Precipitation and Slope Threshold Calculation of Rainfall-Triggered Landslides in Western Oregon

Mariel Jumawan, Middle Tennessee State University

BACKGROUND

Landslides are a costly and deadly natural hazard whose frequency around the globe is increased by climate change and urbanization. Landslides also affect third-world countries the most, causing thousands of deaths and billions of infrastructure damage.

Multiple factors, such as topography, geology, rainfall, land cover, and earthquakes, play an important role in triggering landslides. Because monitoring of precipitation is readily accessible at landslide-prone locations and shallow landslides and debris flows are initiated by precipitation, precipitation have been used to calculate rainfall thresholds for regional real-time landslide hazard maps.

It is important to calculate the precipitation and slope thresholds for landslides because the criteria for the occurrence of a shallow landslide are high daily rainfall and weathered material along a slope.

OBJECTIVE

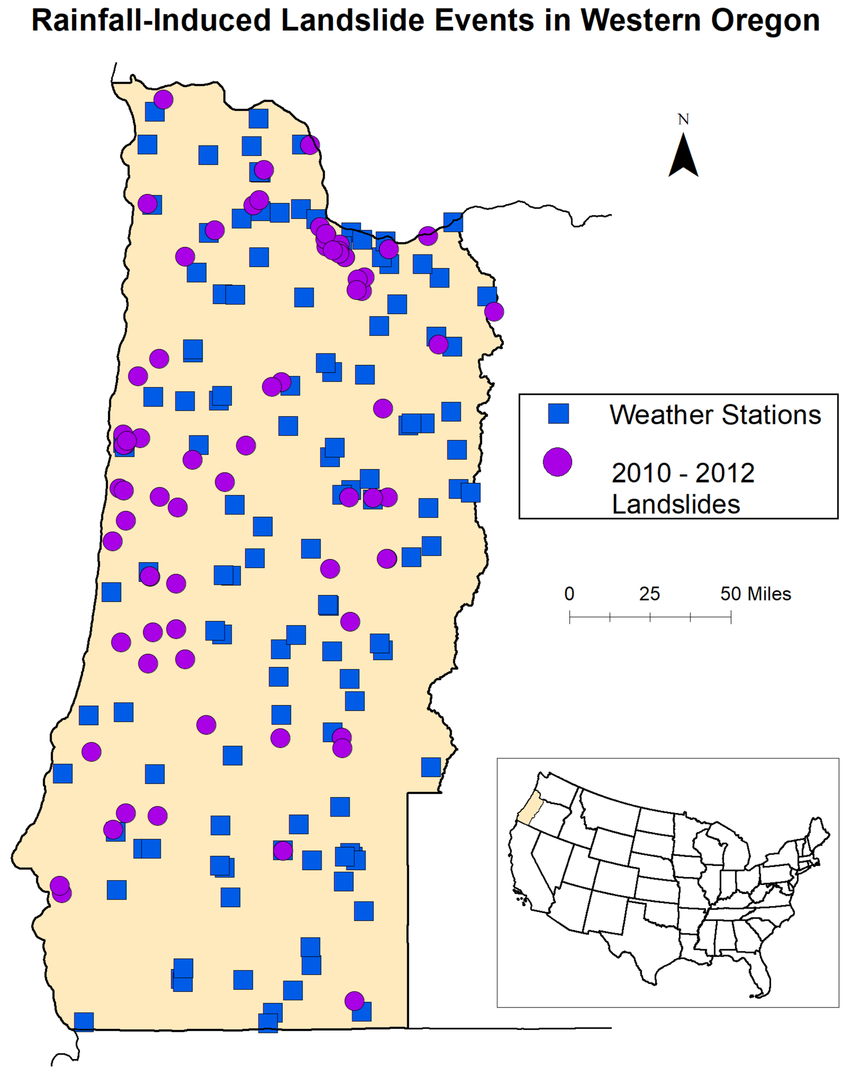
Calculate the threshold value for precipitation and slope that has led to past rainfall-triggered landslides in Oregon, United States.

STUDY AREA

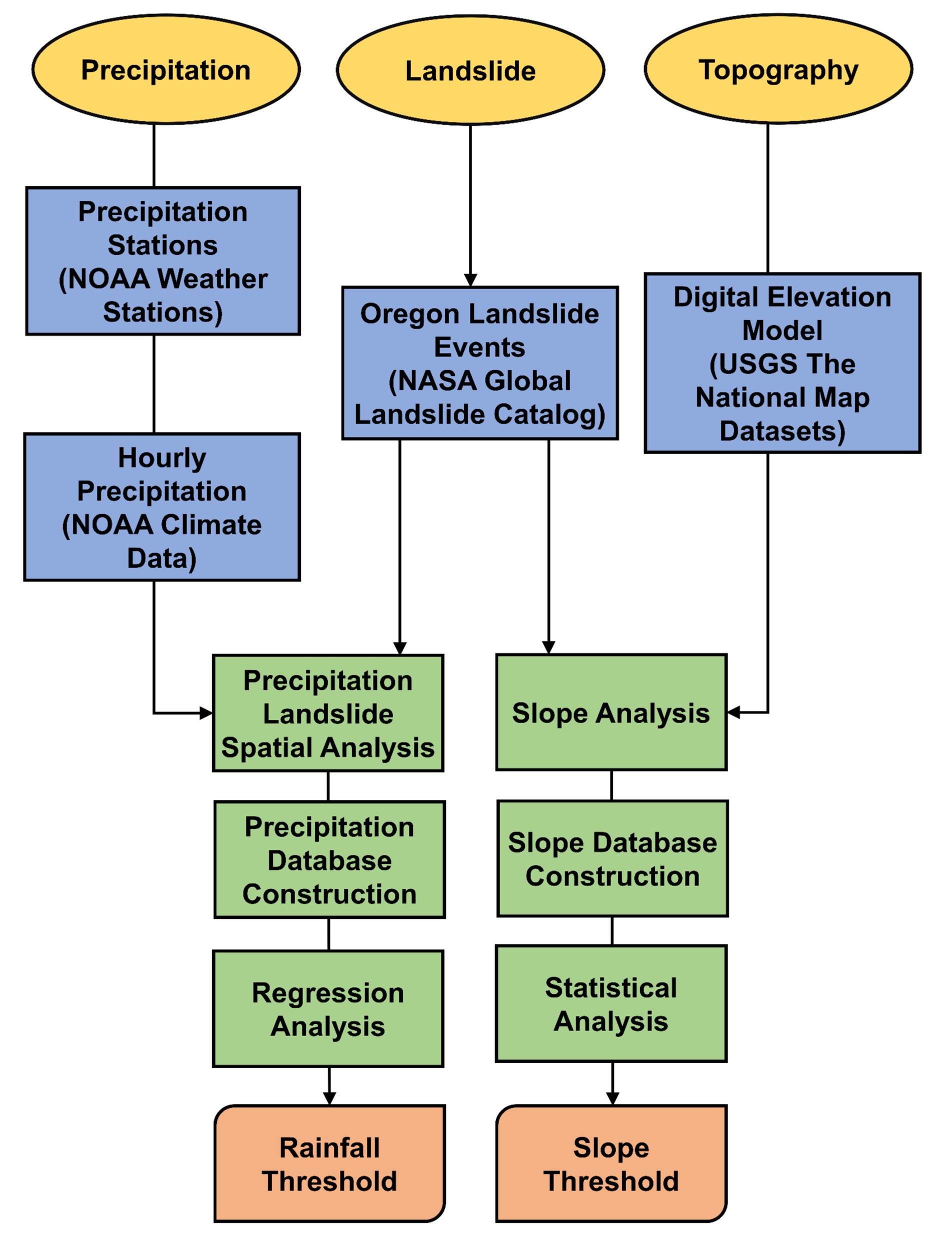
- In the United States, Oregon is among the top five states with a prevalent count of landslide occurrence. Most landslides occur in western Oregon, which are initiated by heavy rainfall instead of earthquakes.
- Oregon is in the Pacific Northwest region of the United States and has a mild climate. The cool and low-variation in temperature of the Pacific Ocean keeps the western coast cool, classifying the region with an oceanic climate.
- The 30-year normal precipitation in inches for the coast of Oregon is in the range of 70-100 inches, with precipitation of 40-60 inches further in land from the coast.

- Area of study: **Western Oregon**
- Time of study: 2010 – 2012
- Total landslides: 80

Rainfall-Induced Landslide Events in Western Oregon



METHODS



Data: Precipitation Stations. The list of precipitation stations in Oregon were retrieved from the National Oceanic and Atmospheric Administration's (NOAA) Weather Stations. Data was downloaded in both csv and shapefiles format.

Data: Hourly Precipitation. The hourly precipitation data for Oregon was retrieved from NOAA's Climate Data. Unfortunately, the most recent data for hourly precipitation stopped at the year 2013 so the earliest data available for the case study were 2010 to 2012.

Data: Digital Elevation Model. Oregon Digital Elevation Models (DEM) were retrieved from USGS The National Map Datasets. The spatial resolutions of each raster were 3-meter.

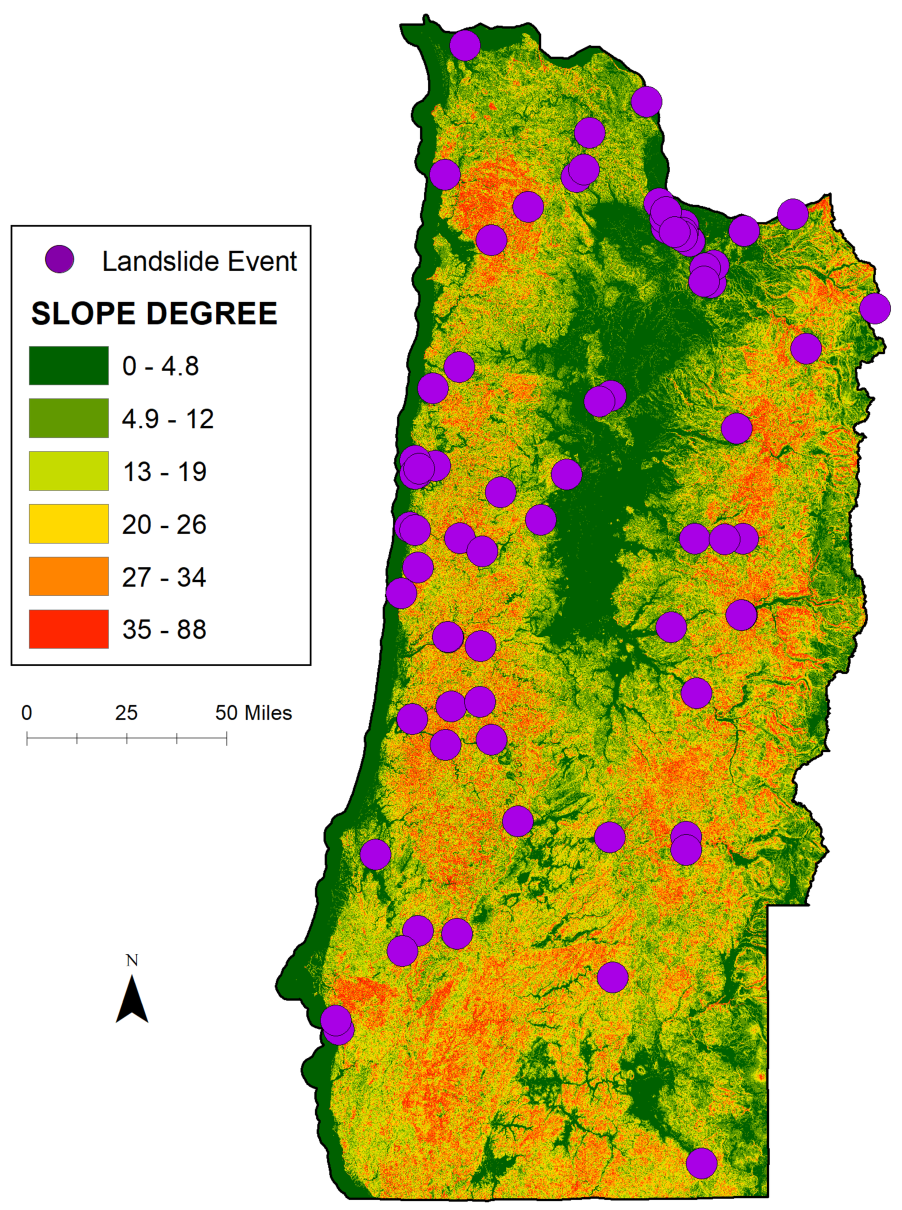
Data: Oregon Landslides. The collection of Oregon landslide events were downloaded from National Aeronautics and Space Administration's (NASA) Global Landslide Catalog. This is a global database of landslide events that were reported by NASA, scientists, and citizen scientists. Within the database, the following information were contained: event date, event time (few), event description, source name, landslide catalog, landslide trigger, x-y coordinates of landslide events, and more. Parameters were used to filter data related to our study area and timeframe.

PRECIPITATION

- ArcGIS software was applied to connect and portray the precipitation and landslide data into one table.
- In the new database, the duration, intensity, and magnitude of each landslide event were calculated. Some weather stations did not have hourly precipitation data during landslide event and thus alternative nearby stations were used for data. Landslide events with no hourly precipitation data or lack of nearby weather stations were removed.
- A table was created using logarithmic functions on both x- and y-axis (duration and intensity, respectively). Landslide events with a similar duration and intensity values were removed and portrayed as one, unique event due to the difficulty faced in calculating slope of the line for the precipitation threshold. The final number of landslide events were 52.
- Two log-log graphs were created: one to represent the full list of landslides and the other to represent landslides with a more accurate hourly precipitation data (distance between weather station and landslide event <= 11 miles). Lines were individually created for each landslide percentage occurrence (0%, 10%, 30%, 50%, 70%, 90%, and 100%), and the slope for each line was calculated to find the y = mx + b formula for each line.

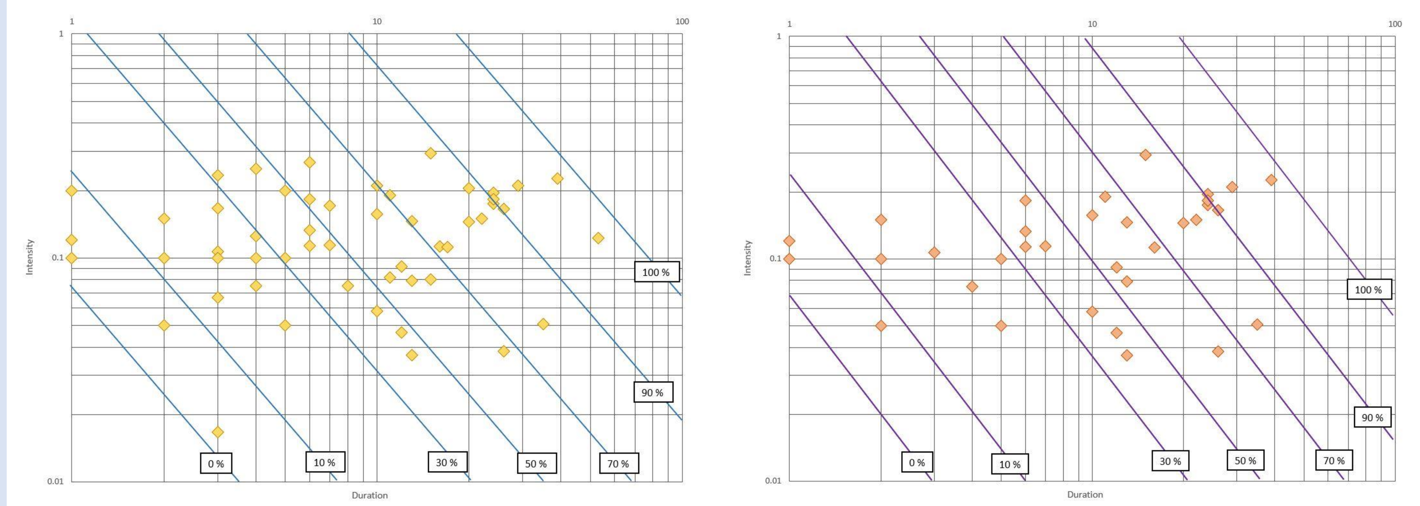
SLOPE

- ArcGIS software was utilized to merge and analyze downloaded .tif files from USGS TNM Datasets. Specifically, the following input raster files were used for our study area: 47w123-125, 46w122-125, 45w122-125, 44w122-125, and 43w123-125. With such a large area, the spatial resolution of the DEM had to be decreased from 3-meters to 30-meters.
- With slope analysis, the degrees of slopes in the DEM were classified using Jenks. Specific slope values were recovered for each landslide location.
- A database was constructed with the landslide locations and slope values. Excel was used to calculate the average, maximum, minimum, and standard deviation of the degree of slope from each landslide location.



RESULTS

PRECIPITATION



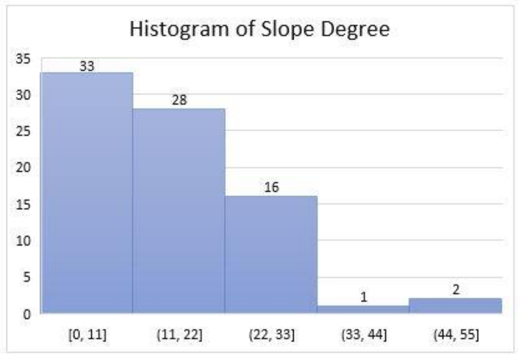
Left: Log-log graph for all landslides (total 52 landslides).
Right: Log-log graph for landslides with <= 11 miles distance from station.

Slope-Intercept Equation of Landslide Occurrence		
Percentage of Landslide Occurrence	All Landslides	Landslides with <= 11 Mile Distance from Station
0%	y = (-14.2857)x + 2.2857	y = (-12.1212)x + 2.3030
10%	y = (-14.2857)x + 3	y = (-12.1212)x + 2.9697
30%	y = (-14.2857)x + 7.2857	y = (-12.1212)x + 6.8485
50%	y = (-14.2857)x + 11.4285	y = (-12.1212)x + 9.0606
70%	y = (-14.2857)x + 14.2857	y = (-12.1212)x + 14.0606
90%	y = (-14.2857)x + 50.7143	y = (-12.1212)x + 40.9697
100%	y = (-12.1212)x + 52.4242	y = (-14.2857)x + 71.4286

- The slope for the graph portraying all landslides is greater than the more accurate precipitation landslide data. This could mean that the intensity of the precipitation event that triggered the landslides is more relevant than duration in these landslides. Alternatively, errors from using hourly precipitation from a rain gage farther than 11 miles is not an accurate representation of the precipitation event that triggered the landslide event.
- The slope-intercept equations mean that any duration and intensity value lower than the line in the graphs above represent the percentage of landslide occurrence. According to the calculations in this case study, a landslide with a precipitation duration and intensity value above below the line for 0% will have a very low, if 0%, chance in the occurrence of a landslide. A landslide with a precipitation duration and intensity value above the line for 70% landslide occurrence will have a 70% chance (or more) landslide occurrence.

SLOPE

Statistics	
Average	14.80564174
Maximum	54.7332993
Minimum	0
Standard Deviation	11.2557852



- The large value of the standard deviation (sd = 11.255) indicates that there is a large variability of spread of data points, with a cluster in the slope degree range of 0 to 22 degrees. As most landslides occurred on a hill according to NASA's Global Landslide Catalog, this is not an accurate representation of slope for the landslide events.
- The main cause of this error is the degradation of the DEM's spatial resolution. This means that the slope within a 30-m x 30-m area has been averaged with the slope values of its neighboring cells.
- The best solution to this problem is to use a DEM with a high spatial resolution and a smaller study location since maintaining a large area of study could lead to a lengthy and unstable software application.
- The method of calculating the precipitation threshold is a useful process in the design of an early warning system for an area predisposed to landslides.
- Future addendums to this case study could be the calculation of the slope stability, with application of soil integrity, soil moisture, and other hydrological data.