# Disaster Resilience from the Lens of Earth Observation in the Digital Era

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Australia

# Presentation Outline:

- Brief introduction on the research team and the capabilities in Land, Geospatial and Disaster management
- Global disasters – facts and figures
- Local disasters – representative cases
- EO Applications
  - Baseline Mapping, Monitoring & Forecasting, Post-Disaster Needs Assessment
- Published research in disaster mapping, key messages
- Potential concepts for land use planning and disaster resilience

# Earth Observation and AI Research Group

Group Lead: A/Prof. Dr Jagannath Aryal

**Office:**
The University of Melbourne, Melbourne Connect, Carlton, VIC 3053, AU

**Research Fellows**

**PhD Researchers**





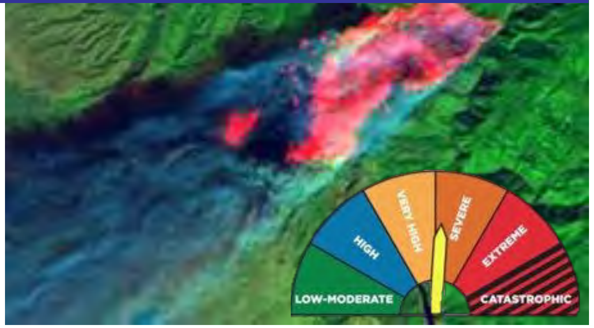




# Representative projects

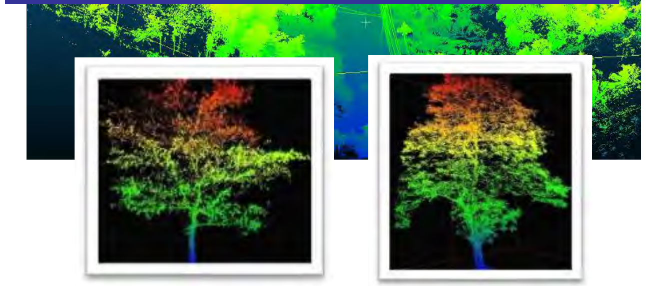
## Urban Feature Extraction

## Bushfire Severity Classification




## Informal Settlement Mapping

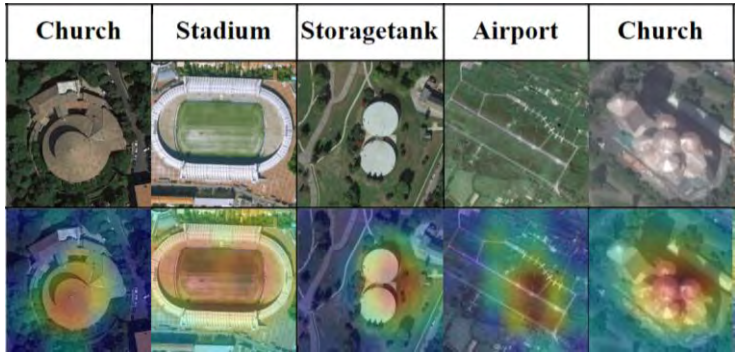
## LIDAR point cloud segmentation for urban vegetation



## Digital Agricultural Services (DAS)

## Urban Sprawl Management

## Land Use Classification



https://eng.unimelb.edu.au/csdila

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CSDILA

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# Centre for Spatial Data Infrastructures and Land Administration

**Faculty of Engineering and Information Technology**

### Our Vision

To drive the evolving concept of spatial data infrastructures and modernization of land administration systems by developing advanced 3D virtual information systems, that integrate, model, and visualize data and make it accessible for solving the demands faced by modern society.

→ More about CSDILA

## News Highlights

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# Centre for Disaster Management and Public Safety

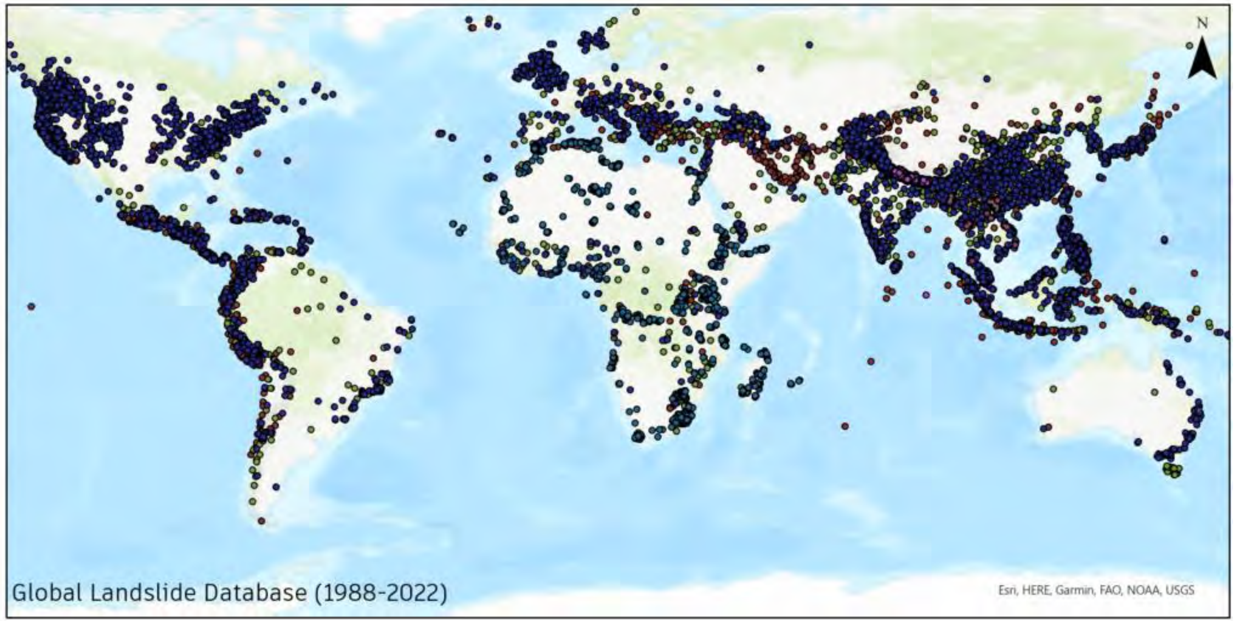


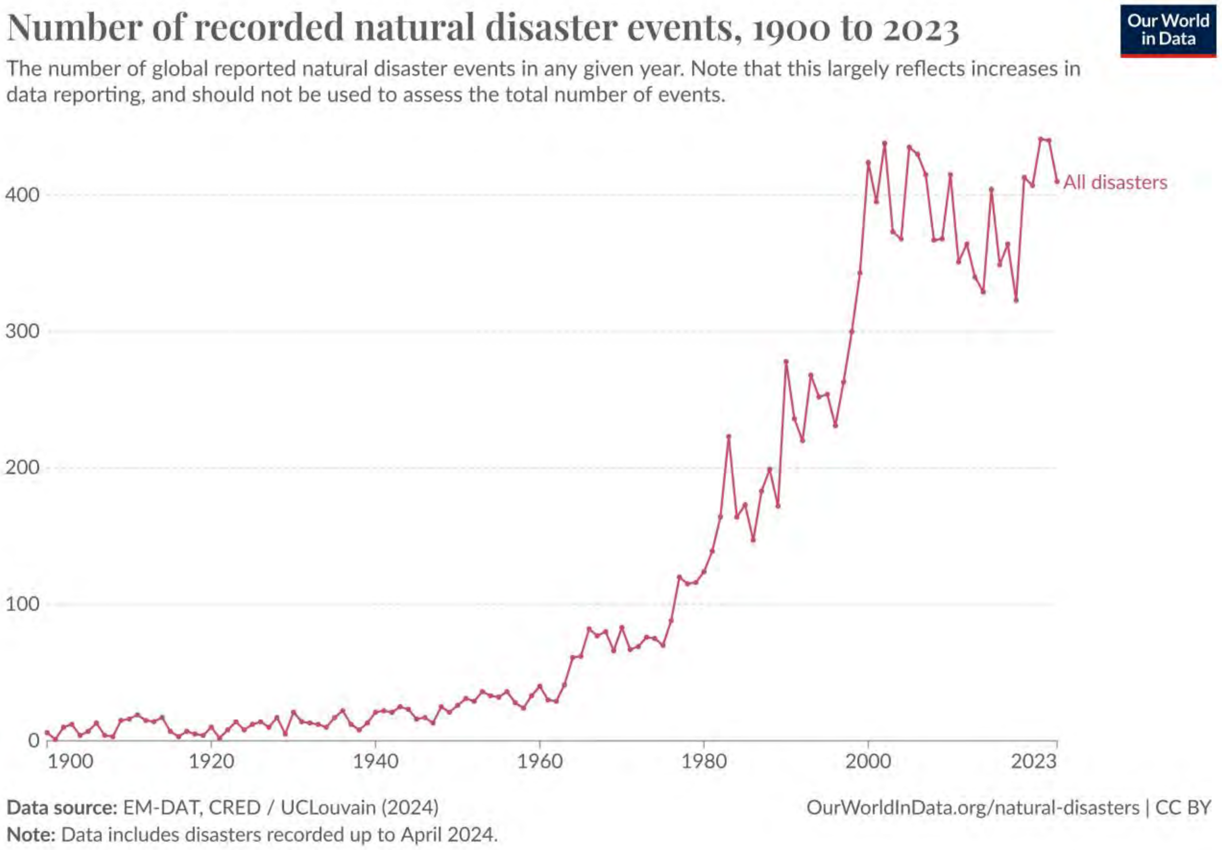
Delivering world-class interdisciplinary research and innovation to improve the whole-system response and resilience of infrastructure, institutions and communities against extreme events and critical incidents, and contribute to the UN Sustainable Development Goals.

# Globally, disasters are happening more frequently

Factors contributing to this trend:

- Climate change
- Population growth
- Urbanisation
- Environmental degradation

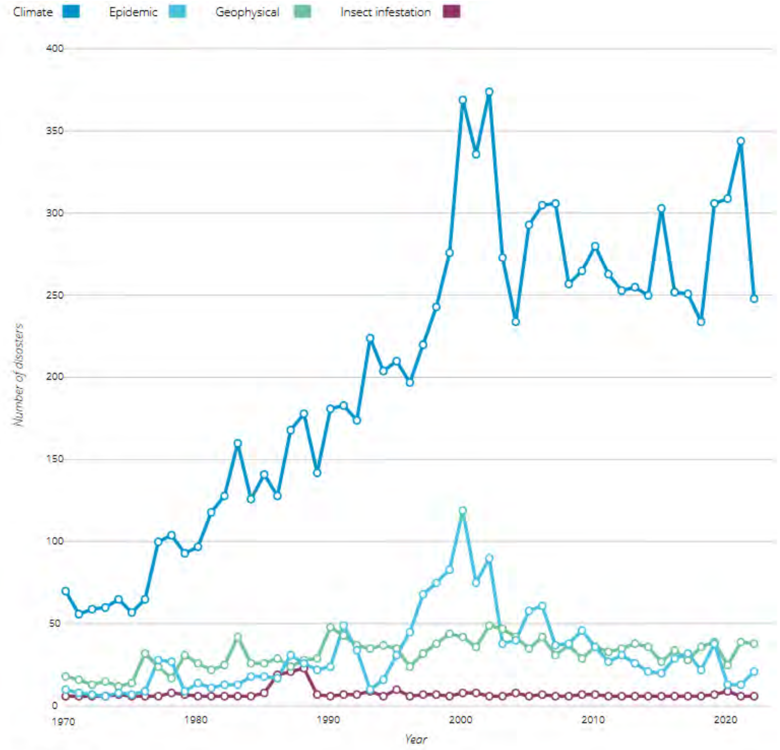



Sourced from: https://ourworldindata.org/grapher/number-of-natural-disaster-events

# More and more disasters linked to climate

## Number of disasters by type per year, 1970–2021




*Source: EM-DAT*

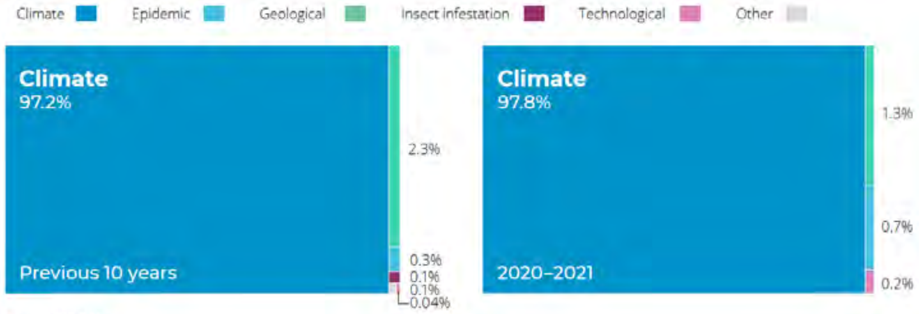
*Notes: The number of climate- and weather-related disasters per year has increased over this period. Meanwhile the number of disasters linked to geological hazards has held steady.*

## Annual disasters caused by wildfires, 1970–2021


*Source: EM-DAT*

*Note: The black dotted line is the trend since 1970. The blue dotted line is the average of the last 50 years.*

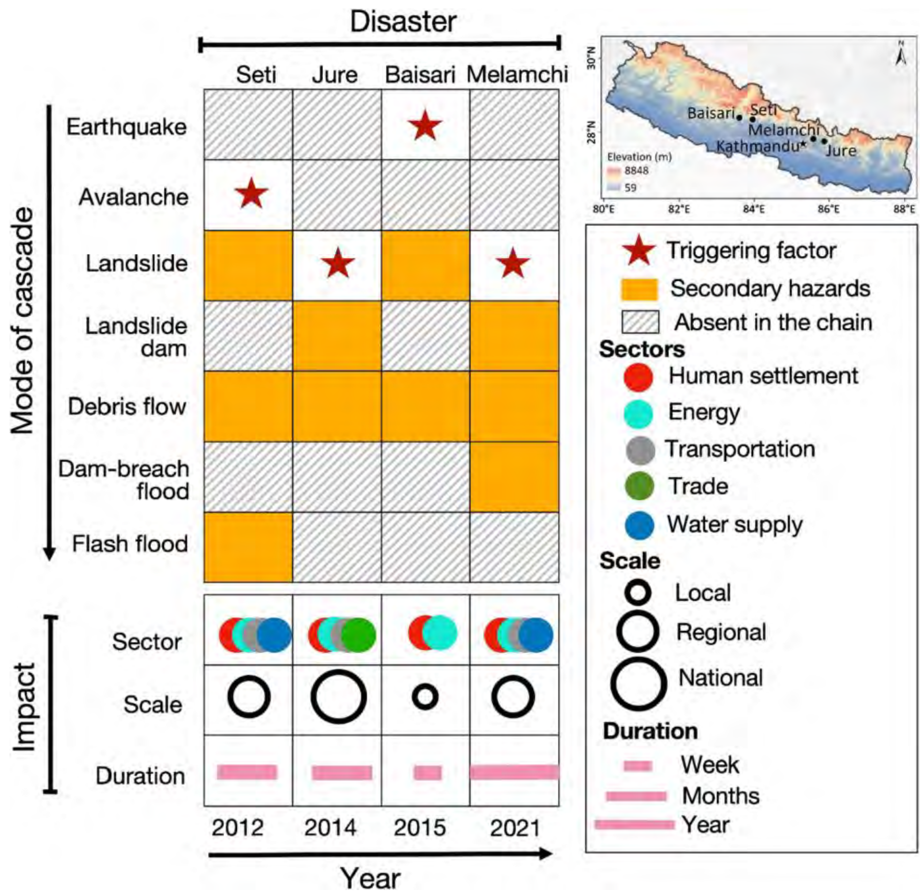
## Percentage of the total number of people affected by disasters every year, by disaster type

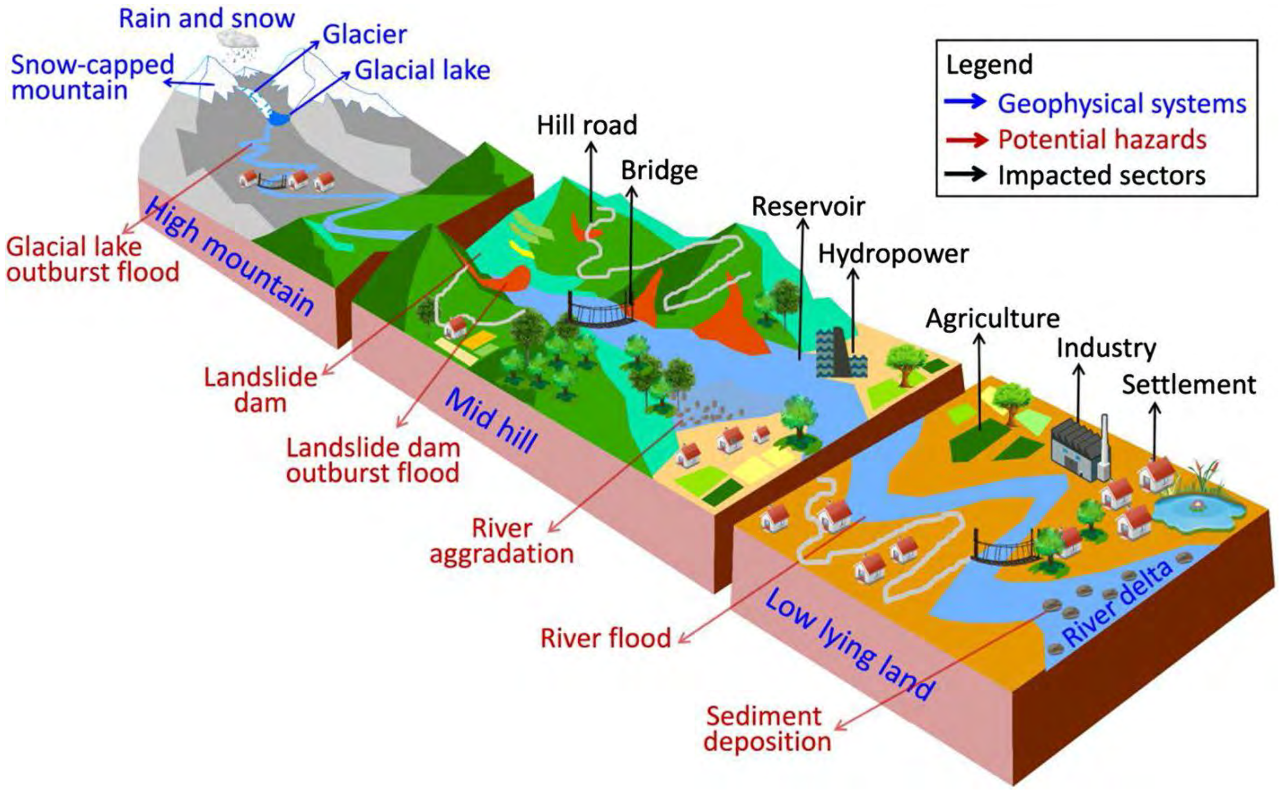



*Source: EM-DAT*

Sourced from: https://www.ifrc.org/sites/default/files/2023-01/20230130_2022_WDR_DataAnnex.pdf

# Disasters in Nepal

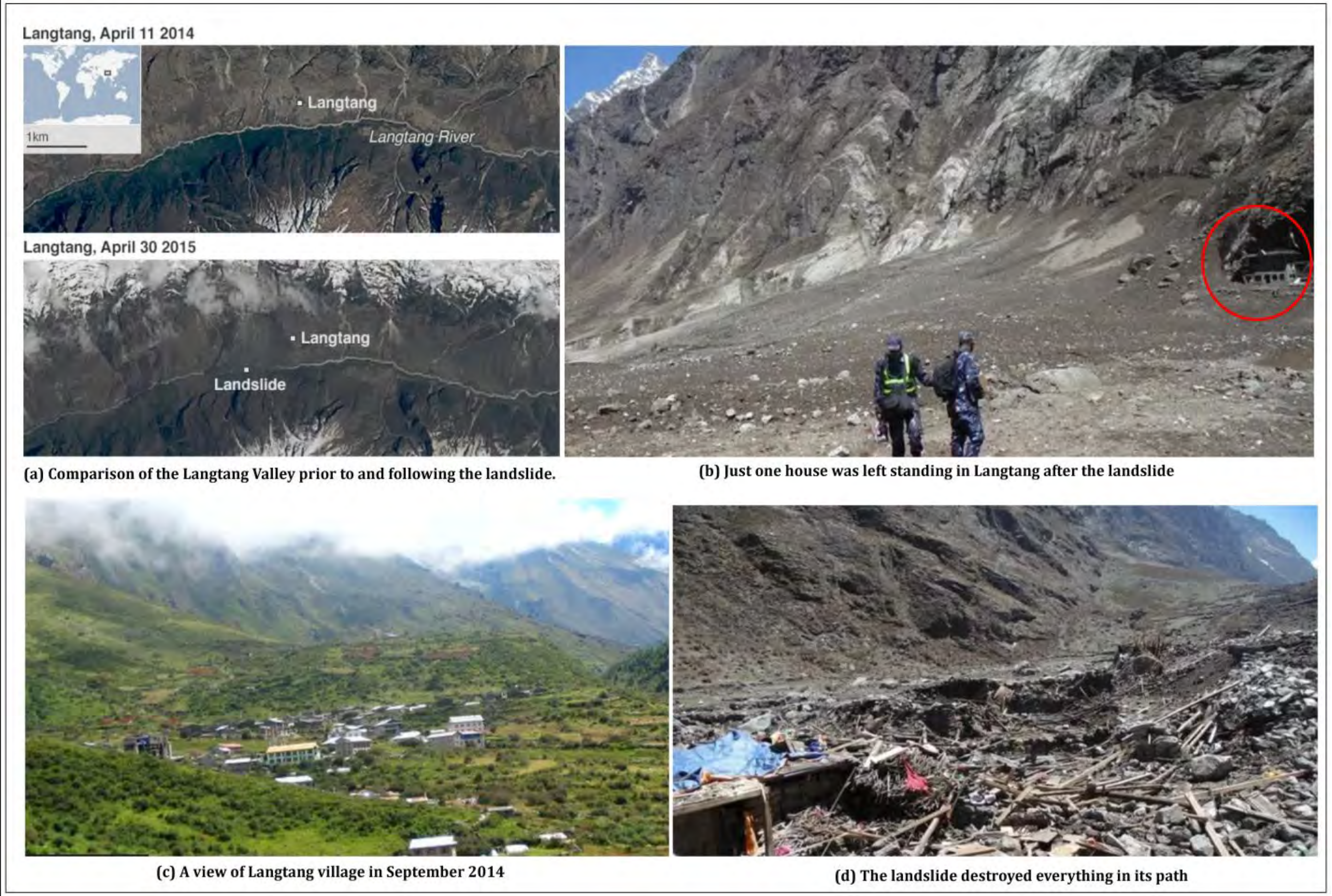



Sharma, S., Talchabhadel, R., Nepal, S., Ghimire, G. R., Rakhal, B., Panthi, J., Adhikari, B. R., Pradhanang, S. M., Maskey, S. & Kumar, S.Increasing risk of cascading hazards in the central Himalayas. *Natural Hazards*. 2023; 119, 1117–1126. https://doi.org/10.1007/s11069-022-05462-0

# Langtang Valley Landslide

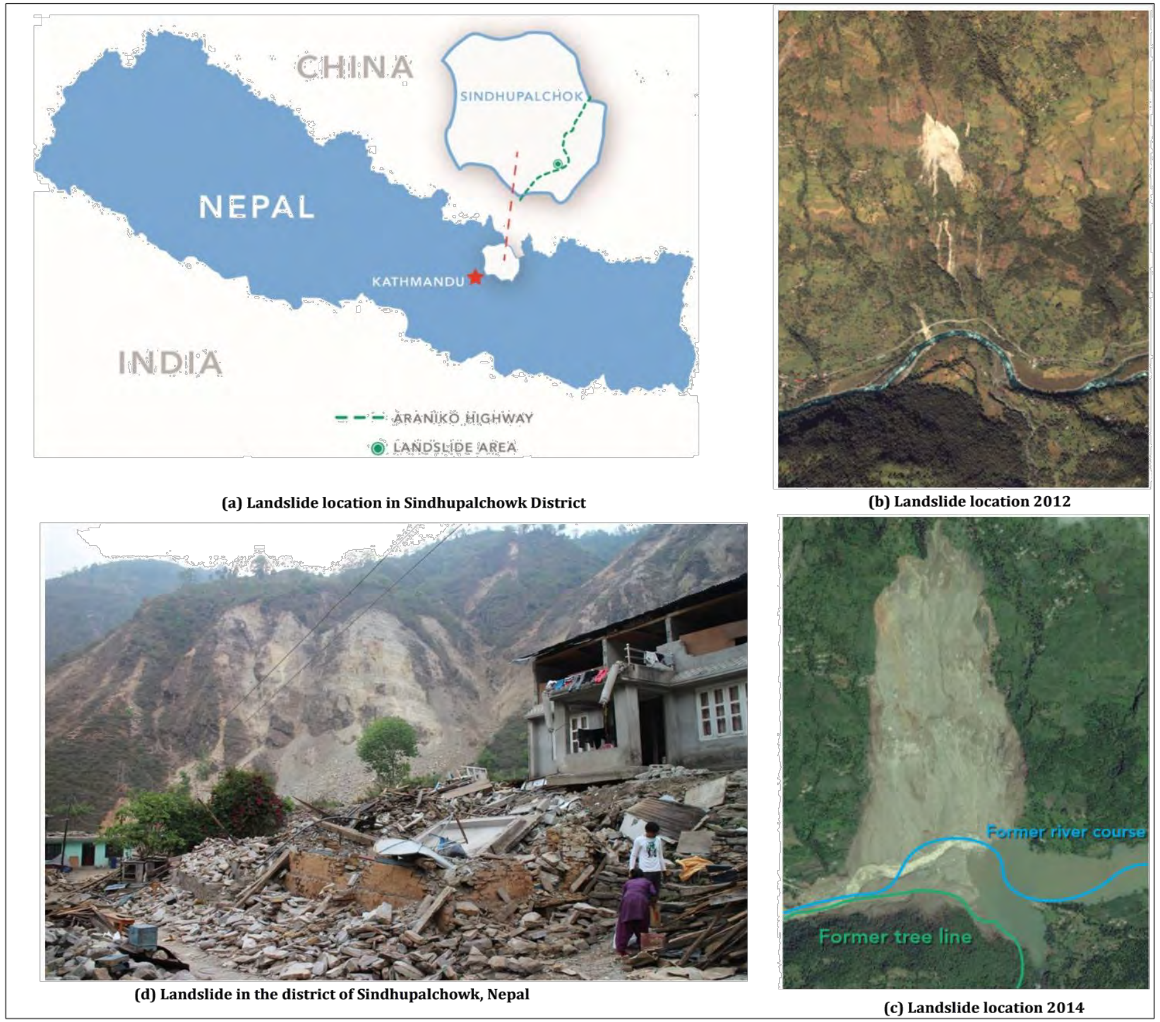
- Latitude: 28.1503° N
- Longitude: 85.6340° E
- Date: April 25, 2015
- Reactivation: Triggered by a 7.8 magnitude earthquake.
- Recurrence Period: Every few decades.
- Effects:
  - Buried Langtang village, approx. 250 fatalities.
  - Long-term community displacement.
- Geospatial Solutions:
  - Satellite imagery for mapping vulnerable areas.
  - Early warning systems using remote sensing.




*Langtang valley condition before and after the landslide.*

# Sindhupalchowk Landslide

- Latitude: 27.8011° N
- Longitude: 85.4867° E
- Date: August 2, 2014
- Reactivation: Prolonged rainfall and geological instability.
- Recurrence Period: 10-20 years during monsoon seasons.
- Effects:
  - Blocked the Arun River, flooding downstream.
  - Major infrastructure damage, loss of life and agriculture.
- Geospatial Solutions:
  - Hydrology modeling using GIS.
  - UAVs for terrain analysis.
  - Landslide susceptibility mapping using DEMs.
  - Community-based monitoring systems.




(a) Landslide location in Sindhupalchowk District

(b) Landslide location 2012

(d) Landslide in the district of Sindhupalchowk, Nepal

(c) Landslide location 2014

*Sindhupalchowk area landslides*

## Daklang Landslide

- Latitude: 27.891° N
- Longitude: 84.903° E
- District: Sindhupalchowk
- Status: Continuously Moving since last 15 Years.

The road section lies in Araniko Highway





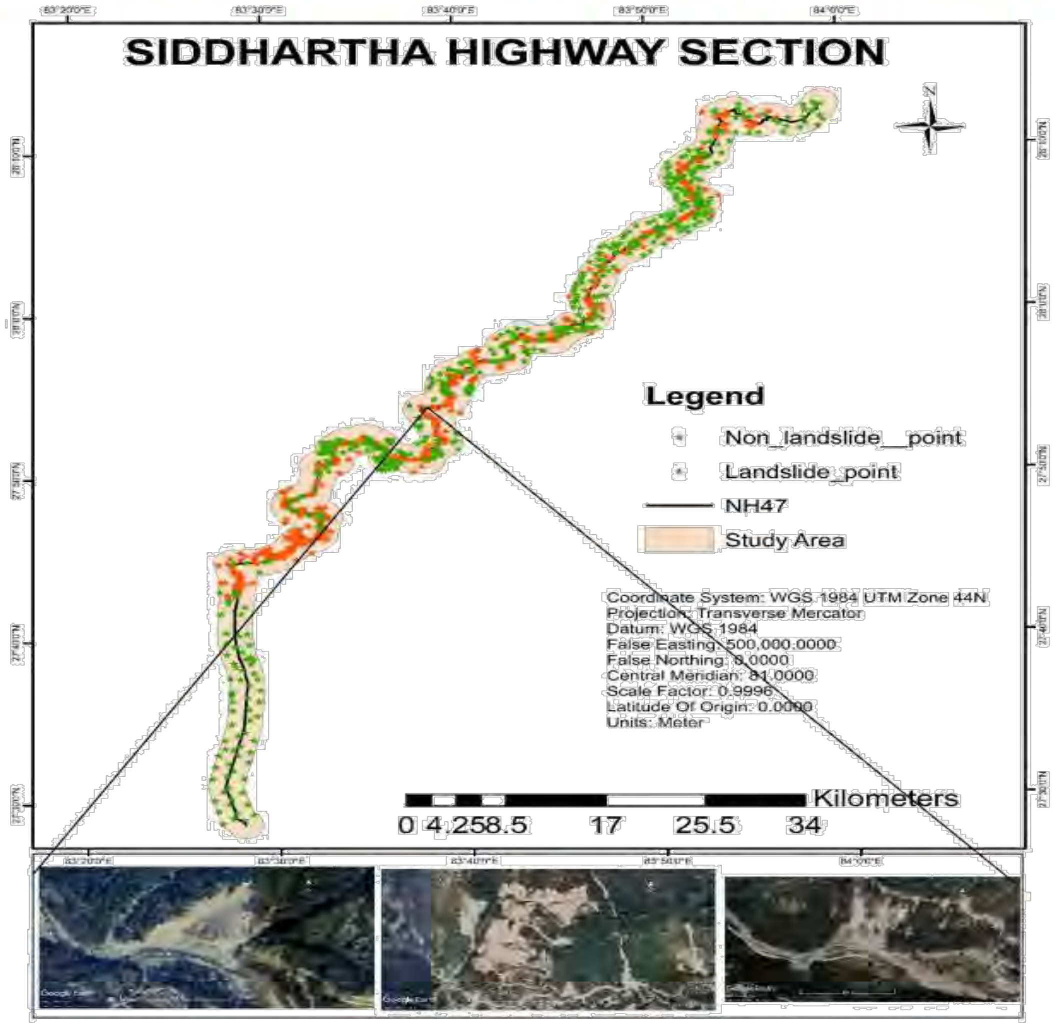
# Jhyaple Khola Landslide

- Latitude: 27.8861° N
- Longitude: 84.6812° E
- Date: September 27,2024
- Reactivation: Triggered by heavy monsoon rains.
- Recurrence Period: Approximately every 10 years during monsoon season.
- Casualties:
  - Confirmed deaths: 35


*Source: Setopati*

# Landslide on Sections of Siddhartha Highway

- Siddhartha Highway connects Terai to mountains, spanning:
  - 27° 41' 53'' N to 28° 12' 30'' N
  - 83° 28' 00'' E to 84° 00' 00'' E.
- Starts at Sunauli, and ends at Pokhara Valley (length: 181 km).
- Major towns: Butwal, Tansen, and Pokhara.
- Butwal–Palpa section prone to rockfalls.
- Essential for trade and rural market access.
- Faces landslide challenges, needing regular maintenance.




*Landslides on Siddhartha Highway Section*

Lack of long-term vision on sustainable and resilient infrastructure development ?


20 years difference

## Development of Disasters in Nepal



20 years difference

## Development of Disasters in Nepal



20 years difference

## Is Development Synonymous to Disaster ?



20 years difference

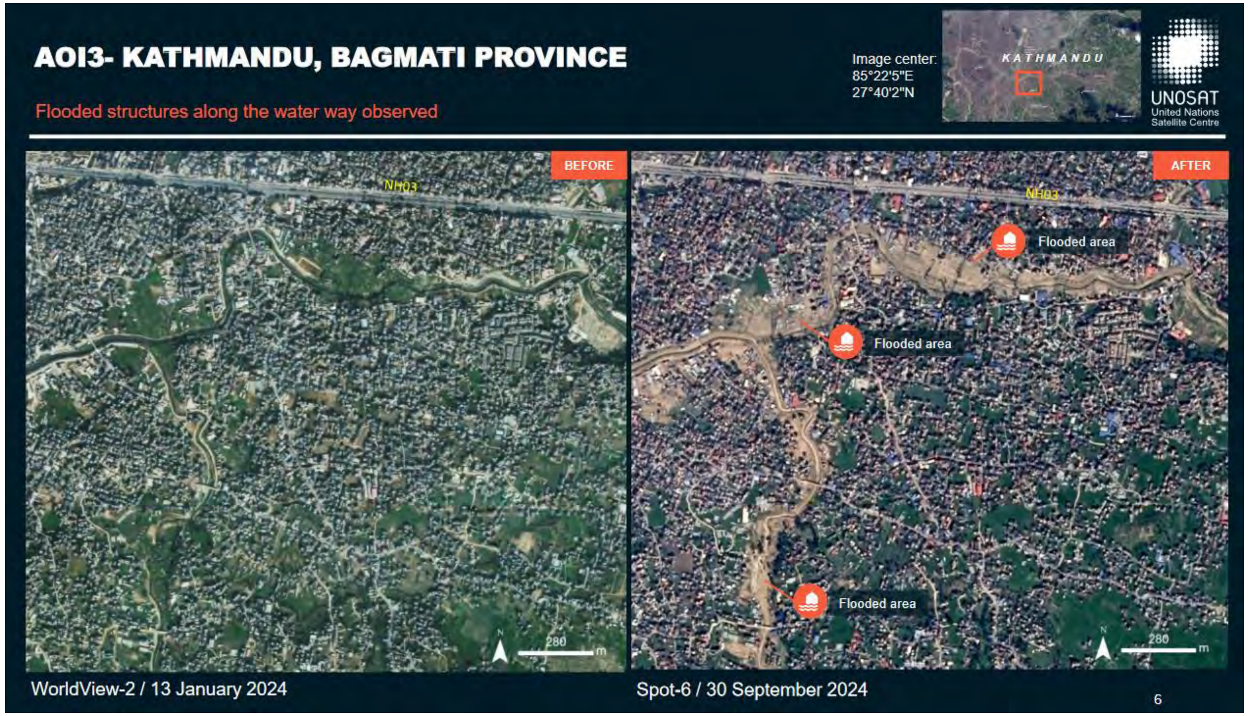
# What are we recently facing?

**© AP/Gopen Rai**
An aerial image of the Kathmandu valley during floods triggered by heavy rain.
Sourced from: https://www.abc.net.au/news/2024-09-29/flooding-and-landslides-in-nepal-kill-over-140/104410096

**© UNICEF/Laxmi-Prasad-Ngakhusi**
A swollen river surges through Kathmandu, Nepal's capital, after the heaviest rainfall in over 50 years.
Sourced from: https://news.un.org/en/story/2024/10/1155246

# Advantage of EO for Disasters Monitoring and Prediction

- Wide area coverage
- Rapid assessment
- Objective data
- Access to inaccessible areas





http://www.eohandbook.com/eohb2015/future_challenges.html

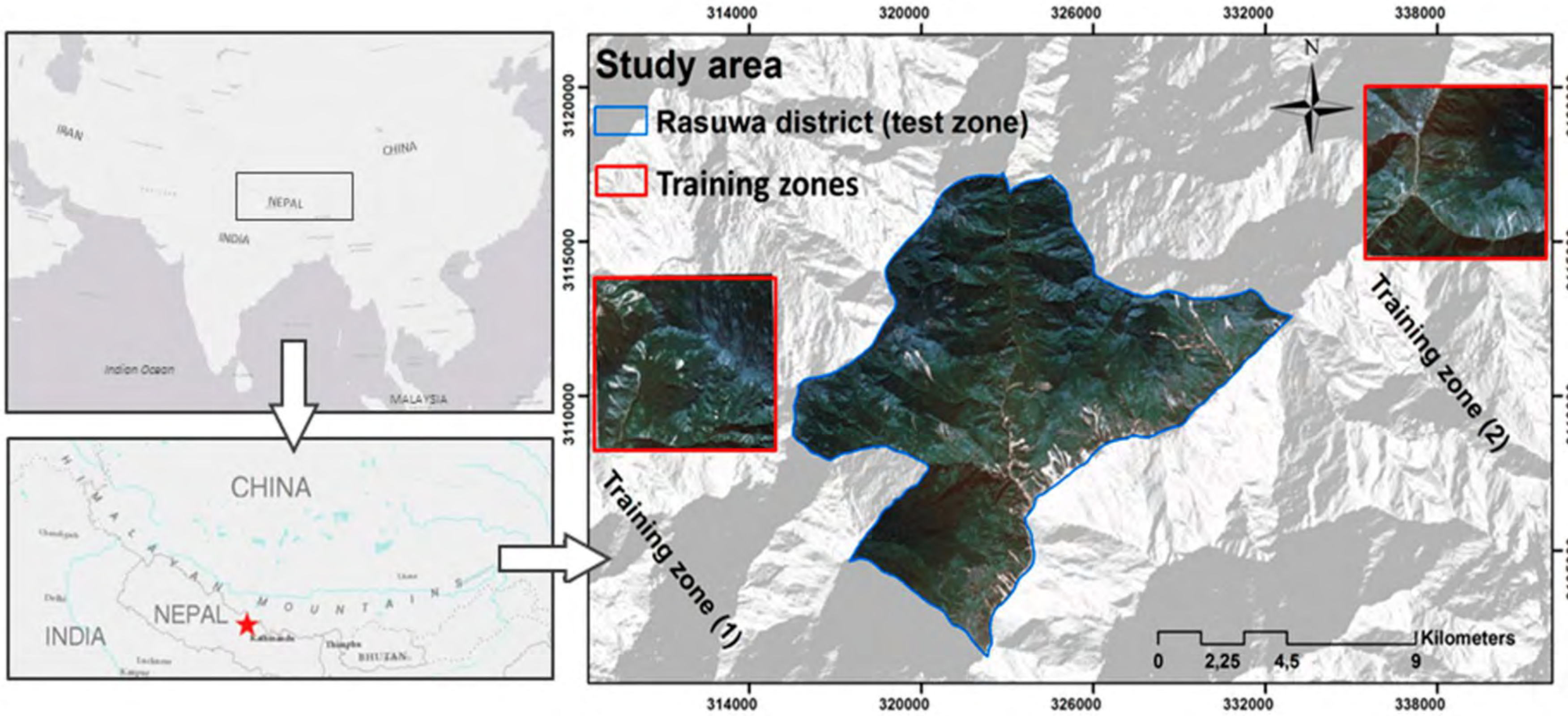
Source: © AIRBUS DS (2024). Map produced by UNITAR / UNOSAT

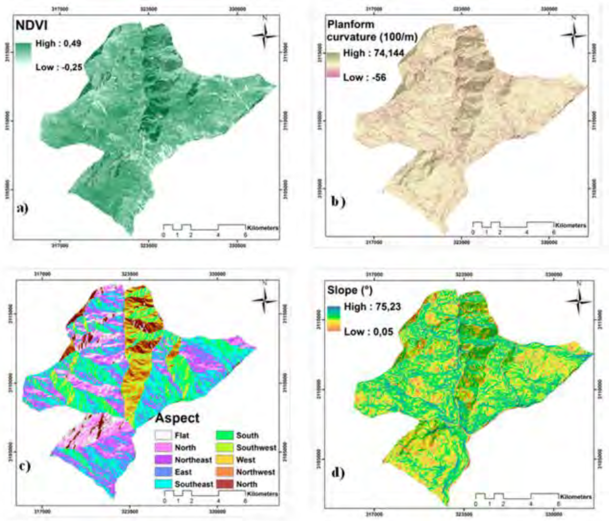
Five examples of published research where EO was used in the disaster context:

1. Deep cognitive imaging systems enable estimation of continental-scale fire incidence from climate data. *Scientific Report (2013)*
2. Fuzzy Shannon Entropy: A Hybrid GIS-Based Landslide Susceptibility Mapping Method. *Entropy (2016)*
3. A new GIS-based data mining technique using an adaptive neuro-fuzzy inference system (ANFIS) and k-fold cross-validation approach for land subsidence susceptibility mapping. *Natural Hazards (2018)*
4. **Evaluation of Different Machine Learning Methods and Deep-Learning Convolutional Neural Networks for Landslide Detection.** ***Remote Sensing (2019)***
5. **Landslide Detection Using Multi-Scale Image Segmentation and Different Machine Learning Models in the Higher Himalaya.** ***Remote Sensing (2019)***

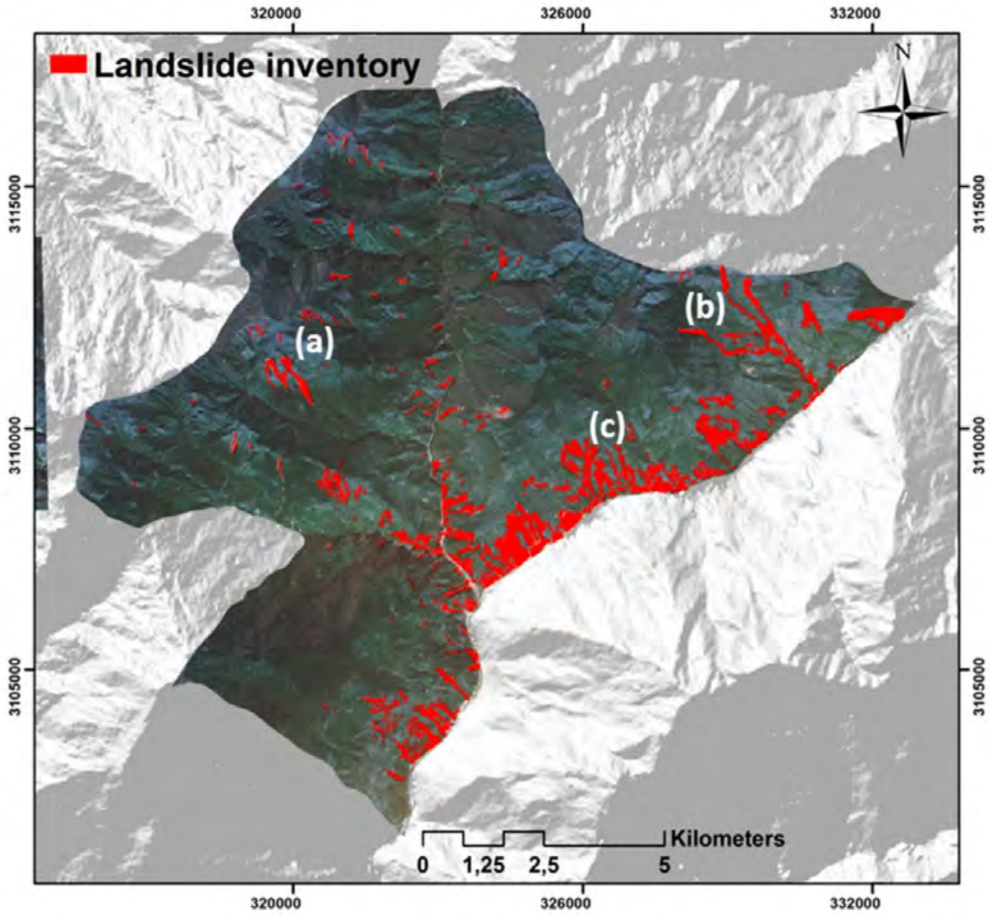
Scientific lens to phenomenon:
a simple case to start modelling.

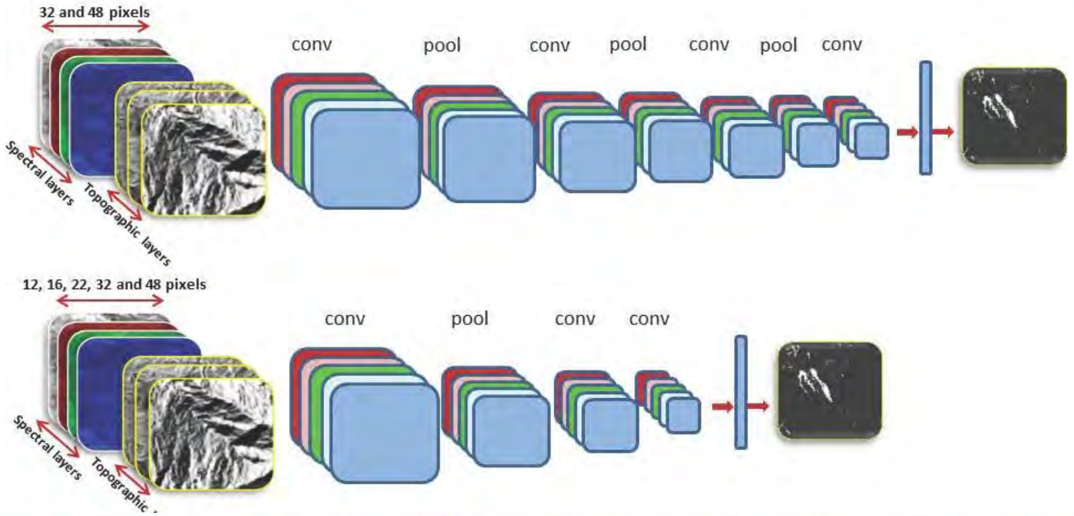
- Nearby fires influence each other
- Good example are ‘V’ line fires
- Spatial proximity and the influence

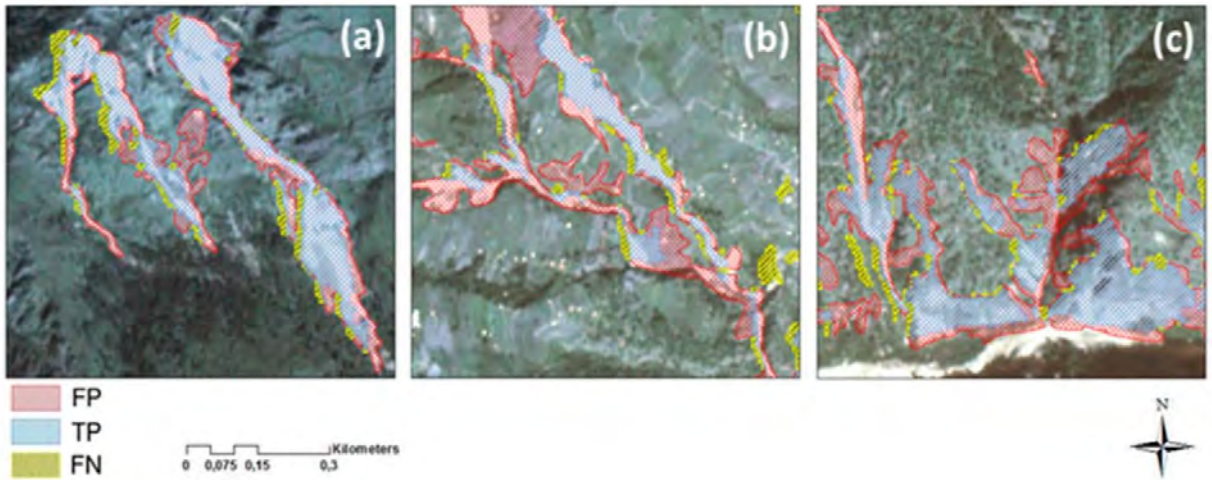



Ghorbanzadeh O, Blaschke T, Gholamnia K, Meena SR, Tiede D, **Aryal J.** Evaluation of Different Machine Learning Methods and Deep-Learning Convolutional Neural Networks for Landslide Detection. *Remote Sensing*. 2019; 11(2):196. https://doi.org/10.3390/rs11020196

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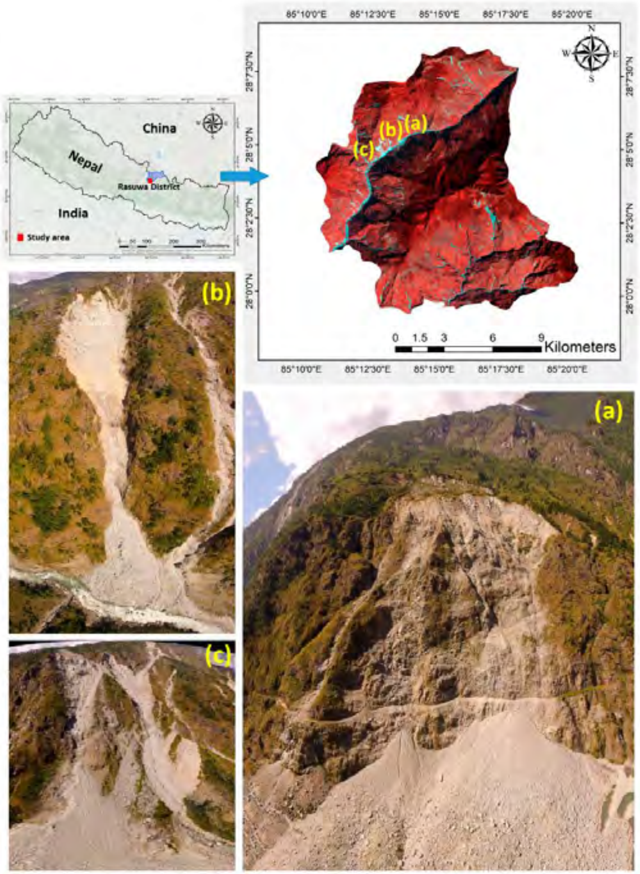


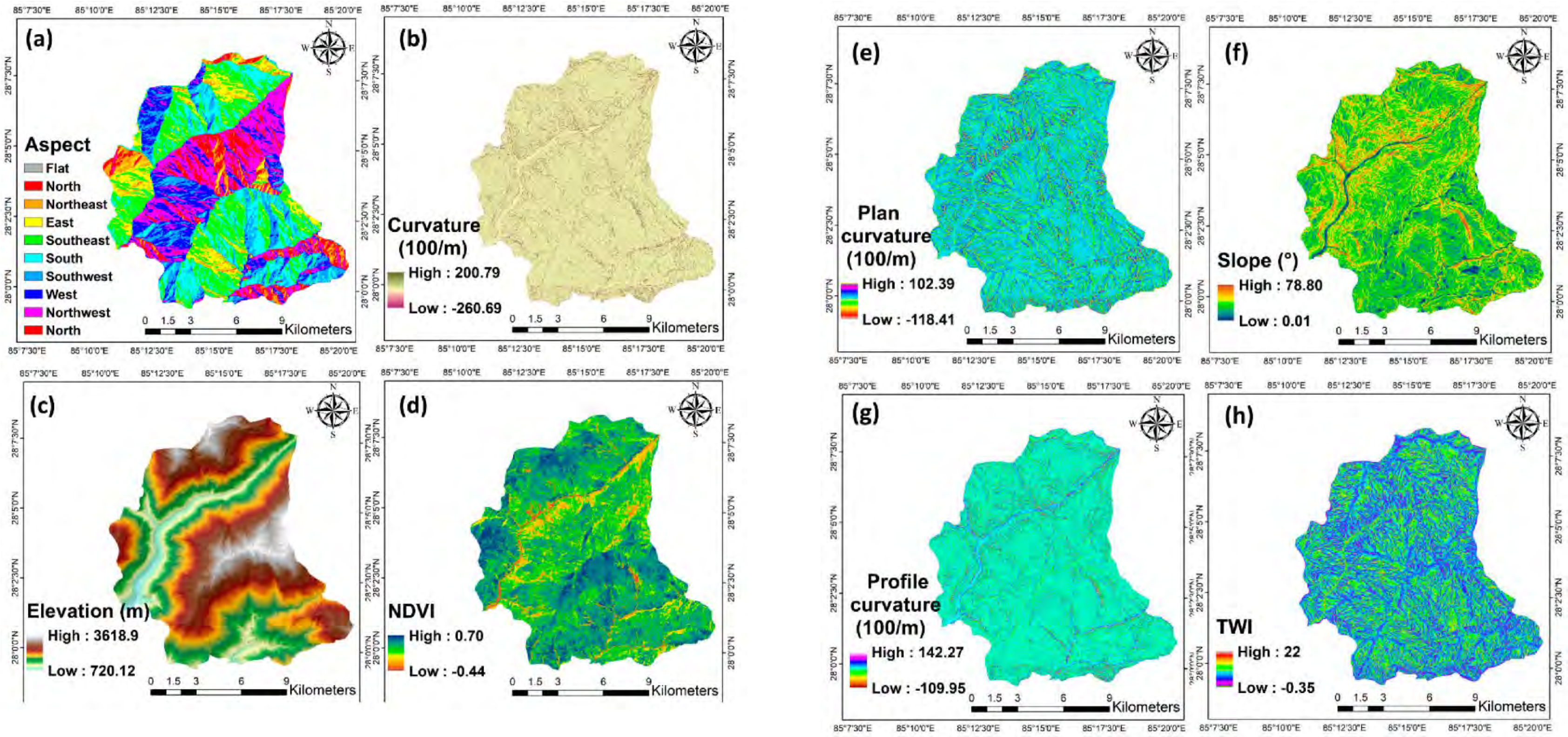


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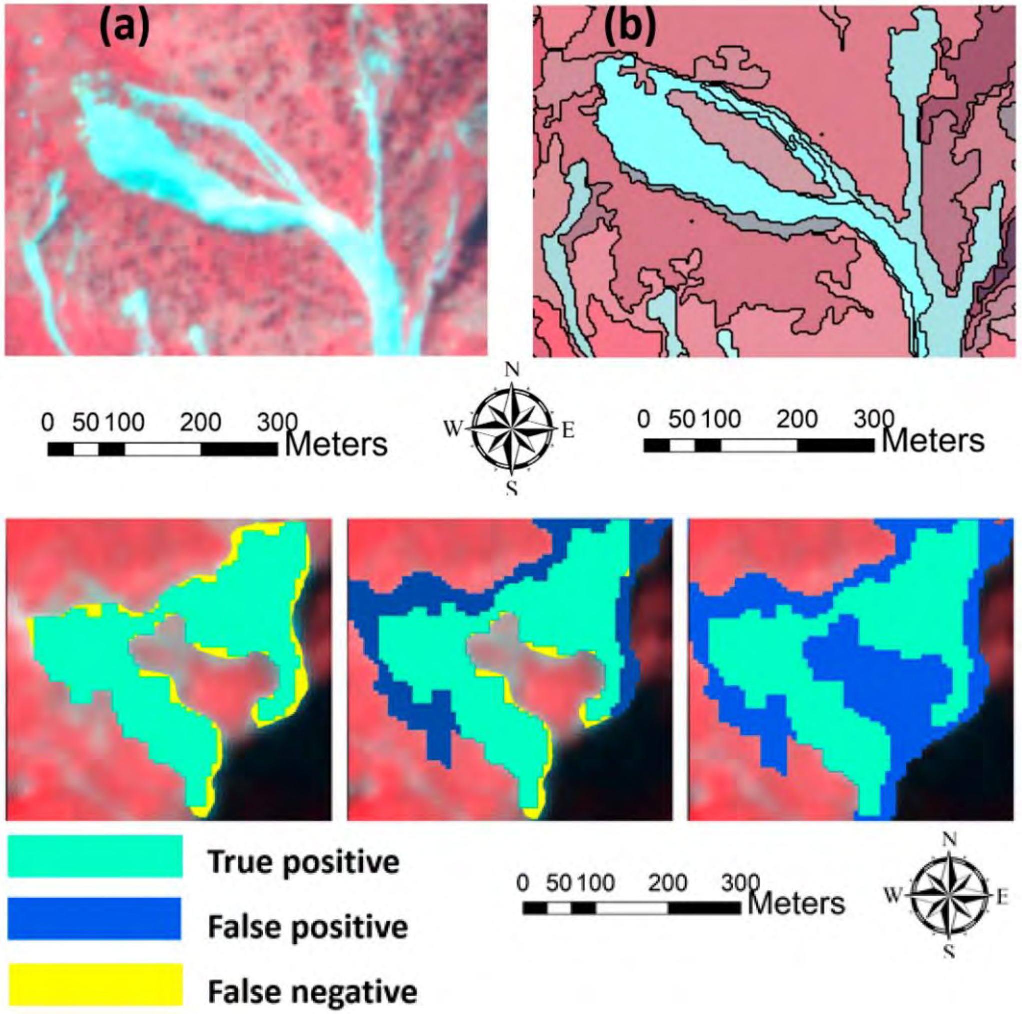


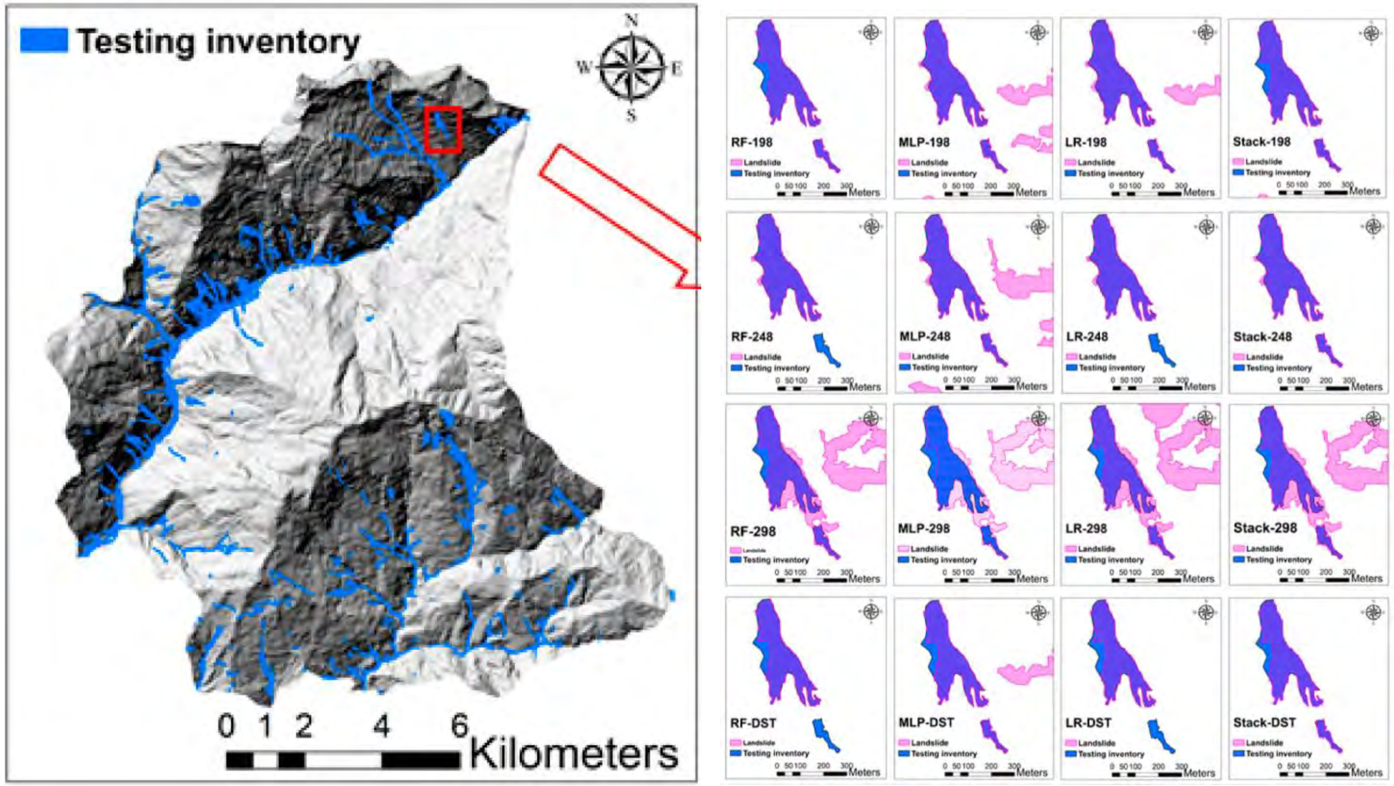


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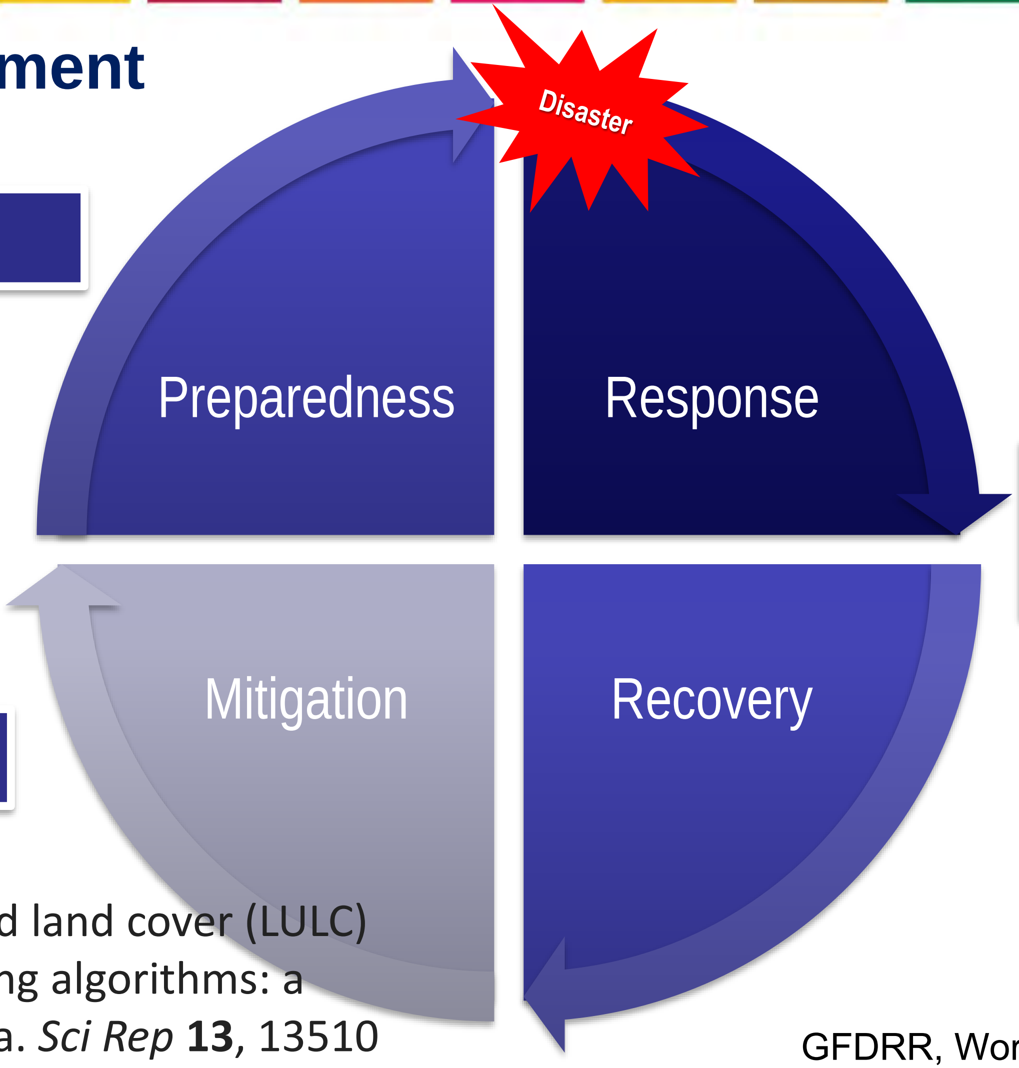
# EO Data for Disaster Management

Baseline mapping




Post-Disaster
Needs Assessment

Monitoring & Forecasting

**Aryal, J**., Sitaula, C. & Frery, A.C. Land use and land cover (LULC) performance modeling using machine learning algorithms: a case study of the city of Melbourne, Australia. *Sci Rep* **13**, 13510 (2023). https://doi.org/10.1038/s41598-023-40564-0

GFDRR, World Bank Group., UNDP, CEOS & EU. *Use of EO Satellites in Support of Recovery from Major Disasters*. (GFDRR, 2019).

## Baseline Mapping

Reference maps that provide a comprehensive and updated knowledge of the territory and relevant assets in a disaster risk reduction context.

**Vulnerability Assessment**

- Land Cover/Land Use maps
- Population Density maps
- Critical Infrastructure maps
- Socioeconomic Vulnerability maps
- Elevation Models
- Historical Disaster Data

## Monitoring and Forecasting

Maps that provide relevant and up-to-date thematic information that can help planning for contingencies on areas vulnerable to hazards, aiming to minimize loss of life and damage.

**Monitoring**

- Active Hazards
- Environmental Changes

**Forecasting**

- Short-Term
- Seasonal

# Post Disaster Needs Assessment

Maps that provide relevant and up-to-date thematic information for the needs of reconstruction planning and progress monitoring, mapping long-term impact, etc. These maps need to be updated frequently.

## Damage Assessment

- Buildings and Infrastructure
- Agricultural Land

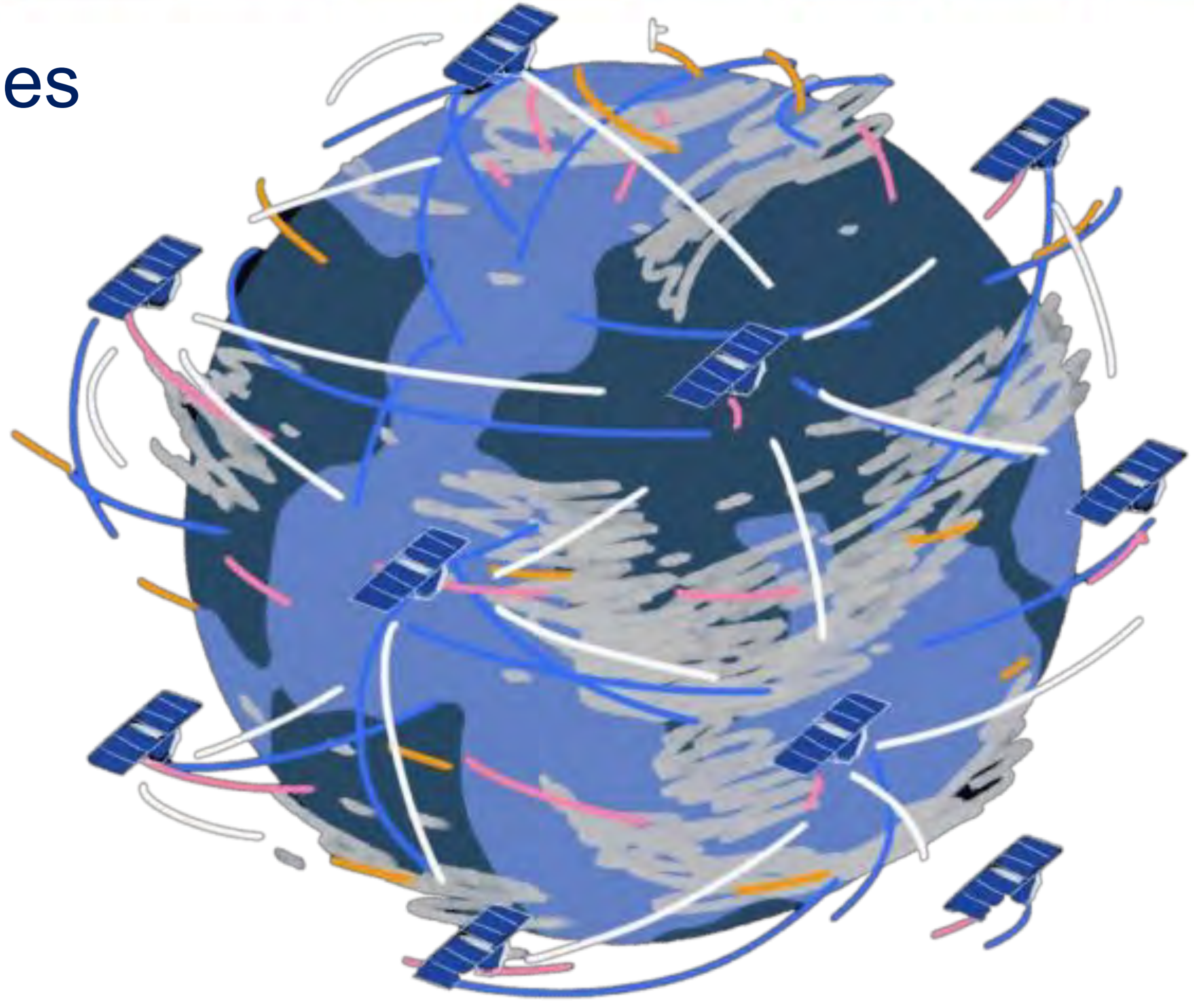
## Impact Assessment

- Population Displacement
- Economic Loss
- Environmental Degradation

# The future of EO in Disaster Studies

- Satellite constellations
  - More data
  - Higher frequency
  - Higher resolution

- AI-powered analysis



https://leanspace.io/eo-constellations/

# Key Messages

**Message to YPs:**

- Engage with fundamentals
- Familiarise with the market trend
- Develop skills in intelligent approaches
- Be an enabler and part of the change making process

**Message to Established Professionals:**

- Reflect on the capabilities developed over the years
- Coach to YPs and transmit your experience
- Work along with scientists / academics
- Contribute to develop policies based on scientific evidence / publications.

**Message to academics / educators:**

- Publish regularly in high impact journals and magazines
- Develop teaching materials based on published research
- Think globally and act locally
- Invite professional bodies to review the curriculum / syllabus every 3-5 years
- Develop the accredited Bachelor / Master and international standard PhD program

# Concepts / facts to be considered in Land Use planning and disaster resilience

- Nature-based solution
- Geological structure – a bitter truth for Nepal
- Ecological processes and their understanding
- Infrastructure resilience
- Low-altitude Economy
- Digital Twin


VICTORIA
State
Government

# THANK YOU !

# Questions

# Acknowledgement

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