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MOUNT BAKER AVALANCHE SUSCEPTIBILITY

Analysis using LiDAR data and Advanced Geoprocessing

By Lindsey Hannah

1. OBJECTIVE

The goal of this analysis was to classify the avalanche risk of a typically snow covered recreation area based on topographical characteristics such as slope, aspect, and curvature. Avalanches are often fatal natural events, with 7 avalanche related deaths recorded last season (2017-2018) in Washington State alone (https://www.nwac.us/accidents/statistics/).

However, avalanche prone areas can often be predicted based on landscape characteristics. Temperature and snow events can also contribute to a higher avalanche susceptibility, and knowing these risk factors is important for anyone participating in winter recreation activities near sloped and snow covered areas. This analysis and subsequent maps are intended to be a resource for persons seeking to identify and understand these risks before heading into backcountry areas.

There are different theories on what characteristics contribute to higher avalanche susceptibility, and to conduct this analysis, several references were used to establish a risk classification. I based my avalanche risk factors on work cited in Mohammed, Naqvi, & Firdouse, (2015). This study found that for their area of focus, avalanches were most likely to occur on terrain with slopes between 25-45 degrees, aspects facing North, Northeast or East, and terrain curvatures of positive 1 or greater. Another paper, Marana, B. (2017), was also consulted to confirm the aspect risk factors.

2. DATA

The area chosen for this study was Mount Baker in Washington State. This location was chosen based on the availability of the LiDAR data, its year round snow coverage and heavy snowfall, and Mount Baker's usage for recreational activities such as mountaineering, snowmobiling, snowshoeing and backcountry skiing/snowboarding throughout the year.

Due to its considerable snow coverage and popularity for outdoor activities, mapping avalanche risk is imperative on Mount Baker to highlight areas to avoid as well as safer routes and areas for recreation, particularly when temperature and snow conditions are prime for avalanches.

The data source for this analysis was LiDAR data obtained from the Washington State Department of Natural Resources data portal (http://lidarportal.dnr.wa.gov/). The data contained 9 separate LAS files with a total of 262,156,294 data points.

3. RESULTS

Using the LiDAR data, the 9 LAS files were combined in a LAS database. A DEM was created from the bare earth LiDAR returns in ArcScene. Its worth noting that the first returns and average returns were almost identical. This is because the study area is mostly snow and ice covered, or bare rock.

The DEM was exported to ArcMap and a custom raster analysis formula was created using algebraic expressions based on topographic characteristics to arrive at an Avalanche Risk Index. I used the process as outlined in this tutorial (http://desktop.arcgis.com/en/arcmap/10.3/manage-data/raster-and-images/wkflw-performing-raster-analysis-using-algebraic-expressions.htm#ESRI_SECTION1_F7B75AC02F144B1987440F91779C3C8F) but I edited the parameters to align with the findings of the study by Mohammed, Naqvi, & Firdouse, 2015.

Using the Image Analysis window in ArcMap, I created a custom formula based on the slope, aspect, and curvature of the DEM created from the LiDAR points. The highest topographic risk factor for avalanches are where slopes are between 25 and 45 degrees, the aspect is N, NE or E, and the curvature is >1. The authors of the reference study I referred to included terrain type in their analysis, such as forested, rocky, or bare ground, but for my study area, most surfaces were snow or ice covered year round so this condition was left out.

Using the custom raster math formula, pixels were classified using a binary method and assigned either a 1 or a 0 for each topographical characteristic as noted in table 1 below. In this case, a 1 represents a high risk and a 0 represents a lower risk. For instance, pixels with a slope of 30 would be assigned a 1 due to the higher likeliness of avalanches on slopes of this angle, where a slope with a value of 15 would be assigned a 0.

Table 1

	Assigned a 1	Assigned a 0
Slope	Between 25 and 45 degrees	All other slope angles
Aspect	N, NE and E (0-112.5)	All other aspects
Curvature	>1	All other curvatures

The Avalanche Risk Value was calculated by summing the binary assignment of the slope, aspect and curvature of each DEM pixel. The formula used was as follows:

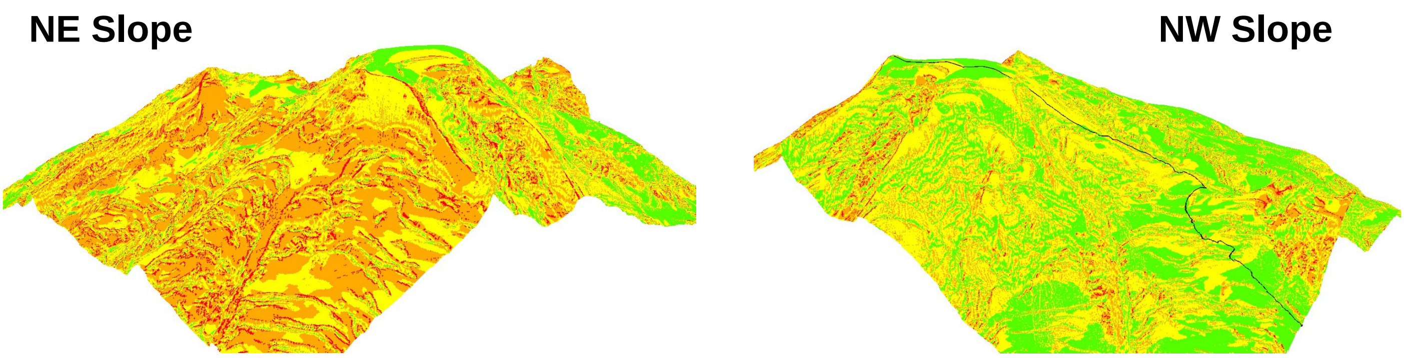
Avalanche Risk Value= Slope + Aspect + Curvature

The resultant Avalanche Risk Value was between 0 and 3. Avalanche risk was classified from Low to Very High, with 0 representing a "low risk", and 3 representing a "very high risk".

Color	Avalanche Risk Index Value	Avalanche Risk
	0	Low
	1	Moderate
	2	High
	3	Very High

Areas of high to very high risk should be avoided, particularly when snow and temperature conditions are conducive to avalanche events.

I found that the NE slope of Mount Baker is the most dangerous and prone to avalanches while the SW and Southern slope poses a much lower risk. North and Northeast aspects receive less sunlight, which yields a more powdery snow which can be prone to avalanches. Peaks and ridgelines, with high slopes, showed a higher risks than valleys and flatter areas, which was expected. Overall, the resultant Avalanche Risk map aligned with my expectations and predictions.



Mount Baker Avalanche Risk, Viewed from the NE slope and NW slope
The typical summit mountaineering trail is also shown, in black.

4. CONCLUSIONS AND FUTURE WORK

While the typical Mt. Baker summit trail traverses through areas of lower susceptibility to avalanches, backcountry users should always be aware of the present danger of avalanches, even in areas of "low risk".

Future studies are recommended to examine past avalanche events to determine the strength of correlation between the model and parameters used to create the Avalanche Risk Index in this study and actual avalanche events.   Other factors, such as underlying rock lithology, soil type, or vegetation can also be brought into the raster algebra model to enhance and hone the Avalache Risk Index formula.

5. REFERENCES

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