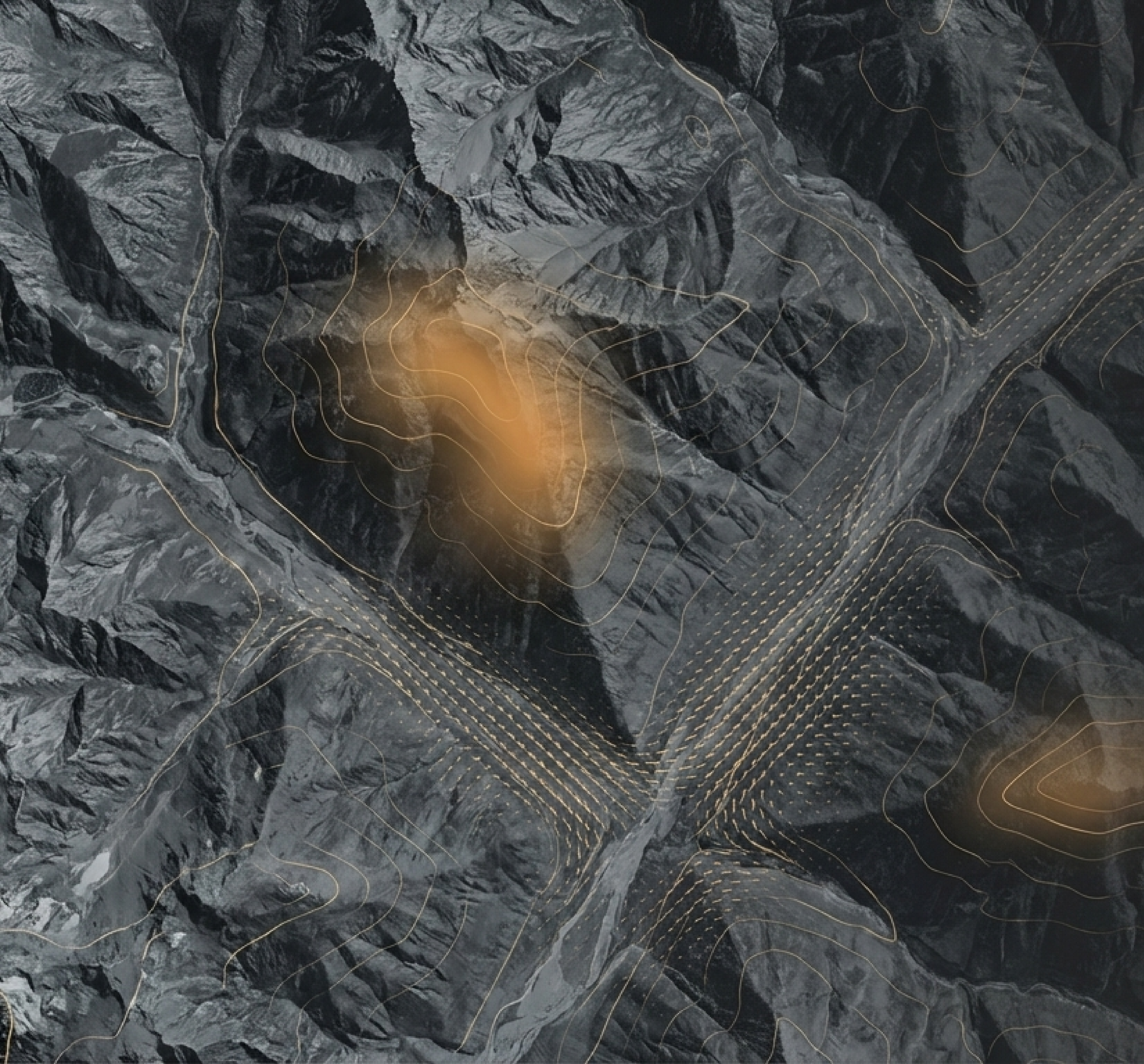
- **Key Finding 1:** Land reclamation involving valley infilling altered regional hydrology, promoting soil liquefaction.

PART 2: THE DISASTER CHAIN



- **Key Finding 2:** The failure of a check dam, intended as a mitigation measure, amplified the landslide's volume and potential energy, worsening its impact.

"The results underscore the need for regions with loess... to carefully evaluate the detrimental effects of terrain modifications." — Jian Guo & Yifei Cui



A Sharper View

Harnessing New Technologies
for Monitoring and Analysis

From Sky to Safety: UAVs for Hyper-Local Exposure Mapping

Unmanned Aerial Vehicles (UAVs) can generate high-resolution 3D models and imagery, enabling a detailed assessment of landslide exposure at the household level.

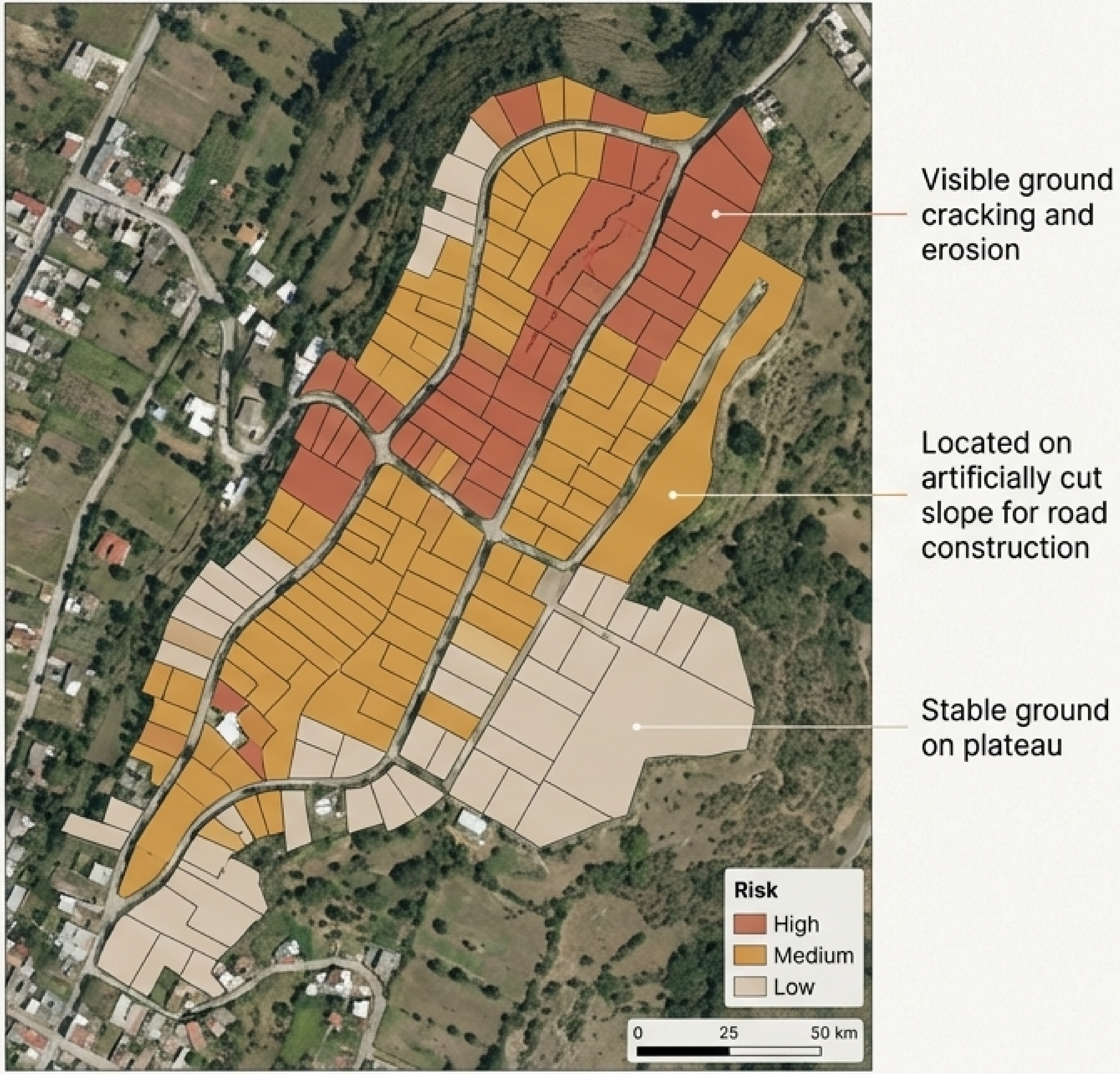
Case Study: Tlatlauquitepec, Puebla, Mexico

High Exposure
9.8% - 35 properties on land with existing instability (cracking, erosion, past landslides)

Medium Exposure
45.5% - 163 properties on or near steep, modified slopes

Low Exposure
44.7% - 160 properties on flatter, more stable ground

Advanced remote sensing tools like UAVs move risk assessment from a regional overview to actionable, property-specific insights, crucial for targeted risk management and community planning.



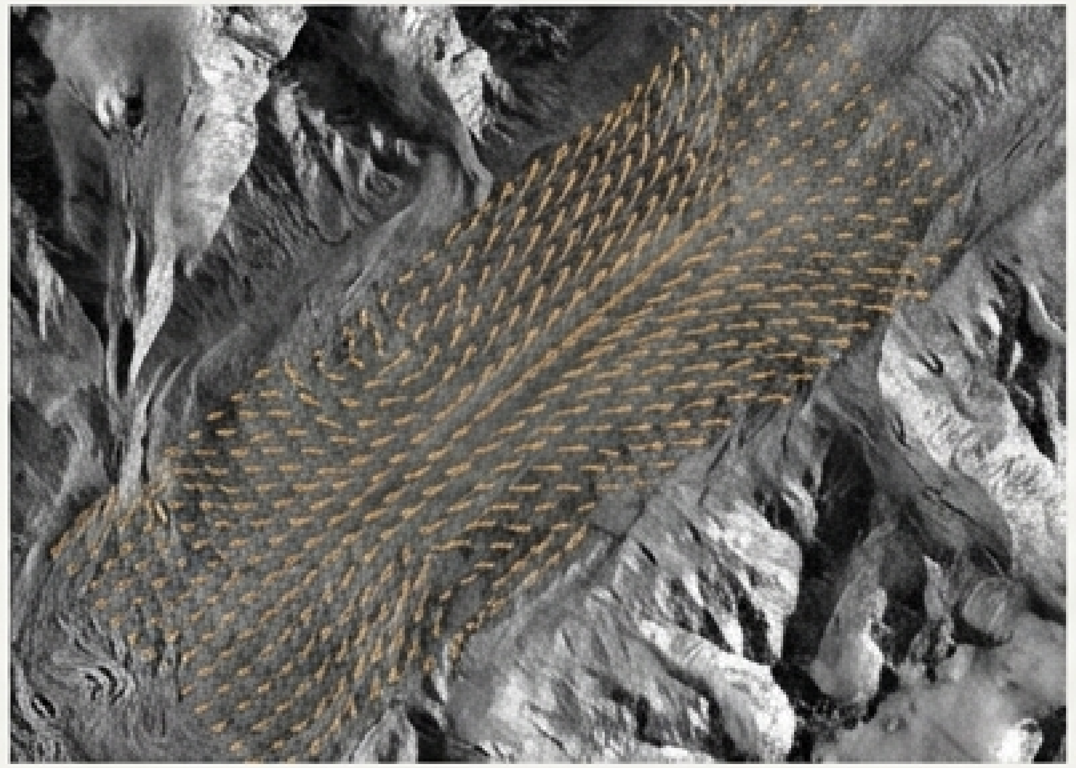
Map of landslide exposure

Optical Flow: A Unified Algorithm for Multi-Source Motion Tracking

Technology spotlight in Inter: The AkhDefo open-source Python library.

Core Insight: The optical flow algorithm can measure displacement and quantify mass movements by analyzing a wide range of imagery, moving beyond static analysis to near real-time observation.

Sentinel-1 Radar Backscatter



Displacement vectors quantifying glacier creep.

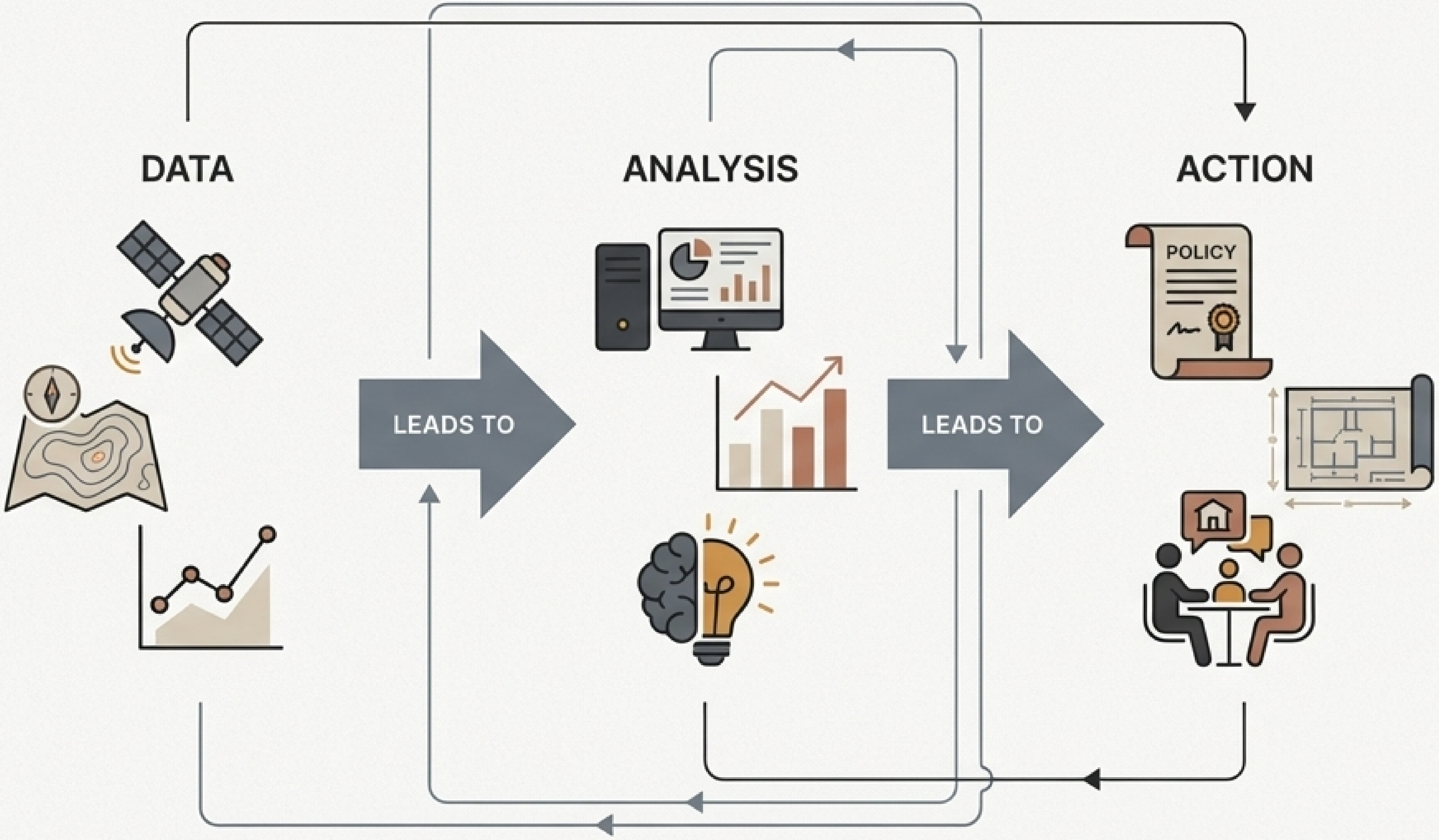
PlanetScope Optical Imagery

Tracking rapid, large-scale landslide motion.

Live Webcam Feed

Real-time detection of rockfall from a static camera.

The ability to process optical, radar, and live-stream video with a single algorithmic framework represents a state-of-the-art leap in creating responsive, robust, and cost-effective monitoring systems.



From Data to Action

Building Frameworks for Integrated Risk Reduction

Interweaving Systems of Knowledge

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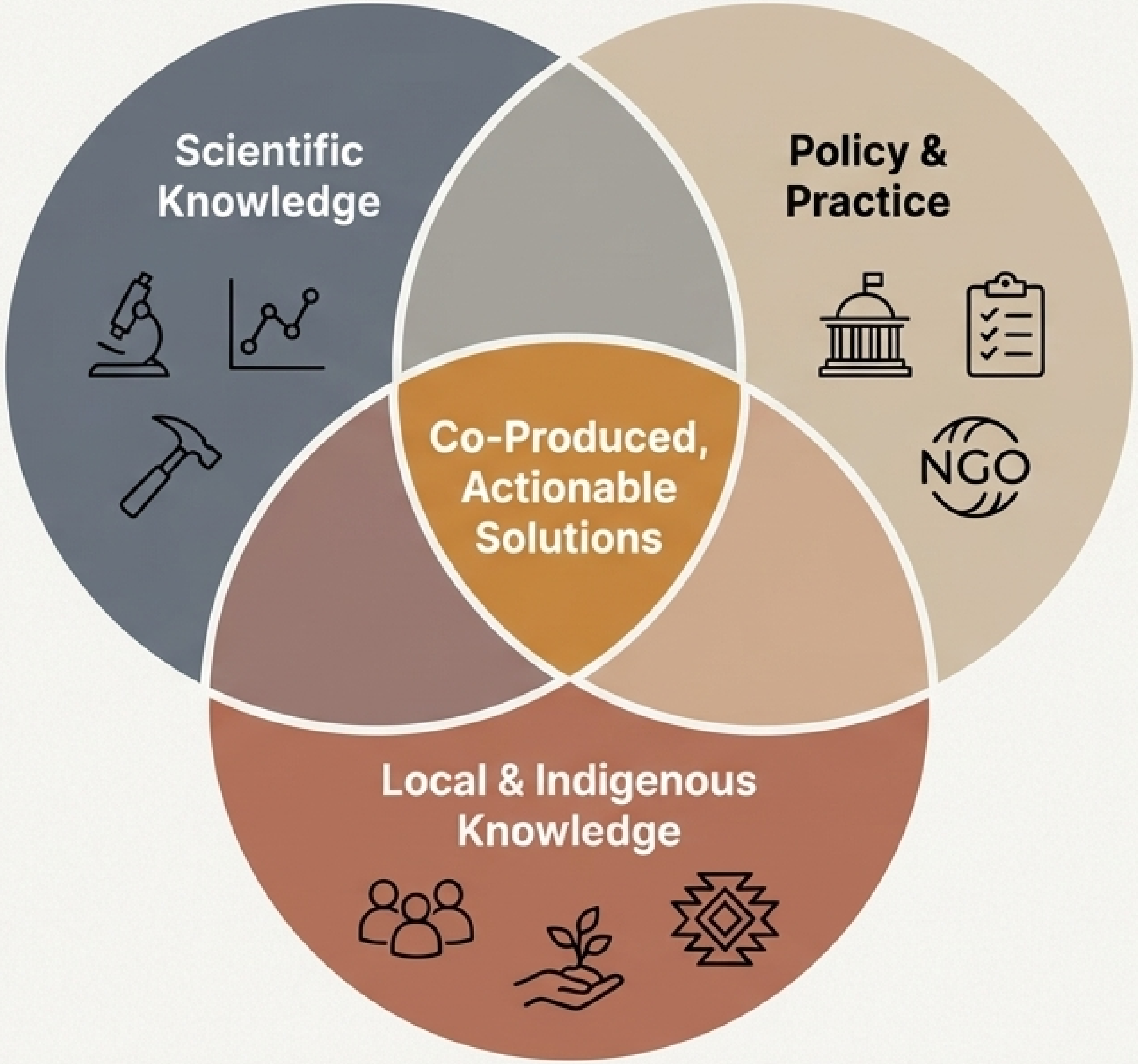
Transdisciplinary Research (TDR) is a paradigm shift that moves beyond disciplinary silos. It advocates for the co-production of knowledge through the collaborative engagement of scientists, policymakers, practitioners, and local communities.



> "TDR transcends traditional academic boundaries, fostering collaboration between scientists, policymakers, practitioners, and communities to address complex environmental and societal challenges."
>
> — Irasema Alcántara-Ayala

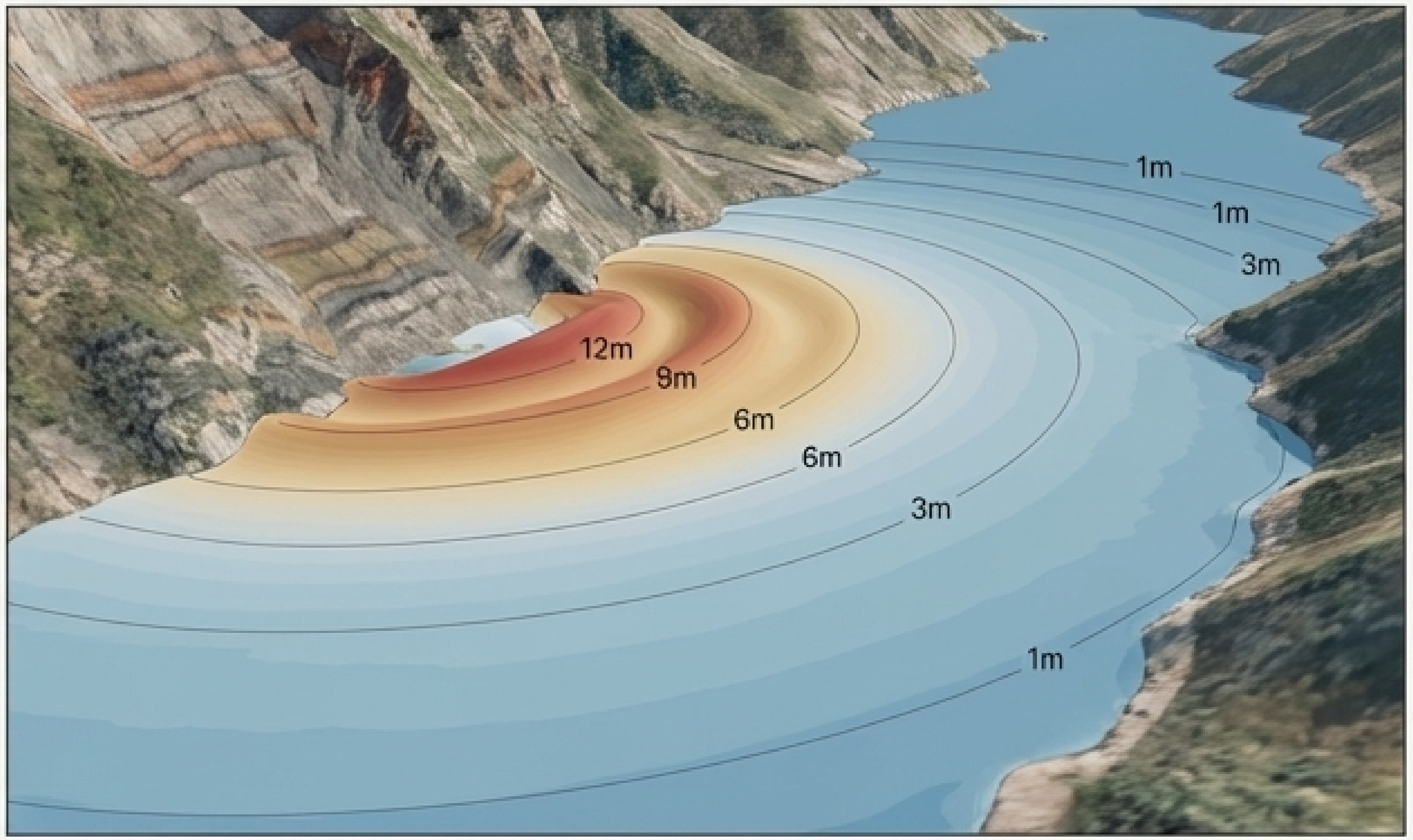
Modeling the Cascade: Simulating Landslide-Induced Tsunamis

Core Insight: Predicting the full impact of a landslide that enters a body of water requires a fluid-solid coupling model that simulates both the land movement and the resulting waves.

Technology Spotlight: A novel model coupling Ls-Rapid (progressive landslide model) with COMCOT (tsunami model).

Ls-Rapid: Simulating the Rock Mass Collapse

COMCOT: Simulating the Resulting Impulse Waves



Advanced numerical simulations are essential tools for understanding and mitigating multi-hazard events, allowing for better prediction of impact zones and improved disaster preparedness.

The Futunture of Landslide Science: A Pivotal Shift

The research presented showcases a fundamental evolution in our approach to landslides. We are moving away from a purely reactive stance toward a proactive and integrated one. This shift is built on three pillars:

A Deeper Understanding

Recognizing the complex, interconnected triggers that combine natural forces with human influence.

A Sharper View

Leveraging revolutionary technologies (UAVs, Optical Flow, Advanced Modeling) to monitor, measure, and predict risk with unprecedented precision.

A Collaborative Framework

Embracing transdisciplinary approaches that co-produce knowledge and ensure solutions are scientifically sound, locally relevant, and actionable.

The future of landslide safety lies not in a single discipline, but in the integration of technology, deep science, and community partnership to build a more resilient world.

Explore the Full Volume

Understanding Triggers

- Characteristics of Earthquake-Induced Landslides - Tiwari
- Role of Land Cover and its Changes - Gariano et al.
- Amplification of Landslide Hazards Due to Terrain Modification - Guo & Cui

New Monitoring & Analysis Technologies

- From Sky to Safety: Unmanned Aerial Vehicles - Sánchez-Rojo et al.
- Optical Flow: A Multifaceted Approach - Muhammad & Suriev
- Monitoring and Characterization of Surface Movements - Carlà et al.
- A Novel Fluid-Solid Coupling Model - Lu et al.

Frameworks for Risk Reduction

- Interweaving Systems of Knowledge - Alcántara-Ayala
- Implementation of the Early Warning Technology - Konagai et al.

Case Studies & Regional Reports

- Rock Avalanches of North-Eastern Transbaikalia - Zerkal & Barykina
- Landslides Risk Reduction with Focus on Mitigation in India - Parkash et al.

The International Consortium on Landslides (ICL)

This research is part of a global effort to promote understanding and reduce landslide disaster risk, contributing to the Kyoto Landslide Commitment 2020.

www.landslides.org

Journal Information

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