Assessment of earthquake-triggered landslide hazard for estimation of risk to critical infrastructure: A Global Model

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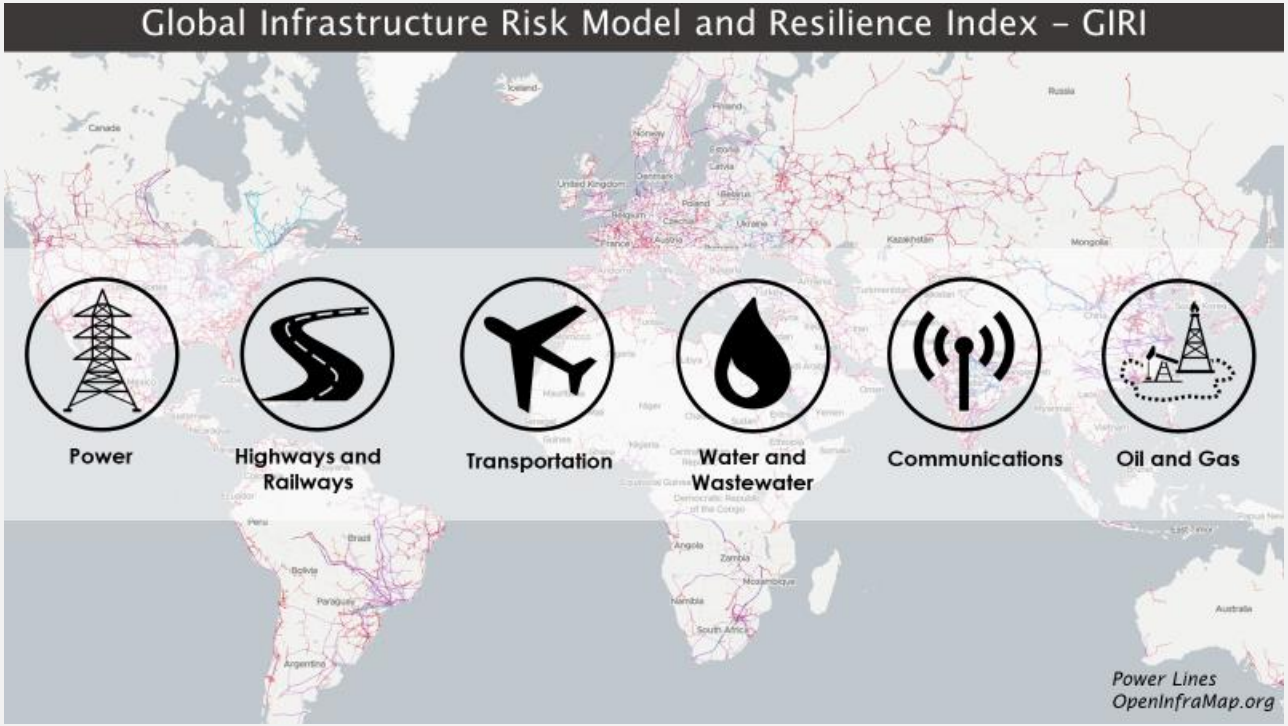
Motivation: CDRI's Flagship project "GIRI"

CDRI
Coalition for Disaster Resilient Infrastructure

Flagship Report on Disaster and Climate Resilient Infrastructure



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Challenge: Global assessment of risk posed by landslides to critical infrastructure

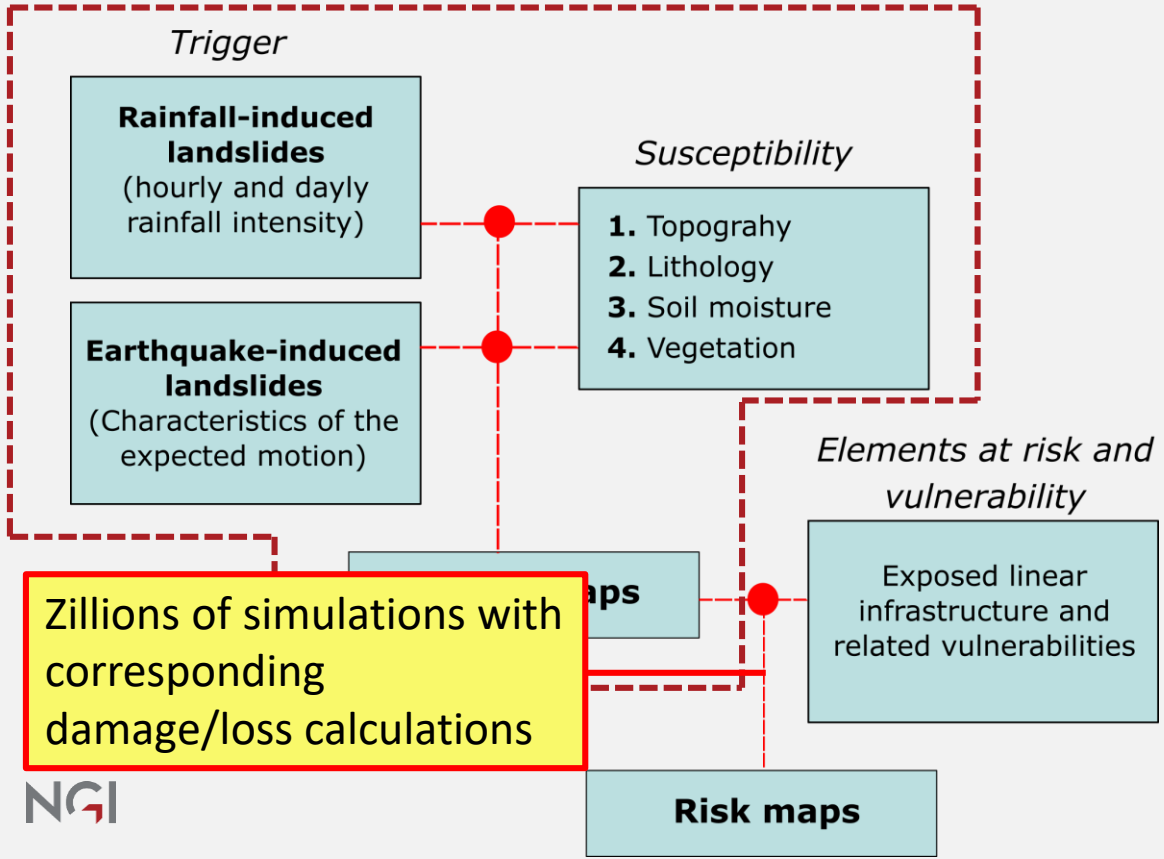
The most frequent geohazard is landslide. However, much of the damage and fatalities caused by landslides are attributed to their triggering events, like earthquake or tropical cyclone, in the disaster databases.

Landslide induced by a magnitude 7.6 earthquake in El Salvador along Pan American Highway

Example: Wenchuan earthquake of 2008

About 25% of the 87,000 casualties (69,000 confirmed killed and 18,000 missing) caused by Sichuan Earthquake of 12th May 2008 were due to the landslides triggered by that event (Zhang et al. 2014).

GIRI model for calculations earthquake- and rainfall-induced landslide risk



NGI developed the GIRI Landslide hazard model

Based on the landslide hazard approach in the GAR 2009, 2011 and 2013 (Nadim et al., 2006, Nadim et al. 2013, Jaedicke et al., 2014)

GIRI Earthquake-induced landslides susceptibility model

Information	Dataset	Resolution (at equator)
Slope	Derived from MERIT-Hydro DEM	3'' ≈ 90 m
Lithology	Global Lithological Map (GLiM)	.shp
Soil moisture	ERA5 Soil moisture climatology	0.25° ≈ 28 km
Land cover	ICDR Land Cover 2020	0.0027° ≈ 300 m

$$S = \prod_i w_i S_i$$

where

- w_i are the weights of the **slope**, **lithology**, **vegetation** and **soil moisture** parameters
- S_i is the degree of susceptibility of the slope, lithology, vegetation and soil moisture

3'' resolution over the world

Example: Slope susceptibility index, S_r

$$S = (S_r \cdot [1 + 0.25\ (S_l - 1)] \cdot [1 + 0.25\ (S_h - 1)] \cdot S_v)$$

Range of slopes angle (unit 1/100 degrees)	Classification	S_r
0000 – 0600	Very low	0
0601 – 1200	Low	1
1201 – 1800	Moderate	2
1801 – 2400	Medium	3
2401 – 3000	High	4
3001 – 3600	Very high	5
3601 – 4000	Probably stiff soil	4
4001 - 4400	Probably rock	3
4401 - 5000	Probably hard rock	2
> 5000	Stable hard rock	1
No Data	No Data	No Data

Slope obtained from MERIT DEM

- 90 m resolution
- Reclassified into 5 susceptibility classes

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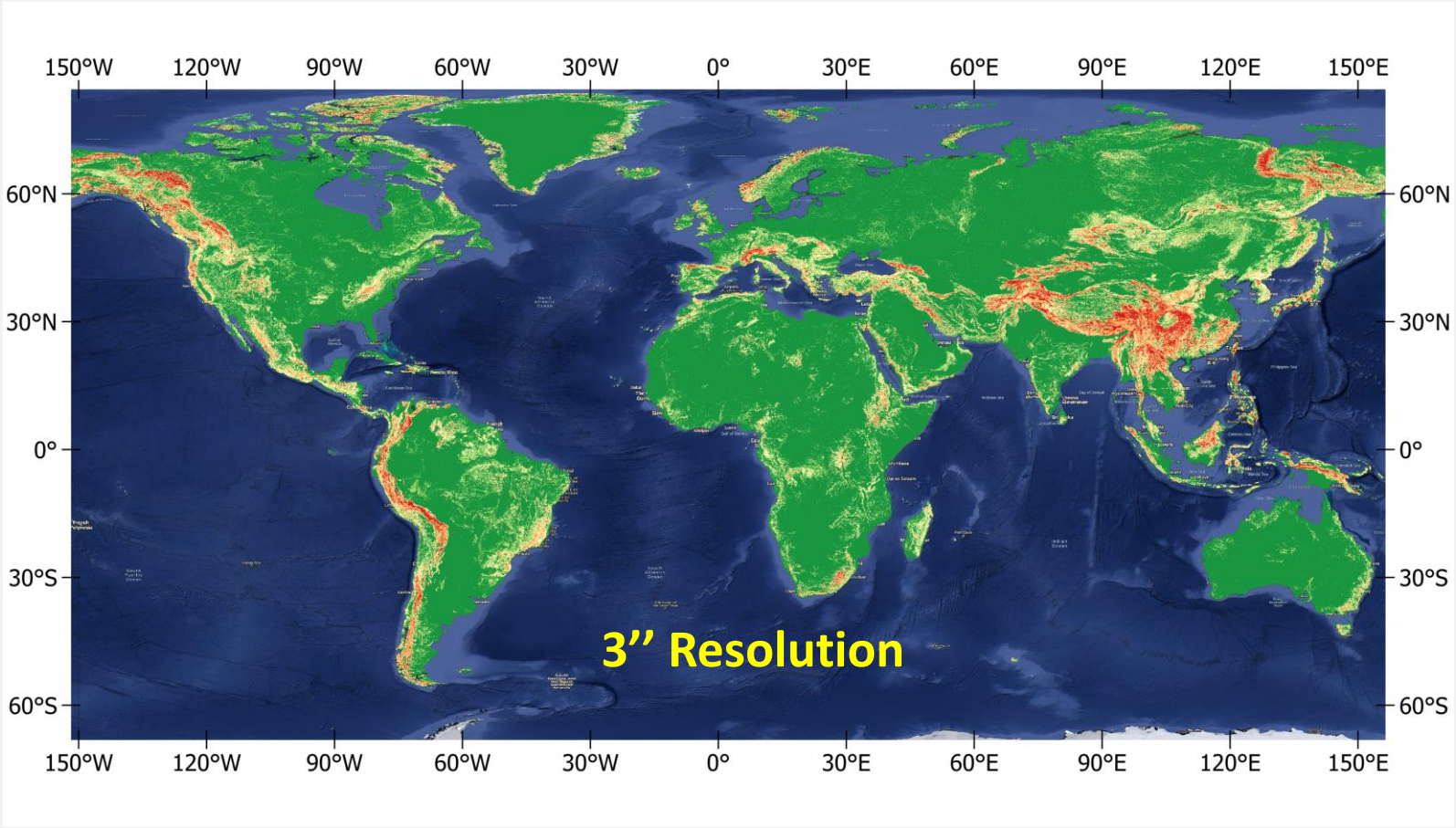
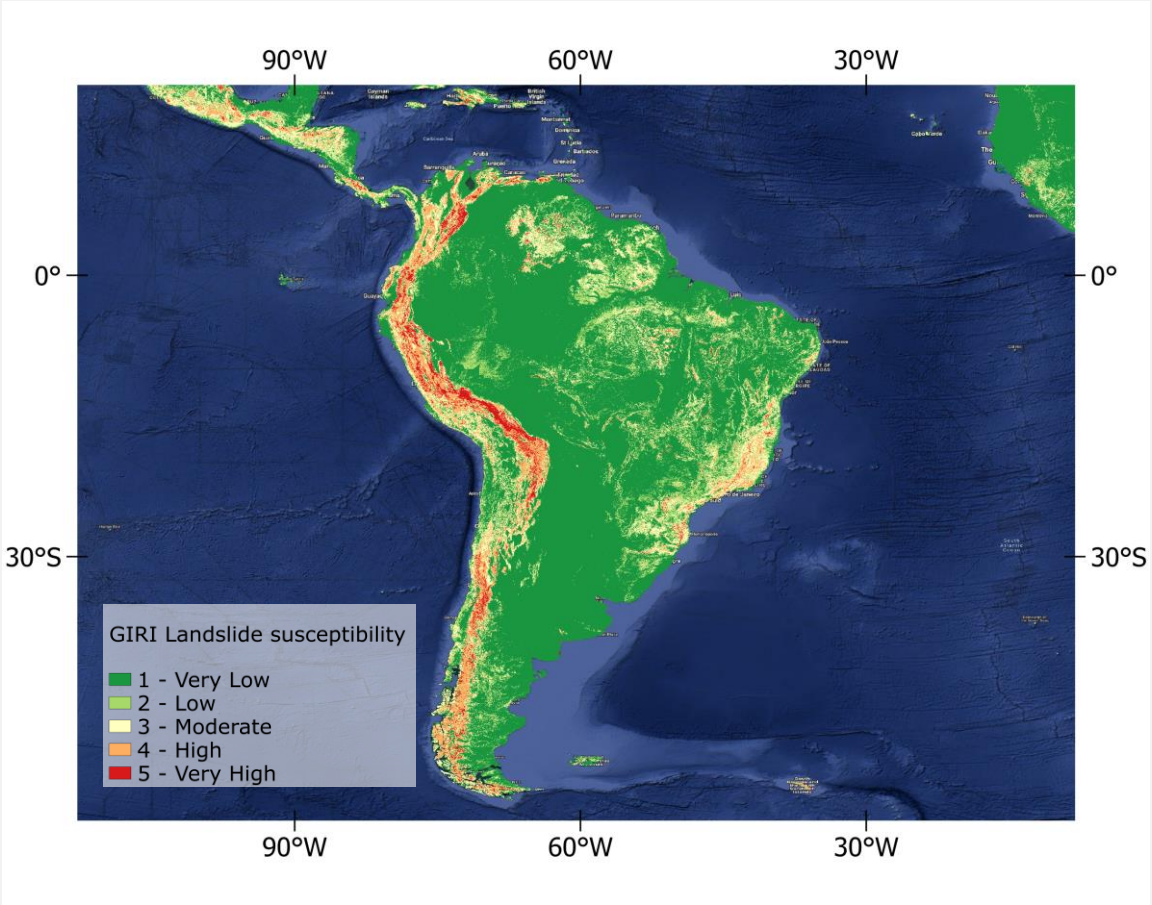
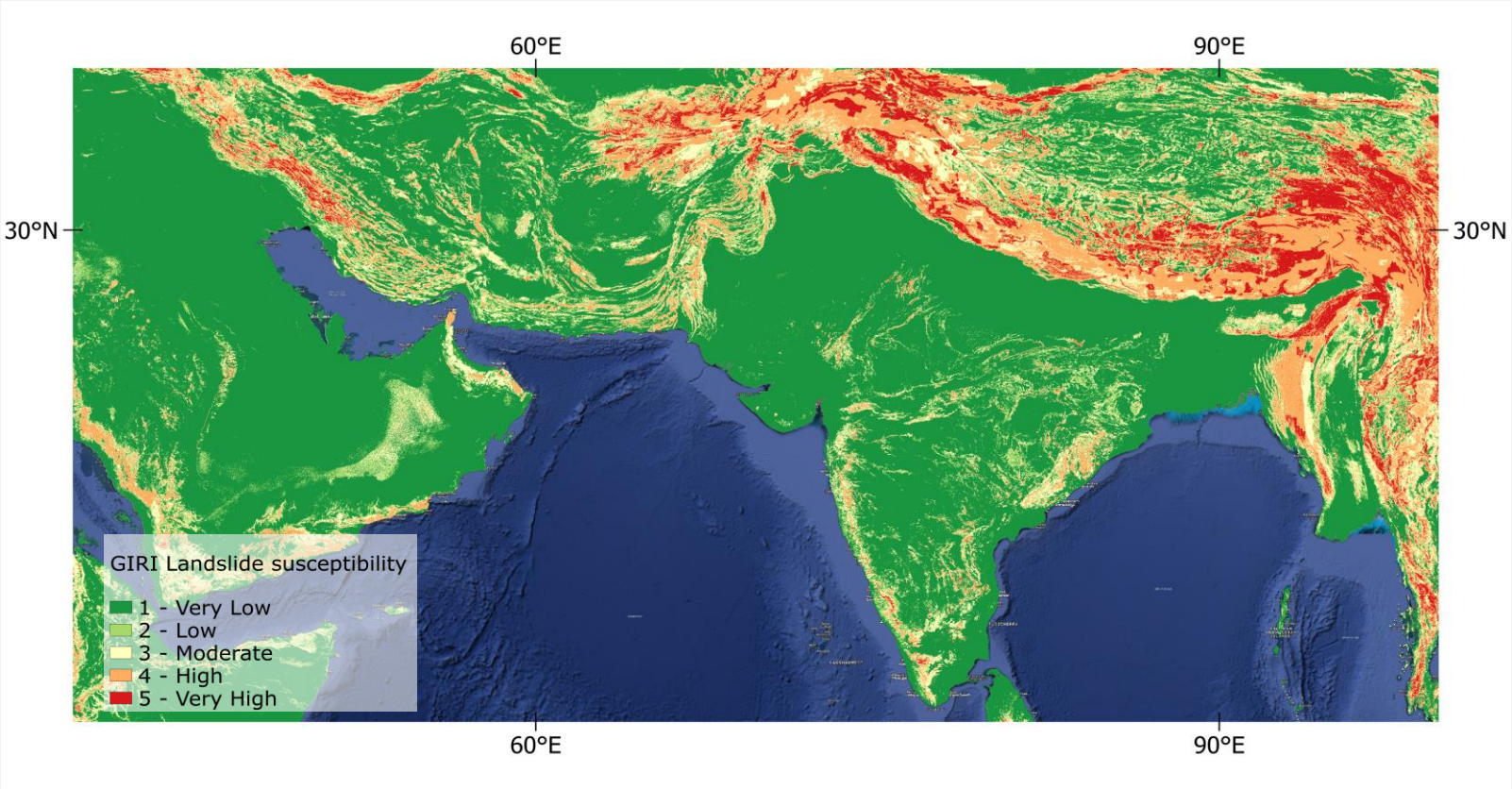
GIRI – Global earthquake-induced landslide susceptibility map



Earthquake-induced landslide susceptibility in Latin America



Earthquake-induced landslide susceptibility in South Asia



Calibration of earthquake-triggered landslide model

In the GAR model, the hazard index for earthquake-induced hazards was “translated” to annual probability of a large landslide in an 1km x 1km area.

The same relative scale is used in the GIRI model, but the probabilities are adjusted such that the total number of significant landslides triggered by earthquake is consistent with the latest estimates according to the World Bank report[1] from 2020 (~130,000 landslides globally each year).

[1] *The World Bank. The Global Landslide Hazard Map. Final Project Report. 26 June 2020.*

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GIRI Earthquake-induced landslides hazard model

The susceptibility index and the peak ground acceleration (PGA) are combined to produce the landslide hazard map for a given earthquake scenario.

PGA (g)	Susceptibility category				
	Susc. 1	Susc. 2	Susc. 3	Susc. 4	Susc. 5
0.05g ≤ PGA < 0.15g	~ 0	~ 0	~ 0	0.1%	0.5%
0.15g ≤ PGA < 0.25g	~ 0	~ 0	0.1%	0.5%	1%
0.25g ≤ PGA < 0.35g	~ 0	0.1%	0.5%	1%	5%
0.35g ≤ PGA < 0.45g	~ 0	0.5%	1%	5%	10%
PGA ≥ 0.45g	~ 0	1%	5%	10%	40%

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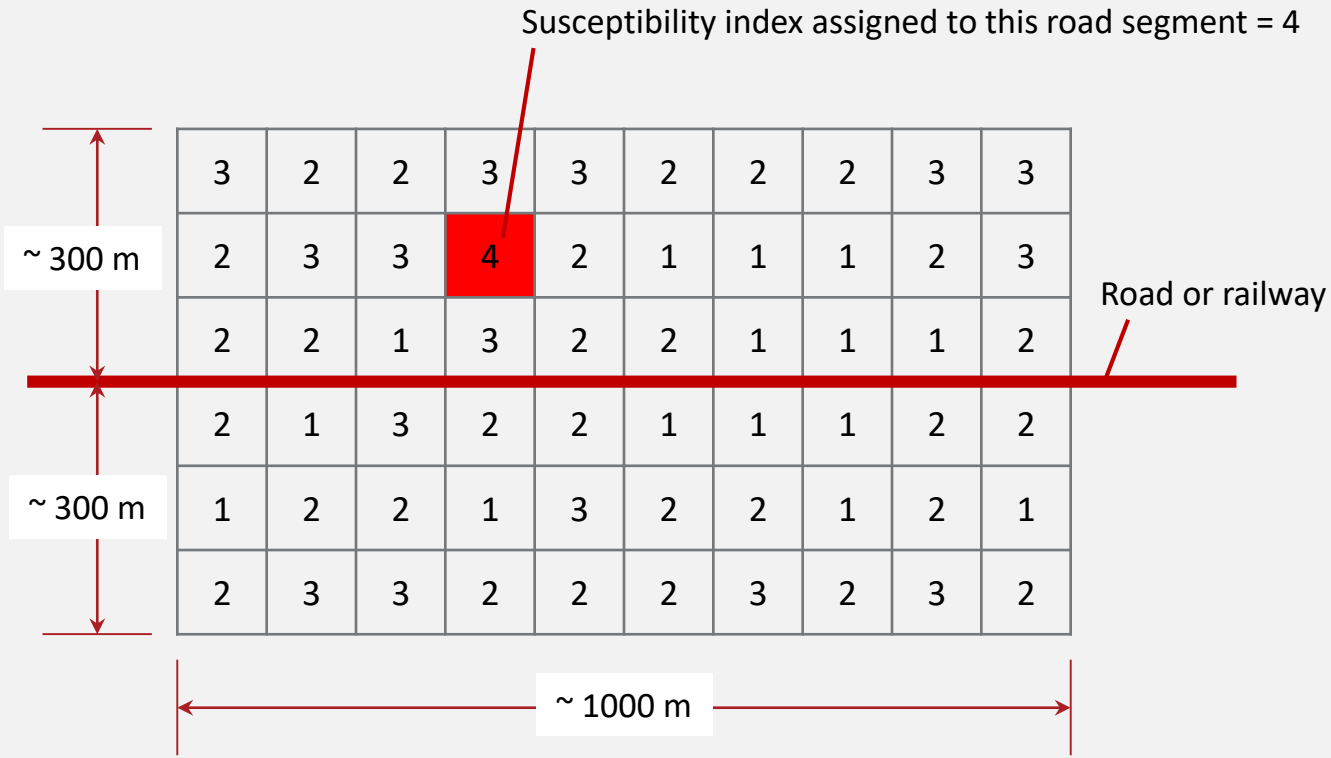
Using the susceptibility categories of GIRI model for first-pass risk assessment of roads and railways



Concluding remarks

- Developing models for earthquake-induced landslides on national, regional and local scales is much more challenging than developing a global model.
- The calibrated global model predicts that most earthquake-induced landslides occur in areas with susceptibility categories 2 and 3, rather than those with susceptibility categories 4 and 5!
- The scenario-based approach used in the GIRI project for assessing the annual losses (i.e. risk) due to earthquake-induced landslides is a brute-force approach that should be improved and stream-lined in future studies.

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Thank you for your attention