Modeling Surface Roughness to Increase Inventories of Prehistoric Landslides in the Green River Watershed, Washington

By

Rebecca Garriss
Portland State University, 1721 SW Broadway St., Portland, OR 97201

Abstract

Quantitatively analyzing the age of prehistoric landslides around the world is essential to interpreting the frequency and conditions under which the slope failed. Understanding the conditional frequency of past landslides can give us better predictions for future slope failure. Age dating prehistoric landslides can be challenging due to the difficulty of finding datable organic material within the landslide deposit and so an age-roughness model needs to be applied. An age-roughness model quantitatively assigns age based on smoothing of the landslide deposit with time. A good place to test this model is in the Green River Watershed (GRW), located in King County, Washington. Hillslopes in this area are composed of unconsolidated glacial sediments and are prone to failure from climatic and tectonic conditions and incising by lateral migration of the Green River. The standard deviation of slope within a landslide deposit is a useful tool in determining relative age. Three different window sizes (3, 15, 30 m) were tested with the best window size of 15 x 15 m determined from cross cutting relationships and previous work done in the North Fork Stillaguamish River by LaHusen et. al. (2016). The 15x15 window does a good job of capturing the standard deviation of the gradient in both small and large deep seated landslides. The mean of the standard deviation can tell us relative age of these prehistoric landslides in relation to each other and allows us to determine potential frequency of landsliding in the Green River Watershed.

Keywords: Prehistoric landslides, surface roughness, age dating, standard deviation, hillslopes, relative ages

Using Surface Roughness as a model to determine age of prehistoric landslides

By Becky Garriss

Landslides (Mapping for susceptibility)

- Why do we care how old a landslide is?

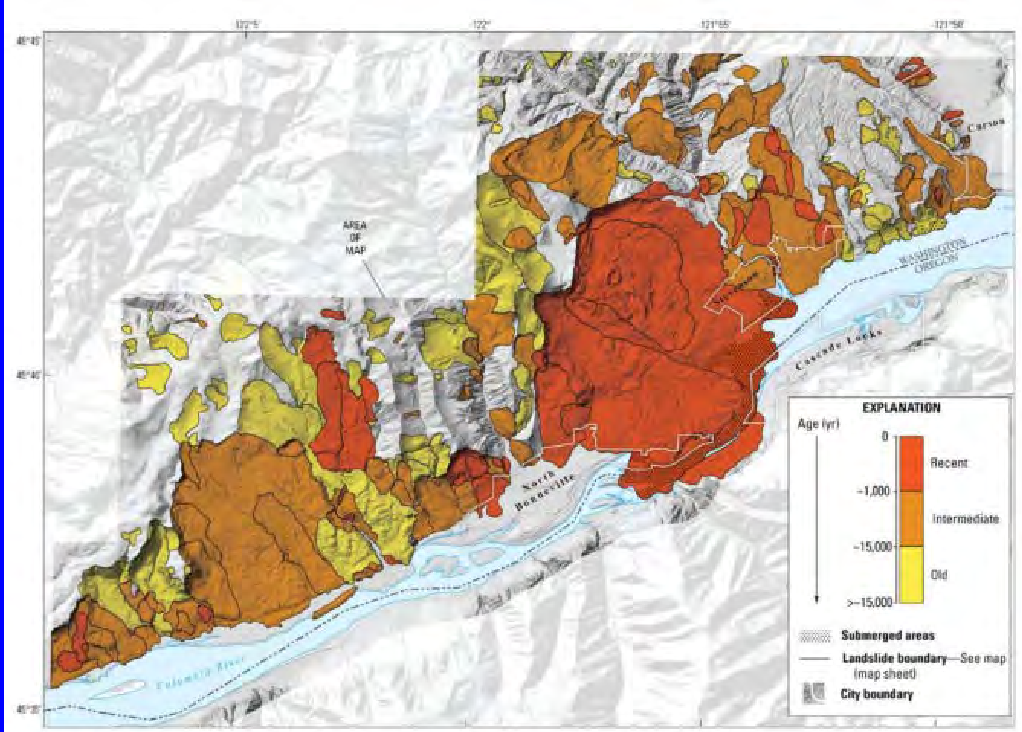
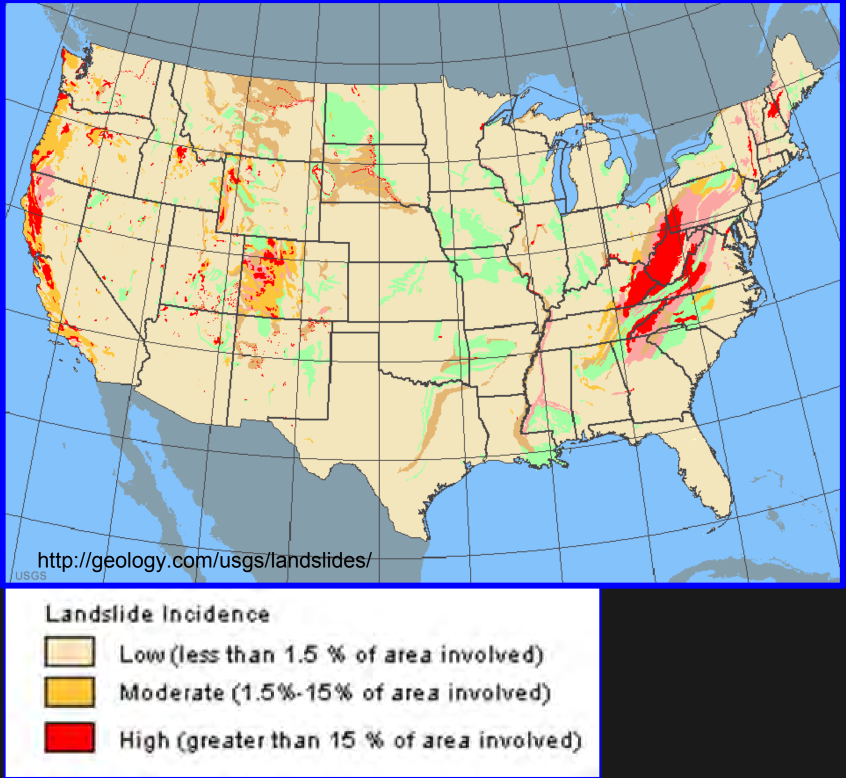


Figure 6. Simplified map of landslides in map area showing estimated age ranges of mapped landslides.



How does surface roughness relate to age?

- Surface roughness as an age proxy
- <u>Younger landslide</u>
  - Rougher surface
  - Higher standard deviation
- <u>Older landslide</u>
  - Smoother surface
  - Lower standard deviation

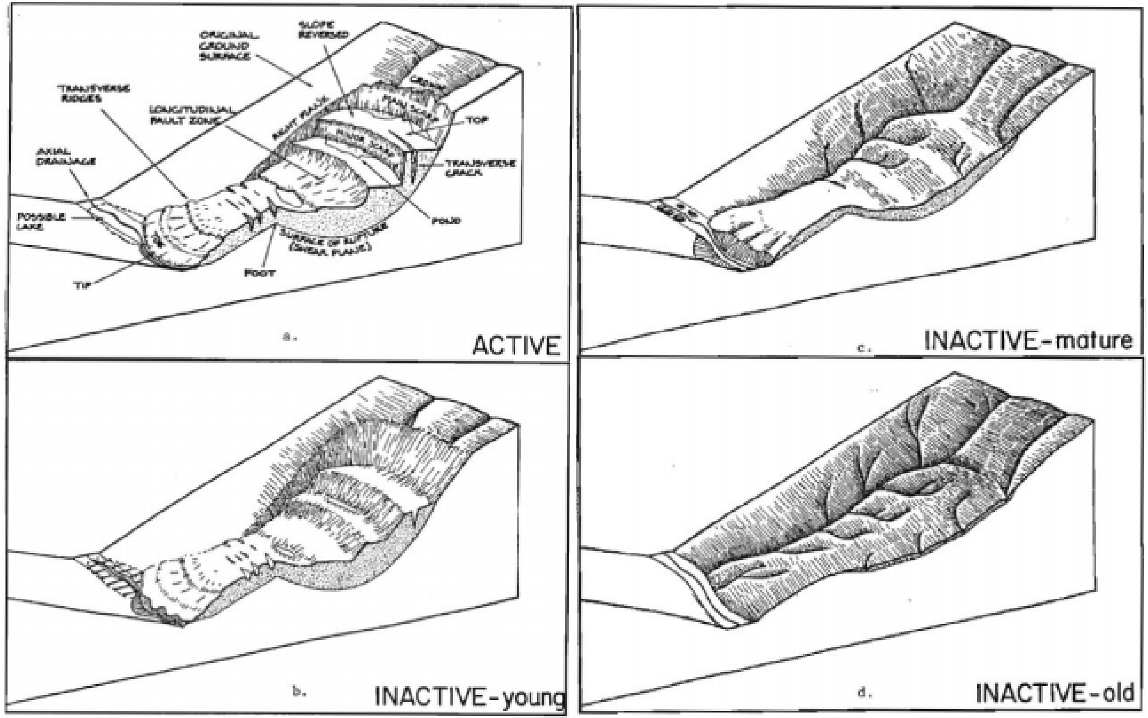
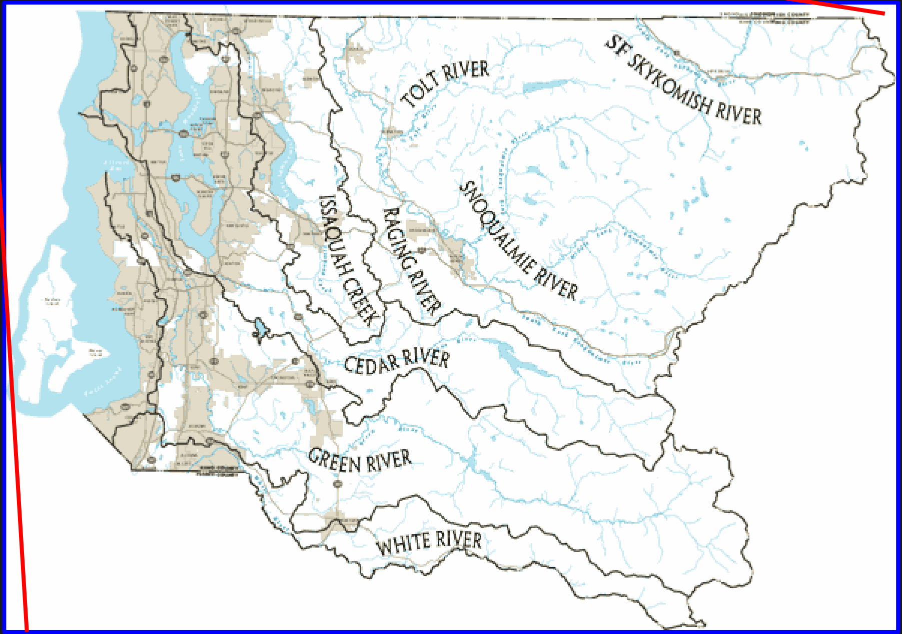


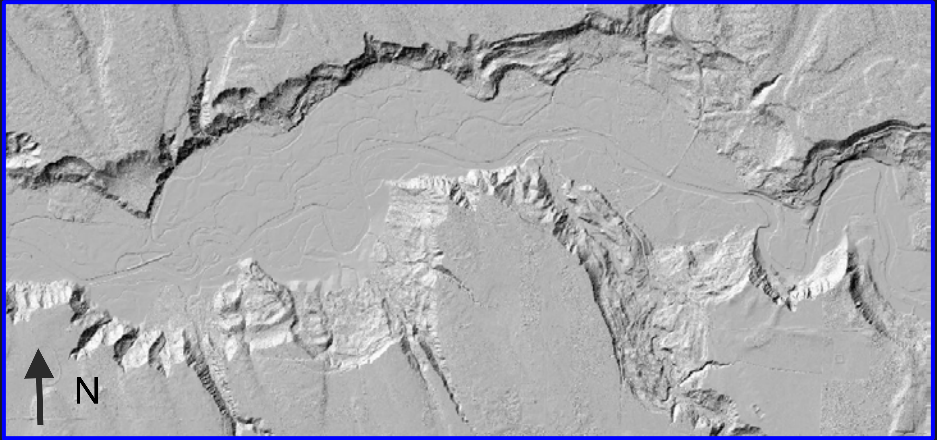
Figure 2. Diagrams showing smoothing of landslide deposit features through time (McCalpin, 1984).

BACKGROUND: Green River Watershed (GRW) study site

- Southern Puget Lowlands (King County, WA)
- ~ 65 miles long
- Hillslopes consist of unconsolidated glacial sediments deposited from the LGM
- Many prehistoric landslides

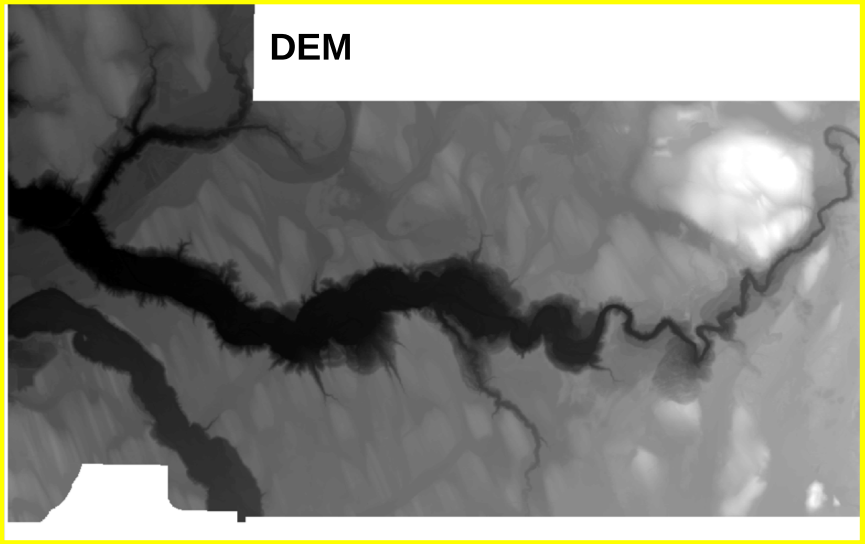


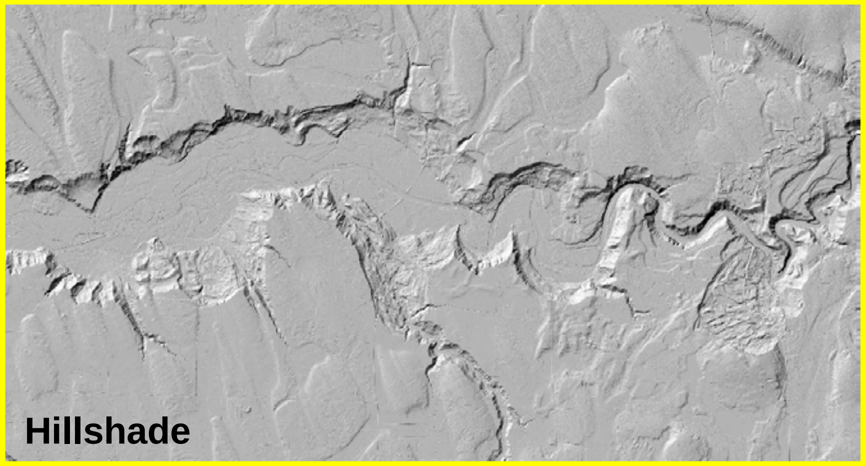
kingcounty.gov

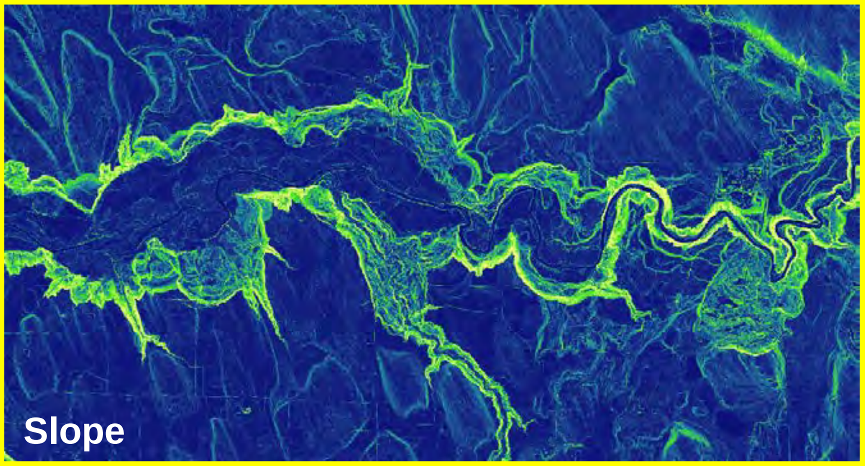


Step 1

- DEM from kingcounty.gov
- Create Rasters
    - Hillshade
    - Slope (degrees)

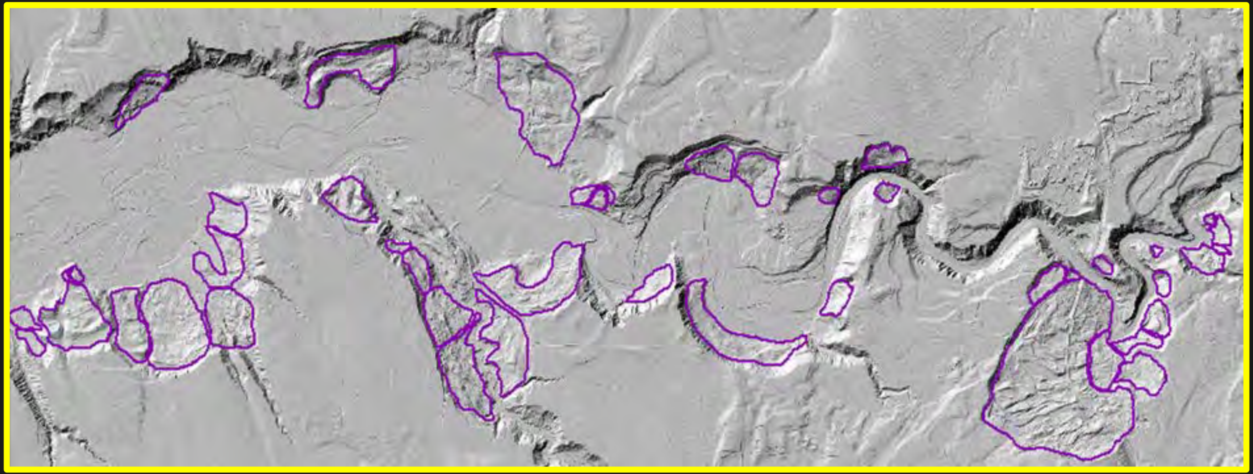


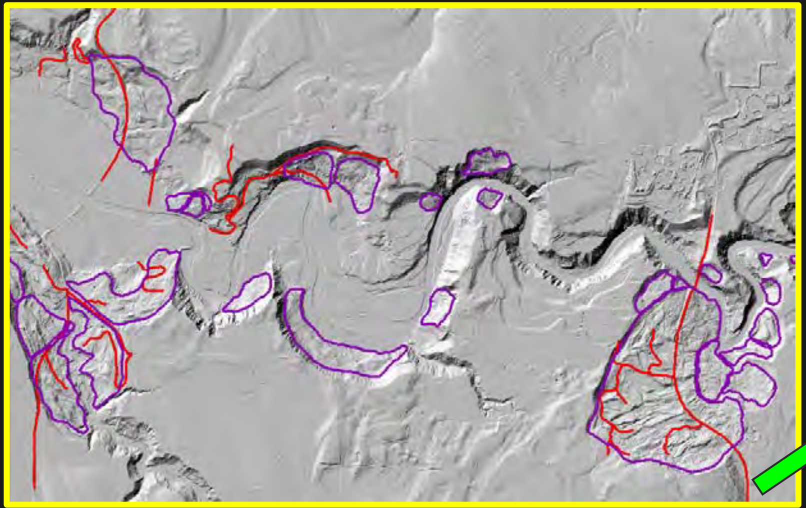




Step 2

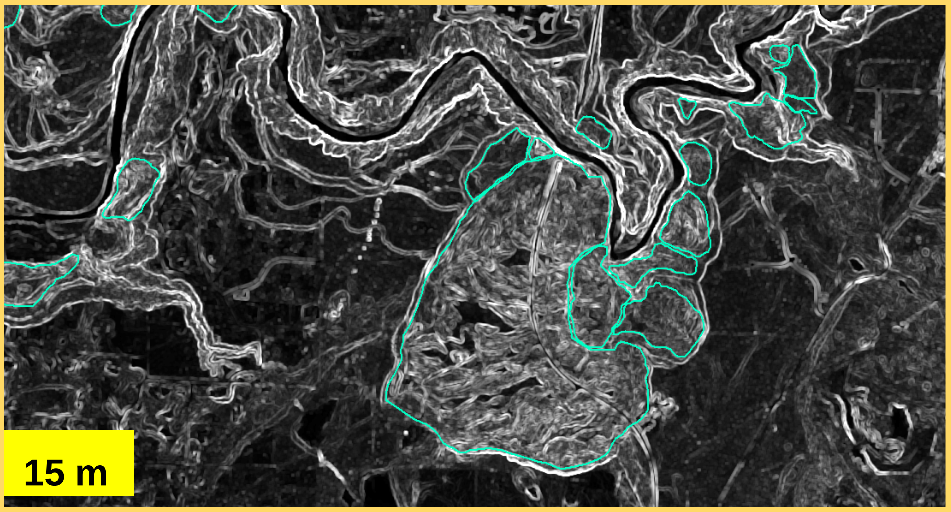
- Map landslide deposits (excluding scarps and incised toes)
- Add ‘Roads’ and ‘Rivers’ layer
- Buffer
  - 10 meters (~32 ft)
- Clip roads and rivers in landslide deposit
- Delete

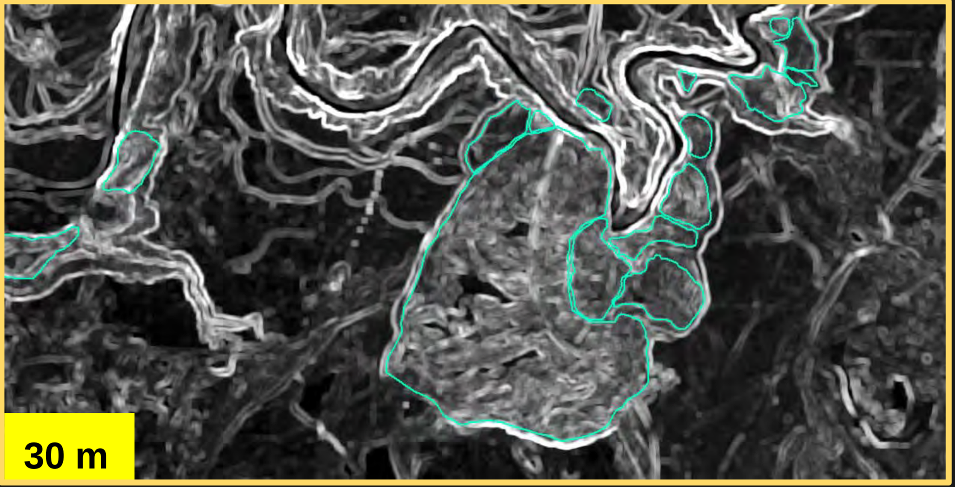




Step 3

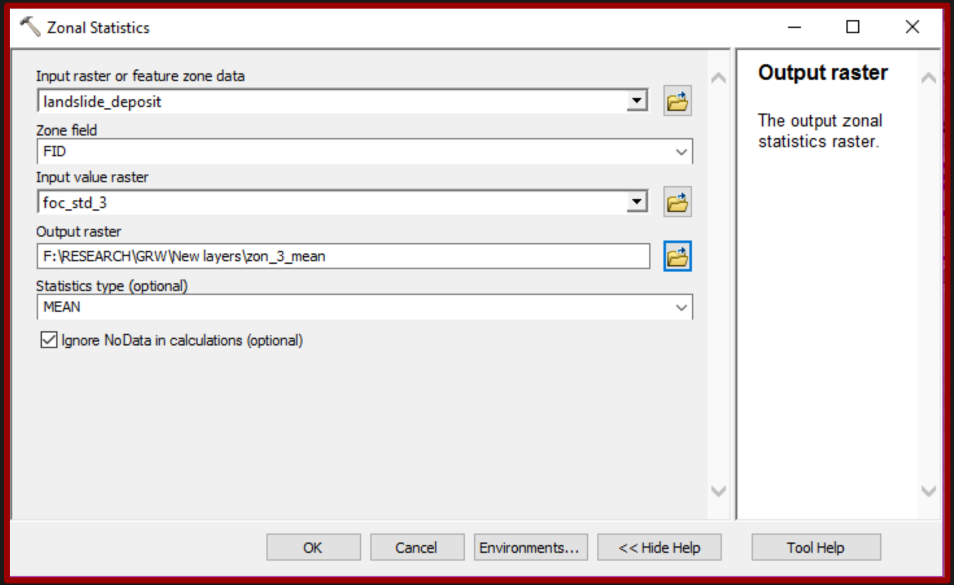
- Create a Roughness Raster
  - Standard deviation of gradient
  - Spatial Analyst: Focal Statistics
  - Three different window sizes
    - 3, 15, 30 meter

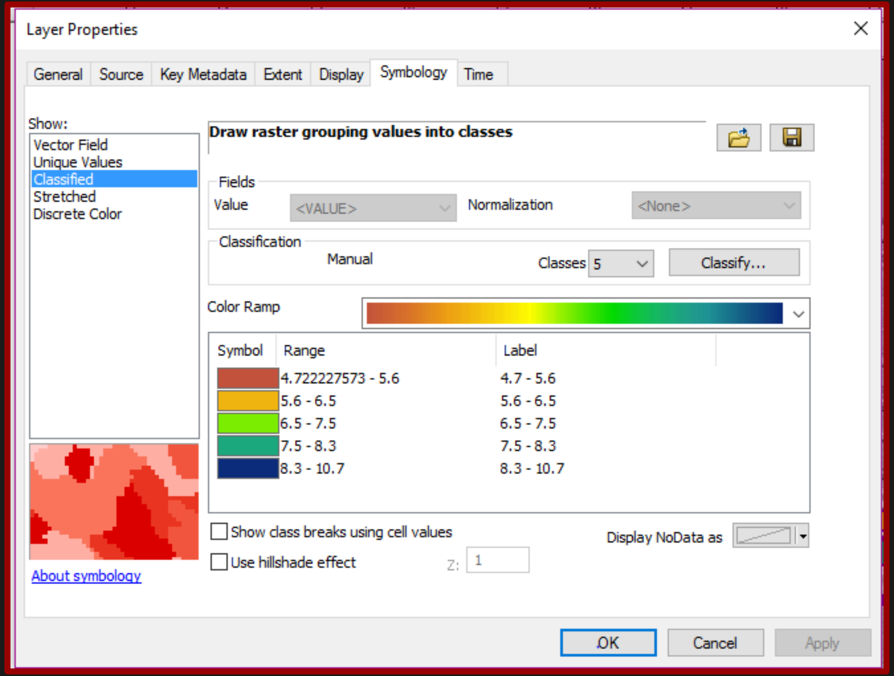




Step 4

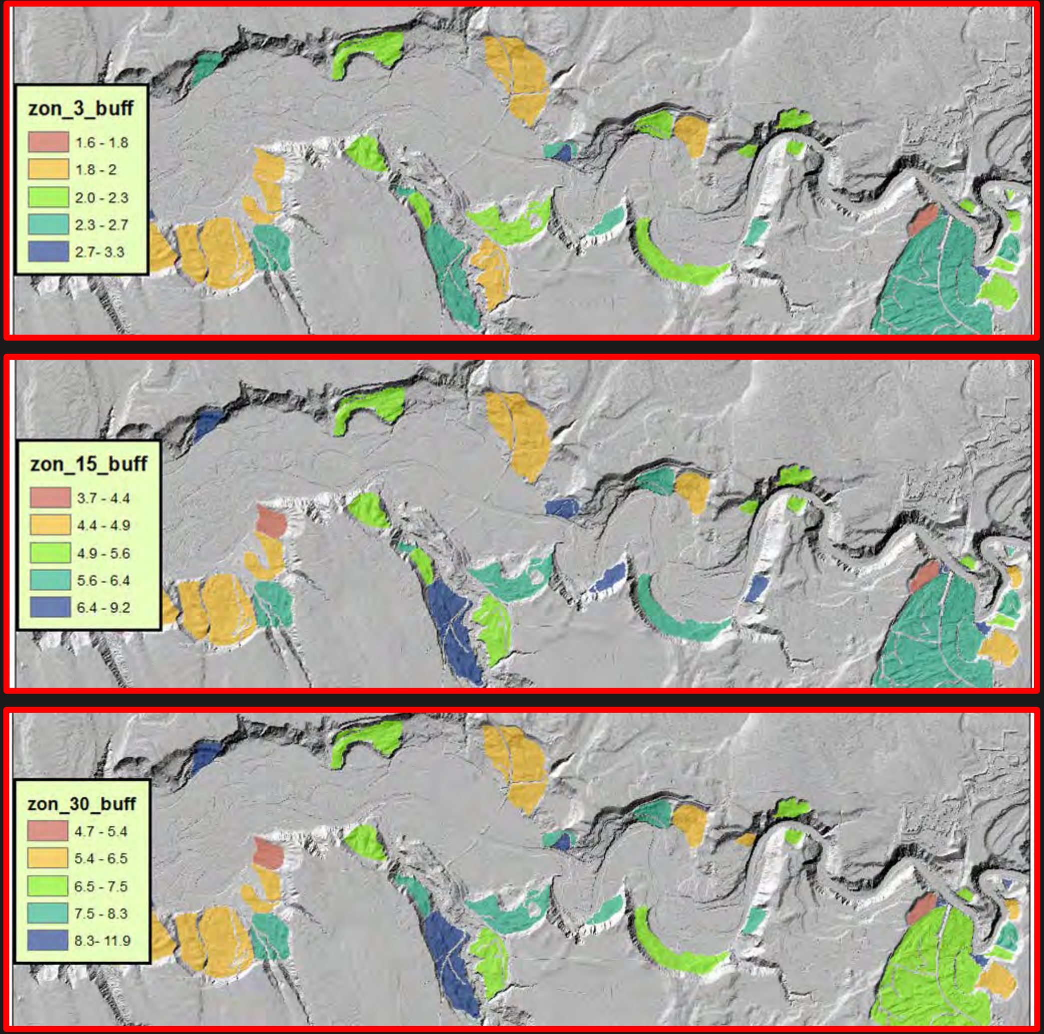
- Find the mean of the standard deviation within each landslide polygon
    - Spatial Analyst: Zonal Statistics
- Symbology
    - Classify



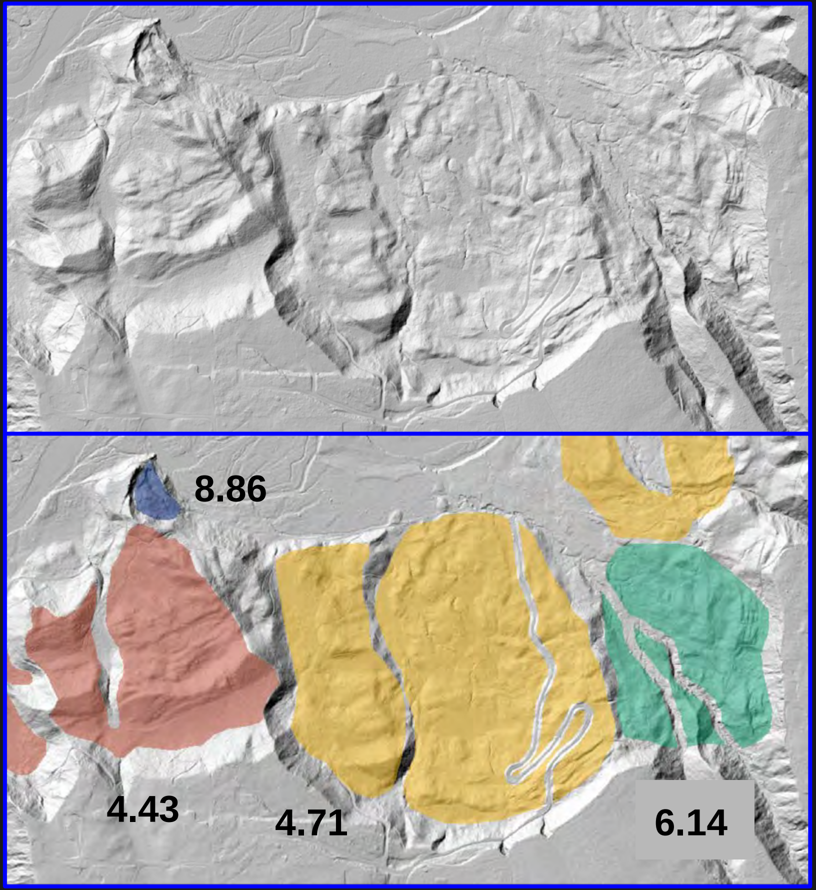


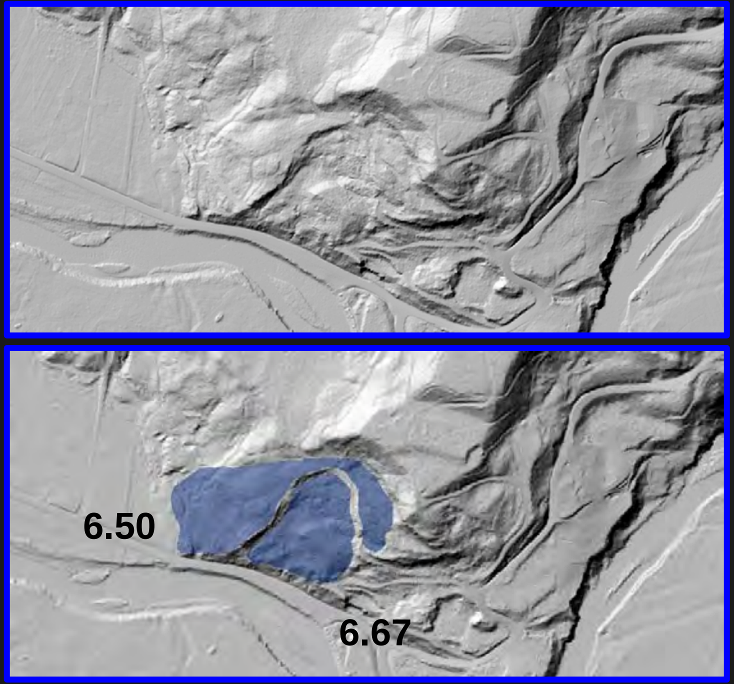
Results

- Best window size determined from cross cutting relationships and work by LaHusen et. al. 2015
- Blue = Youngest
- Red = Oldest



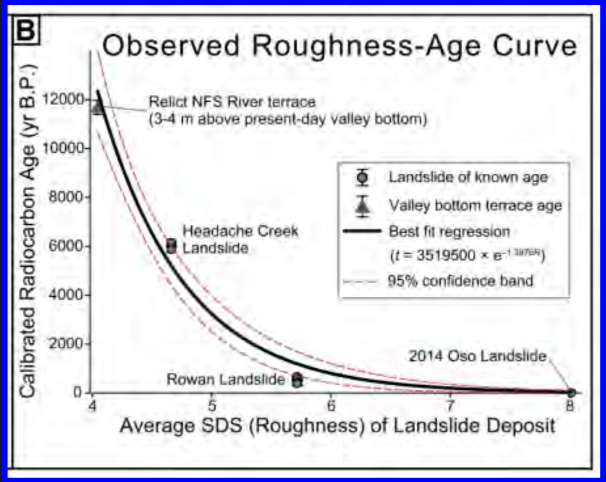
Cross-cutting relationships





Previous work done in the North Fork Stillaguamish River

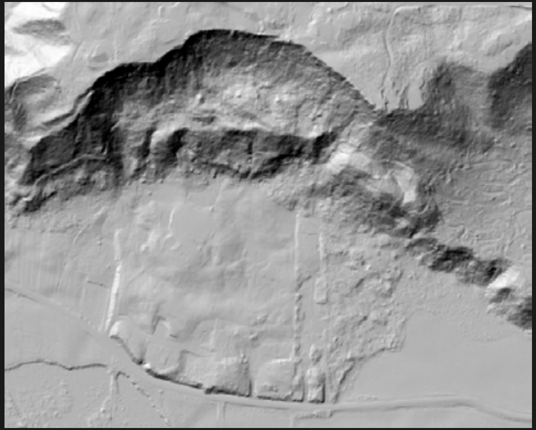
- LaHusen et. al. 2016
- North of the Green River Watershed
- Glaciolacustrine sediment
- Acquired 10 actual dates for two prehistoric landslides
    - Study site had a total of 25 landslides
- Best window size for observed roughness is 15 x 15 m

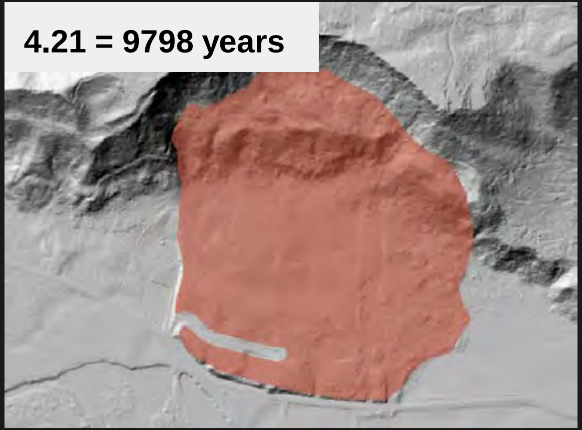


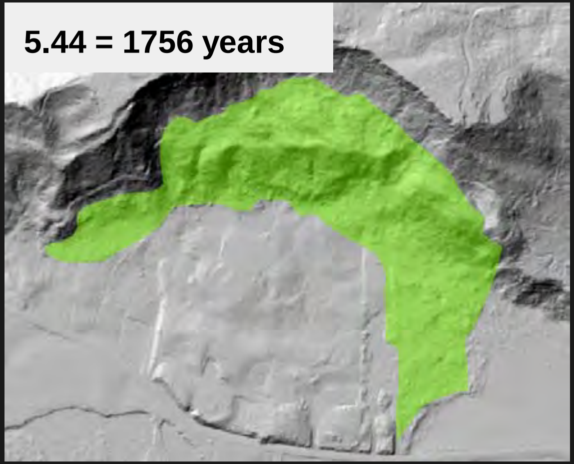
Landslide #	Mean Roughness (15 m)	Calculated Age (15 m)	Observed Roughness equation
0	8.864	15	3519500*EXP(-1.3976R)
1	6.573	361	
2	4.759	4546	Age Range = 9 to 18795
3	6.666	317	Number of landslides = 58
4	6.504	397	Average age = 3082
5	4.610	5601	
6	5.925	891	
7	4.900	3735	
8	5.361	1962	
9	5.439	1758	
10	7.117	169	
11	3.744	18795	
12	5.968	839	
13	4.862	3937	
14	5.210	2421	
15	6.372	477	
16	4.776	4444	
17	5.618	1369	
18	4.205	9867	
19	4.103	11377	
20	6.183	622	
21	6.228	584	
22	4.303	8603	
23	6.165	638	
24	6.115	683	

Possible Errors

- Age determined by accuracy of mapping
  - Are deposits naturally eroding or have they been unnaturally modified?
- Model assumes constant parameters
  - Same climate patterns
  - Steady erosion rate
  - Not tectonically triggered







Conclusion

- Numerically modeling a landslide is possible using standard deviation of slope
    - In a glaciolacustrine environment
- Correct window size is determined from cross cutting relationships
- Accuracy of landslide mapping is crucial for model to work
    - Landslide deposit only
    - No scarps or man made modifications
- Need actual dates to compare standard deviations of surface roughness
- Great tool for use in increasing landslide inventories with relative ages.

Thank you!

Have a great winter break!