Brandon Couch

506: Lab #3

My goal in this lab was to analyze the risks for landslides throughout Mt. Rainier National Park using Light Detection and Ranging (LIDAR) data. I based my research off of an article by Jebur, et.al[1] that studied landslide susceptibility in an area of Malaysia and applied some of their findings to my study of Mt. Rainier. However, while that study used many different conditioning factors that could increase an area's susceptibility to landslides, I decided to limit my focus to just two factors. These factors are slope and curvature. Slope refers to how steeply inclined a surface is, while curvature refers to how much a surface bulges in or out at any given point; in other words, how concave or convex the surface is.

The data I used for this study covers all of Mt. Rainier National Park. I obtained this information from the Puget Sound LIDAR Consortium from data collected by Watershed Sciences, Inc. between September 0f. 2007 and October of 2008. The data files included a digital elevation model (DEM) and a hill shade model, which are Figure #1 and Figure #2, respectively. I chose to study Mt. Rainier because it's the tallest mountain in this state that I have grown up in the shadow of my entire life. I realize that a mountainous area such as that park would be potentially prone to landslides and other debris flows. In regards to reliability, the document was submitted to the National Park Service by Watershed Sciences, Inc. which would seem to suggest a degree of integrity and accuracy.

[1] Jebur, M. N., Pradhan, B., & Tehrany, M. S. (2014). Optimization of landslide conditioning factors using very high-resolution airborne laser scanning (LiDAR) data at catchment scale. Remote Sensing of Environment, 152, 150-165.

To start my analysis, I created a slope model (Figure #3) based on the DEM using the built-in slope function in ArcGIS Pro. Lighter areas on this map represent shallower slopes, while darker areas represent steeper slopes. Next, I calculated a model of surface curvature based on the DEM using the built-in curvature function in ArcGIS Pro. (Figure #4) Areas with a negative measurement shown in orange are concave, while positive measurements shown in blue are convex. Areas that are within ten units of zero (0) are marked as flat and are shown in white.

Based on the study by Jebur, et. al, surfaces with a slope between 25 and 50 degrees appeared to be the most susceptible to landslides, while surfaces with a flat terrain (not concave or convex) were also more likely to produce landslides. Using this information, I created an algebraic expression using the raster calculator in ArcGIS Pro to make a model that would produce a basic risk index model. First, the expression would assign a binary variable each for slope and curvature for each pixel; for slope, the variable would be set to one if the slope for that point fell between twenty-five and fifty degrees, while all values outside that range would be set to zero. Likewise, for curvature the value would be set to one if the point's curvature was within ten units of zero, identifying the surface as relatively flat, while all points outside this range would be set to zero. Finally, the two binary variables for slope and curvature were added together, resulting in an index value ranging from zero to two. The specific equation used is as follows:

$$index = ((slope \geq 25) AND (slope \leq 50)) + ((curvature \geq -10) AND (curvature \leq 10))$$

Areas with an index of zero had the lowest chance of landslide as they did not fall within either the slope or curvature range. Areas with an index of two had the highest risk for landslides as they were within both the slope range and had a lack of major curvature.

Looking at the risk index model shown in Figure #5, we can see that the areas most vulnerable to landslides would be the slopes around the river and glacial valleys extending out towards the edges of the park, especially in the North and the East. The area around the summit appears to be particularly vulnerable as well. I suspect that these areas show up as more vulnerable because they may be more prone to the effects of weather, which may make the ground more unstable. Keeping in mind, the study that I based this off of only used landslides specifically caused by water and did not account for other forms of debris flows such as avalanches, rockslides, or lahars. It would be interesting to re-do this study based on additional conditioning factors as well as accounting for different types of debris flows in order to develop a more detailed risk map. I was originally going to include altitude as a conditioning factor, but most of the park was already above the most vulnerable altitude range in the study I based this off of. I was also thinking of including aspect data, which is the direction each slope is facing, but realized the aspect most likely to result in landslides would be different for Mt. Rainier than in the Malaysia study as it is in a completely different part of the world.

Figure 1

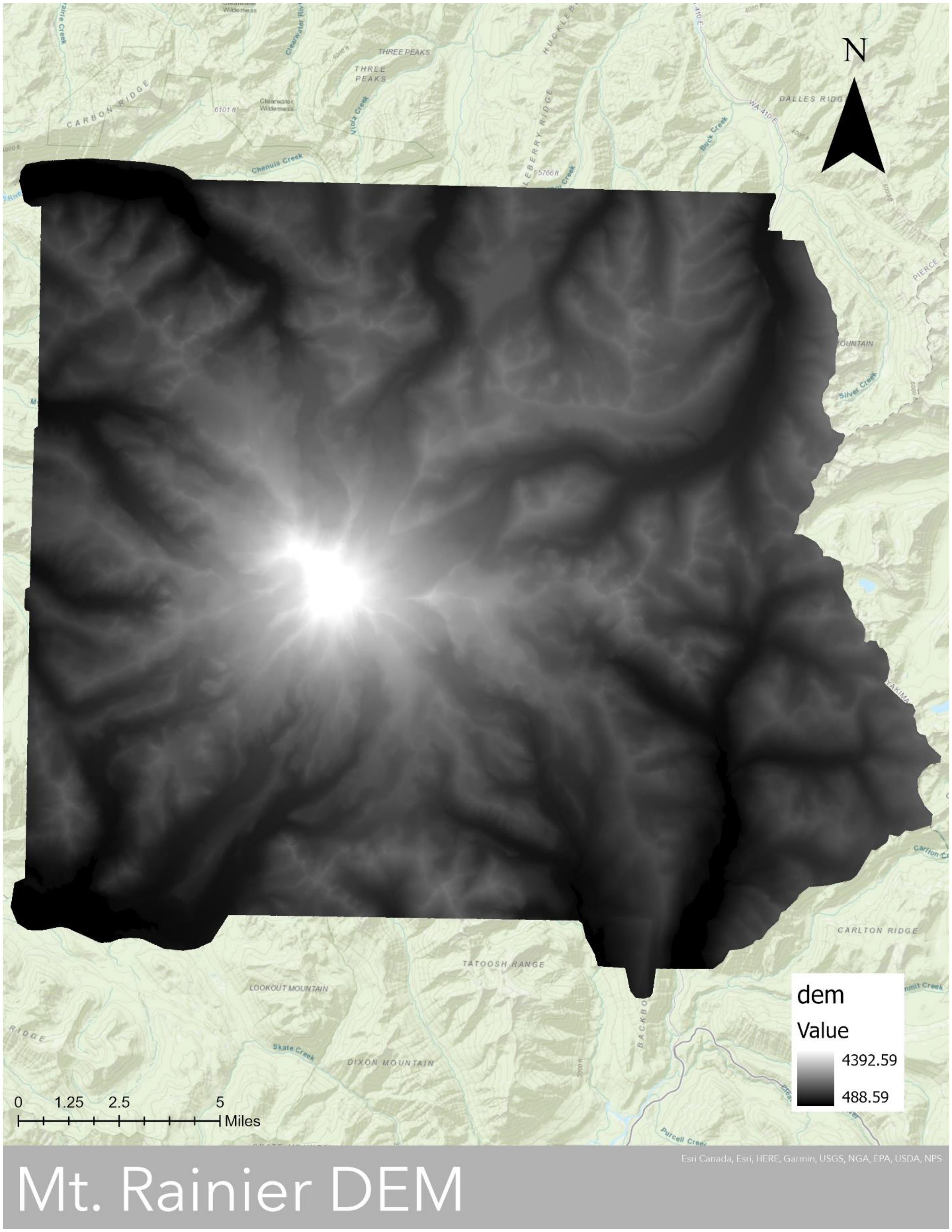
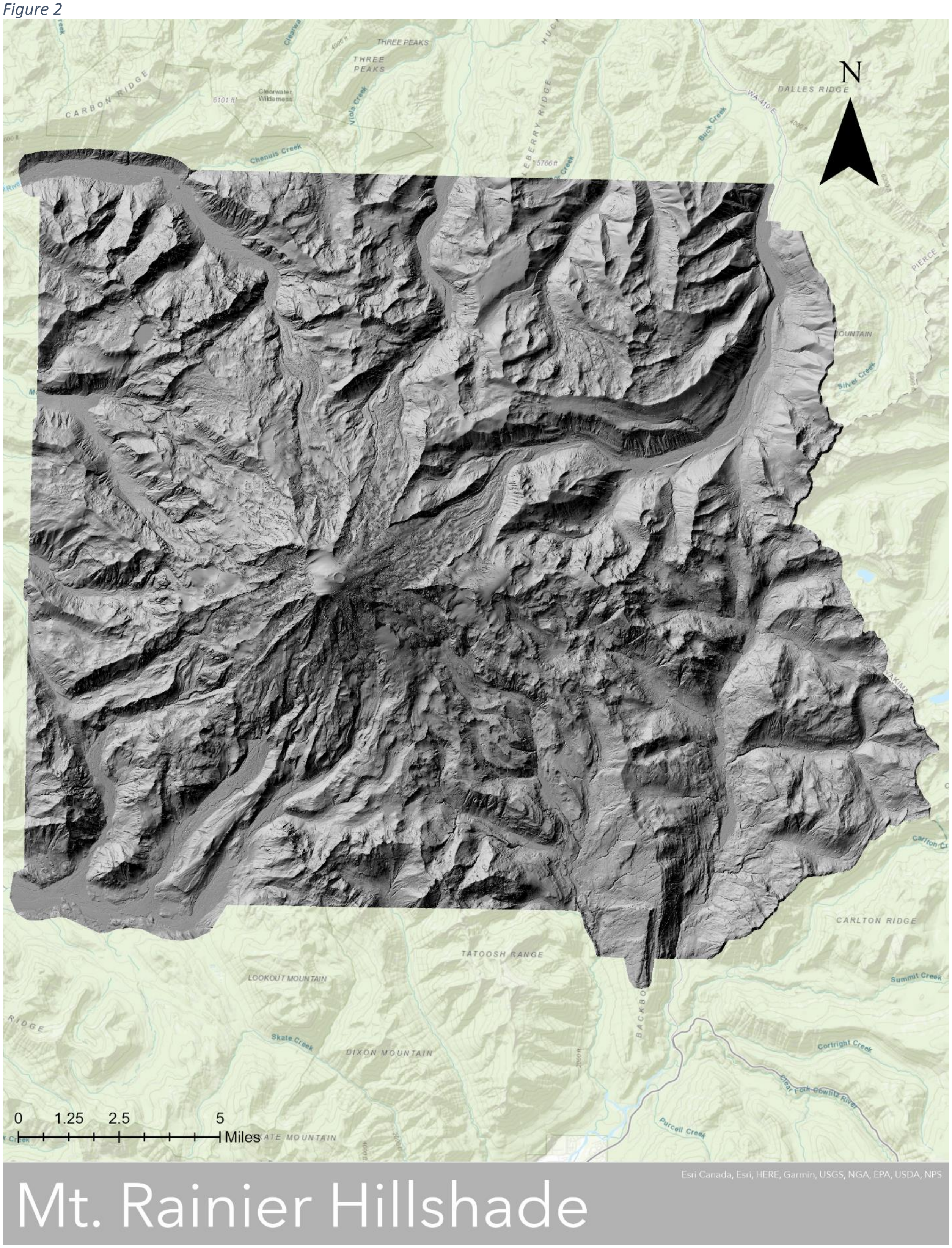
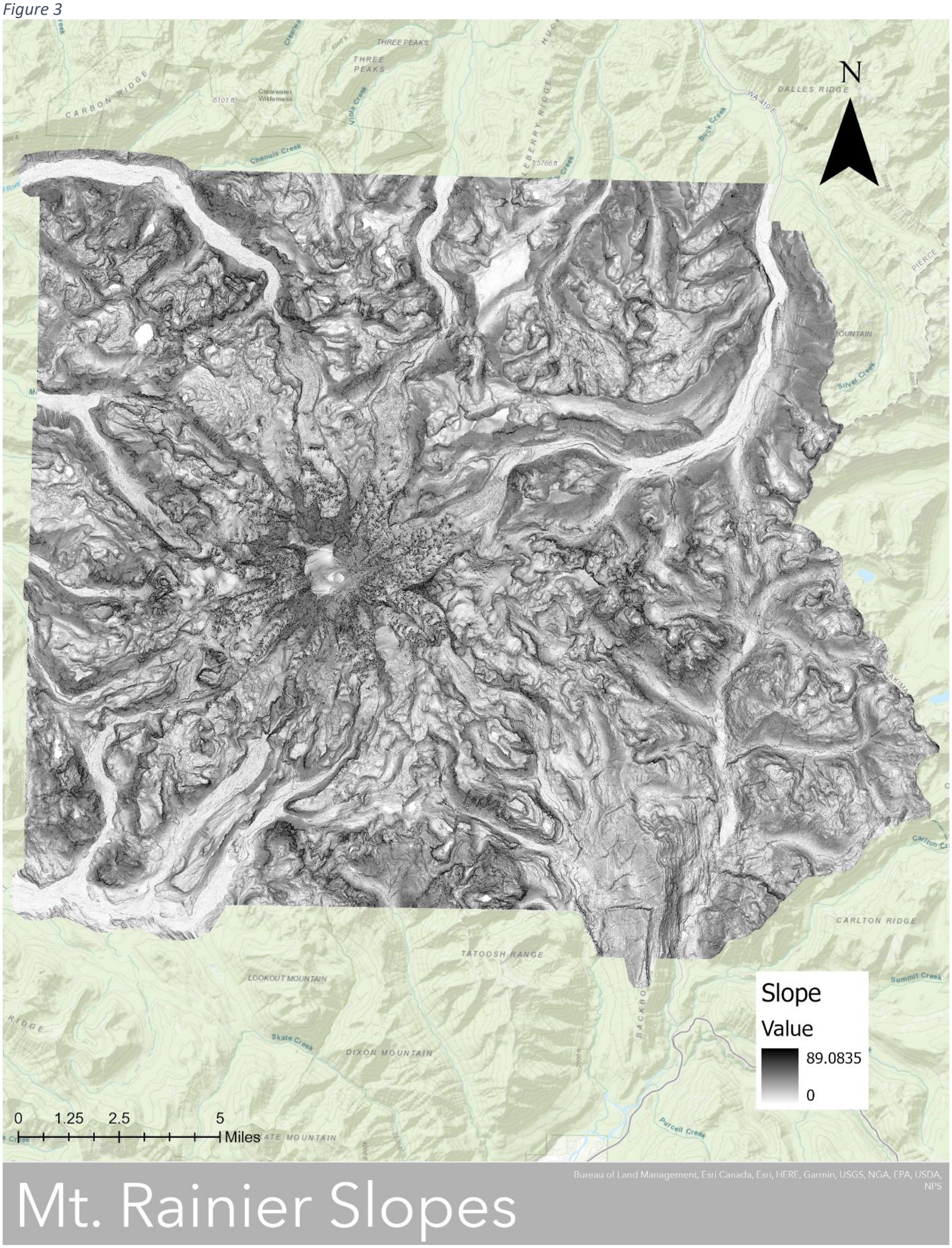

N
dem
Value
4392.59
488.59
0 1.25 2.5 5
Miles
Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
Mt. Rainier DEM

Figure 2



N
THREE PEAKS
CARBON RIDGE
Clearwater Wilderness
Chenuis Creek
DALLES RIDGE
WA-410 E
Silver Creek
CARLTON RIDGE
TATOOSH RANGE
LOOKOUT MOUNTAIN
Summit Creek
Skate Creek
DIXON MOUNTAIN
Cortright Creek
Clear Fork Cowlitz River
Purcell Creek
0
1.25
2.5
5
Miles
Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
Mt. Rainier Hillshade

Figure 3



N
THREE PEAKS
CARBON RIDGE
Clearwater Wilderness
Chenuis Creek
DALLES RIDGE
WA-410 E
Silver Creek
CARLTON RIDGE
TATOOSH RANGE
LOOKOUT MOUNTAIN
Skate Creek
DIXON MOUNTAIN
Summit Creek
Purcell Creek
Slope
Value
89.0835
0
0 1.25 2.5 5
Miles
Mt. Rainier Slopes
Bureau of Land Management, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS

Figure 4

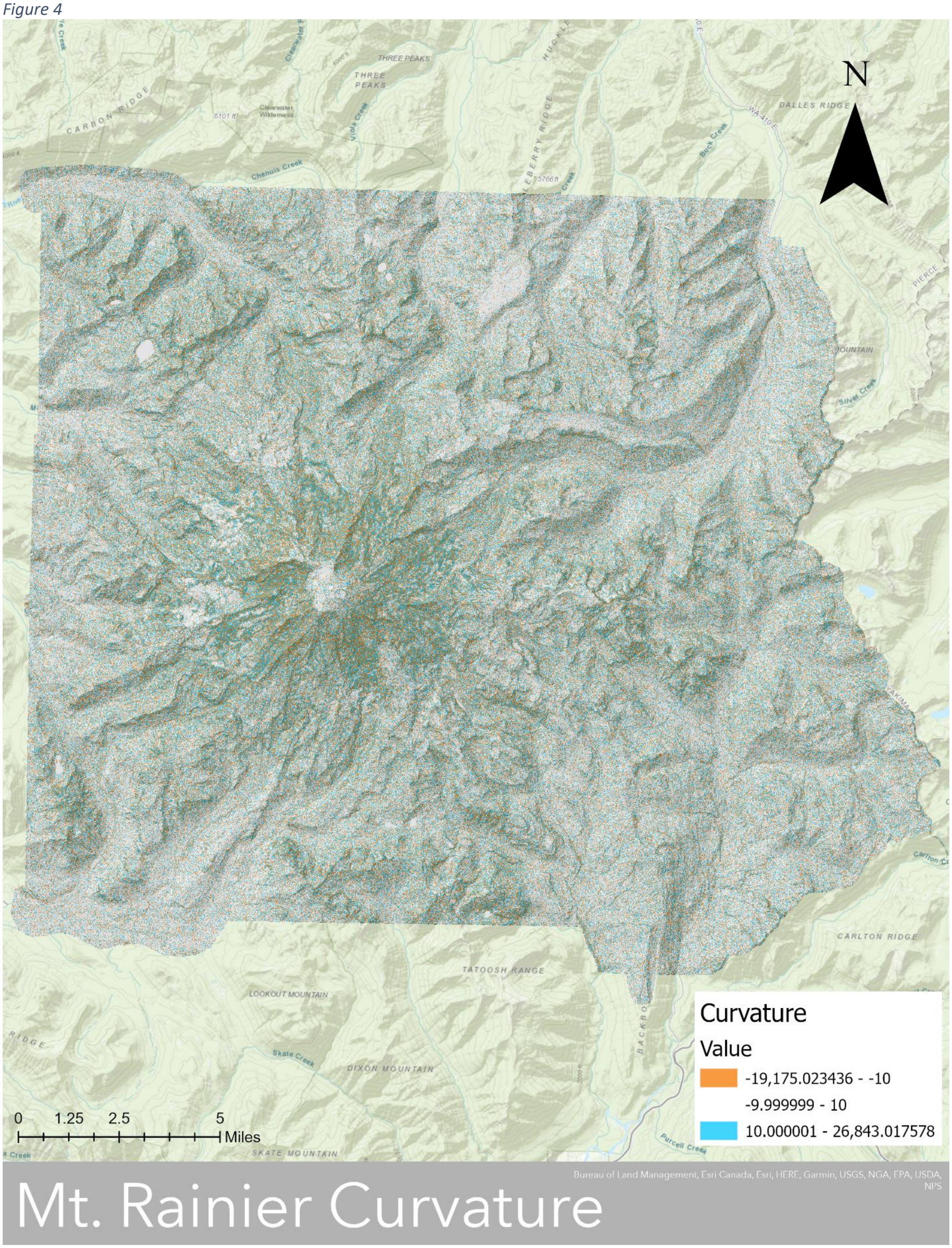
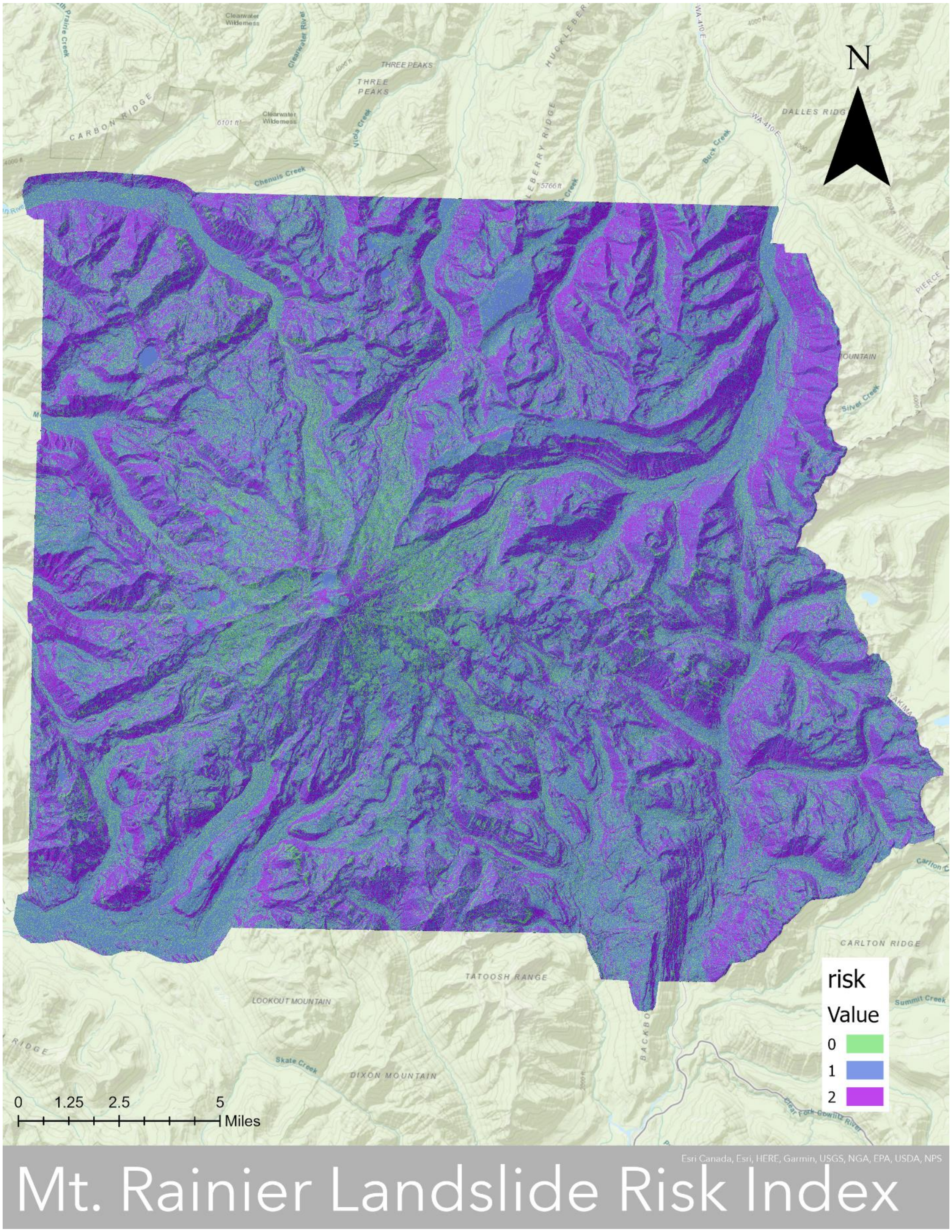

N
Curvature
Value
-19,175.023436 - -10
-9.999999 - 10
10.000001 - 26,843.017578
0 1.25 2.5 5
Miles
Bureau of Land Management, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
Mt. Rainier Curvature
CARBON RIDGE
THREE PEAKS
DALLES RIDGE
TATOOSH RANGE
LOOKOUT MOUNTAIN
DIXON MOUNTAIN
SKATE MOUNTAIN
CARLTON RIDGE
Skate Creek
Purcell Creek
Silver Creek
Chenuis Creek
Clearwater Wilderness

Figure 5


N
risk
Value
0
1
2
0 1.25 2.5 5
Miles
Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
Mt. Rainier Landslide Risk Index
CARBON RIDGE
THREE PEAKS
DALLES RIDGE
TATOOSH RANGE
LOOKOUT MOUNTAIN
DIXON MOUNTAIN
CARLTON RIDGE
Chenuis Creek
Skate Creek
Summit Creek
Silver Creek
Buck Creek

Sources:

- Jebur, M. N., Pradhan, B., & Tehrany, M. S. (2014). Optimization of landslide conditioning factors using very high-resolution airborne laser scanning (LiDAR) data at catchment scale. Remote Sensing of Environment, 152, 150-165.
- Data source:

  http://pugetsoundlidar.ess.washington.edu/lidardata/restricted/filegeodatabase/mtrainierNP/index.html

- https://desktop.arcgis.com/en/arcmap/10.3/manage-data/raster-and-images/wkflw-performing-raster-analysis-using-algebraic-expressions.htm
- https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/raster-calculator.htm