**CE 560 Advanced GIS**

**Final Project Report**

**Instructor:** Dr. Tracy Arras

**Title:** Lidar-derived surface roughness as a parameter for determining slope failure type

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## Introduction

Surface roughness is a parameter that is used to measure how much the ground surface elevation changes relative to a certain point. It can be calculated in different ways, but one of the most common is to take the standard deviation of slope (SDS) within a certain window centering around a point, and averaging that value for all the points on the surface (Grohmann et al. 2011). Surface roughness of landslides can be an indication of the material of the landslide as well as the relative age of the landslide (Booth et al. 2017). For example, landslides in bedrock are likely to be rougher than landslides in soil, and historic landslides are likely to be rougher than prehistoric landslides. I can use preexisting landslide inventory data combined with digital elevation models (DEMs) to determine the average roughness of landslide deposits within my study area, and determine the correlation between roughness and movement type (McKean & Roering 2014). Depending on the strength of this correlation, roughness could potentially be a parameter used to estimate the movement type of a slope failure. In this analysis I compared the average roughness of mapped landslides (slides) to the average roughness of debris flows (flows), and ran a statistical analysis to determine if the roughness values for each slope failure type were different.

## Study Area

My study area is a 30x23 mile rectangular area south of highway 20, which connects Newport and Corvallis (figure 1). I chose this area for its high concentration of deposits and its proximity to a major road in the area.

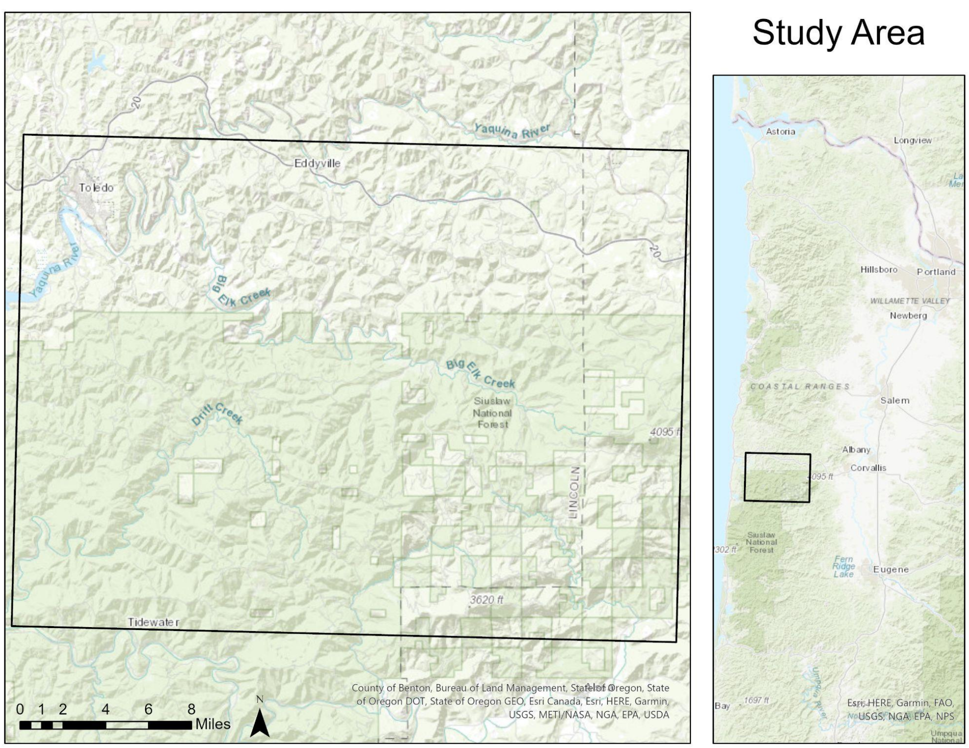


**Figure 1:** Study area chosen for this analysis.

## Data Sources

I used two data sets for this analysis. The first was the Statewide Landslide Information Layer for Oregon (SLIDO) from the Oregon Department of Geology and Mineral Industries (DOGAMI). This dataset contains a landslide inventory for the state of Oregon that consists of shapefile layers that define the deposits (figure 2), head scarps, and other scarps of identified landslides, as well as some attributes about the slides such as movement type, age, and geology.

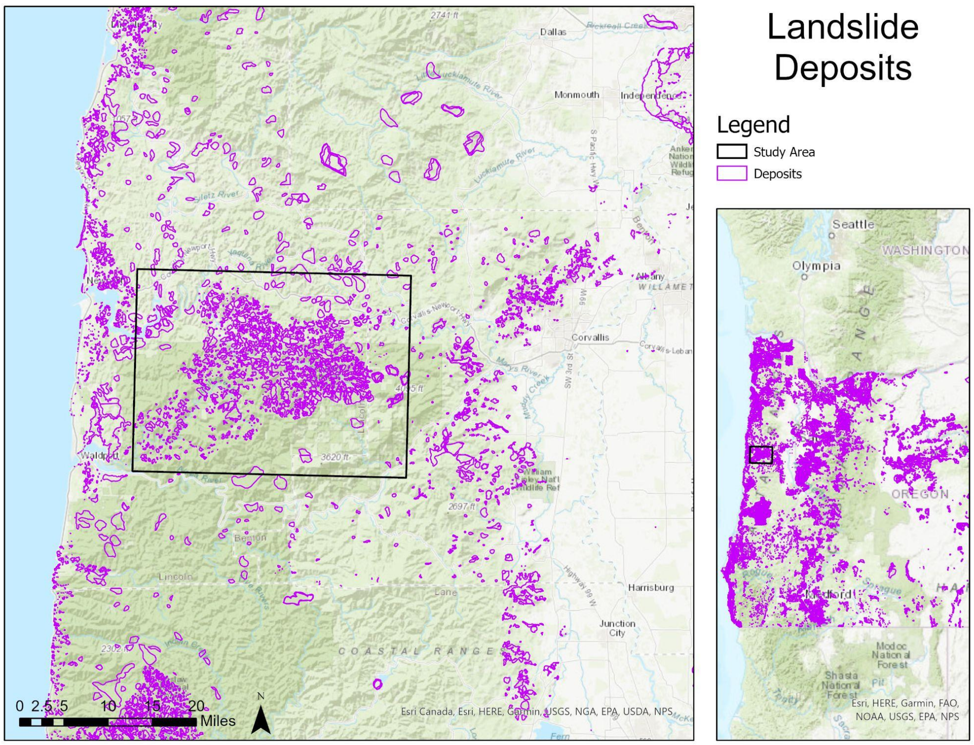


**Figure 2:** Mapped deposits as polygon shapefiles from SLIDO.

The second was bare earth digital elevation models (DEMs) from the DOGAMI Lidar Viewer. This dataset contains available and downloadable LiDAR files for the state of Oregon (figure 3).

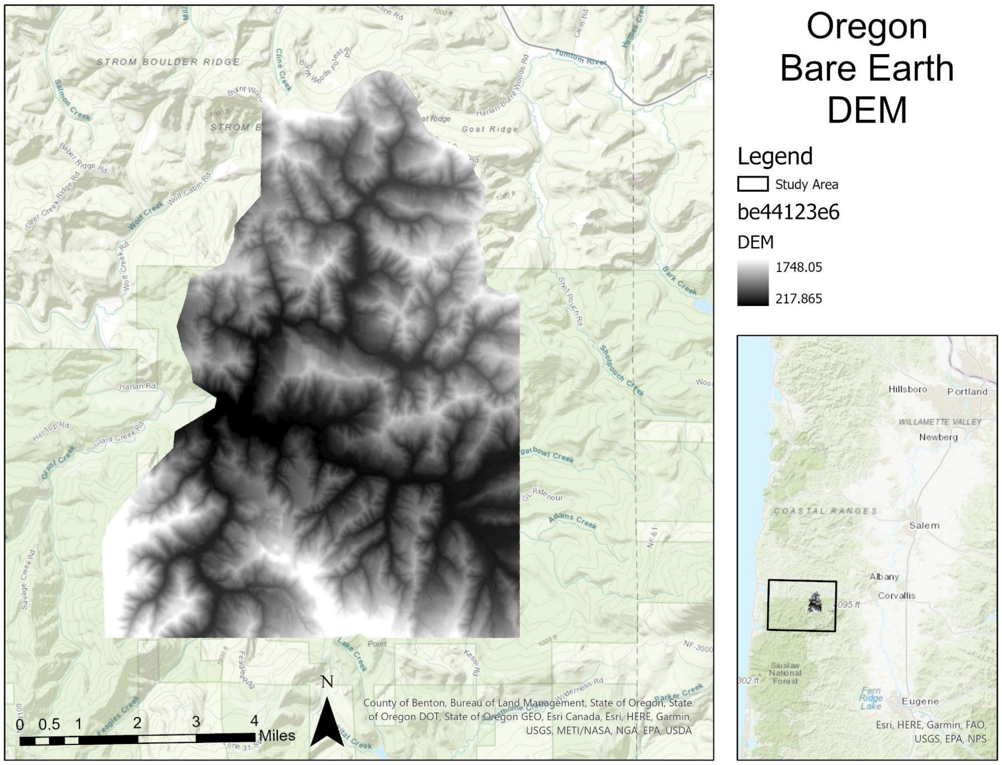


**Figure 3:** Example of a bare earth DEM downloaded from DOGAMI Lidar Viewer.

## Methodology

The methodology for this analysis was modified from Garriss (2019). I began by adding the landslide inventory deposit polygons into ArcGIS Pro, and determining a criteria for choosing deposits to analyze within my study area. I chose historic deposits with movement type slide or flow, and a confidence level moderate or high. Figure 4 is a map displaying the deposits that met this criteria and were used in the analysis. I downloaded the lidar bare earth DEMs that covered all of the slides within the study area and used those raster layers to generate slope maps (figures 5 and 6). Once I had slope calculated at each pixel I was able to run the Focal Statistics tool to calculate the SDS at each pixel using a 3 x 3 cell sampling window (figure 7). The last ArcGIS step was to determine the average roughness value within each deposit polygon and export those values as a table, which I was able to do using the Zonal Statistics as Table tool. From this data I ran an unpaired student t-test to determine if the mean values of roughness for slides and flows were statistically different.

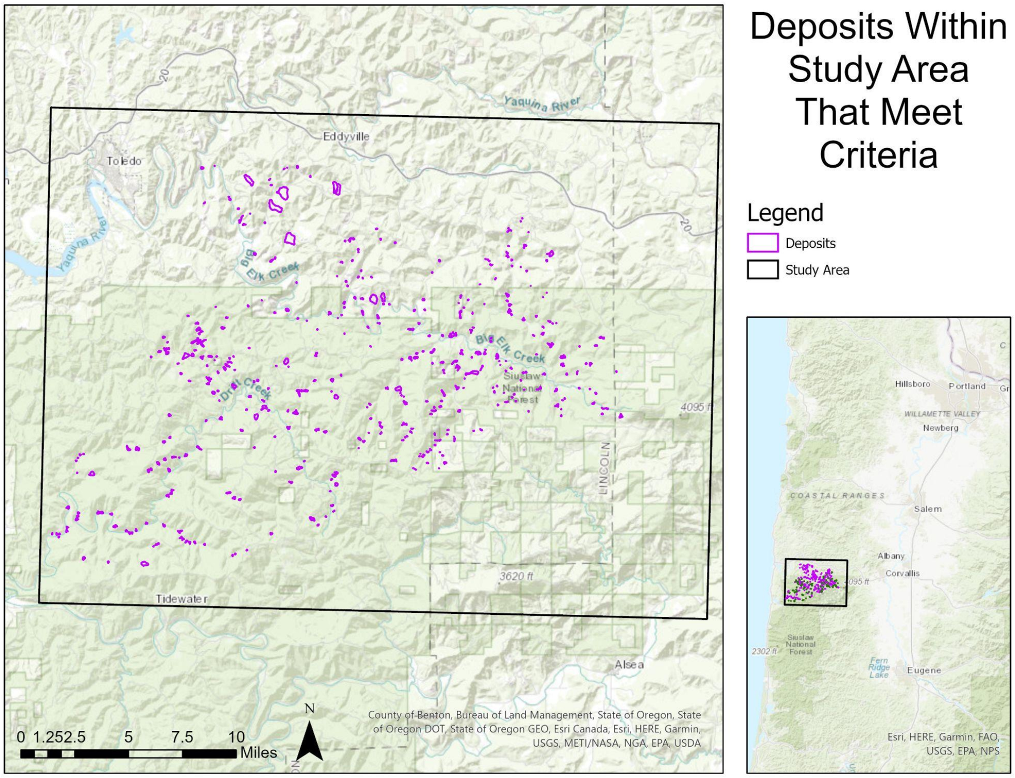


**Figure 4:** Mapped deposits within the study area that meet criteria.

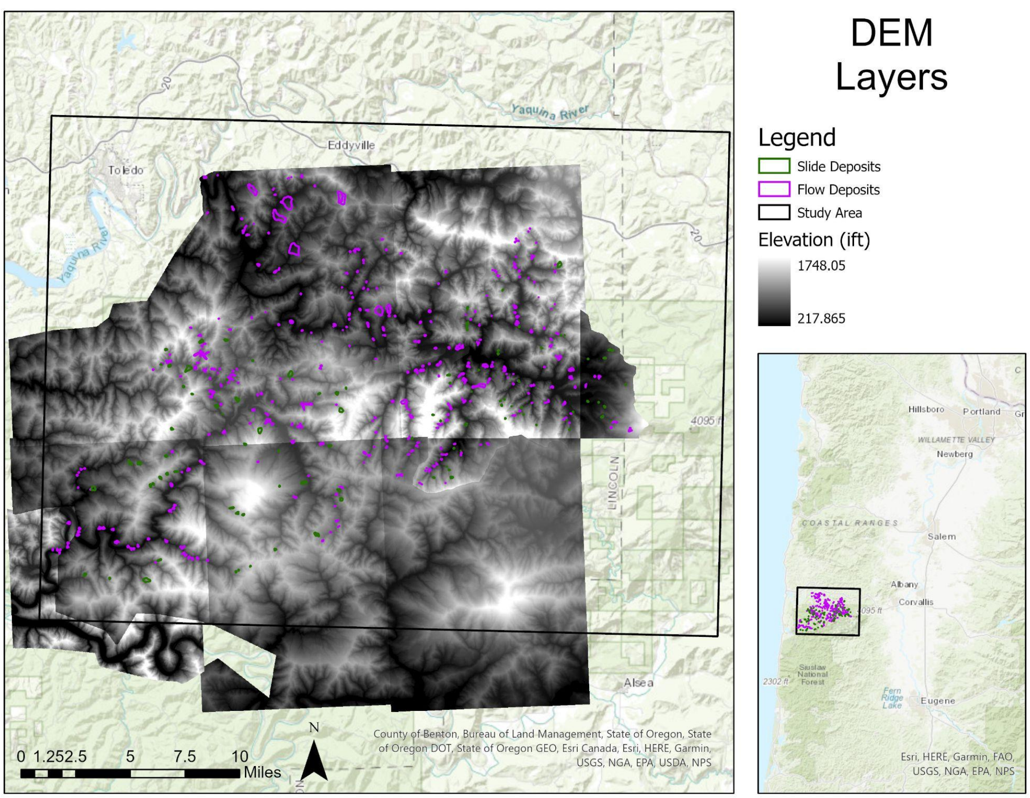


**Figure 5:** DEM layers that cover the extent of selected deposits.

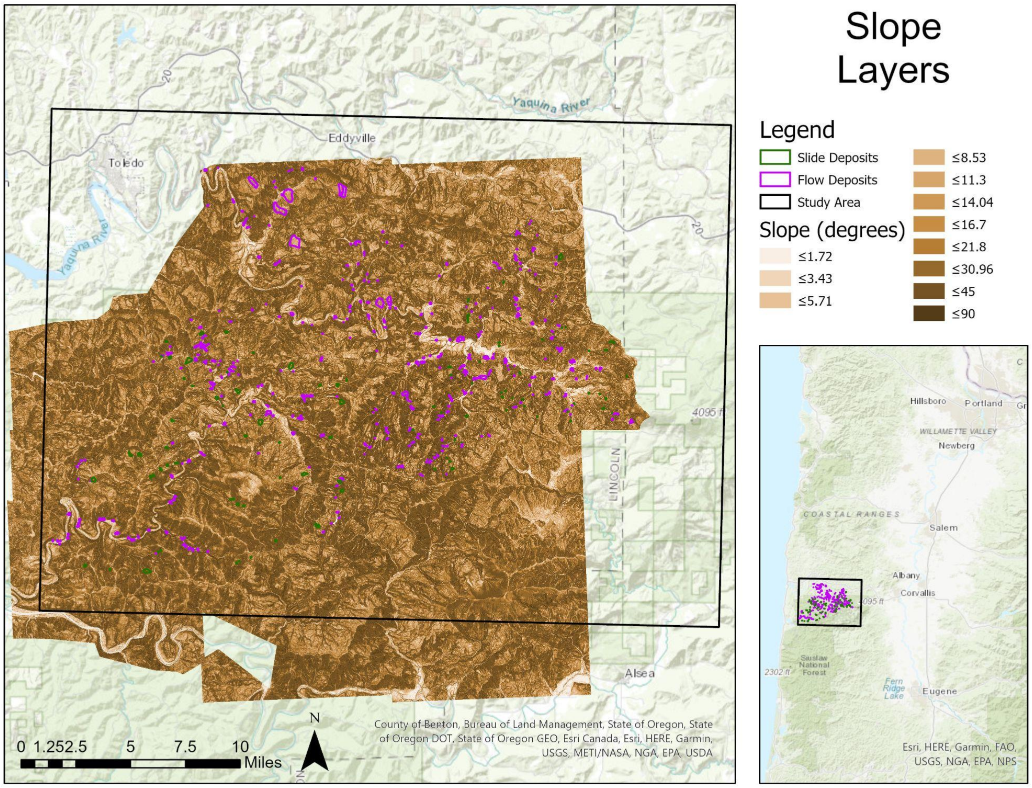


**Figure 6:** Slope maps generated from DEM layers.

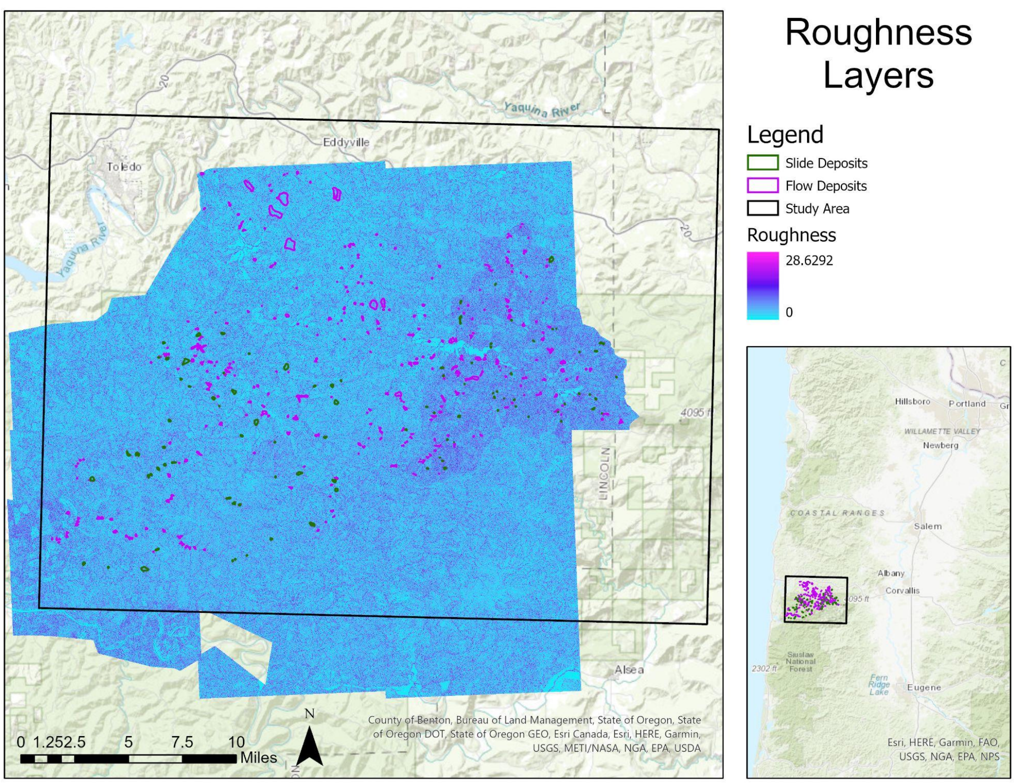


**Figure 7:** Roughness layers generated from slope layers using Focal Statistics Tool.

**Results**

I plotted the roughness values for the different slide and flow deposits and a box and whisker plot (figure 8) and ran an unpaired student t-test to determine the p-value associated with the roughness data (table 1). The inputs for the student t-test include the mean, standard deviation, and sample size of the two datasets being analyzed. The p-value represents the probability that the difference between two data sets is coincidental. The smaller the p-value, the more likely two datasets are statistically different. The threshold for determining if datasets are different is not defined, but $p = 0.1$, $p = 0.05$, and $p = 0.01$ are commonly used values. The p-value for this analysis is 0.0003, which strongly suggests that the datasets are different, even with a very conservatue p-value threshold.

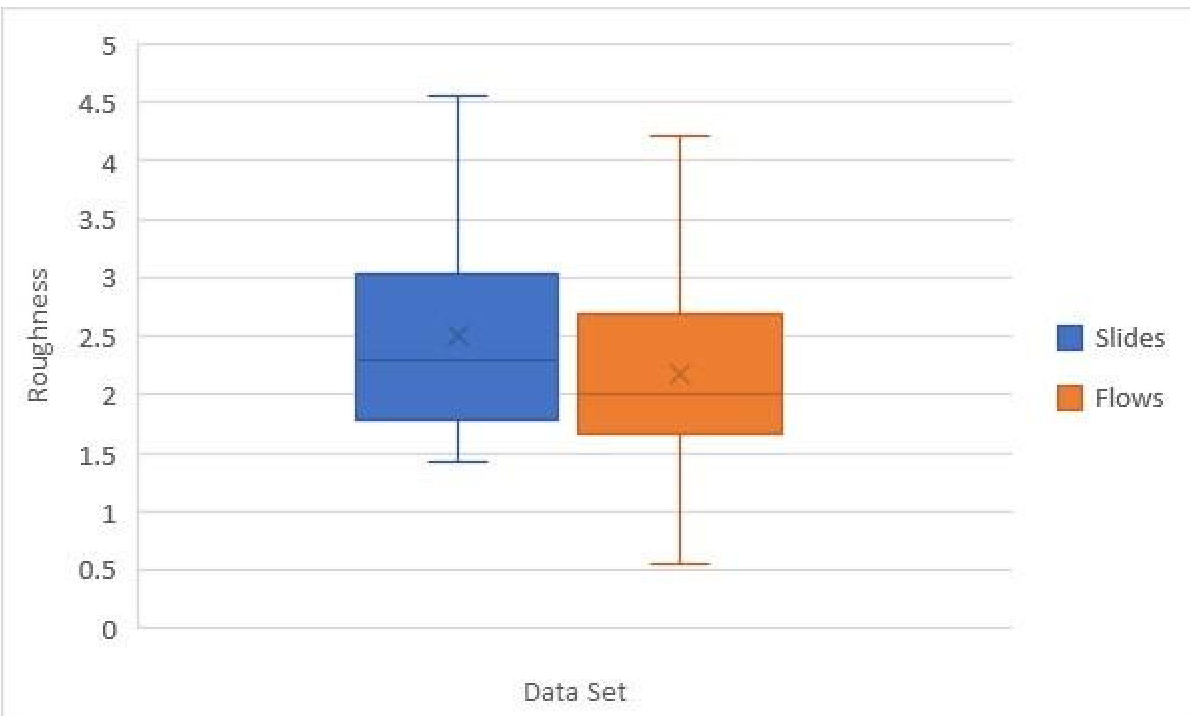


**Figure 8:** Box and whisker plots of roughness data.

**Table 1:** Values used in statistical analysis, and resulting p-value of data.

| Movement Type | Mean | Standard Deviation | Sample Size | P-Value |
|---|---|---|---|---|
| Slide | 2.498 | 0.802 | 97 | 0.0003 |
| Flow | 2.181 | 0.759 | 375 | |

## **Conclusion**

Based on my analysis, there is strong statistical evidence that landslides have higher surface roughness than debris flows, and that roughness could be used as a parameter to estimate slope failure type. There were some possible sources of error within my analysis that would need to be minimized or eliminated in order for more faith to be placed in my results. The first is an analysis of the way I defined surface roughness. Standard deviation of slope as roughness is the most common in literature, but the potential fallback of this method is that slope is a directionless measurement, but slope direction can be important when analyzing roughness. For example, the point of a cone shaped feature should have a high roughness value, but if all of the points around the cone have very similar slopes, the standard deviation and resulting slope value would be very small. A definition of roughness that takes direction into consideration might therefore be a more accurate measure of surface roughness.

Other possible sources of error come from the landslide inventory data itself. This analysis assumes that the polygons outlining the deposits were created carefully, and not quickly created to roughly outline the locations of deposits. It also assumes that the movement type assigned to each deposit is correct. In order to accurately determine the type of slide, field checks would be required, and it is unlikely that most of these deposits were studied in the field.

Finally, DEM data contains holes which can cause outliers in the roughness data. A more thorough analysis would require that the holes in the DEM be filled and any outliers be removed.

Despite the possible errors in this approach, it is an excellent starting point for continued research into the link between roughness and slope failure type, and further supports roughness as a parameter for analyzing landslide characteristics.

**References**

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Garriss, R. N. 2019. "Modeling surface roughness as an indicator of age and landslide susceptibility, and the spatial inventory of prehistoric landslides: Green River Valley, Washington." Dissertations and Theses. Paper 5175. https://pdxscholar.library.pdx.edu/cgi/viewcontent.cgi?article=6247&context=open_access_etds.

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McKean, J., and J. Roering. 2004. “Objective landslide detection and surface morphology mapping using high-resolution airborne laser altimetry.” Geomorph., 57(3-4), 331-351

Oregon Department of Geology and Mineral Industries: DOGAMI Lidar Viewer: https://gis.dogami.oregon.gov/maps/lidarviewer/

Oregon Department of Geology and Mineral Industries: SLIDO Statewide Landslide Information Layer for Oregon: https://gis.dogami.oregon.gov/maps/slido/