Landslides


SR 20 8/11/13

"Did you see it?"


SR 20 8/22/14

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Rainfall-triggered Landslides in Pacific Northwest: Future hazards and risks

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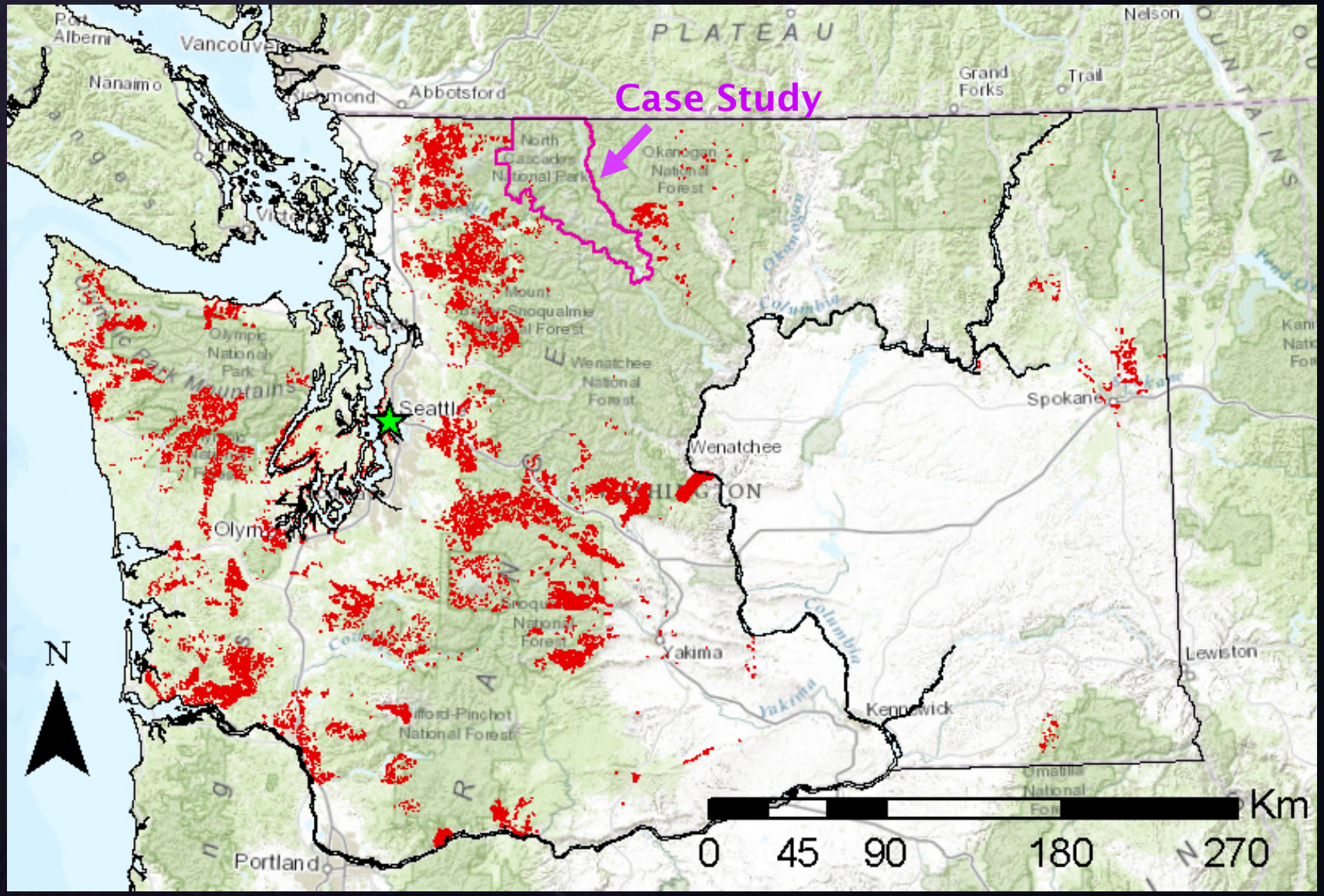
Key Questions

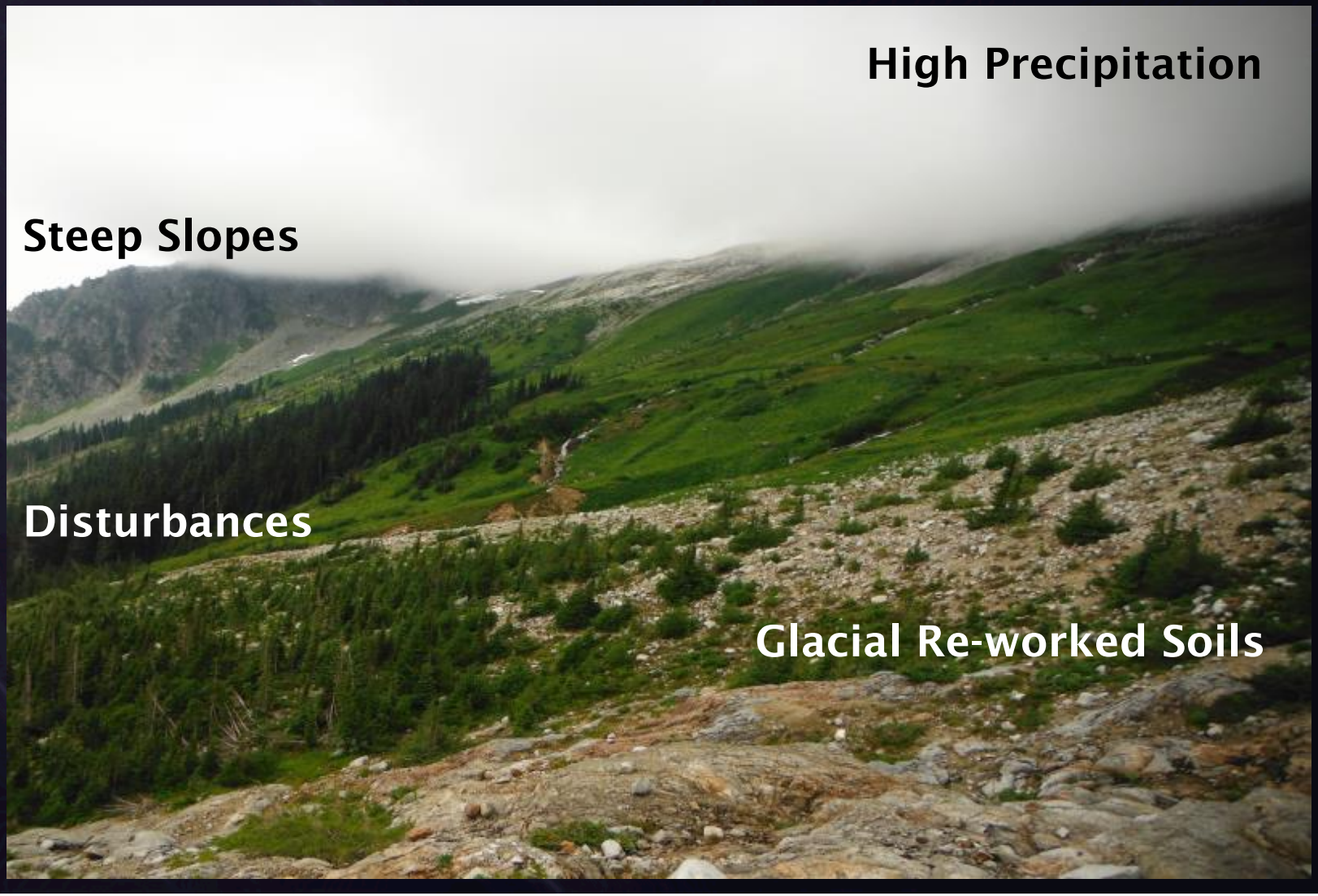
- Why is the Northwest prone to landslides?
- What climate-related changes might alter the likelihood of landslides?
- Where and when might these changes occur?

Mt Rainier National Park, Nov. 2006

Washington Landslides



Landslide Territory



PNW Climate Projections

- Increased annual precipitation amount
- Seasonal changes in precipitation amount
  (↑ Fall, Winter, Spring, ↓ Summer)
- Increases in precipitation intensity – downpours
  (days with >1 *in* [25 *mm*] ↑ by 19% by 2050s)
- Decreases in snowpack

Photo – Jay Goodrich

Slope Stability

- Inherent (static or slowly changing) factors

- Dynamic (fast changing) factors

Inherent Stability

Site Characteristics

- Slope
- Curvature
- Aspect
- Elevation
- Lithology
- Land use – land cover

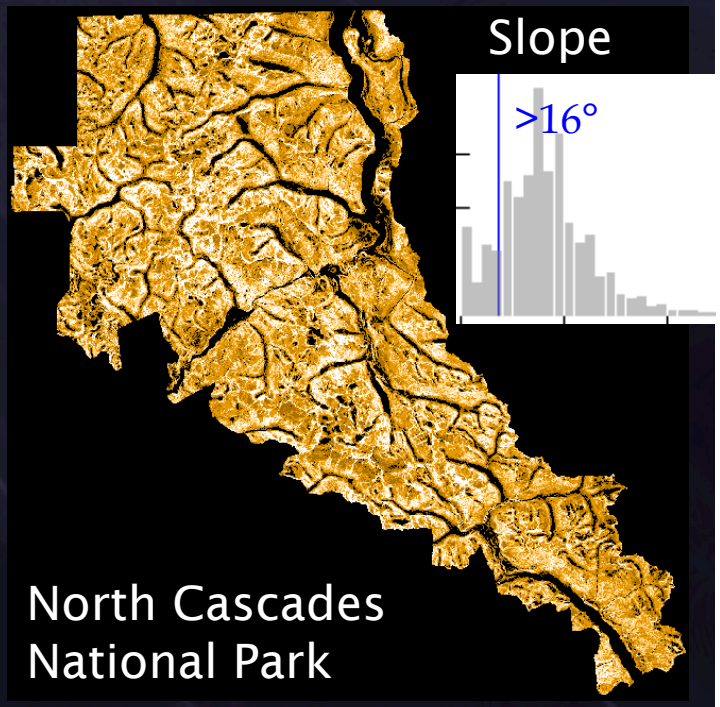
Frequency Ratio

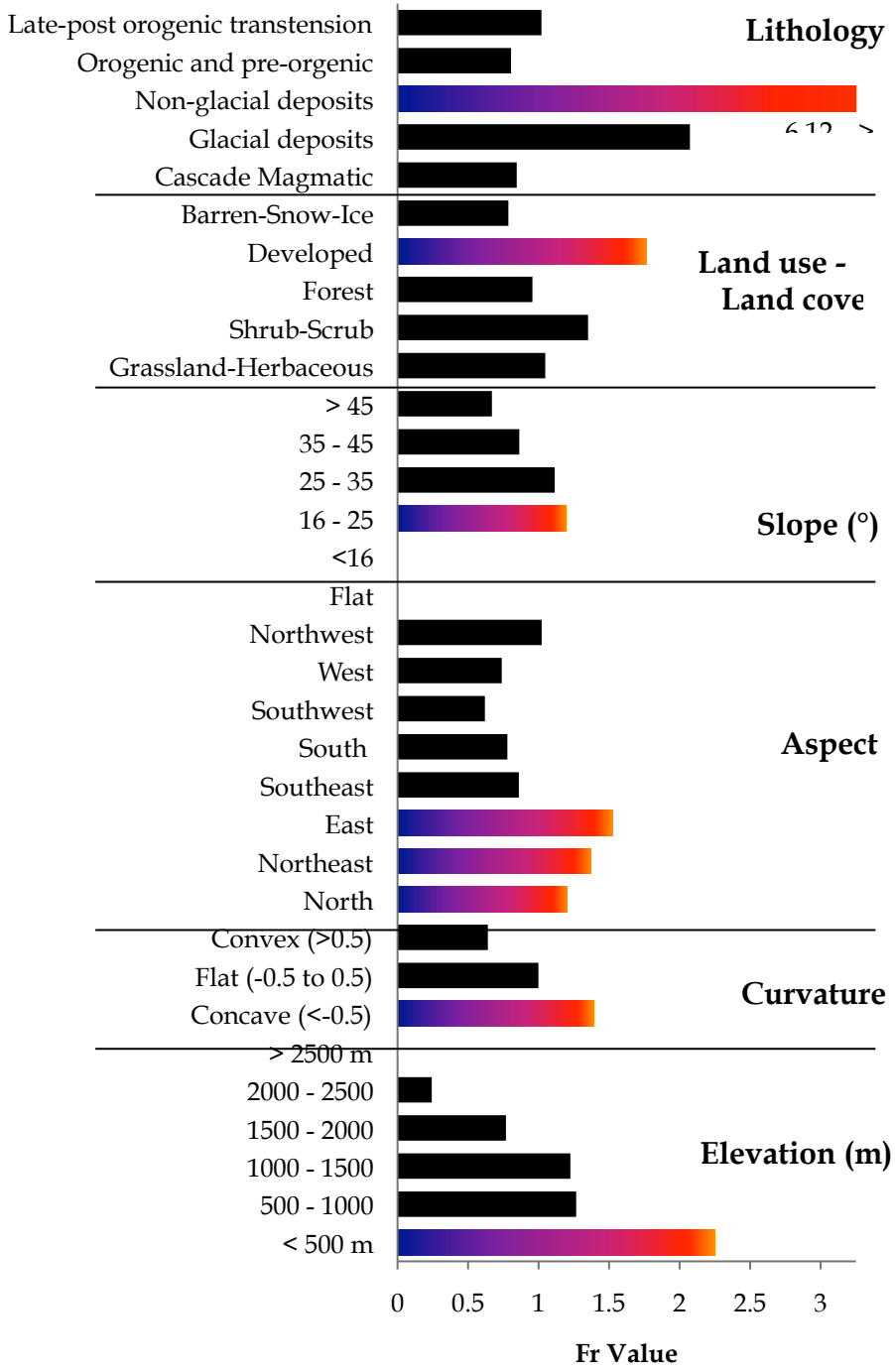
$$Fr_{cb} = \frac{Landslide\ Area_{cb} / Landslide\ Area_T}{Study\ Area_{cb} / Study\ Area_T}$$

- Fr = Frequency Ratio value
- c = Surface characteristic
- b = Bins of characteristic
- T = Total area

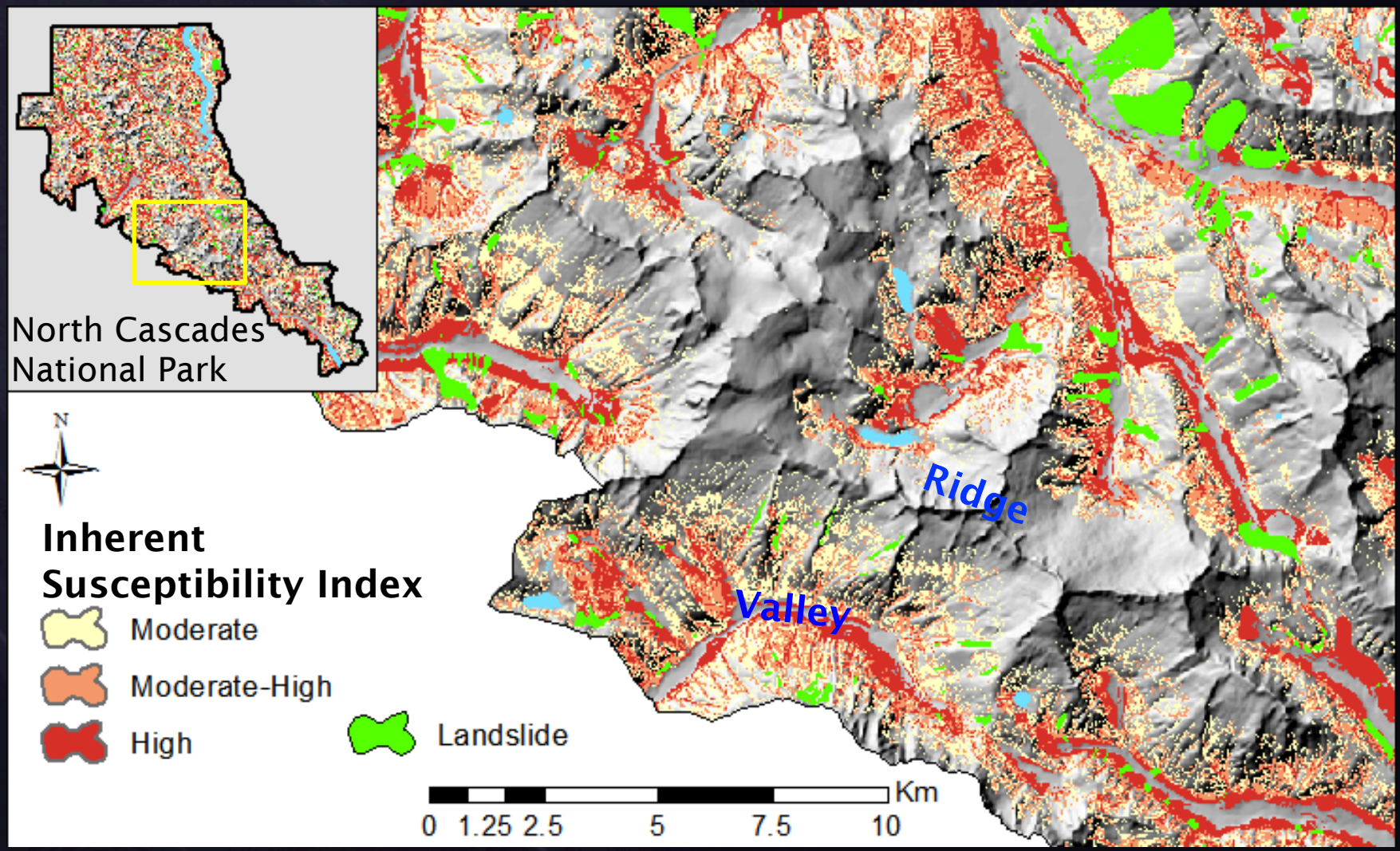
Based on Kirchbaum et al. 2012; Lee & Pradhan 2007

Landslide association with surface characteristics





Inherent Stability Index



Dynamic Stability

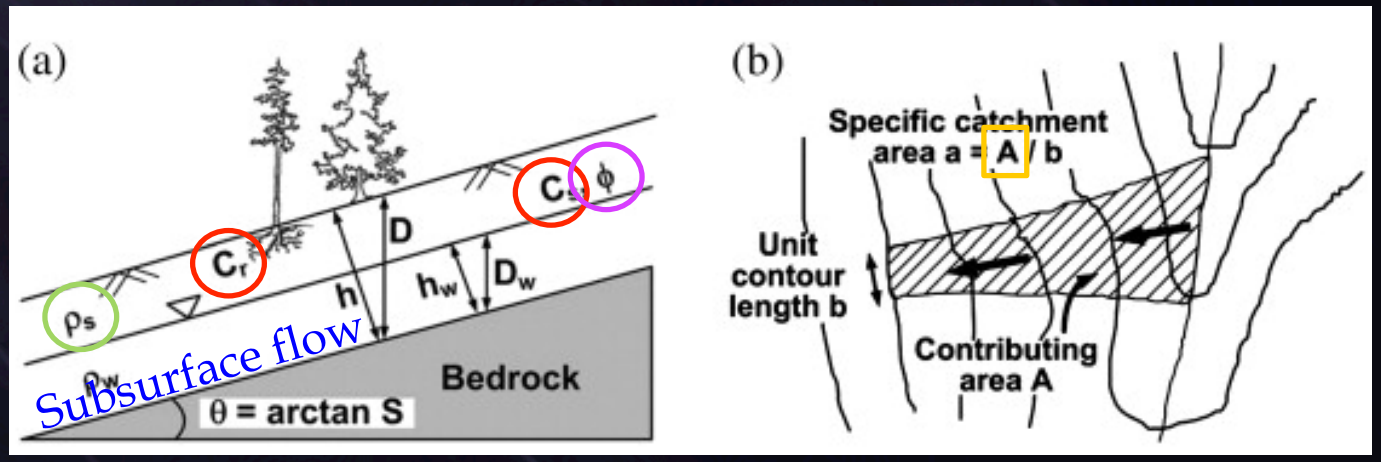
$$\text{Factor of Safety} = \frac{\text{Resisting strengths}}{\text{Driving forces}}$$

Factor of Safety

$$FS = \frac{C^* + \cos\theta \tan\emptyset [1 - (\rho_w / \rho_s) R_w]}{\sin\theta}$$

$$C^* = \frac{C_r + C_s}{h \rho_s}$$

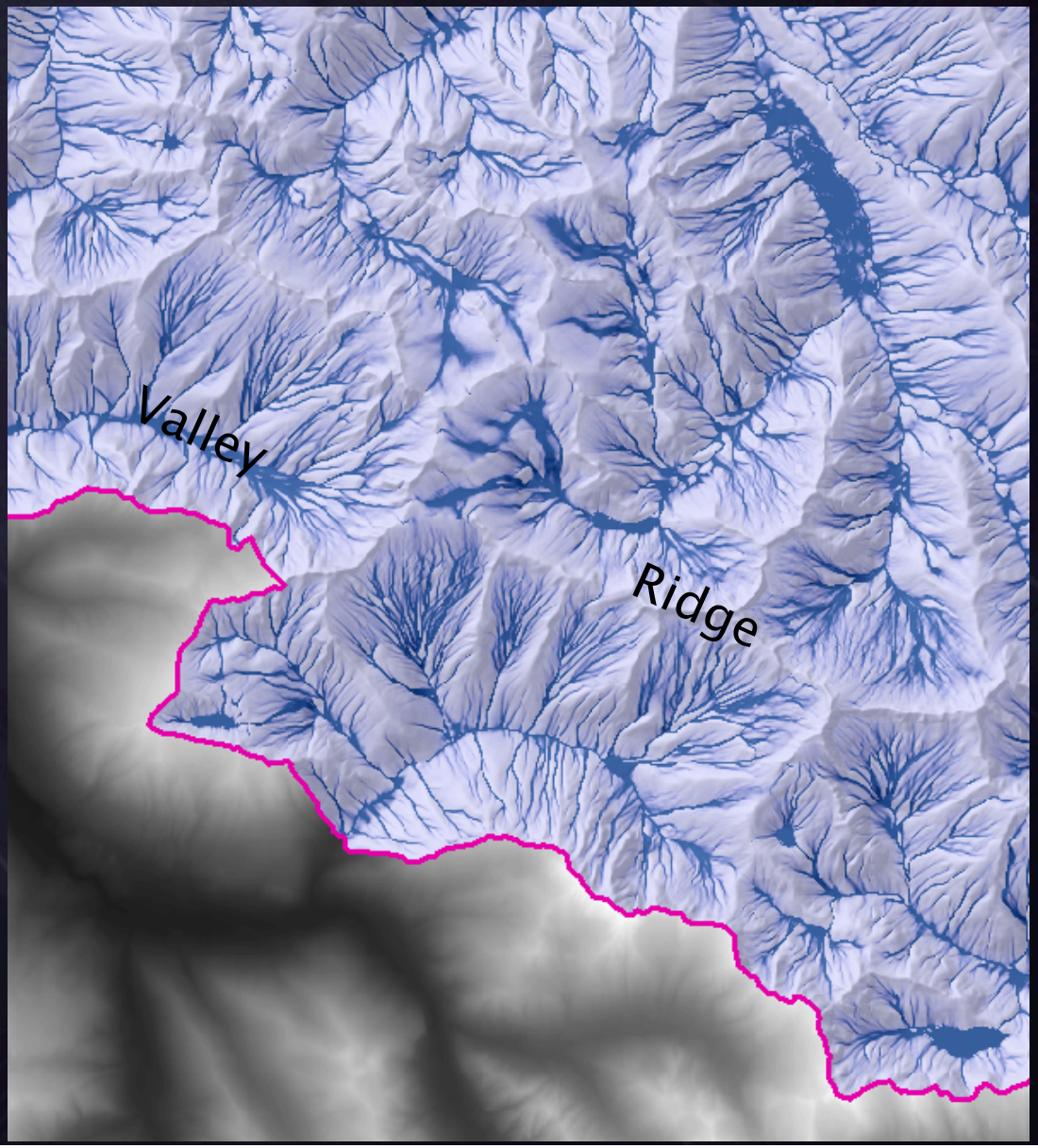
$$R_w = \frac{h_w}{h} = \min\left(\frac{R_e A / w}{T \sin\theta}, 1\right)$$

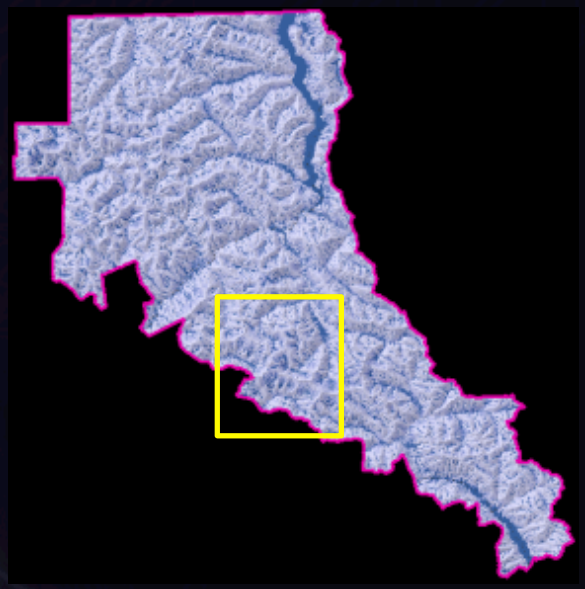


Shalstab Model

Based on Montgomery & Dietrich 1994; Deb & El-Kadi 2009

Soil layer saturated - proportion



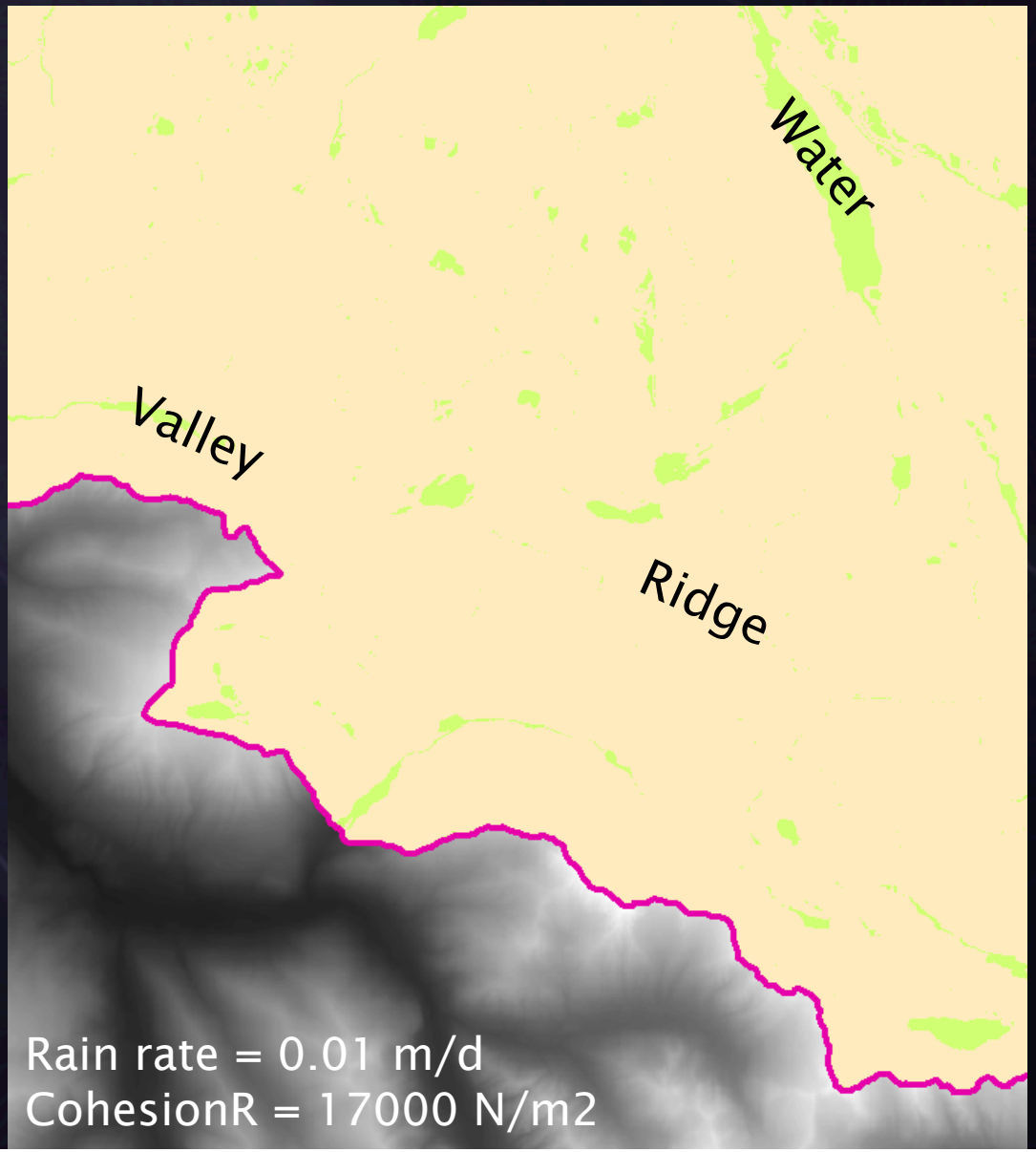


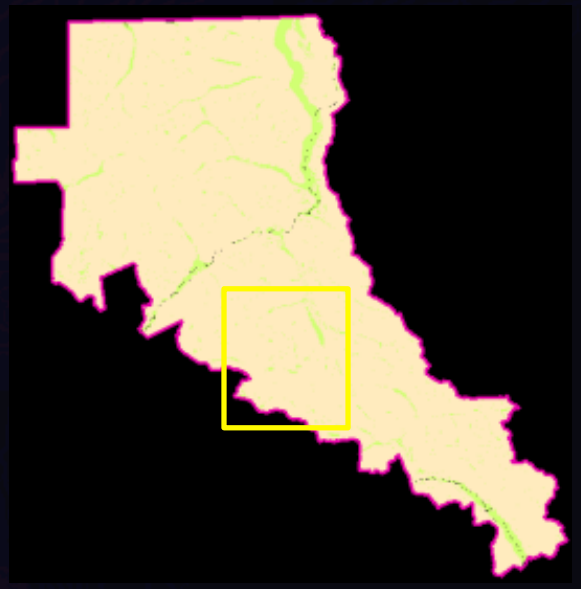
Legend

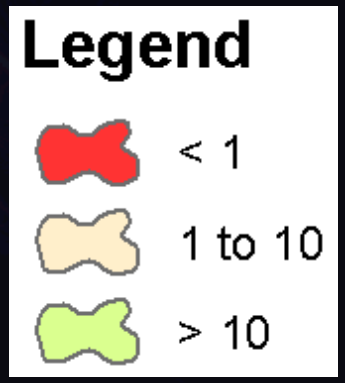
High : 1

Low : 0.02

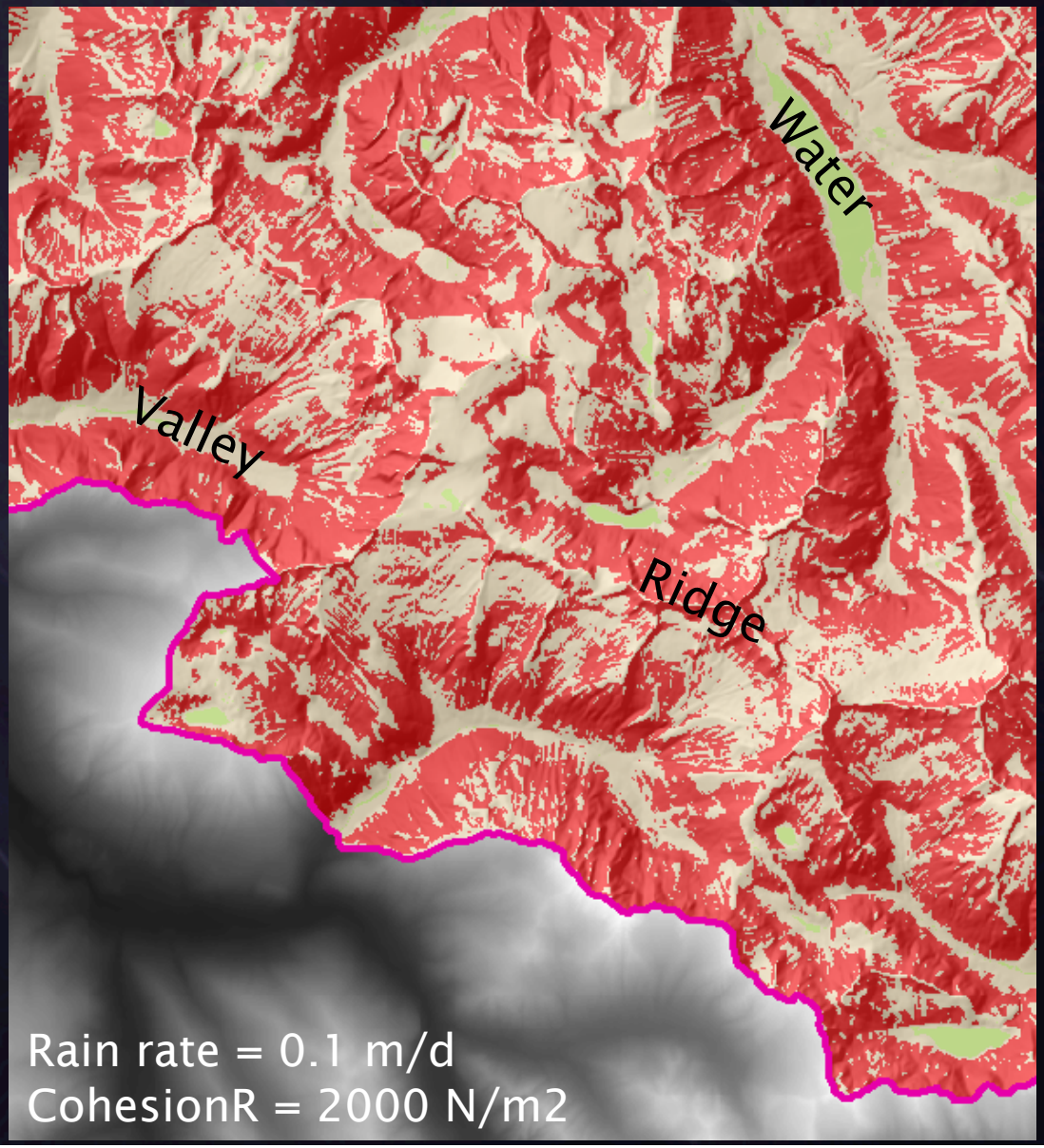
Factor of Safety

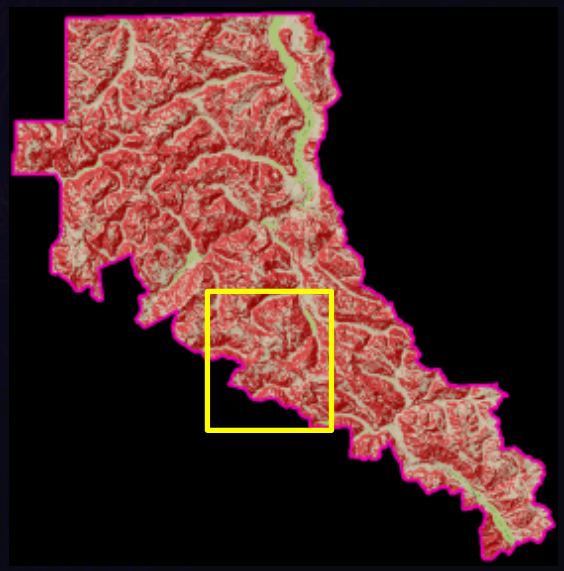


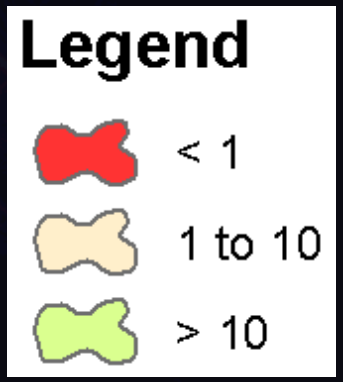




Factor of Safety

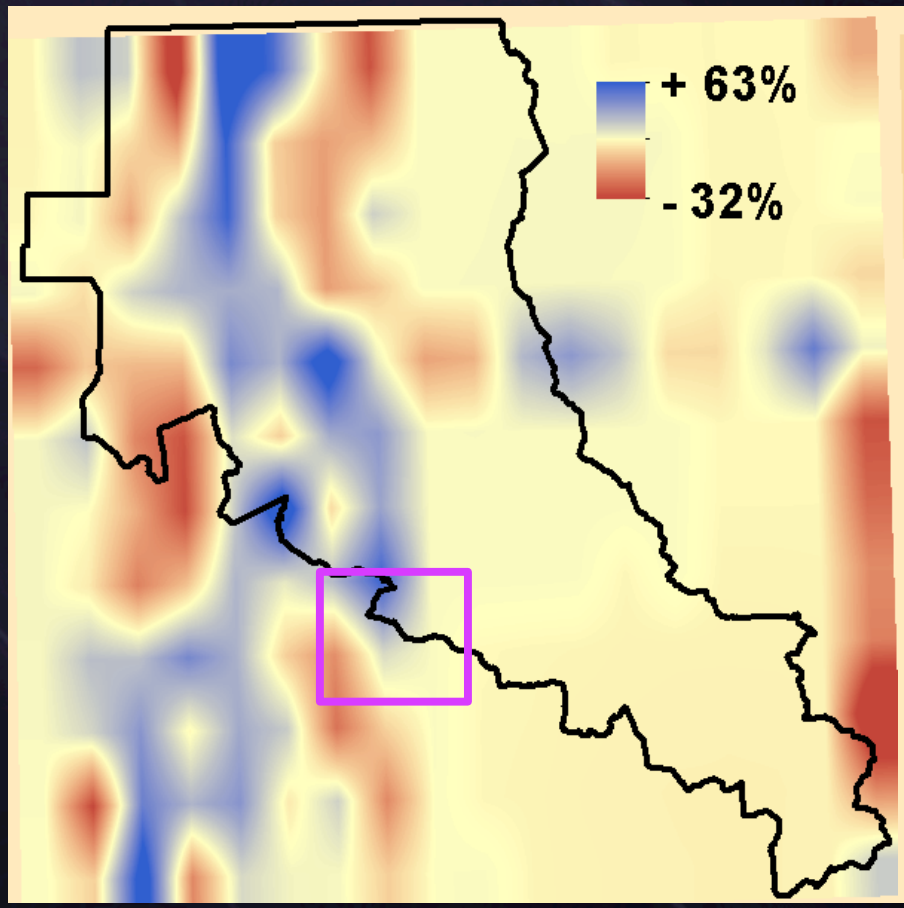




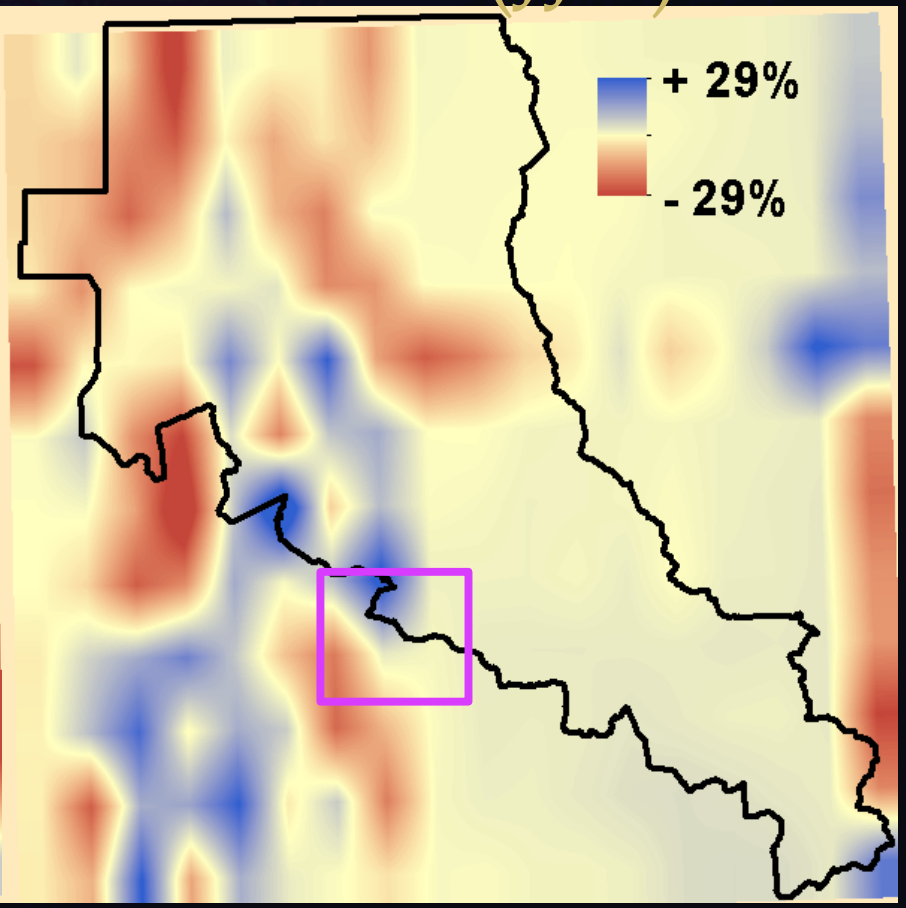


Precipitation Percent Change by 2040s

November

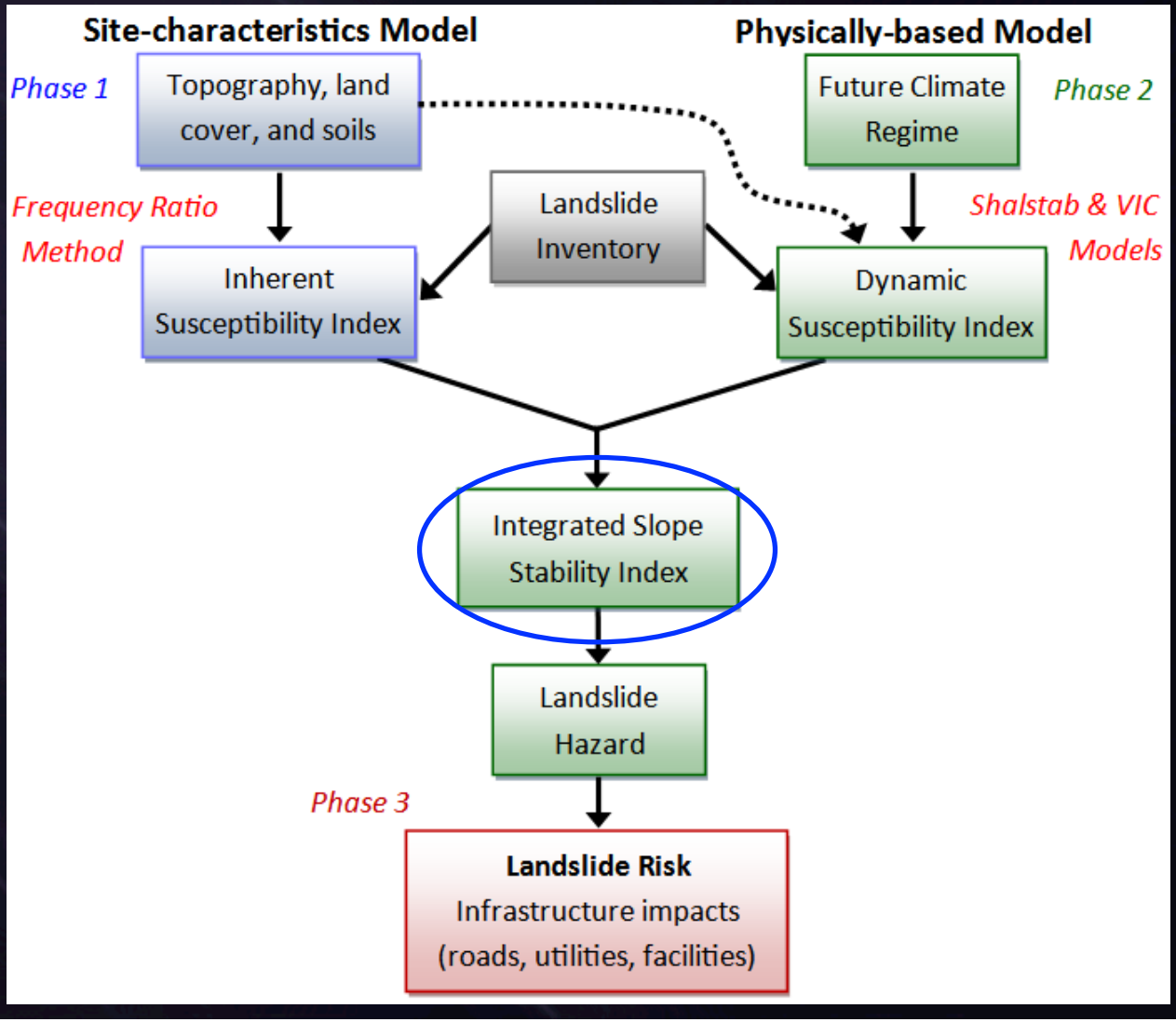


Summer (JJA)



Statistical downscaled ECHAM5; Hamlet et al. 2013

Integrated Model



Summary

- Pacific Northwest represents a natural laboratory for studying landslides
- Landslides depend on both inherent and dynamic factors
- Increased precipitation may shift dynamic drivers to increasing instability varying in space and time
- Integrated model will capture geologic and hydro-climatic factors
- More information on landslide locations and triggers is needed

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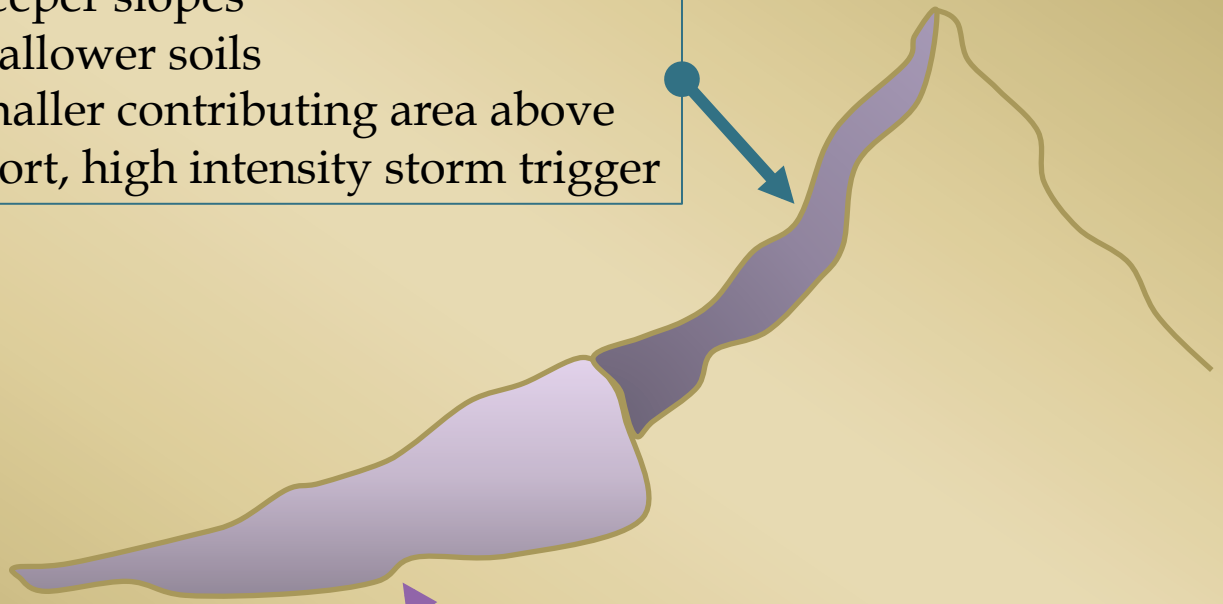
Acknowledgements

- Funded by Northwest Climate Science Center US Department of the Interior, USGS and National Science Foundation - CBET
- National Park Service
- Climate Impacts Group – Climate data

Extra Slides

Mechanism Differences

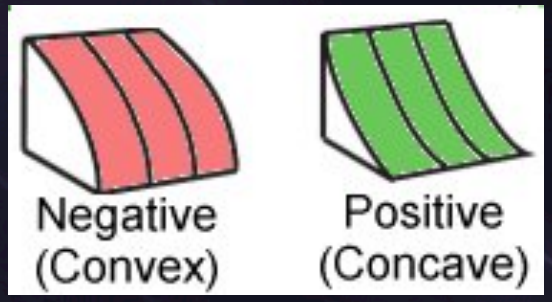
Steeper slopes
Shallower soils
Smaller contributing area above
Short, high intensity storm trigger



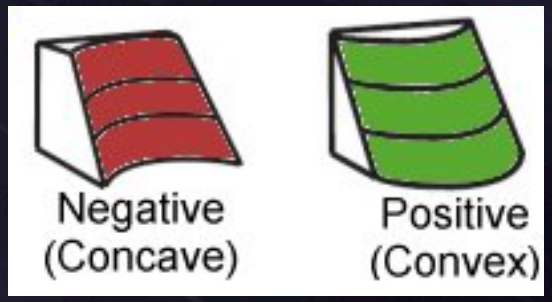
Gentler slopes
Deeper soils
Larger contributing area above
Longer, moderate intensity storm trigger

Curvature

Profile



Planar



Total