The Effect of Climate Change on Landslides

Nathasya Christien

Based on Crozier (2010)

Today's Relevancy: Recent news from Indonesia

Landslide disaster in North Sumatra
(December 6, 2025)

Source: Antara News

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- Cyclone-induced floods and landslides impact North Sumatra.
- Public has pointed out how this disaster is also human-induced.

Influential Papers on This Topic

Most cited papers as seen in Mendeley search engine

Physics of Slope Stability

Definition

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Interpretation:

- If $FS > 1$, slope is stable.
- If $FS = 1$, slope is at point of failure.
- If $FS < 1$, slope will slide.

Physics of Slope Stability

Let

- c : cohesion
- γ : bulk density
- z : vertical depth
- β : slope angle
- u : porewater pressure
- ϕ : angle of internal friction

We expand the terms, such that the **resisting force** becomes

$$s = c + (\gamma z \cos^2 \beta - u) \tan \phi$$

and **driving force** becomes

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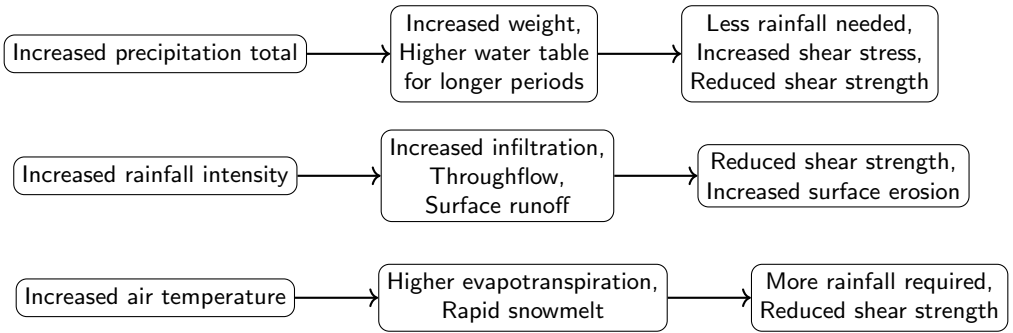
How heavy rainfall reduces shear strength:

- Increases water weight
- Increases porewater pressure
- Reduces soil suction
- Weathering cycles

Physics of Slope Stability

Slope stability responses to climatic factors change



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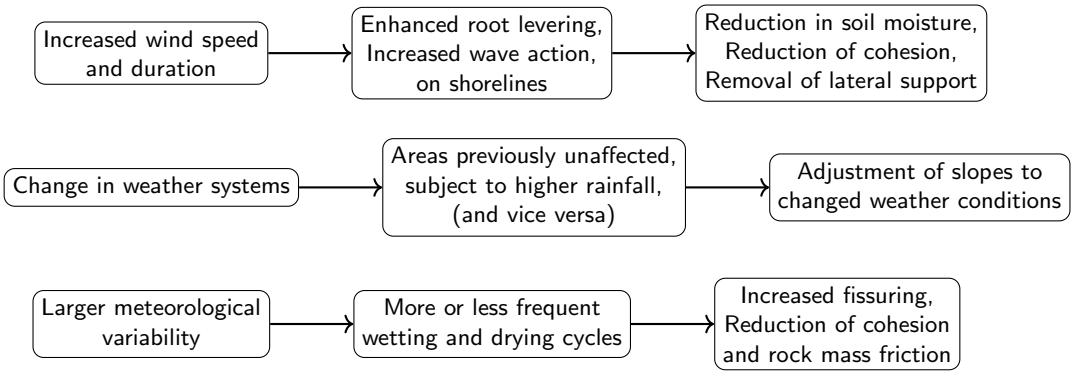

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Key hydrological factor::

Failure requires water to *accumulate* in the slope:

$$\text{Infiltration rate} > \text{Drainage rate}$$

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Soil *infiltration capacity* governs how much rainfall actually enters the slope.

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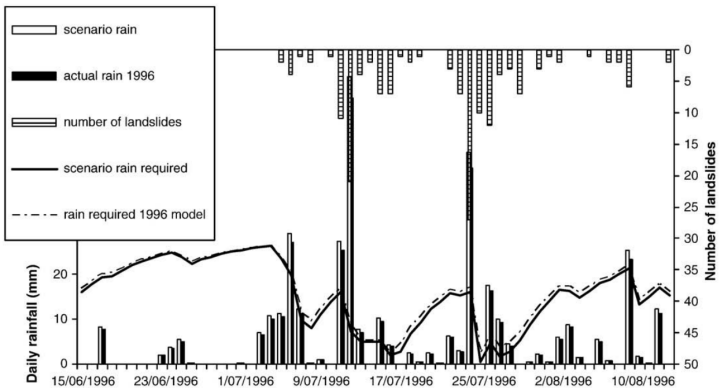
Example in Hong Kong (So, 1971):

- $\sim$702 landslides triggered by $\sim$400 mm rainfall in one day.
- 35% occurred in forested areas, despite covering only 8% of the affected region.

Climate-Landslide Model Results: Antecedent water status model



Author's model applied in Wellington City, New Zealand

- The model empirically estimates the amount of event rainfall required to initiate landslides for the next 24 hour periods.

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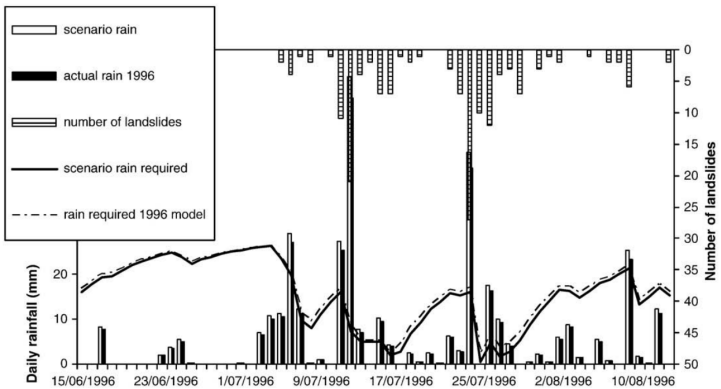

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- From IPCC downscaled prediction, we expect 8% increase of a 100-year daily rainfall.

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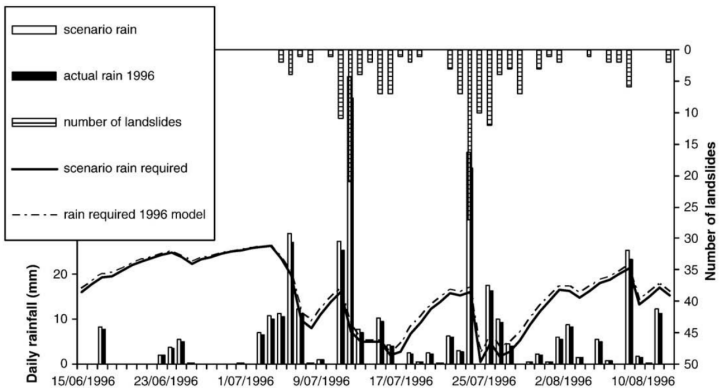

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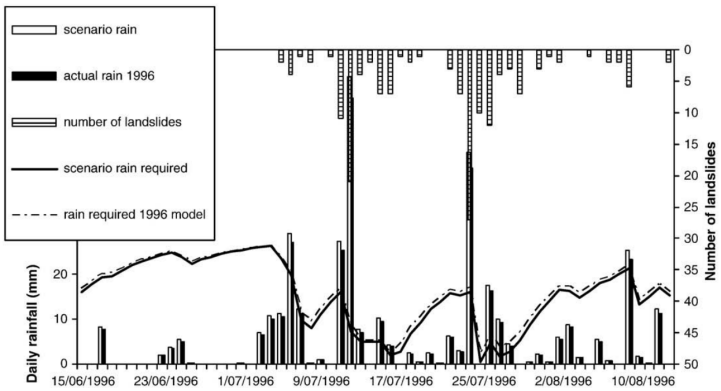

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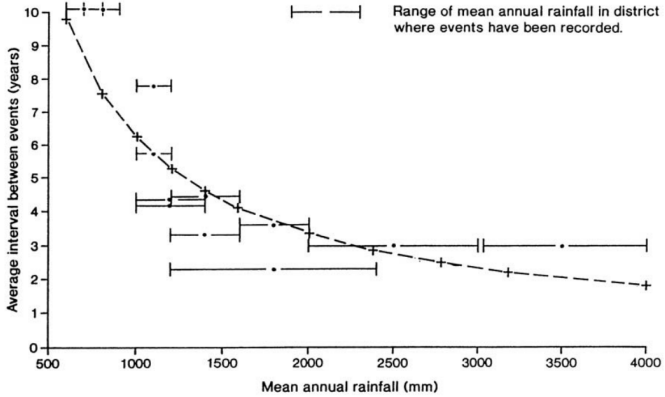
- With climate change scenario, two extra days of landslides could occur.
- Limitation: Downscaled rainfall data had too many uncertainties.

Climate-Landslide Model: Regional empirical approach



The frequency of landslide events (y) vs mean annual rainfall (x) around New Zealand (Hicks, 1995)

- Collected from 12 different catchments in New Zealand.

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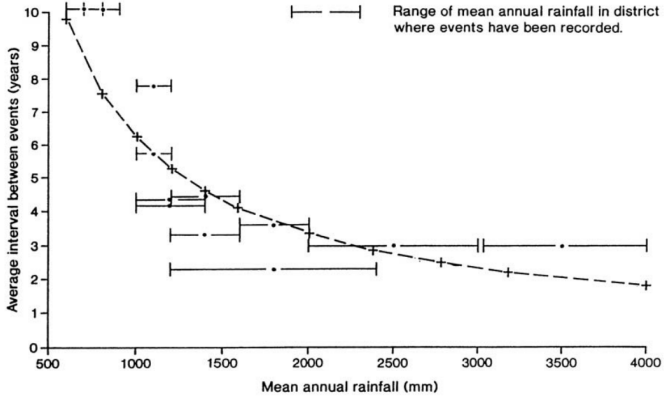

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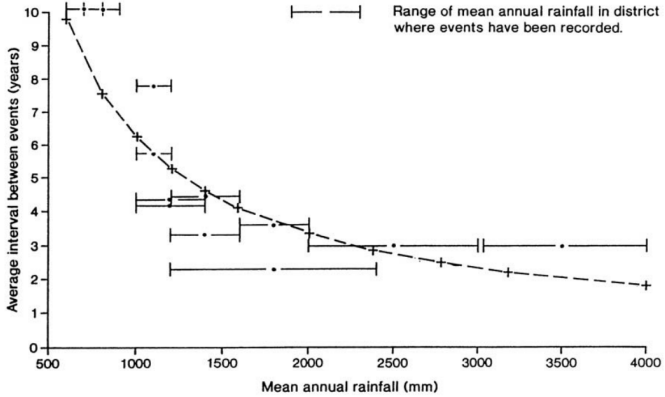

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- The standard error of the estimate y is 1 year.
- An 8% rise in an area with annual rainfall of 1000 mm $\rightarrow$ number of events from 16 to 20 over a 100 year period.

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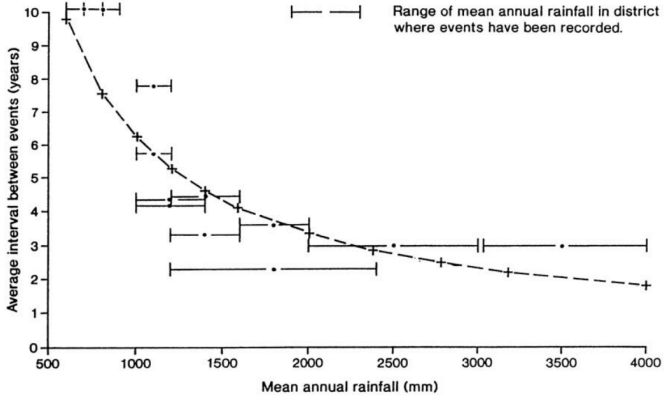

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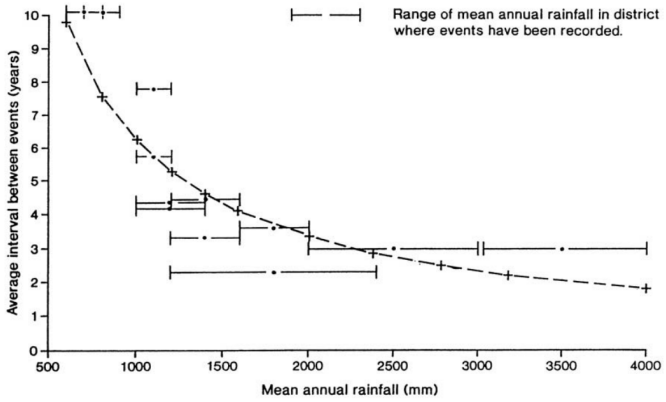

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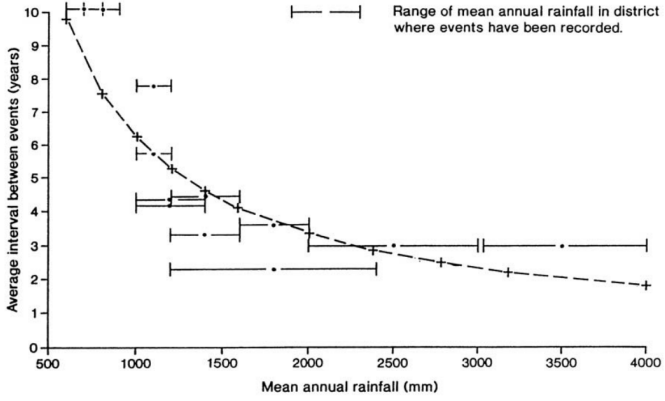

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- Uncertainty factors:
  - Predicted low and high estimates of mean precipitation is too large.
  - The standard error is still large.
  - Could not capture the full range of terrain, material, and vegetation throughout the country.

The Human Factor

Contrast in landslide distribution between forested and pasture slopes in Manawatu, New Zealand (Feb 2004)

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- Examples from New Zealand:
  - Conversion from forest to pasture increases landslide probability by $3\times$.
  - Sedimentation rate increased by $5\times$ after European farming practices started.
  - Complete deforestation will increase runoff 28%, whereas climate-driven runoff increase is 15% by 2080.

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2. However, prediction is extremely uncertain.
3. Human land-use changes often dominate.
4. We need collaboration between climate and slope-stability modellers.