

Avalanche Start Zone Suitability Mapping

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-
- [Abstract](#)
 - [Introduction](#)
 - [Study Area and Data Sources](#)
 - [Data Manipulation and Results](#)
 - [Discussion](#)
 - [References](#)
-

Abstract

Pine Pass, British Columbia, is a well-traveled corridor along the Hart Highway, north of Prince George and south of Mackenzie. A lack of accessible terrain and avalanche information online in the Pine Pass area prompted the work for this project. An avalanche start zone suitability map could be a useful tool for evaluating risk to area users and could be a stepping stone to a more advanced analysis investigating snow volumes and accumulation, run-out distances and levels of risk along the main travel corridor and around popular backcountry use areas. A DEM was used to create two analysis factor rasters for input into a multi-criterion evaluation tool in ArcMap, resulting in an avalanche start zone suitability map.

Introduction

There is a certain level of risk to traveling through mountainous terrain in the winter. While using public corridors such as highways or the railway, we put our faith in transportation management authorities to ensure safe road and travel conditions where possible. However, travel by ski or snowmobile on unmarked routes in the backcountry requires knowledge and experience, particularly in terms of the terrain and the risk of avalanches occurring. Since these unmarked areas are largely unregulated and unmanaged, users must take precaution and learn how to read the terrain and determine the level of avalanche hazard themselves.

Navigation aids including topographic maps, a compass and GPS, as well as avalanche safety gear (shovel, probe and transceiver) are often staples to a winter backpack. The Canadian Avalanche Centre (CAC) avalanche bulletins, as well as on-site snow pack assessments, help to determine regional and localized snow pack stability and trends, respectively. While the in situ decision-making process that occurs while traveling in avalanche terrain is critical, having prior knowledge about likely areas of avalanche release can benefit users and their decision-making process. An avalanche hazard map, developed with a GIS model, can serve as a tool for this purpose.

Currently, there is no existing avalanche hazard map available for the Pine Pass area. Parks Canada has established Avalanche Terrain Maps for popular areas in each of their mountain parks (http://www.pc.gc.ca/pn-np/ab/jasper/visit/visit7a9_e.asp). These are web-based maps, and provide a 3D image of the area, along with avalanche zone polygons draped over top. While a product similar to that created by Parks Canada is beyond the scope of this project, a map highlighting the key avalanche start zones is well within it.

Mapping avalanche terrain is not a new science. Experts in the Swiss Alps began hand-mapping avalanche paths in the late 1800's (Frutiger 1980). DEM use to extract terrain data, as well as integrating snow pack data from field observations, seems to be common as seen in Gruber (2001), McLaren (2000), and Scott (Unkn.Year). Satellite imagery (McLaren 2000) has also been used for ground cover training areas, confirming avalanche path extent and for overlay on a map product. McLaren (2000) completed a suitability analysis using GIS for avalanches in the Coast Mountains near Vancouver. Originally described in Jamieson and Geldseltzer (1996), McLaren (2000) used 4 key factors in the multi-criterion analysis (MCE): slope, aspect, terrain shape (concavity) and groundcover. The factor and category (class) weighting was based on Canadian Avalanche Association data collected from reported avalanche incidents between the 1984 and 1996. Only slope and groundcover were used in this analysis, however. The aspect

and terrain shape factors were eliminated for three reasons: 1) the relatively comparable weights assigned to the aspect and terrain classes assumed their application would make little difference in the MCE, 2) the software (IDRISI) used to create the terrain shape layer in the original project was not available for this project, and 3) finding alternative methods to create the terrain shape layer was beyond the scope of this project.

The project objectives include manipulating DEM data to create input rasters for a multi-criterion evaluation. The weighted overlay tool in ArcToolbox is used for the multi-criterion evaluation and will produce a raster illustrating avalanche start zone suitability.

Study Area and Data Source

The study area includes the Pine Pass area, covered on DEM mapsheet 93O (clipped to UTM range: E 499900 to 532000 and N 6162500 to 6138700). The 25-m resolution image (NAD 83, zone 10) was obtained from the GIS DEM folder on UNBC Ninkasi server.

A Landsat 5 Thematic Mapper satellite image was downloaded from the University of Maryland's Global Land Cover Facility to determine treeline for the ground cover raster. The image (path 49, row 21) datum is in WGS 84, was captured on August 8, 1992.

Data Manipulation and Results

Ground Cover

Using the DEM, a ground cover raster (fig. 1) was created using the reclassification tool in Spatial Analyst. For simplicity, ground cover was divided into two classes: non-forested (alpine) and forested (below treeline). Treeline was estimated by visually analyzing a satellite image draped over the DEM, and using the Identify tool to determine pixel (elevation) value at points that appeared to represent 'treeline'. The two new classes were separated by the threshold elevation of 1550m; pixels with values less than 1550 and greater than 1550 were assigned a weight value (table 1). The weight value represents the proportion of avalanche accidents by ground cover from 1984 to 1996 in Canada (Jamieson and Geldseltzer 1996). A standardized scale between 1 and 100 was used instead of 0 to 1 as utilized in McLaren (2000), as only integer values were allowed in the reclassification fields.

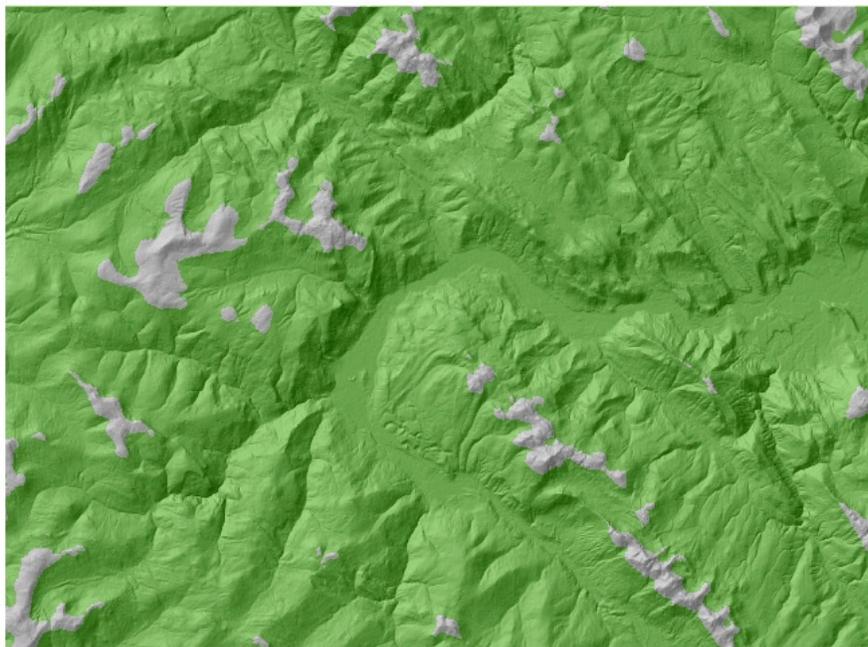


Figure 1. Groundcover raster output, draped over hillshade DEM; opacity 50% (grey = non-forested/alpine; green = forested).

Table 1. Weighting applied to ground cover class raster.

Ground cover class	Weight
Non-forested (> 1550 m)	89
Forested (< 1550 m)	11

Slope

The slope raster (fig. 2) was created in the same way as the groundcover raster, using the DEM and reclassification tool. The three classes represent slope categories upon which avalanche frequencies are generally known to occur. Jamieson and Geldseltzer (1996) reported that most avalanche accidents occurred on slopes between 25° and 40°, while few occur on slopes < 25° or > 40°. The weight values (table 2) represent the proportion of accidents that occurred within the slope class during the period of 1984 and 1996 in Canada .

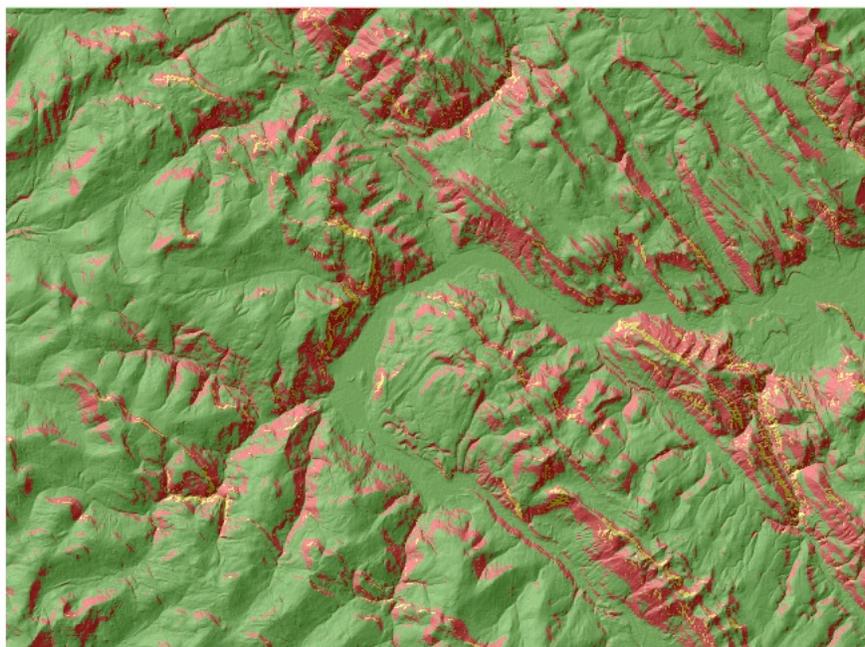


Figure 2. Slope gradient raster output, draped over hillshade DEM; opacity 50%. (Green = <25°, Yellow = 25-40°, Red = > 40°)

Table 2. Weighting applied to slope classes.

Slope class	Weight
< 25°	9
25° – 40°	83
> 40°	8

Multi-criterion Evaluation

The new raster layers, each with weighted criteria, were loaded into the Weighted Overlay wizard in Spatial Analyst to perform a multi-criterion evaluation. Four output suitability classes resulted (table 3). Since the two intermediate classes had similar values (47 and 49), they were merged into one class. The final suitability map, as a result, represents three classes: least suitable, moderately suitable and most suitable as avalanche start zones (fig. 3).

Table 3. Weighted overlay results. Classes 2 and 3 were merged into one class.

Start Zone Suitability Class	Pixel Value
1	10
2	47

3	49
4	86

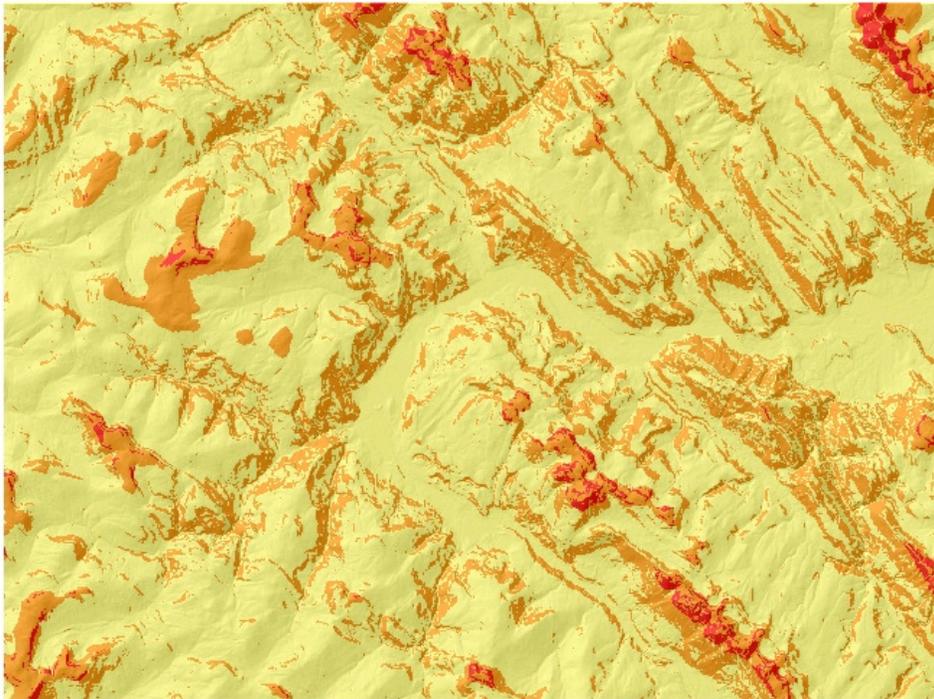


Figure 3. Weighted overlay result, draped over hillshade DEM; opacity 50%. Three suitability classes: Yellow = Least suitable, Orange = Moderately suitable, Red = Most suitable.

Discussion

Use of the weighted overlay tool was successful in merging the two weighted factors to create the suitability raster. The output was simple, likely due in part to using only two factors (ground cover and slope gradient) with only two and three classes each, respectively.

To create a meaningful application, the suitability raster should be used in conjunction with human user data. Backcountry trails, highways, logging roads and railway data could be overlaid to enable user risk analysis. Using additional avalanche data (i.e. run-out distance) intersected with human use and infrastructure data, a model estimating risk to user areas could be established. Further, particularly in the case of recreational backcountry use (i.e. skiers and snowmobilers) poster maps could be established at trailhead kiosks, highlighting popular travel routes and the levels of risk that may exist in those areas.

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[TOP](#)