Term Project

Examining the Field Sampling Viability of Burned Watersheds in the Oregon Cascades

https://web.engr.oregonstate.edu/~pimontc/

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CE 513

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Introduction

Forested headwaters are a key source of water for most major population centers in the Western United States, particularly in Oregon. Large wildfires (megafires) present a critical threat the health of these forests, and thus the water supply of downstream communities (Bladon et al., 2014). Wildfire influences key portions of the hydrologic cycle, including net precipitation, evapotranspiration, and infiltration (runoff partitioning) through the destruction of live over and understory vegetation, as well as soil organic matter. This leads to altered hydrograph signals such as decreased time to peak, higher runoff ratios, and increased baseflows. These disturbances also increase the delivery of sediment and nutrients to aquatic ecosystems and ultimately cause concerns for reservoir lifespan and drinking water treatment (Paul et al., 2022).

The severity at which wildfire burns within a watershed depends on a variety of topographic factors (Dillon et al., 2011), all of which can influence antecedent soil/fuel moisture conditions, wind, and fuel pre-heating. Soil hydraulic properties, namely saturated hydraulic conductivity, also has high spatial variability, with some of that variability being link to variations in topography, although the research is very limited (Wang et al., 2008)(Jencso, unpublished data). Infiltration rates, which are controlled by soil hydraulic conductivity as well as sorptivity (capillary action) are typically reduced post-fire due to removal of organic matter at the surface and the creation of a hydrophobic layer. Sorptivity, which controls early-time infiltration, is particularly affected by hydrophobicity (Ebel & Moody, 2017). To measure this, tension infiltrometers which do not have ponded heads are ideal for these scenarios (Ebel, 2019). Automated versions of these can be built, but they are sensitive to inclination.

What is dNBR?

dNBR stands for difference normalized burn ratio and is derived for wildfires using remote sensing data. The near-infrared (NIR) and short-wave infrared (SWIR) bands respond differently to healthy vegetation, which reflects near infrared and absorbs short-wave. Normalized Burn Ratio for an image is calculated from these with the equation NBR = (NIR -

SWIR) ÷ (NIR + SWIR). Since higher NBR means healthier vegetation, dNBR subtracts the NBR from a post-fire image from a pre-fire image.

Objectives

The objective of this project will be to calculate the average dNBR (differenced normalized burn ratio) from rasters for burned watersheds, as well as topographic factors such as slope, aspect, and topographic wetness index (TWI) to see how these correlate with dNBR and make inferences about potential soil hydraulic properties. Using the slope of the watershed, I will create a cutoff to determine how much of the watershed it is possible to sample using the automated minidisc infiltrometers used in Madsen & Chandler (2007).

Study Area

For this project, 2 potential burned watersheds the burned in the 2022 Cedar Creek fire were chosen. The Cedar Creek fire started in August of 2022 and burned over 50,000 hectares of forested land. Most of the area burned was in the Willamette National Forest and is part of the Middle Fork Willamette River basin, which serves as a source of drinking water and power for several downstream communities. Forest overstories are comprised largely of Douglas-fir (*Pseudotsuga menziesii*), Western Hemlock (*Tsuga heterophylla*), and Western Redcedar (*Thuja plicata*) in wetter areas with Red Alder (*Alnus rubra*) and Bigleaf Maple (*Acer macrophyllum*) in Riparian areas.

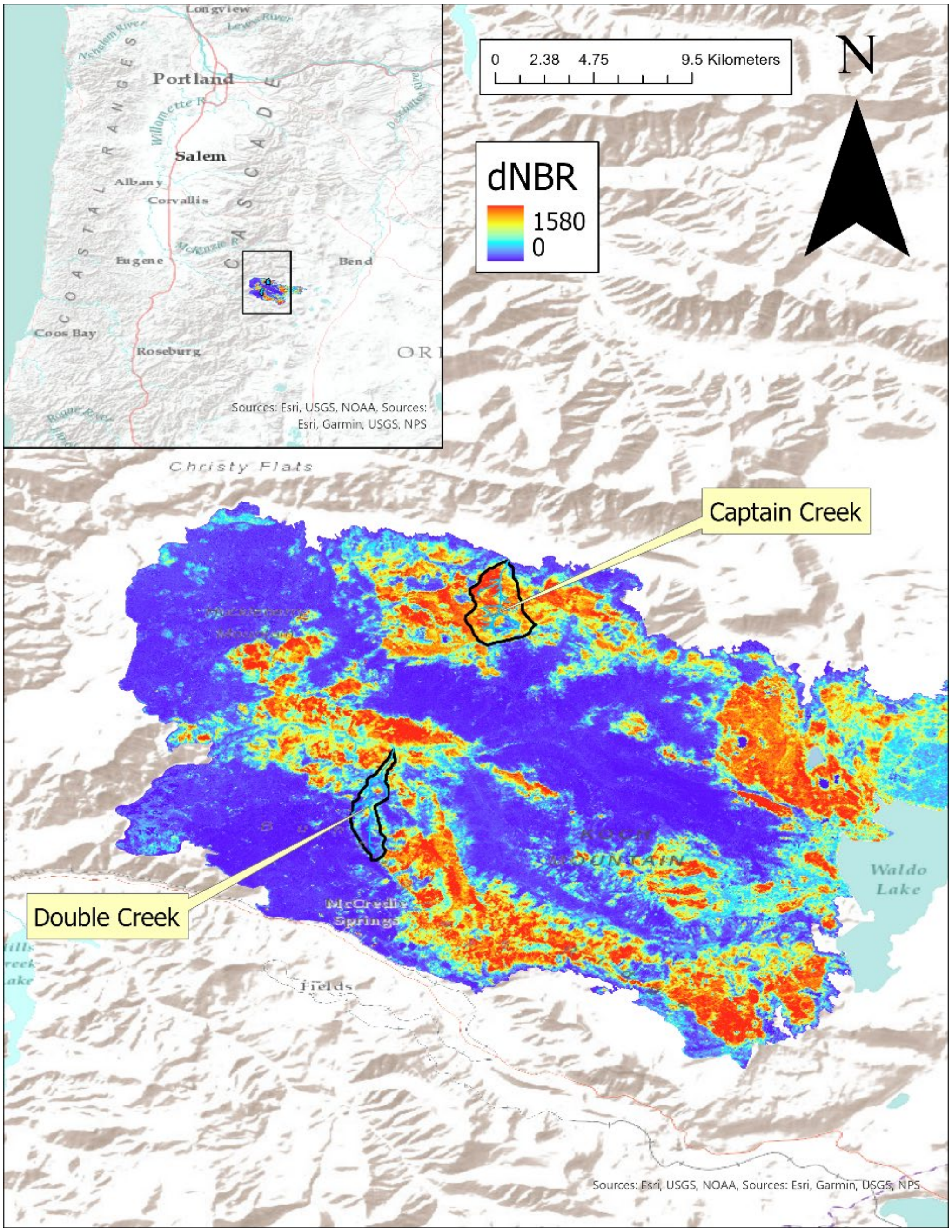

Figure 1. Site Overview. Burn severity of the Cedar Creek fire and the two selected watersheds, Double Creek and Captain Creek.

Data Sources

Figure 2: Table 1. Data sources with units, map projections, and web addresses.

	Units	Projection	Source
Oregon 10m DEM	Feet (vertical)	NAD 1983 Oregon Statewide Lambert	ftp.gis.oregon.gov - /framework/elevation/DEM/Statewide_Filegeodatabase/
dNBR	Meters	Albers Conical Projection	https://www.mtbs.gov/direct-download
Road Network	Feet	NAD 1983 Oregon Statewide Lambert	https://spatialdata.oregonexplorer.info/geoportal/details;id=4376d18d31904356b004e90e9e60b4af

Unburned areas on dNBR maps can have negative values due to vegetation growth (especially in clear cut areas). So that these negative values don't skew the results, they were reclassified to 0 to indicate unburned condition using the Con tool.

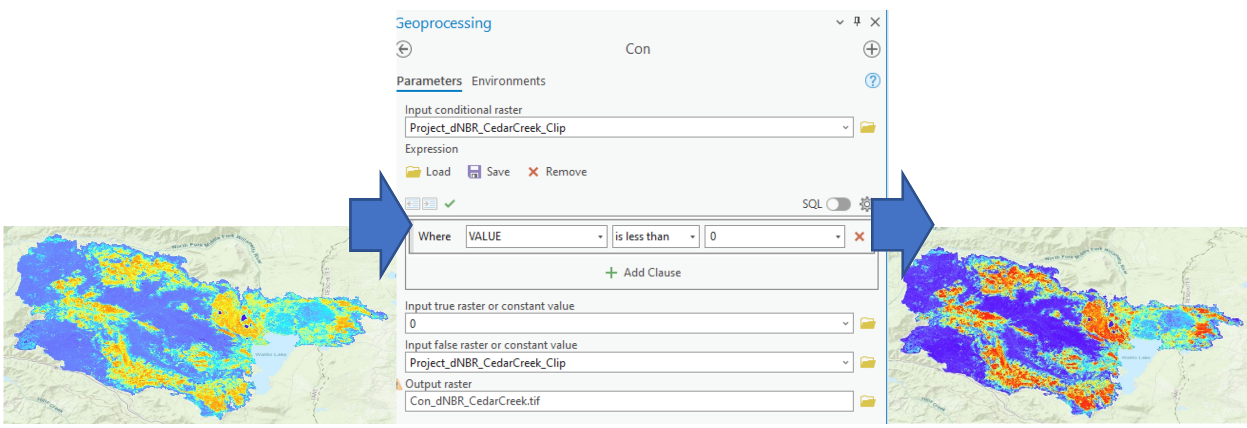

Figure 3. Reclassification of negative dNBR values using the Con Tool.

Watershed Delineation

To properly delineate watersheds from a DEM, I created a model in the model builder. The steps taken were to clip DEM to the burn boundary with a 10 km buffer, fill any sinks with the fill tool, calculate flow direction, then flow accumulation. The flow accumulation raster was used with the gaging station location in the Snap Pour Point tool to find the nearest pour point, which was then used with the flow direction raster to delineate the watershed raster. Finally, the watershed raster was converted to a polygon with Raster to Polygon.

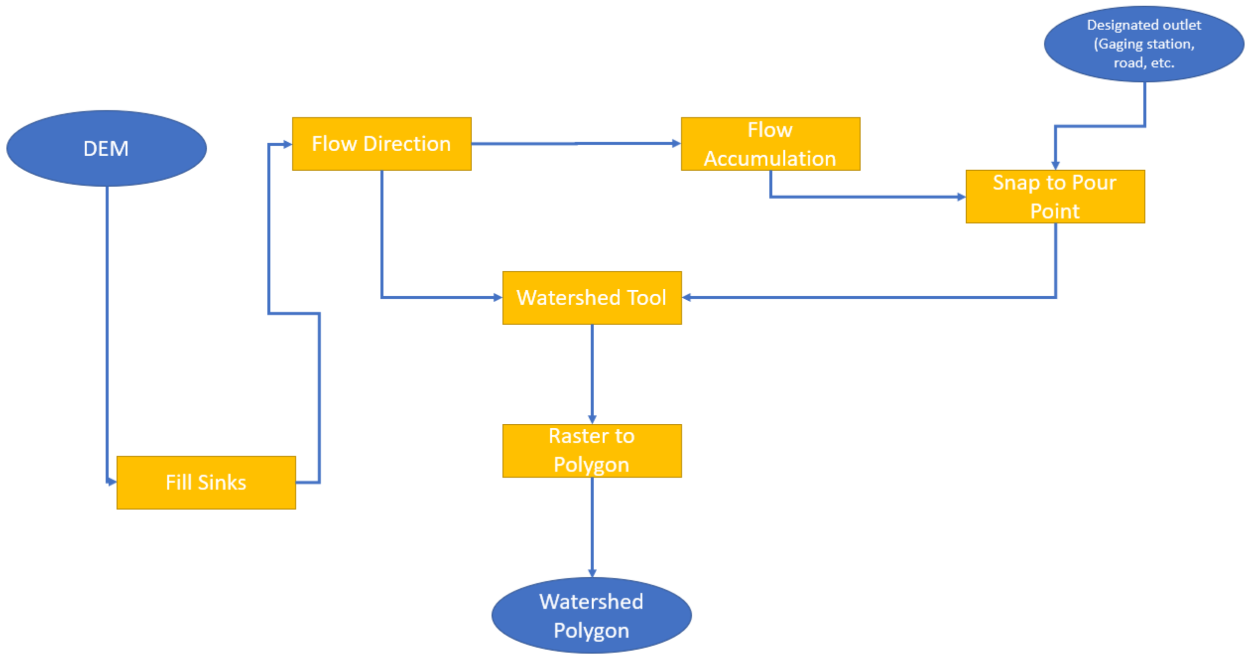

Figure 4. Watershed delineation workflow diagram. Blue ellipses indicate raster or polygon file, yellow rectangles indicate geoprocessing actions.

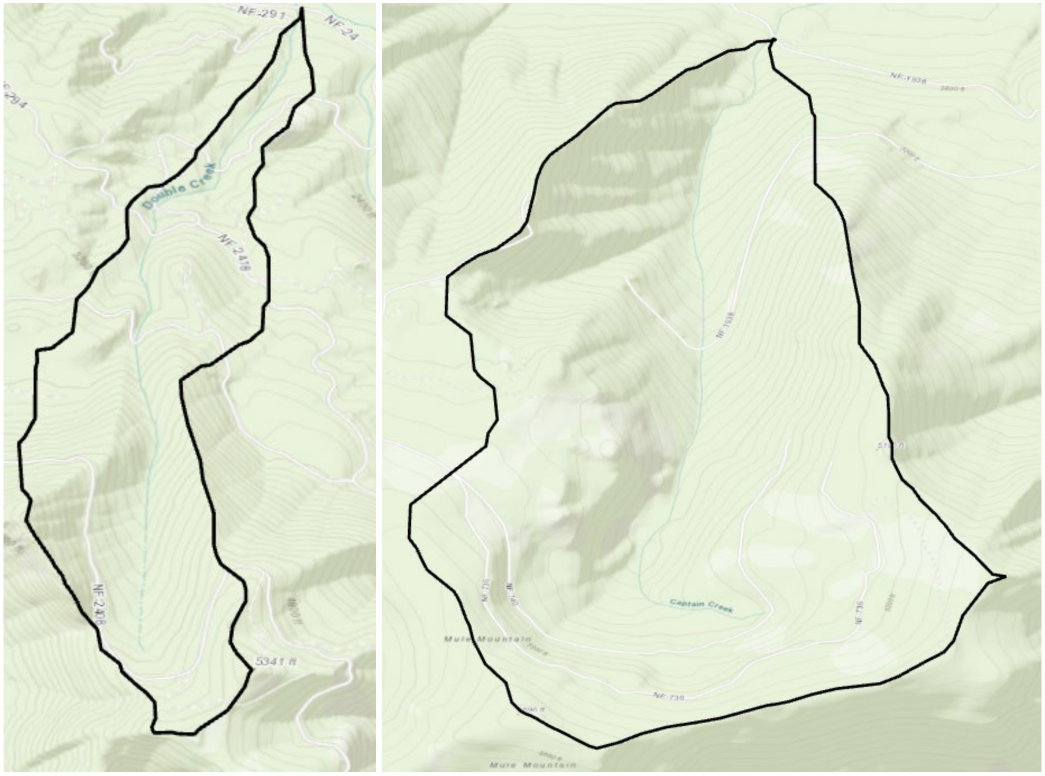

Figure 5. Results of watershed delineation. Left is Double Creek and right is Captain Creek.

Topographic Wetness Index Calculation

Topographic Wetness Index (TWI) is calculated for each cell according to the equation $TWI = ln\frac{scaled\ flow\ accumulation}{\tan{(slope)}}$. From a DEM, this can be calculated by calculating the flow direction, the flow accumulation, then scaled flow accumulation, as well as slope using tools in ArcGIS. The raster calculator with the above equation as the expression can then be used to calculated TWI.

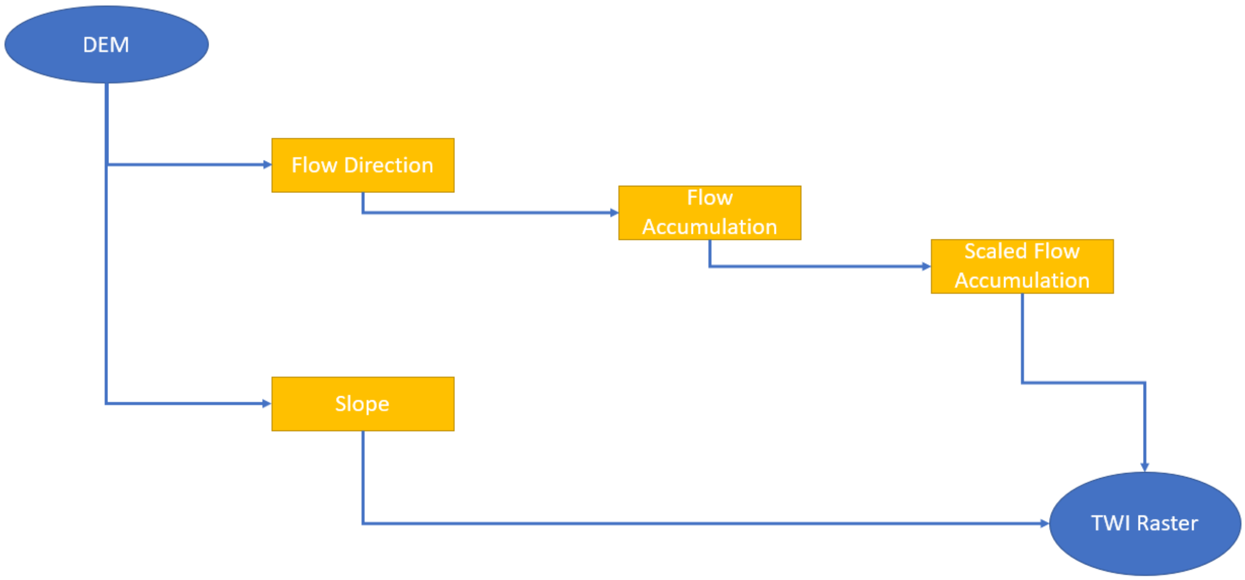

Figure 6. TWI raster workflow diagram. Blue ellipses indicate raster or polygon file, yellow rectangles indicate geoprocessing actions.

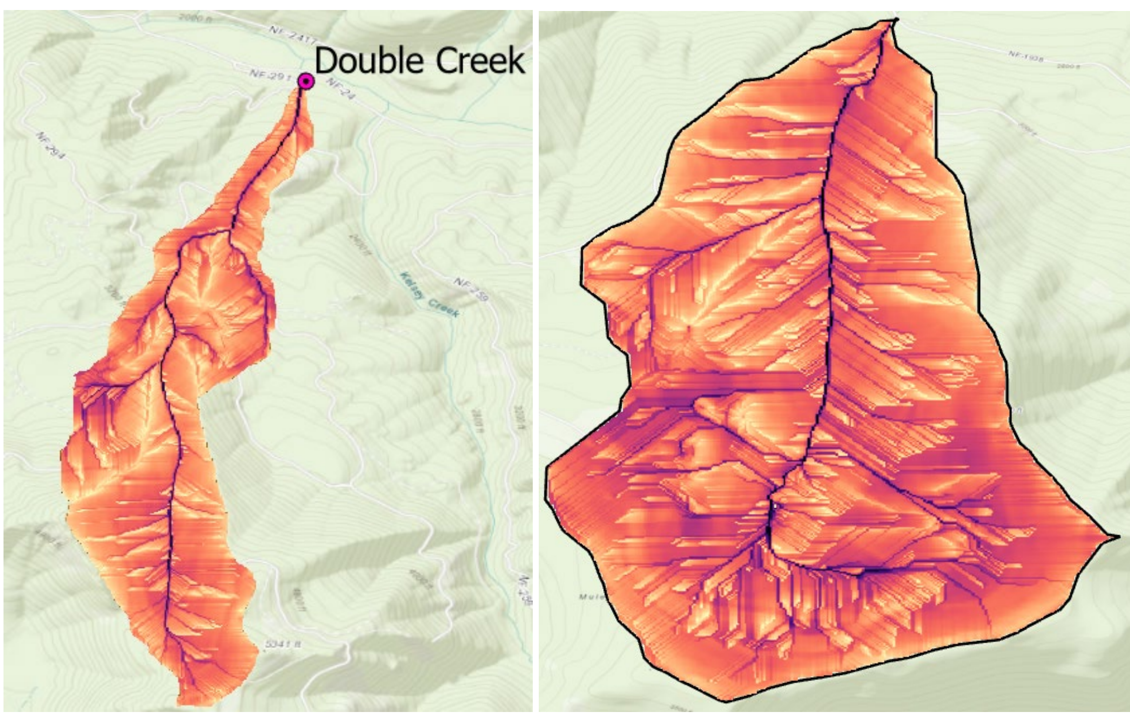

Figure 7. Topographic Wetness Index rasters for each watershed. Left is Double Creek, right is Captain Creek. Darker colors indicate higher TWI while lighter colors are lower TWI.

Once the TWI had been calculated, the rasters were exported from ArcGIS as .tif files and loaded into R for further graphing and analysis using the Raster package.

To determine how much of the watershed could be sampled, the Con tool was used once again, this time on the slope raster to separate areas of the watershed that were greater or less than 25 degrees, the inclination angle at which measurements for the automated minidisc becomes unreliable. Some face cutting can be done to level sampling points in the "Too steep" areas, but their steepness may make accessing them by foot difficult.

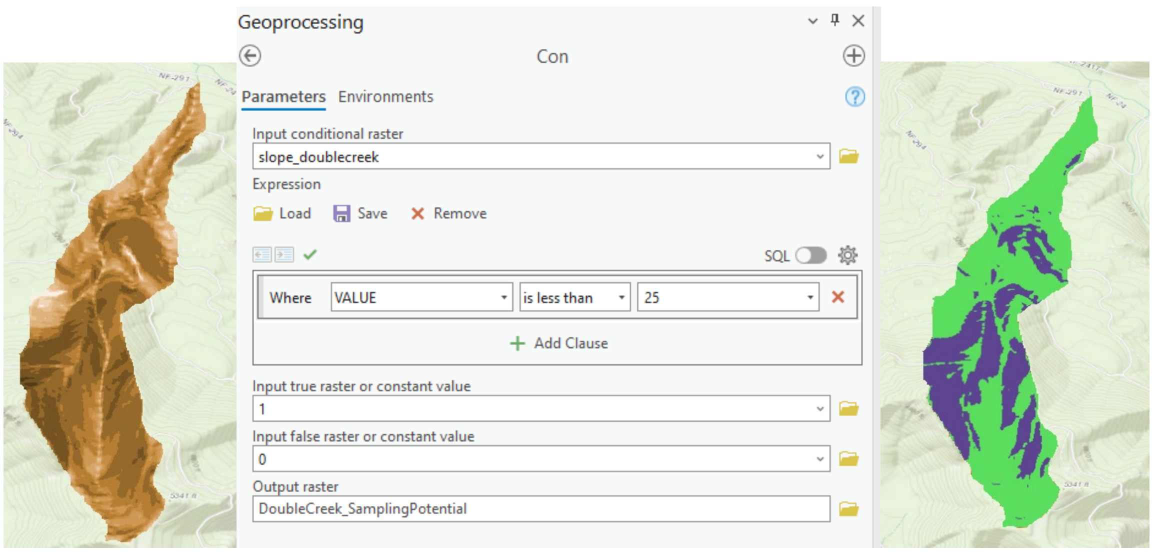

Figure 8. Process of classifying watershed sampling viability.

Results

Topographic Wetness Index and slope were similar in both watersheds, with Captain Creek having slightly higher of both. Captain Creek has nearly double the area of Double Creek and has a greater mean dNBR. dNBR values of above 500 are generally considered "high-severity", which means that the hydrology of this watershed was likely heavily impacted by the fire.

Figure 9. Table 2. Watershed Characteristics

	DOUBLE CREEK	CAPTAIN CREEK
AREA (HA)	361.1	601.6
MEAN SLOPE	21.0	23
SLOPE STANDARD DEVIATION	8.4	10.4
ELEVATION (M)	1181.7	1377.1
TOPOGRAPHIC WETNESS INDEX	6.95	7.1
DNBR	276	797

Burn Severity and TWI

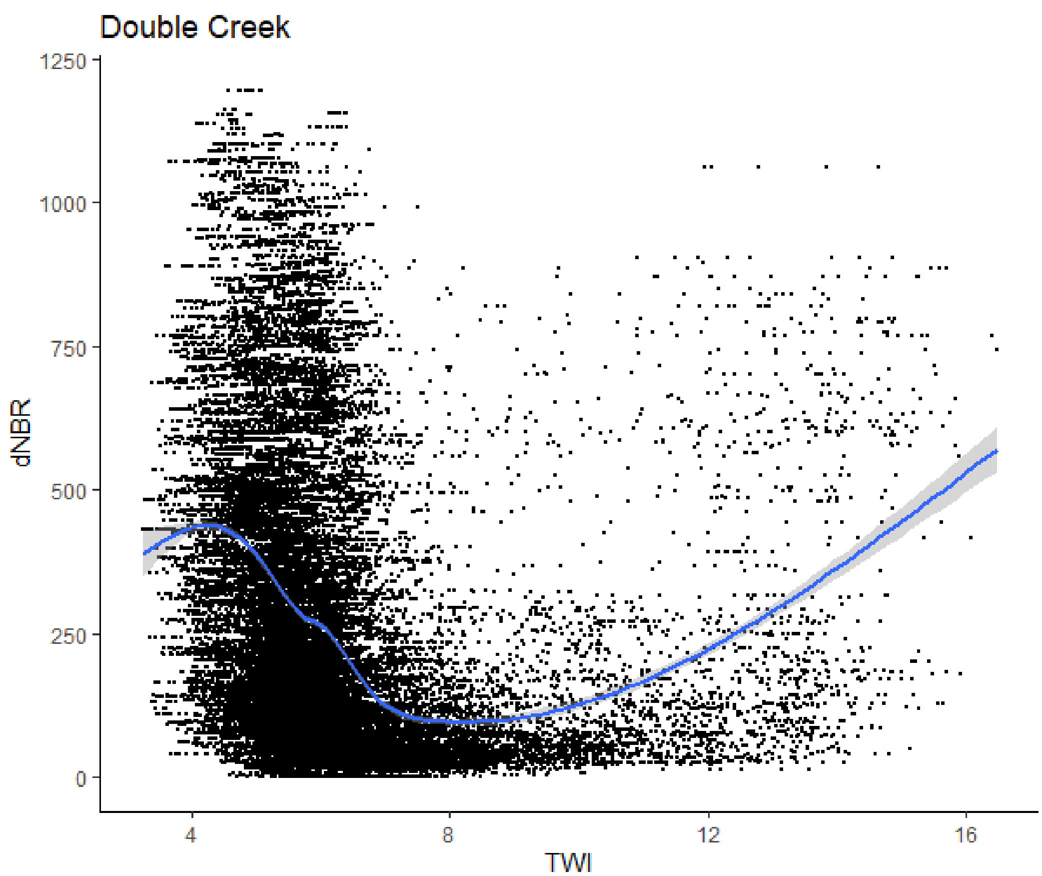

Figure 10. Scatterplot of TWI and dNBR for Double Creek. Blue line is the smoothed conditional mean, with grey area being the confidence interval.

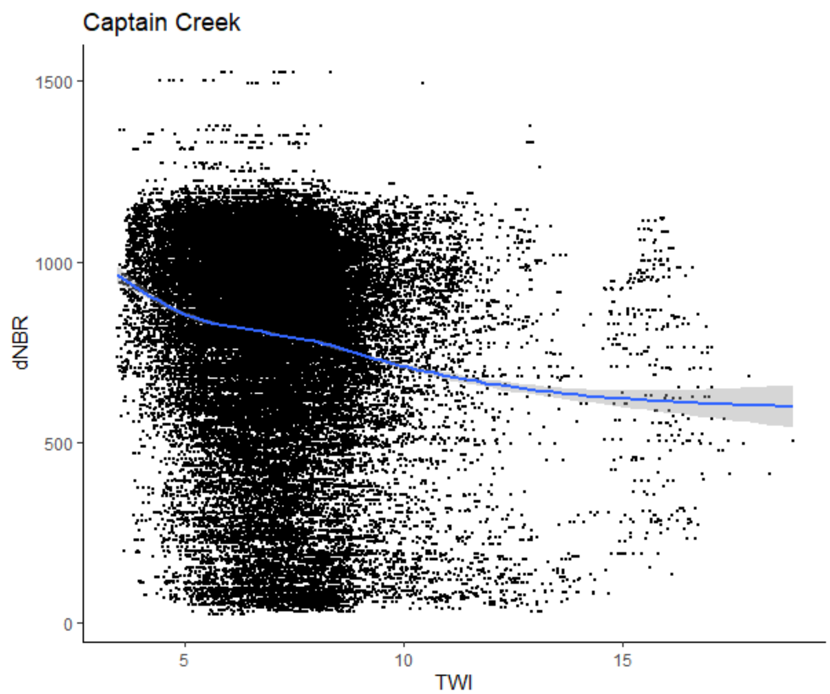

Figure 11. Scatterplot of TWI and dNBR for Captain Creek. Blue line is the smoothed conditional mean, with grey area being the confidence interval.

The correlation between Topographic Wetness Index and dNBR are very tenuous. There appears to be a consistent decrease of dNBR at TWI's between 4 and 8 in both watersheds, but in Double Creek dNBR increases again at higher TWI. This may have been due to several factors, such the direction of approach of the fire, the fact that a substantial portion of the watershed remained unburned, chimney effect winds carrying flames through the lower positions first, or simply because of coincidence due to the fact that a vanishingly small portion of the watershed has TWI values that high. In Captain Creek, the decrease appears to be shallow but relatively consistent, likely due to the fact that all of the watershed above the road as delineated here was burned to some extent (dNBR minimum of 23).

Potential Sampling Areas

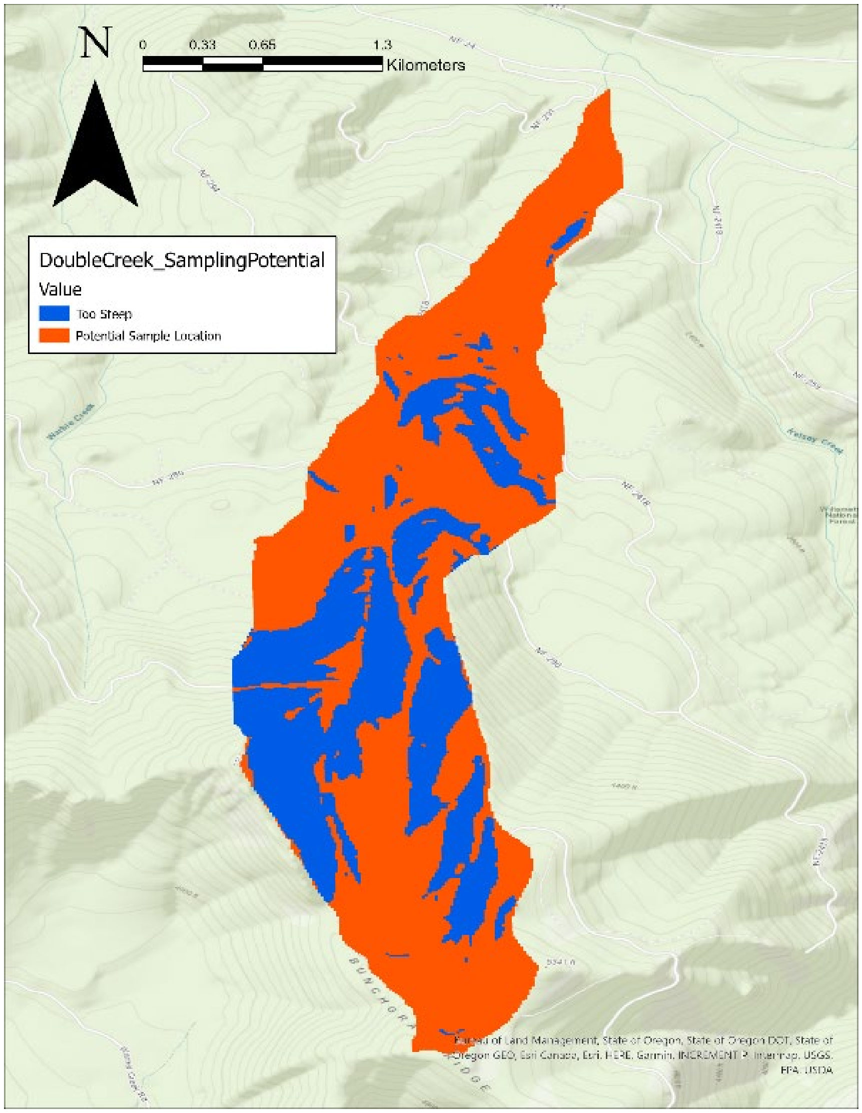

Figure 12. Sampling Potential of the Double Creek Watershed. Orange areas indicate viable sampling areas, whereas blue areas are too steep without site preparation.

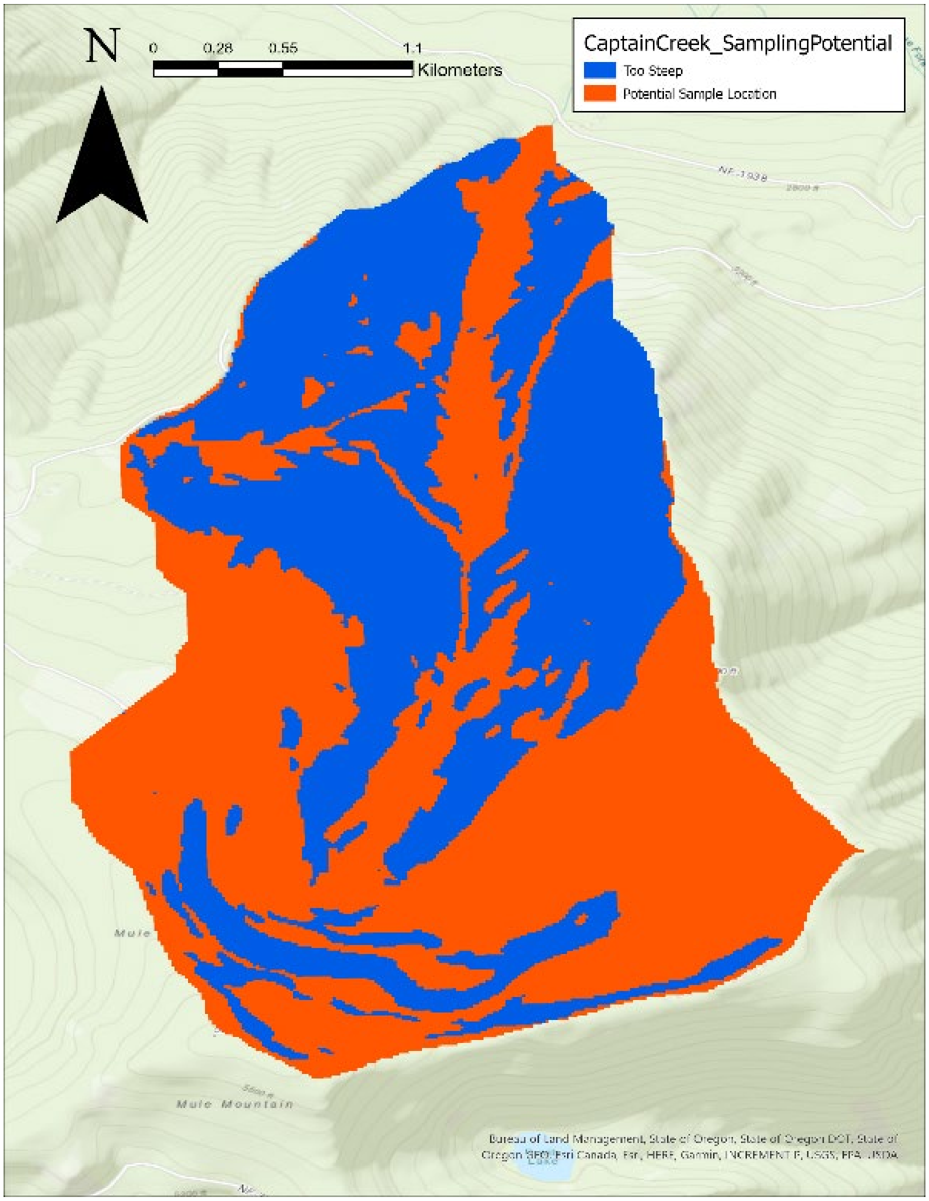

Figure 13. Sampling Potential of the Captain Creek Watershed. Orange areas indicate viable sampling areas, whereas blue areas are too steep without site preparation.

Discussion & Conclusions

Overall, the Captain Creek watershed was much larger and had more steep areas than the Double Creek watershed. This would make a field sampling campaign that covers the entire watershed much more difficult. However, the extreme extent to which it of it burned would likely yield very interesting results of soil hydraulic properties at a spatial scale and contrast more with an unburned reference watershed than Double Creek would. The spatial patterning of burn severity was very weakly associated with Topographic Wetness Index in both watersheds, which is somewhat unexpected. However, fire behavior can be very complex, and potential antecedent fuel moisture and fuel types may not play such a big role when other factors overwhelm them. To further investigate the spatial patterns of burn severity, a larger scale with more watersheds that includes robust multivariate analysis including a range of topographic factors and fuel types must be done. Factoring weather conditions at and preceding the time of the fire should also be included in a robust model.

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