Landslide Hazard Mapping Along the Drainage Basin of the Klanawa River, British Columbia

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Introduction

Landslides are natural hazards that occur all over the world. They are prone to occur on a slope and require a certain trigger, either meteorological or mechanical, prior to failure. Such triggers can be caused by precipitation accumulation which causes the infiltration of water into the surficial soils of a slope and further weaken it, or it can be mechanically induced by human activity or tectonic activity (USGS, 2009).

The modeling of landslide susceptibility is rather important in land management practices. It is possible to predict the susceptibility of landslides in certain areas if particular features of the area are known. These features can include (but are not limited) to: bedrock geology, terrain type, slope, precipitation input, elevation, soil drainage, vertical curvature, slope aspect and landuse cover (Rollerson et al., 2001).

Typically, landslides are very common along drainage basins. In large part, this is because rivers down cut valleys and result in steep side slopes which then exhibit unstable terrain. The main purpose of this study is to assess the landslide vulnerability using GIS techniques of the Klanawa Watershed, located on the southwestern coast of Vancouver Island, British Columbia in the ESRI ArcMap 10.1 program. The methods that are used in this study involve priority-based modeling using parameters such as proximity to roads, proximity to water, slope, and aspect.

Study Area

The Klanawa River watershed is located on the southwestern coast of Vancouver Island, British Columbia (Goetz et al., 2011) at approximately 48°46’43.44’’ N and 124°56’21.04’’ W (Google Earth, 2013). The particular study area, previously done by Goetz et al. (2011), encompasses a total area of 610 km² with 960 m of relief (figure 1) and is just northwest of the main Klanawa River. The geology of this area is primarily composed of grano-diortic rocks and calc-alkaline volcanic rocks; thus, with a combination of high precipitation events of over 3000 mm and the occurrences of logging activity makes this area very prone to landslide activity. The study done by Rollerson et al. (2001) finds most of the landslide occurrences in this area are of debris flows.

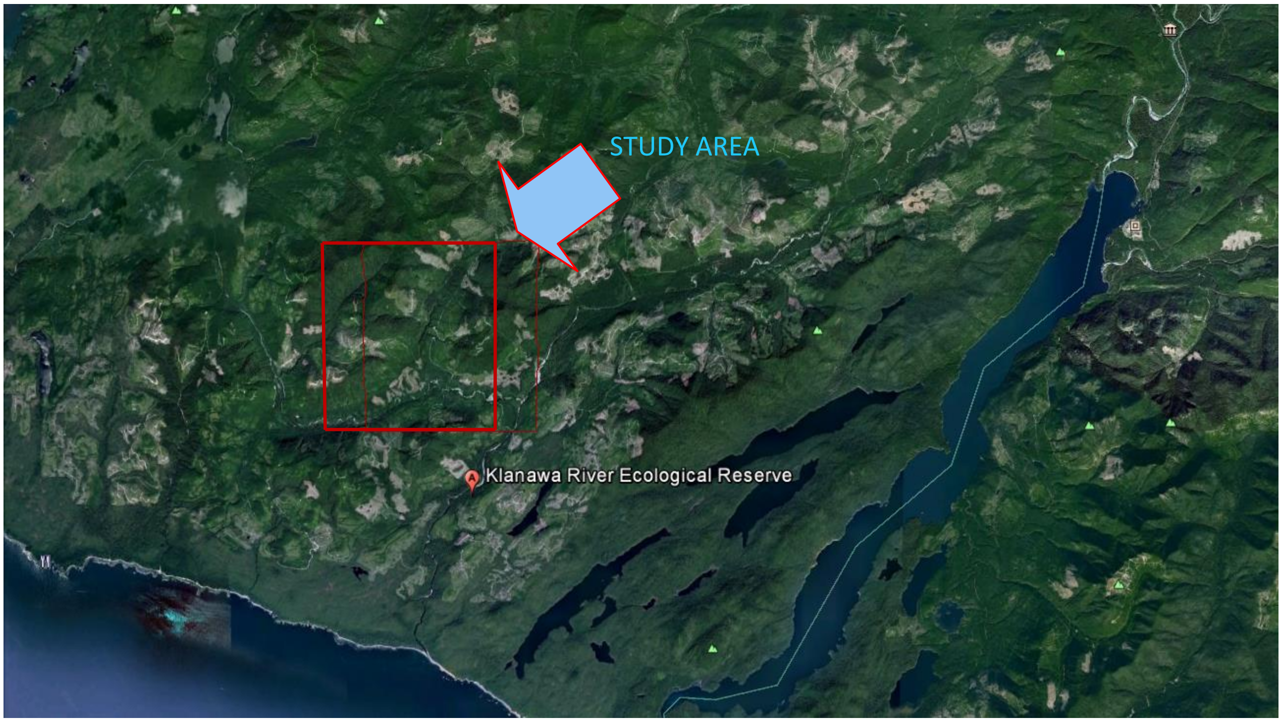

Figure 1 Study site on part of the Klanawa River Watershed

Data Sources and Data Preparation

- BC TRIM data downloaded from UNBC GIS data→http://www.gis.unbc.ca/courses/geog413/projects/index.php for maps 92C 075, 92C 075, 92C 085, 92C 086)
- DEM layer created from BC TRIM data using elevation spot height and contour layers→ further used to create a hillshade layer
- It must be noted that originally I wanted to incorporate the BC Vegetation (VRI) data to include logged areas in the landslide hazard susceptibility analysis; however, the data layer did not provide significant information as it only accounted for vegetation cover on a macroscale rather than a microscale. Thus, it would have been better to obtain cut block information for the BC Government website (via e-mail request)

The BC TRIM data was first converted from SAIF format to Shapefiles , using the FME Universal Translator, which were further able to be used in ArcMap 10.1. The four mapsheets were merged automatically by FME once they were translated. All data were double checked to ensure that each TRIM layer was in NAD 1983 UTM zone 10 format. Once the formatting was suitable, the study area was clipped with the creation of a polygon. This polygon was further used as a "cookie cutter" to clip the necessary layers to the study boundary. As a result, only rivers, lakes, roads, contours and spot heights were clipped for further analysis of this area.

Methodology and Analysis

As mentioned previously, each parameter included in the landslide hazard assessment was done individually in ArcMap. The parameters were researched from other literature which had also included GIS methodologies or just general reference to contributing factors. Each parameter was then classified given a priority value in between 1-10 (depending on the parameter and how many categories were included), 1 being the highest vulnerability value, and 10 being the lowest.

Summary of Steps:

- Proximity to roads and Proximity to rivers→ Spatial Analyst>Distance>Euclidean
- Slope→Spatial Analyst>Surface>Slope
- Aspect→Spatial Analyst>Surface>Aspect
- After each analysis was run, a reclassification of the classes were done using Spatial Analyst>Reclassification>Reclassify
- The hillshade layer created previously is overlaid by the output reclassification

1. Proximity to roads (figure 2): The construction of roads and activity along roadsides indicates some accessibility to the study area, in which case, roads are deemed to be a source of erosion (Goetz et al., 2011). A proximity to roads analysis is conducted by the Euclidean tool in the Spatial Analyst section of ArcMap. A maximum of a 100 m distance was inputted as it is assumed that this is the extent of distance a road will be within to have a significant influence on the probability of a landslide. The priority values were divided into 5 equal classes (table 1).

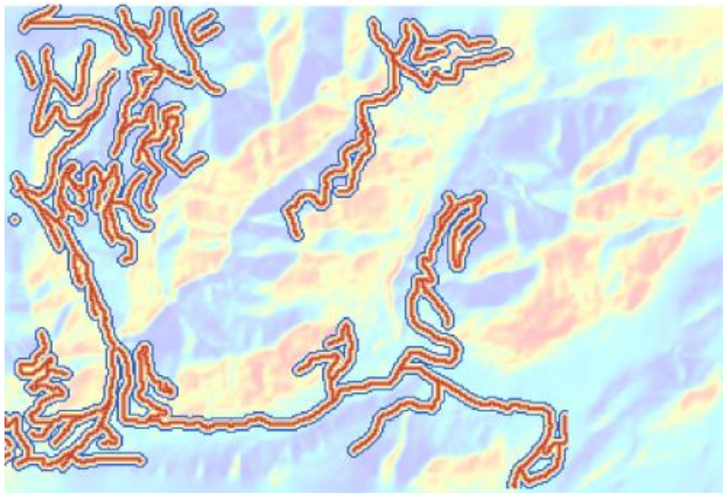

Figure 2   Image of “Distance to Roads” output

Table 1 Priority Values assigned to range of areas within distance of roads: 1=high priority, 5=low priority

Distance	Priority Value
0 m- 20 m	1
21 m- 40 m	2
41 m- 60 m	3
61 m- 80 m	4
81m - 100 m	5

2. <u>Proximity to water</u> **(figure 3):** A study by Barredo et al. (2000) states that instability hazard from high pore-water pressures in the very fragmented landslide deposits can further contribute to landslide initiation. The Euclidean tool was also used for this analysis and maximum distance of 200 m was inputted as distances greater than this did not significantly impact the assessment. The priority values were divided into 8 equal classes using the natural breaks **(table 2).**

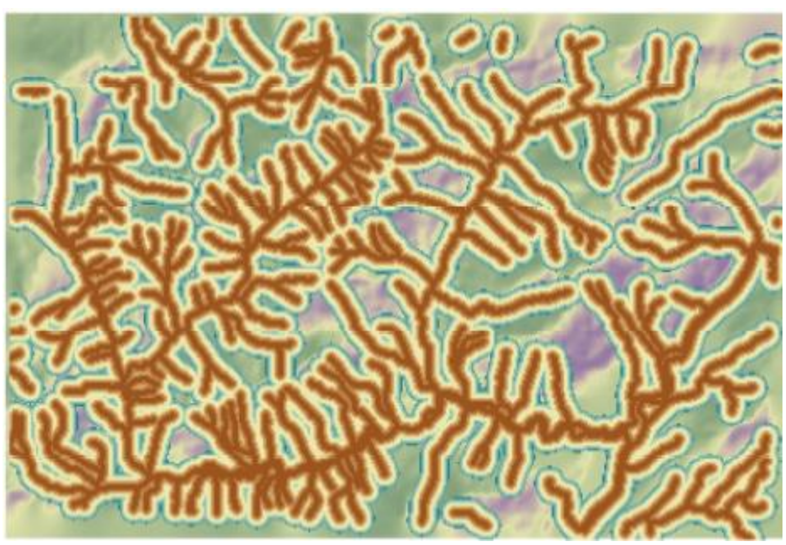

Figure 3   Image of “Distance to Rivers” output

Table 2   Priority values assigned to range of areas within distance of rivers: 1=high priority, 8=low priority

Distance	Priority Value
0 m - 25 m	1
26 m - 50 m	2
51 m - 75 m	3
76 m – 100 m	4
101 m - 125 m	5
126 m - 150 m	6
151 m - 175 m	7
176 m - 200 m	8

3. Slope (figure 4): Most studies show that landslides are prone to occur at high slope angles due to the pull of gravity and amount of material on top of each other (Rollerson et al., 2001). The slope tool was used for this analysis. The slopes were reclassified into 8 classes (table 3) whereby any slope > 46° was given high priority.

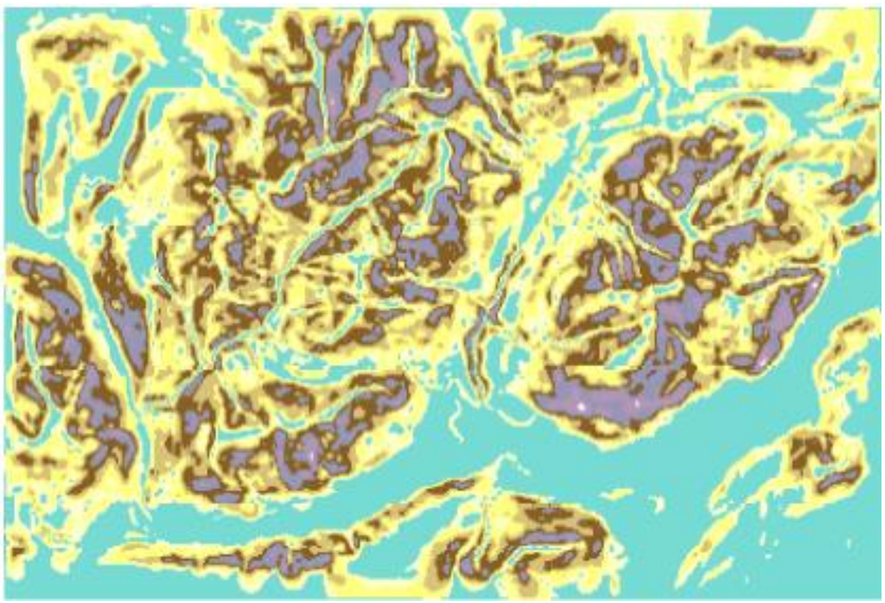

Figure 4   Image of "Slope" output

Table 3   Priority values assigned to slope angle ranges: 1= high priority, 8= low priority

Slope	Priority Value
> 46°	1
41° - 45°	2
36° - 40°	3
31° - 35°	4
26° - 30°	5
20° - 25°	6
15° - 19°	7
0° - 14°	8

4. Aspect (figure 5): Although aspect is used when computing a landslide's vulnerability in literature that I had searched, it did not really mention why aspect plays a significant role in slope instability. In this case, my hypothesis is that southern-facing slopes have more freeze-thaw cycles whereby there is an increase in water input. Thus, this contributes to saturated soil conditions which increases slope instability. The aspect tool was used for this analysis. There were 9 classes that were generated using this tool whereby I ran a reclassification, BUT, only changing the priority values (table 4). This is because the aspect tool had generated labels (i.e. South, North, East, and West, etc,) with specific output values. I had chosen to keep the values as I figured it must be based off a complex algorithm.

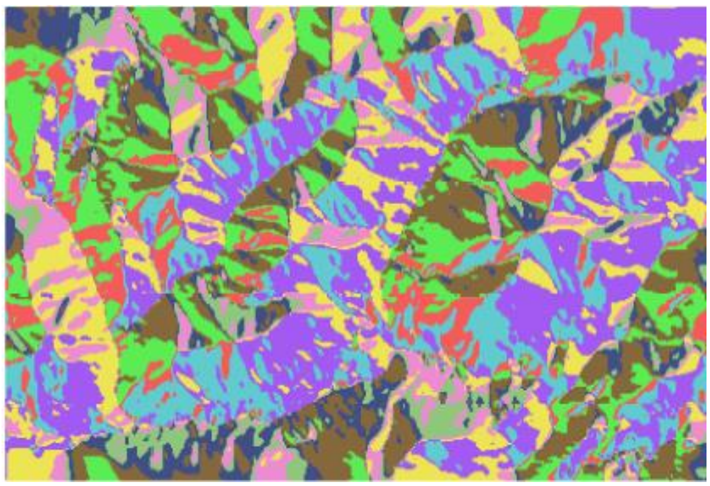

Figure 5 Image of "Aspect" output

Table 4 Priority values assigned to aspect: 1=high priority, 9= low priority

Aspect/Value	Priority Value
South (157.5-202.5)	1
Southeast (112.5-157.5)	2
Southwest (202.5-247.5)	3
East (67.5-112.5)	4
West (242.5-292.5)	5
Northwest (292.5-337.5)	6
North (337.5-310)	7
Northeast (22.5-67.5)	8
North (0-22.5)	9

Final output steps:

- Landslide Vulnerability Output→ Spatial Analyst>Map Algebra>Raster Calculator
- Equation inputted into raster calculator→0.25 * [Reclass_Roads] + 0.25 * [Reclass_Rivers] + 0.25 * [Reclass_Slope]+ 0.25 * [Reclass_Aspect]

Finally, each individual parameter was given a weight and inputted into the raster calculator and combined. Since all the types of literature that had been looked at had a more complex analysis done and also included many more parameters, it was difficult to weight each of the parameters that were used in this study as there was no direct reference point. In this case, each parameter was weighted equally.

After generating the output value which indicated the vulnerability of landslides along the Klanawa River Watershed, it was overlaid on top of the previously generated hillshade. The landslide vulnerability was displayed in 5 classes : very low, low, moderate, high, and very high. Other important features such as roads, rivers, and lakes were also overlaid on the final input map (figure 6).

Figure 6 shows that there is a very high vulnerability of landslide activity on high slopes and are illustrated in very small specks of red. Furthermore, much of the map shows that there is a very low-moderate landslide vulnerability along the northwestern Klanawa drainage basin.

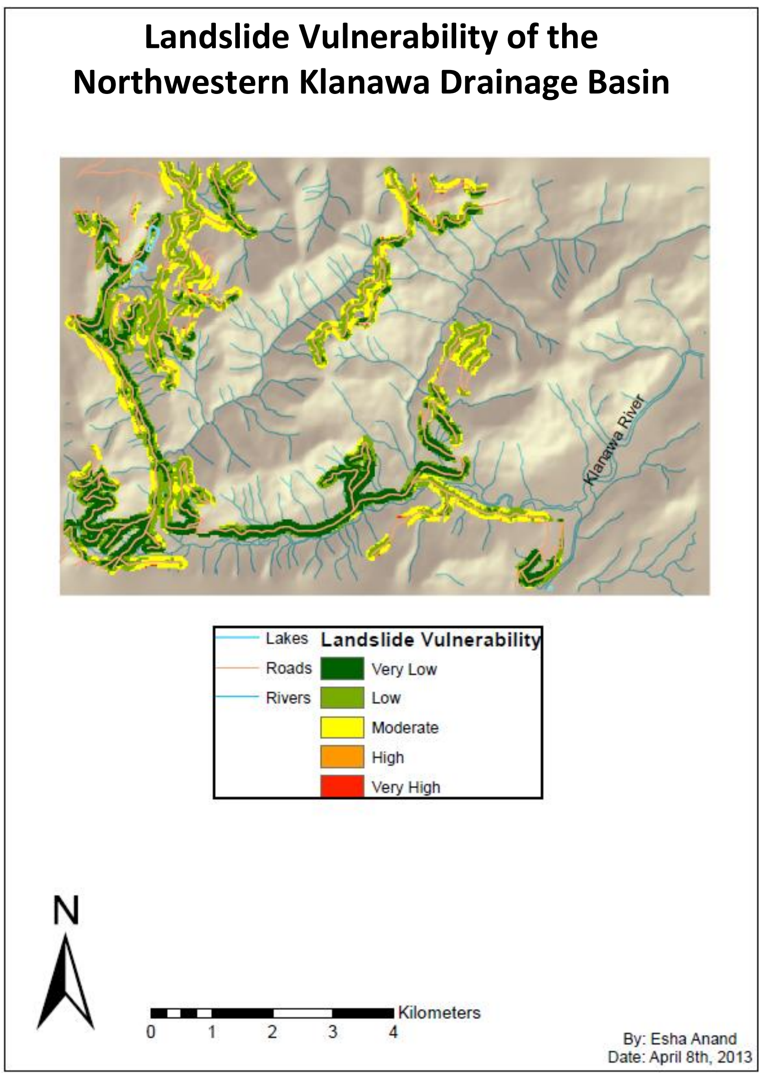

Figure 6 Final Output Map showing the areas that are more susceptible to landslides

Comparison of Literature and Conclusion

The output landslide hazard map of this study was compared to that of Goetz et al. (2011) (figure 7). They had created approximately three models which had all given quite a similar output—this is just one of them. It is quite evident that my final map output does not closely match up to the one created by Goetz et al. (2011), which can be resultant of many factors:

- The study by Goetz et al. (2011) had included a variety of parameters such as forested/logged areas.
- They had also used physically based models which contained a variety of complex algorithms which may have produced different results, and further shown quite inaccurate outputs in my final product

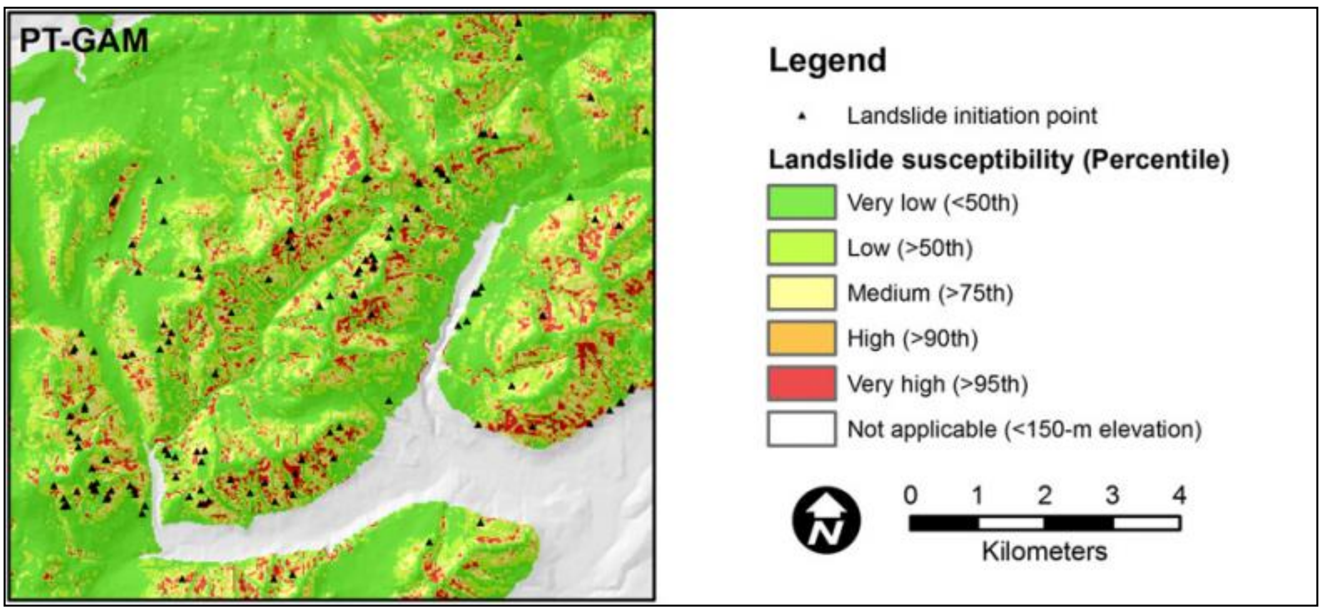

Figure 7 Landslide hazard map showing areas along the Klanawa River Watershed that are susceptible to landslides (Source: Goetz et al. 2011)

If this study had included more parameters such as landuse cover and had further analyzed other factors which vary spatially within a drainage basin that contribute to landslide susceptibility, the final results could have probably produced a more accurate map. Due to the limitations with the retrieval of such data, these factors could not be analyzed and included in this report. Another thing that would change the results of the created output in this study would be resultant of appropriate weightings. That is, if the weights of each inputted parameter were better known (i.e. which parameter is dominant in the analysis over the other), it would provide a better, and perhaps more accurate result.

References

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