A GIS Assessment of Erosion Vulnerability for Unofficial Trails in the Columbia River Gorge

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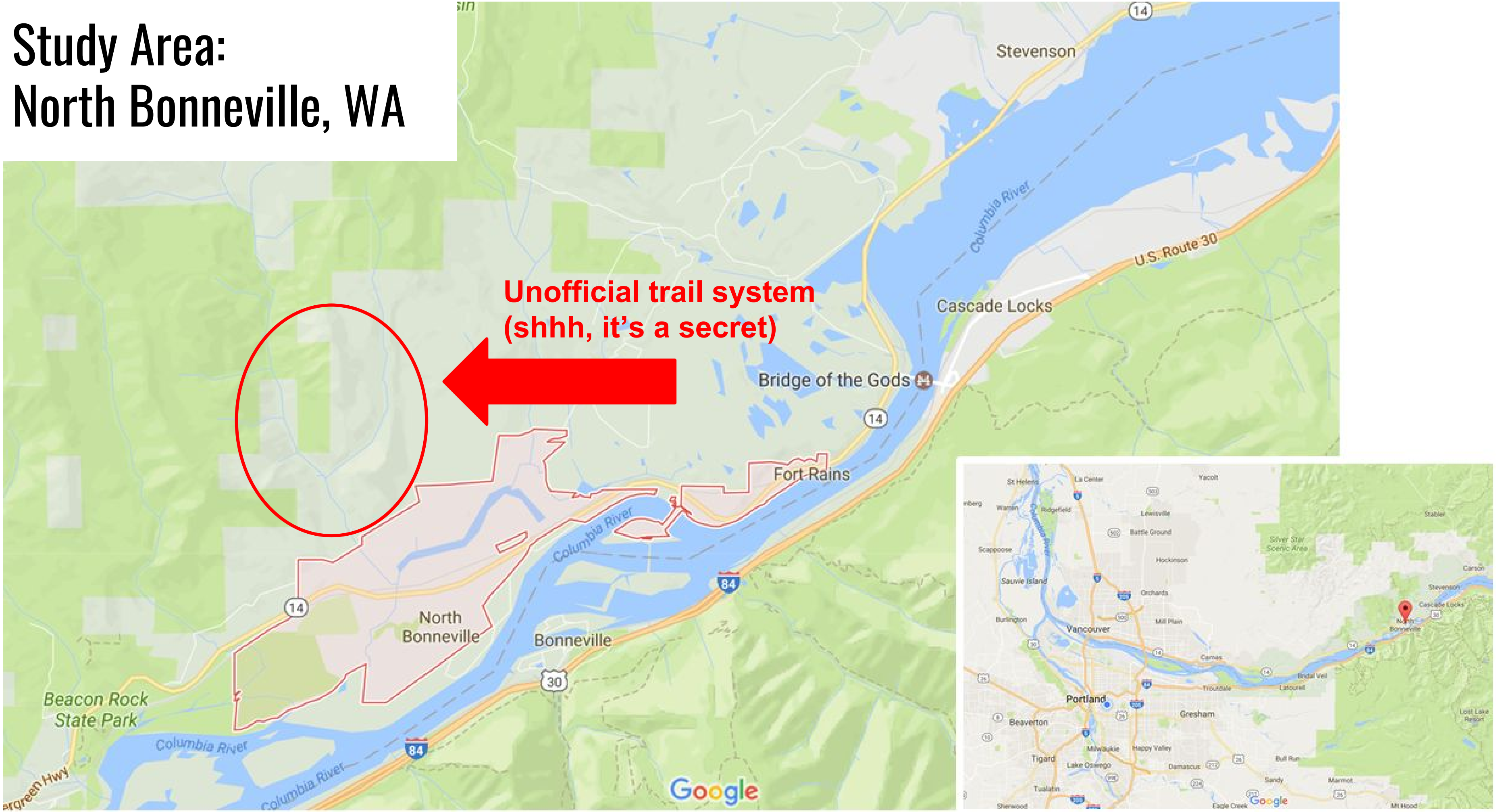
Abstract

The city of North Bonneville, located along the Columbia River Gorge in Skamania County, Washington, is a small town surrounded by scenic natural landscapes. Community leaders of North Bonneville have a vision of becoming a hub for outdoor recreation and a connector to the Pacific Crest Trail and other regional trails. In an effort to advance their vision, a recently founded local community organization named the Bonneville Trails Foundation (BTF) is encouraging the United States Forest Service (USFS) to approve and formalize several existing unofficial trails located just north of the town, known to locals as the Aldrich Butte trail complex. In April of 2017 a focus group was held with community members, trail builders, and the USFS to get feedback about which of the informal trails should be formalized. Following that process, further analysis of trail hazards was requested by the USFS. There are many criteria that the USFS and WTA would like to consider when choosing where to build trails in this area. However, for the scope of this project I will be doing a GIS analysis of the vulnerability of trails to erosion processes to access potential hazards and sensitive areas in the trail complex. I will use a model developed by Józefaciuk & Józefaciuk (1996), Wawer & Nowocien (2007), and A.M. Tomczyk, (2011) that uses slope steepness and soil type to determine water erosion hazards. The potential water erosion indicator is based on soil properties as defined by Wawer & Nowocien (2007). I will determine slope by using a 2 meter DEM obtained from the Washington Department of Natural Resources, and use a soil classification layer from the Soil Survey Geographic (SSURGO) database obtained from the U.S. Department of Agriculture to determine soil type. Trails will be segmented, and each segment assigned a hazard ranking. Finally, each of the unofficial trails will be evaluated for overall erosion vulnerability, and recommendations will be made toward a trail formalization process.

Study Area:
North Bonneville, WA



Bonneville Trail Foundation (BTF)

Discovery Trails
of North Bonneville

Other important partners

FOREST SERVICE
U S
DEPARTMENT OF AGRICULTURE

WASHINGTON
TRAILS
ASSOCIATION
EST.
1966

1. Which trails of North Bonneville’s unofficial trail complex would the community want to formalize?

2. Are these trails actually viable for the formalization process
    a. Are they safe for people?
    b. Are they safe for the environment?
    c. What about land ownership?
    d. etc

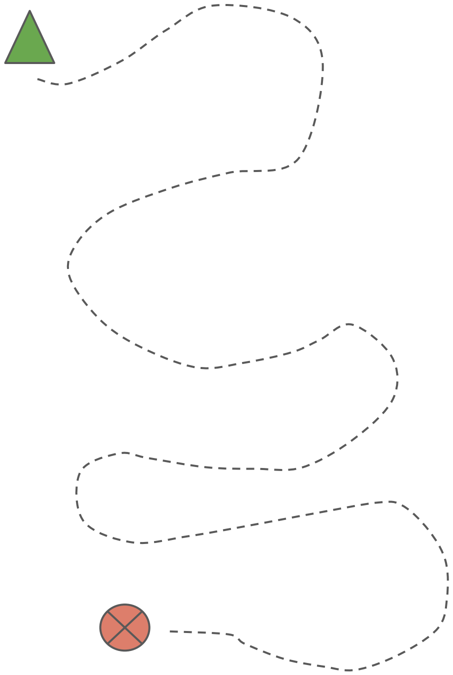
Mapping the Unofficial Trails:

BTF “Trail Gnomes”

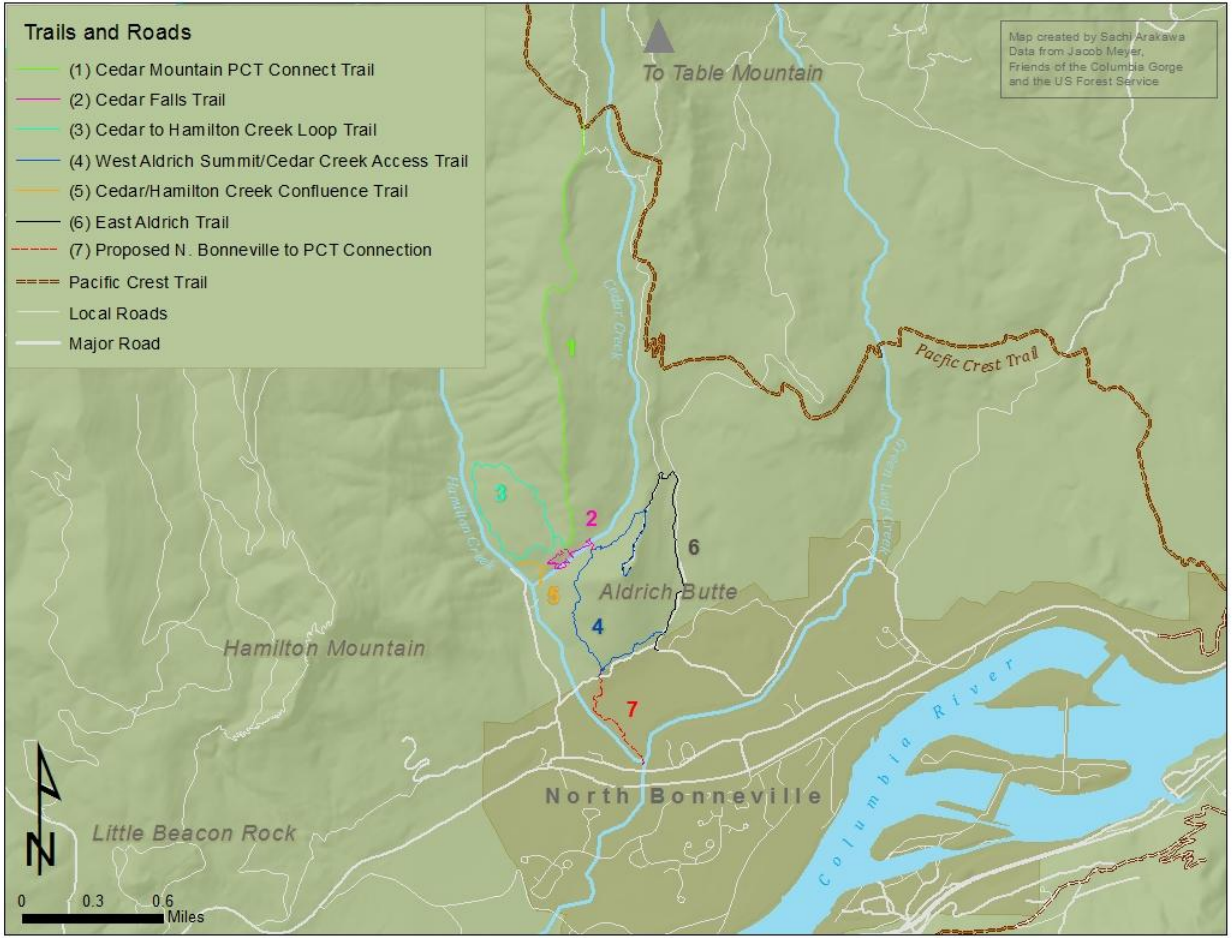
+

Garmin GPS Unit
(not to scale)

=



Resulting map of the unofficial trails (7 total)



Public Participation in Trail Selection & Evaluation

Focus group in
North Bonneville

1 hour, 16 participants
Expert, Intermediate, and Novice users
Representatives from the Forest Service,
Army Corps of Engineers, and Washington Trails Association

Now… what can GIS analysis tell us?

- Land Use
- Environmental Vulnerability
- Potential Hazards
  (Landslides, Erosion)

Process Outline:

- Gather Data
- Lit Review for Appropriate Model
- Analysis
- Conclusions

Data

- LiDAR/DEM/DTM at WADNR's Lidar Portal: http://lidarportal.dnr.wa.gov/
- Soil data from Web Soil Survey (WSS): https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx
- Trail, road, land use, and stream/river data from the Friends of the Columbia Gorge, U.S. Forest Service and Washington Trails Association

Identifying an Appropriate Model

Aleksandra M. Tomczyk

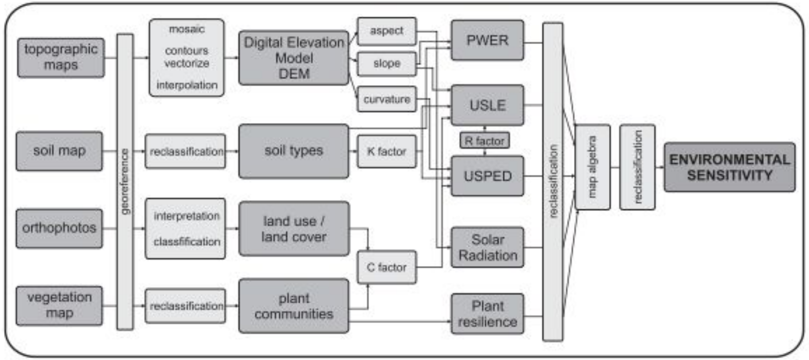


Fig. 4. Steps in the calculation of the environmental sensitivity model of Gorce National Park.

Very simplified for my project

Table 1
Potential susceptibility of soil groups to water erosion (based on Józefaciuk & Józefaciuk, 1996; Wawer & Nowocień, 2007). When two erosion grades are shown in one field, the lower value concerns areas with average annual rainfall < 600 mm and the higher one applies to remaining areas.

Soil groups and theirs susceptibility to soil erosion	Slope (°)					
	0–3	3–6	6–10	10–15	15–20	>20
	Degree of potential water erosion hazard					
Very high susceptibility Loess and less-like, silts	1	2	3	4	5	5
High susceptibility Loose sands, rendzinas	1	1; 2	2; 3	3; 4	5	5
Average susceptibility Weak sands, loamy sands, gravels, old rendzinas	1	1; 2	2; 3	3; 4	4; 5	5
Low susceptibility Light loams, average loams, calcarous loams.	0	1	2	3	4; 5	5
Very low susceptibility Heavy loams, clays, rocky soils, heavy soils with non-calcarous skeleton, peats.	0	1	1; 2	2; 3	3; 4	4

Process Breakdown

1. Divide trail system into equal segments, rasterize
2. Calculate slope and flow accumulation calculation for study area
    a. Identify stream networks
3. Vulnerability Ranking
    a. Reclassify slope and soil type data
    b. “Combine” tool to get new values
4. Zonal statistics to find pour points
5. Watershed delineation
6. Zonal statistics to aggregate vulnerability ranking to watershed
7. Join zonal statistics table to trail data

Vulnerability Ranking Step 1

Reclassify Values

Soil

Slope

slope2
<VALUE>
- 0 - 3
- 3.000000001 - 6
- 6.000000001 - 10
- 10.00000001 - 15
- 15.00000001 - 20
- 20.00000001 - 86.20941162

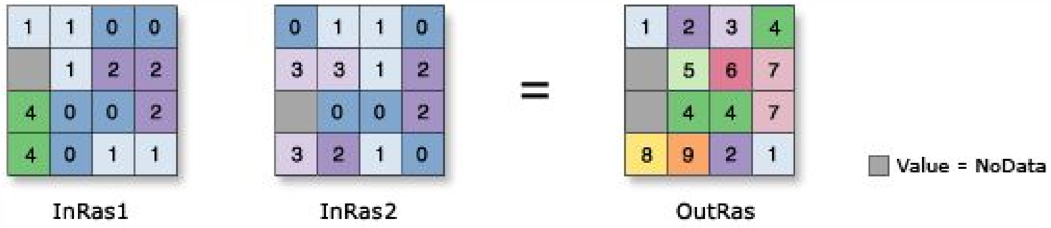
slope_reclass
Value
- 1
- 2
- 3
- 4
- 5
- 6

Map unit symbol and name
1—Andic Cryumbrepts, 5 to 65 percent slopes
2—Arents, 0 to 5 percent slopes
3—Aschoff very gravelly loam, 5 to 30 percent slopes
4—Aschoff very gravelly loam, 30 to 65 percent slopes
5—Aschoff-Rock outcrop complex, 30 to 65 percent slopes
17—Bonneville stony sandy loam
64—McBee silt loam
65—McDoug silt loam
75—Mountzion clay loam, 2 to 15 percent slopes
76—Mountzion clay loam, 15 to 30 percent slopes
77—Mountzion clay loam, 30 to 65 percent slopes
82—Pilchuck very fine sandy loam
87—Pits
90—Riverwash
92—Rock outcrop-Rubbleland complex
93—Rock outcrop-Xerorthents complex, 50 to 90 percent slopes
103—Skamania very fine sandy loam, 0 to 8 percent slopes
104—Skamania very fine sandy loam, 8 to 15 percent slopes
105—Skamania very fine sandy loam, 15 to 30 percent slopes
106—Skamania very fine sandy loam, 30 to 40 percent slopes
109—Skoly stony loam, 2 to 15 percent slopes
110—Skoly stony loam, 15 to 30 percent slopes
111—Skoly stony loam, 30 to 65 percent slopes
112—Skoly-Rock outcrop complex, 5 to 30 percent slopes
113—Skoly-Rock outcrop complex, 30 to 65 percent slopes
115—St. Martin gravelly silty clay loam, 2 to 15 percent slopes
116—St. Martin gravelly silty clay loam, 15 to 30 percent slopes
117—St. Martin gravelly silty clay loam, 30 to 65 percent slopes
120—Stabler loam, 0 to 8 percent slopes
121—Stabler loam, 8 to 30 percent slopes
122—Stabler loam, 30 to 65 percent slopes

OBJECTID *	Shape *	AREASYMBOL	MUSYM	Soil_typ	suceptibility
1	Polygon	WA659	126	Steever-Rock Outcrop Complex	very low
2	Polygon	WA659	161	Xerorthents-Rock Outcrop Complex	very low
3	Polygon	WA659	126	Steever-Rock Outcrop Complex	very low
4	Polygon	WA659	82	Pilchuck Very Fine Sandy Loam	average
5	Polygon	WA659	123	Steever Stony Clay Loam	very low
6	Polygon	WA659	82	Pilchuck Very Fine Sandy Loam	average
7	Polygon	WA659	177	Water	water
8	Polygon	WA659	177	Water	water
9	Polygon	WA659	124	Steever Stony Clay Loam	very low
10	Polygon	WA659	17	Bonneville Stony Sandy Loam	average
11	Polygon	WA659	126	Steever-Rock Outcrop Complex	very low
12	Polygon	WA659	92	Rock Outcrop Rubbleland Complex	very low
13	Polygon	WA659	92	Rock Outcrop Rubbleland Complex	very low
14	Polygon	WA659	123	Steever Stony Clay Loam	very low
15	Polygon	WA659	126	Steever-Rock Outcrop Complex	very low
16	Polygon	WA659	123	Steever Stony Clay Loam	very low
17	Polygon	WA659	123	Steever Stony Clay Loam	very low
18	Polygon	WA659	126	Steever-Rock Outcrop Complex	very low
19	Polygon	WA659	4	Aschoff Very Gravelly Loam	average
20	Polygon	WA659	2	Arents	unknown
21	Polygon	WA659	92	Rock Outcrop Rubbleland Complex	very low
22	Polygon	WA659	124	Steever Stony Clay Loam	very low
23	Polygon	WA659	177	Water	water
24	Polygon	WA659	123	Steever Stony Clay Loam	very low
25	Polygon	WA659	17	Bonneville Stony Sandy Loam	average
26	Polygon	WA659	82	Pilchuck Very Fine Sandy Loam	average
27	Polygon	WA659	64	McBee Silt Loam	very high

Vulnerability Ranking Step 2

Combine Tool



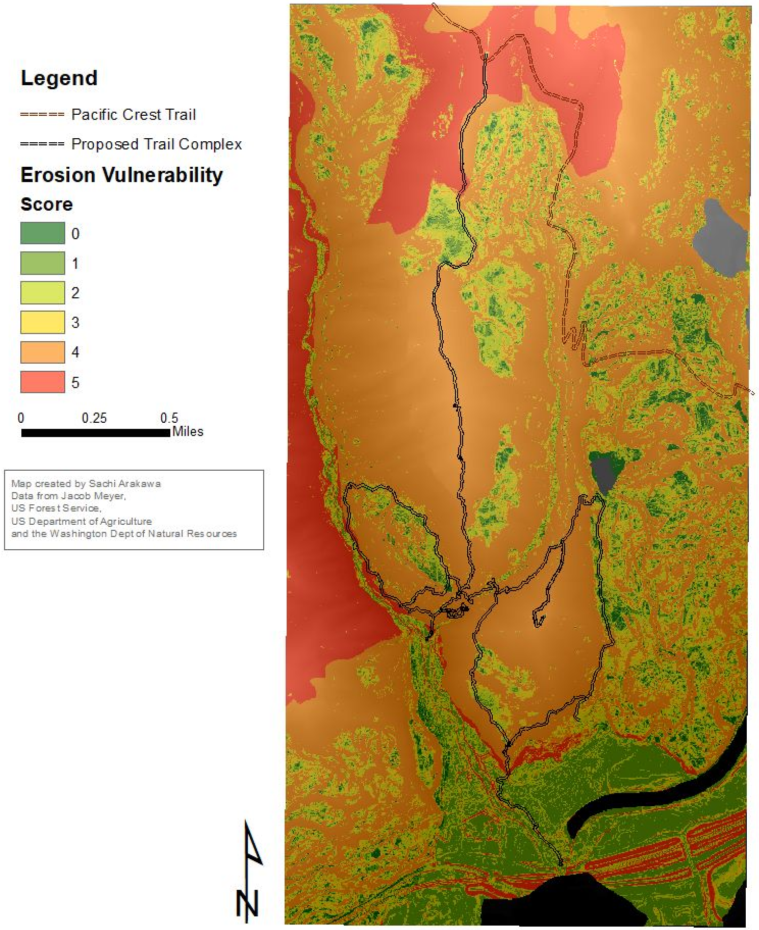
Value	Count	Code
0	5	002
1	5	004
2	3	005
4	2	008

Value	Count	Type
0	5	PAX
1	4	HAR
2	3	WIN
3	3	SAN

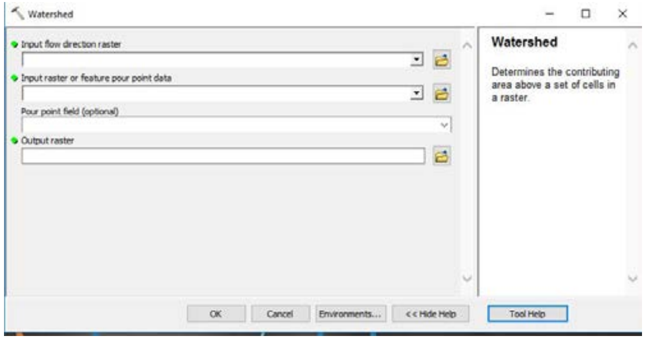
Value	Count	InRas1	InRas2
1	2	1	0
2	2	1	1
3	1	0	1
4	3	0	0
5	1	1	3
6	1	2	1
7	2	2	2
8	1	4	3
9	1	0	2

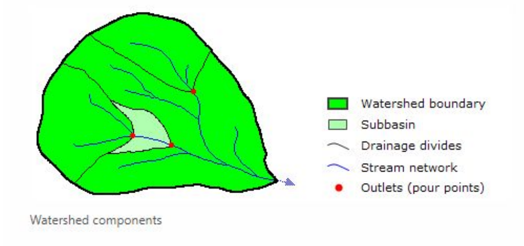
```
OutRas = Combine([InRas1, InRas2])
```

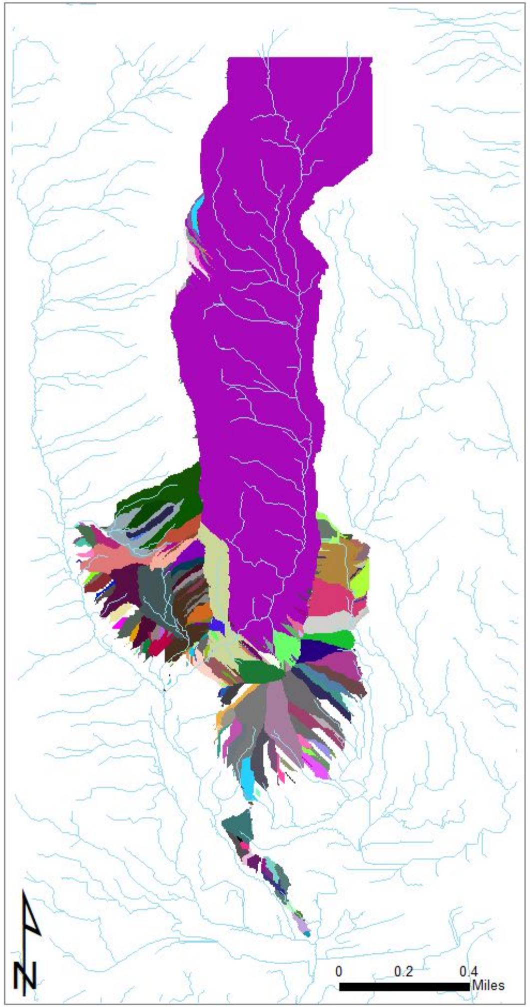
Vulnerability Map



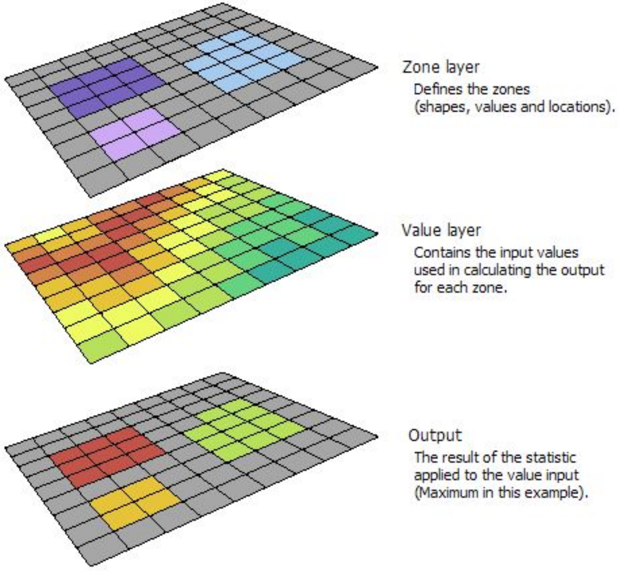
Delineate Watersheds Along Trail Complex



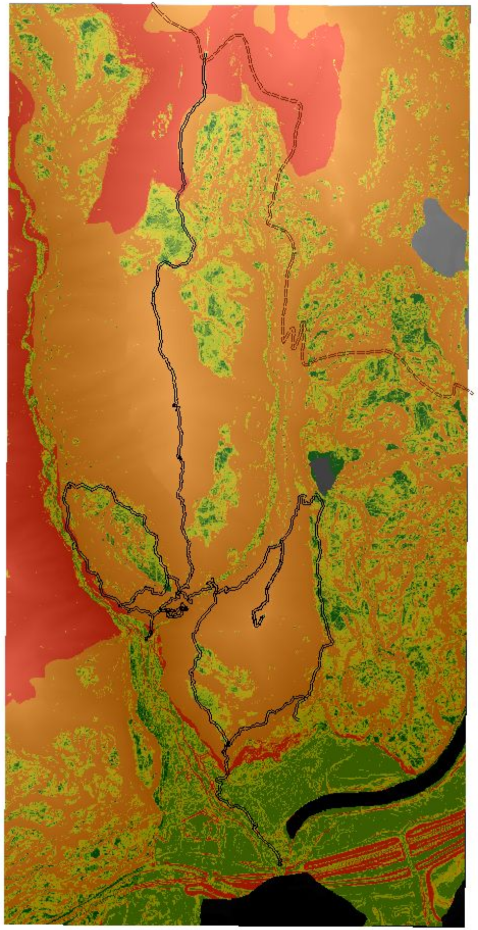




Zonal Statistics

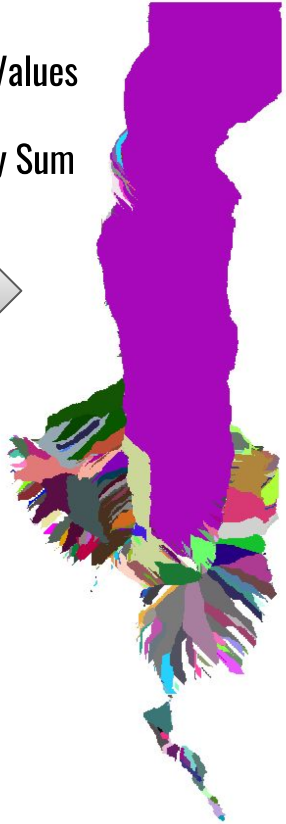


Example inputs and output from Zonal Statistics

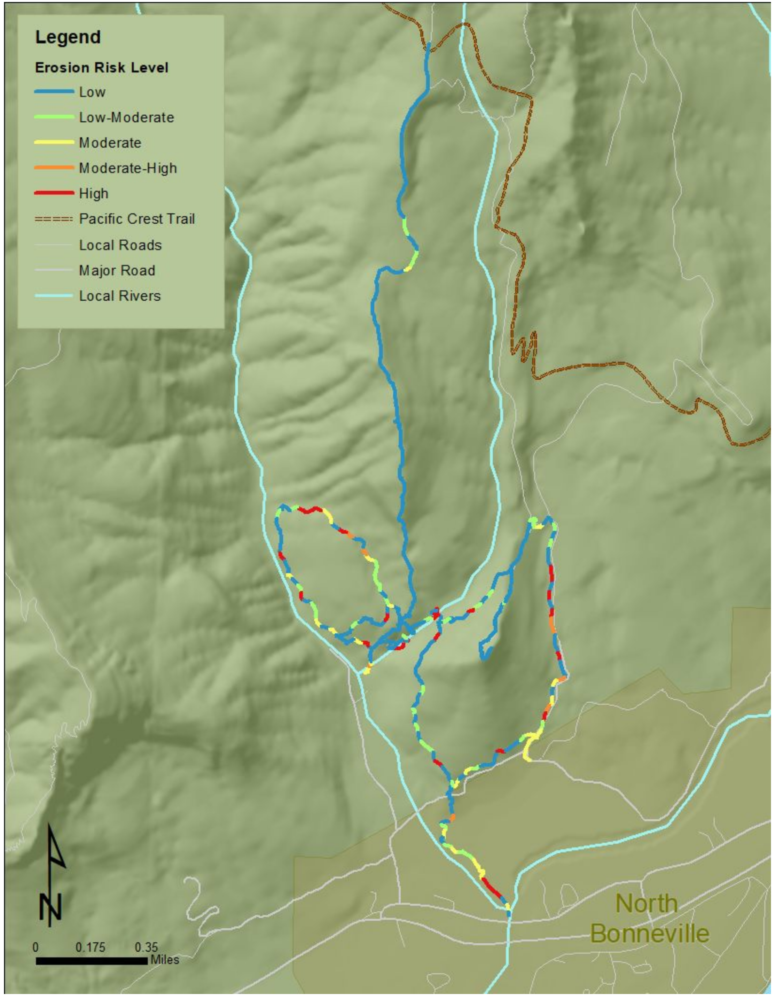


Vulnerability Values Aggregated to Watersheds by Sum

Sum



Results

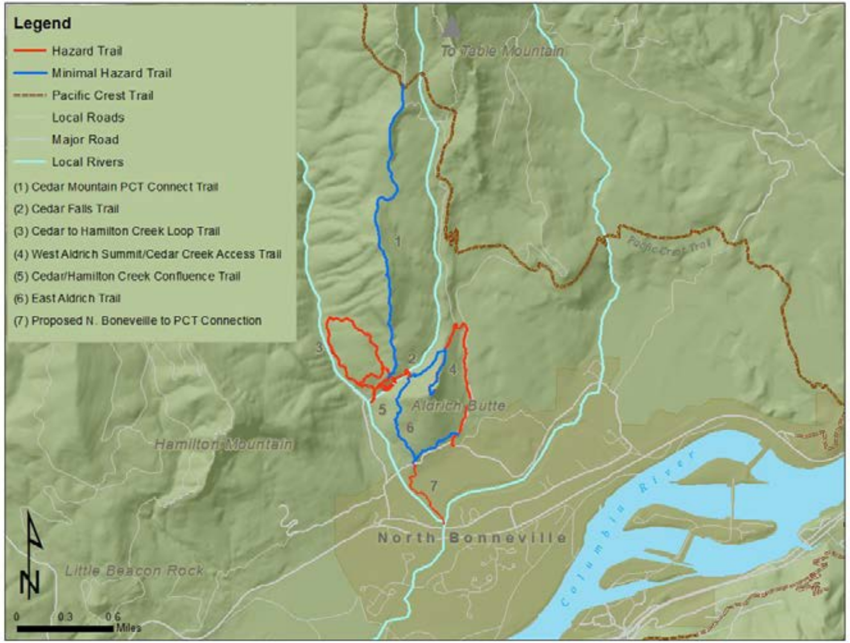


Legend
Erosion Risk Level
Low
Low-Moderate
Moderate
Moderate-High
High
Pacific Crest Trail
Local Roads
Major Road
Local Rivers
N
0
0.175
0.35
Miles
North Bonneville

Results

Trails Most Vulnerable to Erosion:

1. Cedar Mountain to PCT Connect
2. Cedar Falls
3. Cedar to Hamilton Loop
4. West Aldrich Summit/Cedar Creek Access
5. Cedar/Hamilton Creek Confluence
6. East Aldrich
7. Proposed N. Bonneville to PCT Connection



Conclusion

- Several trails in the complex are vulnerable to erosion.
- Trails crossing creeks tended to be more vulnerable, but not exclusively.
- Results matched hazard areas that were pointed out during our focus group (ground truth)

Lessons Learned/Best Practices

1. Scope project conservatively
2. Chose model with discretion (ask an expert! ask two!)
3. Be aware of spatial resolution discrepancies
4. No analysis is complete without groundtruthing

Sources

Pickering, Catherine Marina and Norman, Patrick. "Comparing impacts between formal and informal recreational trails." Journal of Environmental Management Vol 193 (2017). Pages 270-279.

Tomczyk, Aleksandra. "A GIS assessment and modelling of environmental sensitivity of recreational trails: The case of Gorce National Park, Poland." Applied Geography Vol 31 (2011). Pages 339-351.

Józefaciuk, A., & Józefaciuk, C. (1996). Erosion processes studies: Mechanism and applied methodology. Warszawa: Panst. Insp. Ochr. Srod. ser. Biblioteka Monitoringu Srodowiska

Wawer R. and Nowocień E. "Digital Map of Water Erosion Risk in Poland: A Qualitative, Vector-Based Approach." Polish Journal of Environmental Studies Vol. 15 No. 5 (2007). Pages 763-772.

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