# CP vs FP Paper outline

## 3 main messages

1. The effect of forest on landslides might be underestimated
2. climate change isn’t the only factor that leads to landslides
3. The need to apply probabilistic approach in forest management and landslide studies (knowledge gap)

# Outline

1. Introduction
   1. Increased global landslide frequency
      1. Globally
   * Increasing number of landslides globally (Gómez et al., 2023)
   * 2620 fatal landslides from 2004 to 2010, taking 32322 lives away (Petley, 2012)
   * Socioeconomic loss due to landslide accounts for up to 20 billion US dollar annually worldwide (Sim et al., 2022).
     1. in BC

* Pacific Northwest is identified as a landslide hotspot (Dandridge et al., 2023)
* City of Quesnel undergone 810 mm of movement since the late 1998 (Monitoring Program 2020, 2021)
* Regionally, hundreds of landslides occurred in 2020 and 2021, leading to numerous road recovery projects
* Although recent landslide fatalities show a decreasing trend, the economic and social damages cannot be unseen (Strouth & McDougall, 2021)
* According to Government of Canada, “terrestrial landslides … [account] for an estimated $200 to $400 million in direct and indirect costs annually” (*Landslides*, 2013)
* Landslides along the Canadian Railway
  + “Although movement was slow in the late 20th Century, cumulatively it was sufficient to open numerous tension cracks in the main body of the landslide and cause a visible shift in the fence line of the CPR track by the early 2000s (Bunce and Chadwick, 2012).” (Huntley & Bobrowsky, 2014)
  + “Unfortunately, as the magnitude and frequency of landslide activity increases, the frequency of track maintenance and costs rise. Consequently, the economic repercussions of a severed railway here remain pronounced.” (Huntley & Bobrowsky, 2014)
  1. Past studies on triggers of landslides
     1. Climate change
  + Increased landslide prone areas under climate change modeling scenarios (Jemec Auflič et al., 2023)
  + Increased frequency of landslide hazards under climate change scenarios in BC, primarily looks at the changing precipitation pattern (Sobie, 2020)
    1. Land use change
  + Landslides triggered by human disturbance is increasing, including construction, illegal mining, and hill cutting, and might have more effect than climate change (Froude & Petley, 2018)
  1. Knowledge gap
     1. Regional scale landslide phenomenon
  + “While most research tends to centre on basin scale landsliding, focusing on modelling and understanding the mechanisms and precursors that lead to landslide initiation, understanding the relationship between landsliding and climate change is a regional-scale problem which needs to be assessed at this level through regional-scale studies.” (Wood et al., 2015)
  + “When considering the scale of climate change impacts, it is difficult to attribute basin-scale changes in landsliding to specific changes in the climate due to the complexity of the system, and so wider-scale regions should be investigated” (Wood et al., 2020, p. 12)
    1. Landslides aren’t single factor events
  + “Exceedance of a climatic threshold is thus a necessary, but not a sufficient, condition for debris flow occurrence.” (Jakob et al., 2005)
  1. Aim of the paper
     1. Demonstrate the causal linkage between forest cover and regional land stability
     2. Investigate current landslide and forest cover relationship analysis framework
     3. Investigate how other fields of landslide research studies cumulative effects, and its applicability to forest management studies

1. Role of Forest in slope stability
   1. Direct effect (deterministic)
      * + Decreased root cohesion
          - Increased macropores after decomposition of roots
          - Anchoring properties of woody vegetation
          - “When hillslope soils are in a tenuous state of equilibrium, reinforcement by tree roots may provide the criti cal difference between stability and instability during storms or snowmelt [Sidle, 1992]” (Sidle and Ochiai, 2006, p. 94)
          - Roots after clearcut lose their tensile strength 3 to 5 years after harvesting (O’Loughlin, 1974)
      1. Increased pore pressure
   * Extreme precipitation can tip over soil capacity, leading to landslides. In a rainfall-triggered landslides study, 40% of the landslides studied had over 95th percentile rainfall (Kirschbaum et al., 2015)
   * Groundwater level
     + In cases where the increased available recharge raises the groundwater table, the pore pressure of the soil increases and capillary force decreases, leading to decreased sheer pressure, hence slope instability (Germer & Braun, 2011; Panda et al., 2023).
   1. Indirect effect (probabilistic)
      1. The frequency of soil saturation
   * soil fatigue/ threshold behaviour
   * Diagram of a diagram showing the effects of a earthquake

     AI-generated content may be incorrect.
   * According to this figure from McColl, 2022, if a slope is already hovering around the factor of safety = 1 equilibrium, factor such as groundwater can dominate the likelihood of reactivation
   * Seasonal fluctuation of pore pressure exert stresses onto the soil and can lead to slow awakening and degradation of rock mass (Preisig et al., 2016)
   * Deep-seated and clay-rich landslides normally has higher water holding capacity, which responds to long-term accumulation of water, leading to progressive movements (Sidle & Ochiai, 2006)
   * Snow-dominated
     + Loss of canopy cover leads to faster and more rapid snow melt, leading to more drastic seasonal pore pressure fluctuation
     + Under climate change, if winter rain increases, there could be partial melting and freeze-thaw events happening during winter, adding on more pore pressure fluctuation.
   * Rainfall- dominated
     + Higher antecedent soil moisture, leading to more frequent saturation
   1. cumulative effect

* Groundwater aquifer boundaries and extend beyond surface topographic divides (Jencso & McGlynn, 2011; Welch et al., 2012; Winkler, Redding, Spittlehouse, Carlyle-Moses, et al., 2010)
* Slow-moving nature of groundwater can mask/delay the change in flow behavior; research suggested that the effect might not reveal for decades, or the effect can last over water years (Peters et al., 2005; Winkler, Redding, Spittlehouse, Smerdon, et al., 2010)
* Everything that can move a slope from “stable” to marginally stable” faster could alter landslide frequency and magnitude. “Others (e.g. Varnes, 1978 and references therein) have previously commented that a landslide trigger is often only the final action that initiates a marginally stable hillslope, and it may be quite trivial in magnitude” (McColl, 2022, p. 18Past studies on forest harvesting and landslide frequencies

1. Deterministic landslide studies

* Many studies investigating harvesting effect on landslides lack temporal analysis. The frequency density of landslides is often used in comparing pre- and post-treatment period. Frequency density is defined as the number of landslides happened in the basin divided by the area of the basin, which does not represent how landslide occurrence changes in relation to time.
* doesn’t tease out how landslide frequencies change with time but only compare the “frequency of landslides” in different categories
* example from Jakob 2000:A table with numbers and text

  AI-generated content may be incorrect.
* event-base analysis
* use rainfall events as the only predictor of landslide occurrence
  + Johnson et al. use 48-hr rainfall to determine the relationship between harvested and forested sites (2007), Johnson & Edwards pointed out other rainfall factors could also trigger landslides, demonstrating the stochastic nature of landslide activity (2008).
  + In modeling exercises, rainfall is also often the input used to predict landslide events.

1. Attribution science in landslide related studies
   1. causal framework

* The frequency of landslides
* Repetitive movements at the same location
* Similar events happening in the same region
  1. Climate change isn’t the only factor causing the increased in landslide frequency. As there are many factors that could trigger landslides, and often the combination of different factor can lead to triggering effect. The same problem
  + “Exceedence of a climatic threshold is thus a necessary, but not a sufficient, condition for debris flow occurrence.” (Jakob et al., 2005, p. 756)
  + “(it is possible that not the largest but a smaller event following a period with large antecedent rainfall amount may have triggered the landslide)” (Lehmann et al., 2019, p. 9966)
  1. the need to develop regional analysis
  + When the whole system is non-stationary, only regional analysis can shed light on the change in landslide behaviors. This view is supported by the abundance of attributional science approach in dealing with stochasticity of landslide events under climate change
  + Climate change landslide studies
    - landslide pdf methods (still learning)
    - [Landslide inventories and their statistical properties](zotero://note/u/UJ8MMI6R/) (Malamud et al., 2004)

# Questions

* In this paper, should I specifically talk about how deforestation changes hydrology in rain, rain-on-snow, snow dominated regions, and how that affects slope stability? I feel like that might be too process-based and small scale, but at the same time might be beneficial. What’s your opinion on section 2?
* Should we put the emphasis on deep seated landslides? Since the slow moving, reactivated deep seated landslides behaves differently than debris flows (the cumulative effects might be more profound in deep-seated landslides’ failure mechanism?)
* I found a couple papers on a slow-moving landslide in Ashcroft, BC that has been affecting railways since the 1950s : (Bobrowsky et al., 2015; Holmes et al., 2020; Huntley & Bobrowsky, 2014)

# To research

* Attribution science
* Modern causal inference
* Soil fatigue/ threshold behavior
* Deep-seated landslide/ “re-activated” landslides

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