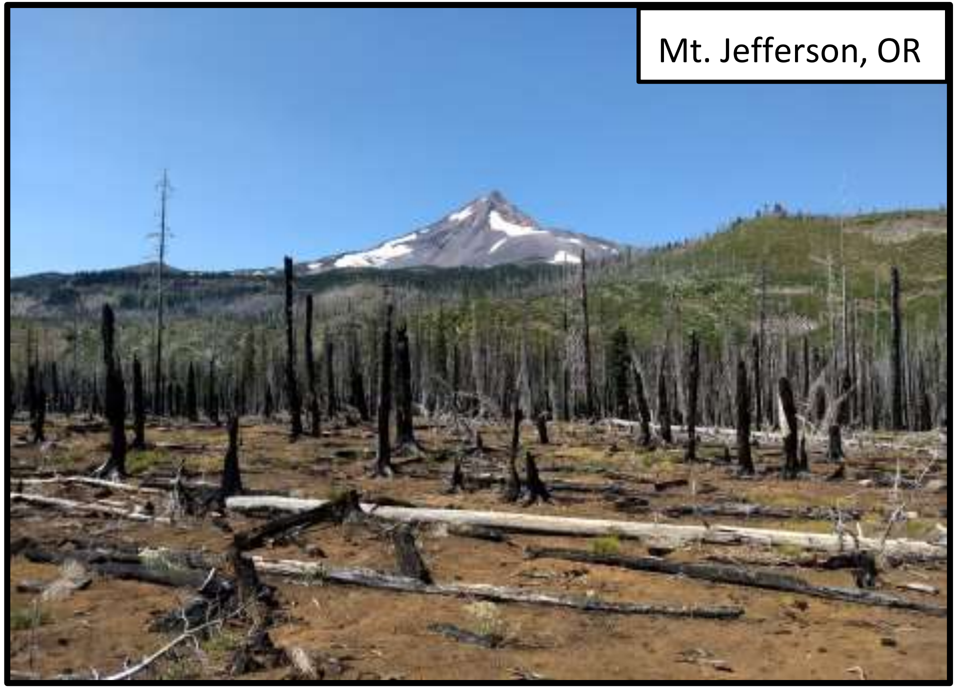
Sebastian Busby
GEOG 593 - FALL 2018

Project Abstract

Topography plays an important role in influencing the behavior of wildfires in forested landscapes. Unlike other factors that change over time (e.g. climate, weather, fuel aridity), topography is relatively static and therefore easier to quantify as an influential factor. Within recently field sampled wildfire perimeters on Mt. Adams, WA and Mt. Jefferson, OR, spatially derived burn severity (RdNBR) was compared to five measures of topography derived from a Digital Elevation Model (DEM) at a spatial scale of 30m. These topographic variables included elevation, slope, Heat Load Index (HLI), Topographic Wetness Index (TWI), and Topographic Roughness Index (TRI). Cell by cell correlation between variables was explored using a correlation matrix in R. Topographic variables were unsurprisingly at least moderately collinear. To account for geographic relationships, a limited number of Geographically Weighted Regression (GWR) models were developed using ArcGIS. Among the two field sites, the TWI GWR model best fit the data and had the highest R2 values (0.92, 0.83). TWI is a steady-state wetness index that indicates where water is most likely to be funneled to and pool in. Intuitively, forest stands with a high moisture content during a fire are less likely to catch fire or burn at high severities. Within these field sites, the TWI appears to be the best topographic predictor of wildfire burn severity.

Keywords: Wildfire, Topography, Burn Severity, Heat Load Index, Topographic Roughness Index, Topographic Wetness Index, Central Cascades, Vegetation Mortality, Forest Regeneration, RdNBR.

Can Wildfire Burn Severity be Explained by Measures of Topography?



Sebastian Busby - DTA Fall 2018

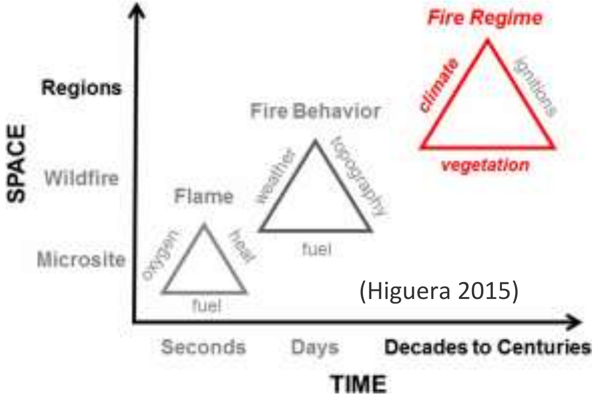
Why do some burned area have nearby live trees, and others don’t?



➔ No nearby live trees (seed source) = poor post-fire tree regeneration

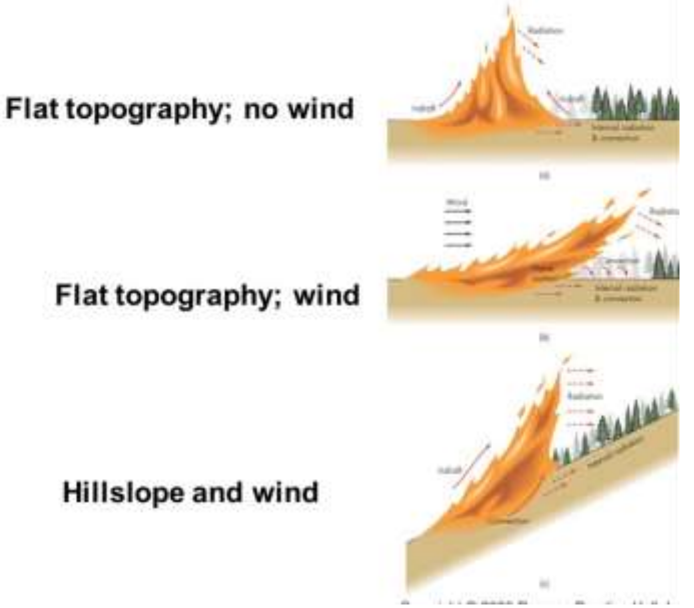
Drivers of Wildfire Burn Severity
(Conceptual Understanding)

1. **Pre-fire Climate**
   a. Winter snowpack, Spring/Summer temperature and precipitation
2. **Weather Conditions During Fire**
   a. Temperature, precipitation, and active winds
3. **Forest Composition**
   a. Certain vegetation is more or less flammable - inhibit or spread fire
4. **Forest Fuel Density**
   a. How dense is vegetation pre-fire; generally more fuel = more fire
5. **Topographic Factors**
   a. Static landscape properties that influence all of the above factors



(Higuera 2015)

Influence of Topography



Topography influences wildfire behavior through:

1. Convective funneling of hot air masses
2. Buffer or funnel for wind
3. Alters the flow and accumulation of precipitation runoff
4. Alters soil and vegetation moisture (slope, runoff)
5. Aspect & Slope alter solar radiation potential (site wetness)

Research Methods

For my field research areas on Mt. Adams and Mt. Jefferson:

1. Derive wildfire burn severity (RDNBR) as my dependant variable from MTBS data (30m resolution)

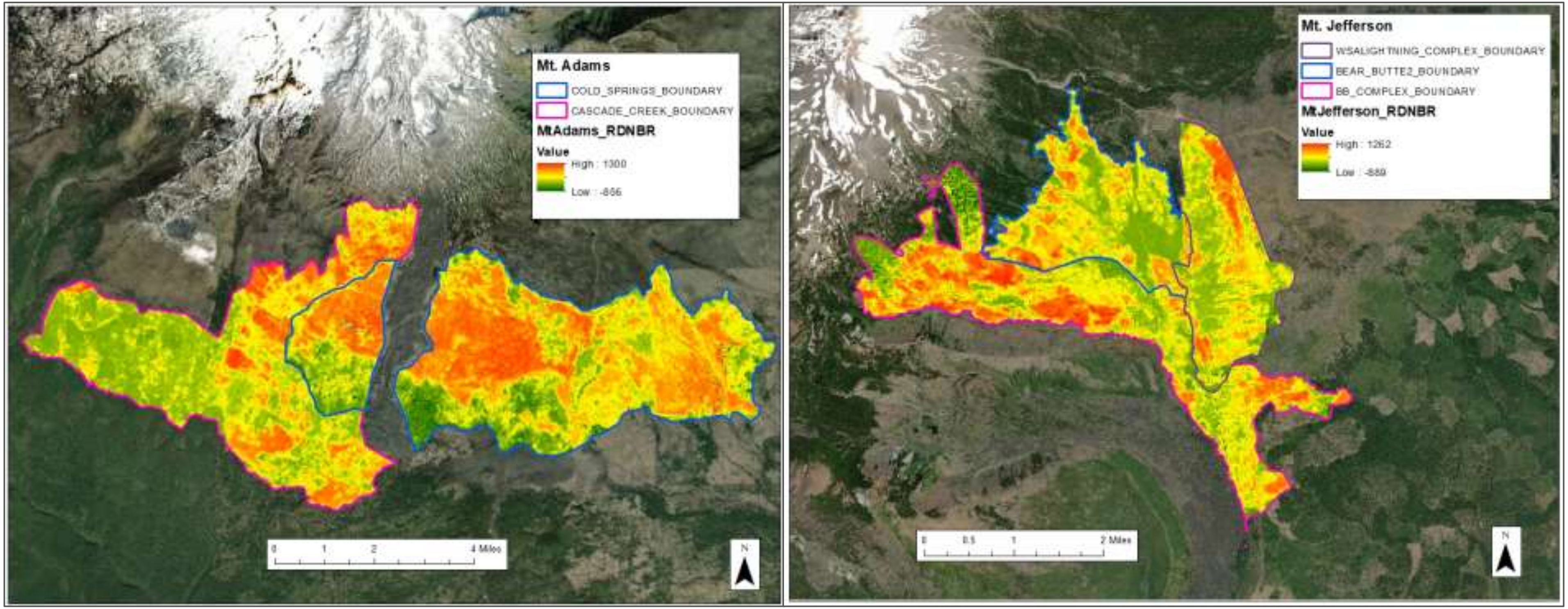
2. Derive topographic explanatory variables from a DEM that may conceptually explain burn severity
   a. Elevation
   b. Slope
   c. Heat Load Index (HLI)
   d. Topographic Wetness Index (TWI)
   e. Topographic Ruggedness Index (TRI)

3. Mask all layers to burn perimeters

4. Explore variable correlation using a correlation matrix in R

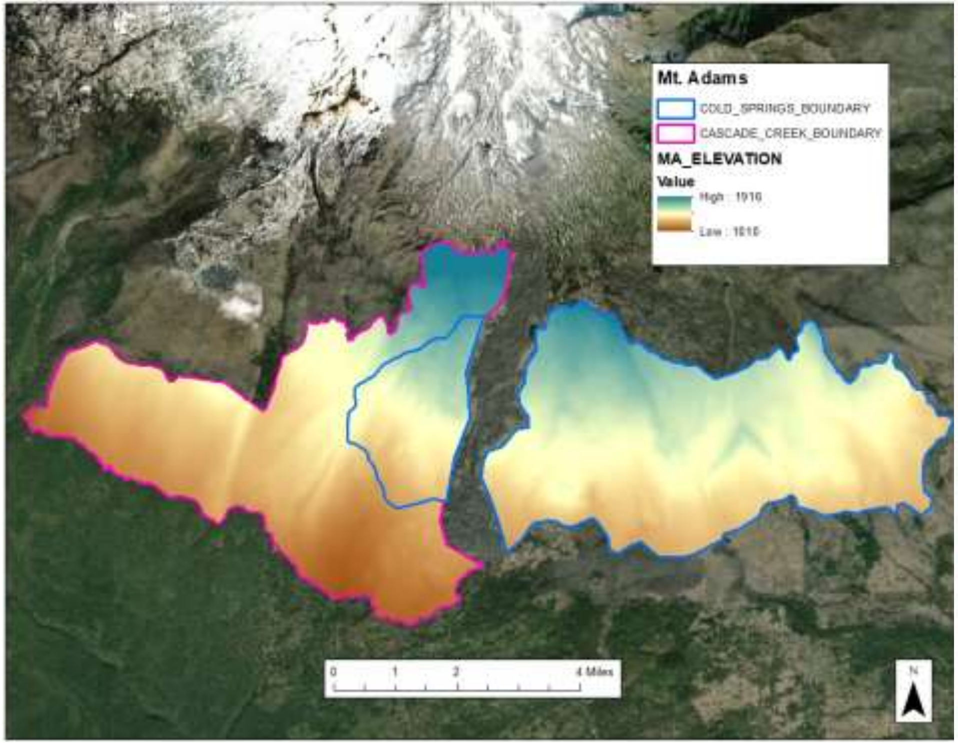
5. Develop Geographically Weighted Regression (GWR) models in ArcGIS

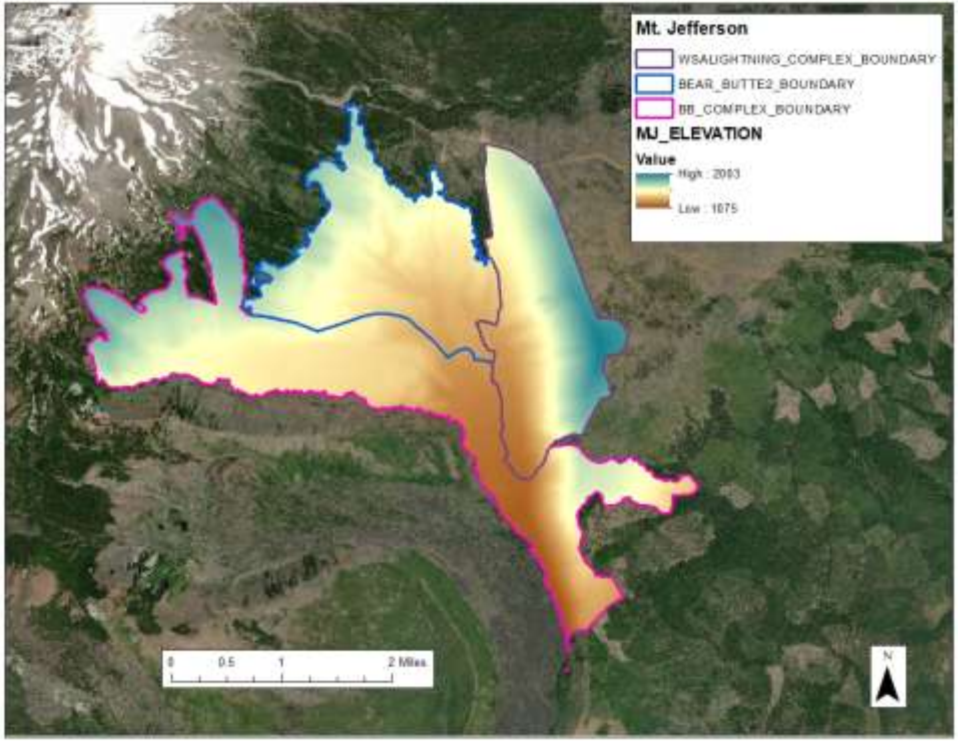
Relativized differenced Normalized Burn Ratio (RDNBR)
Wildfire Burn Severity metric



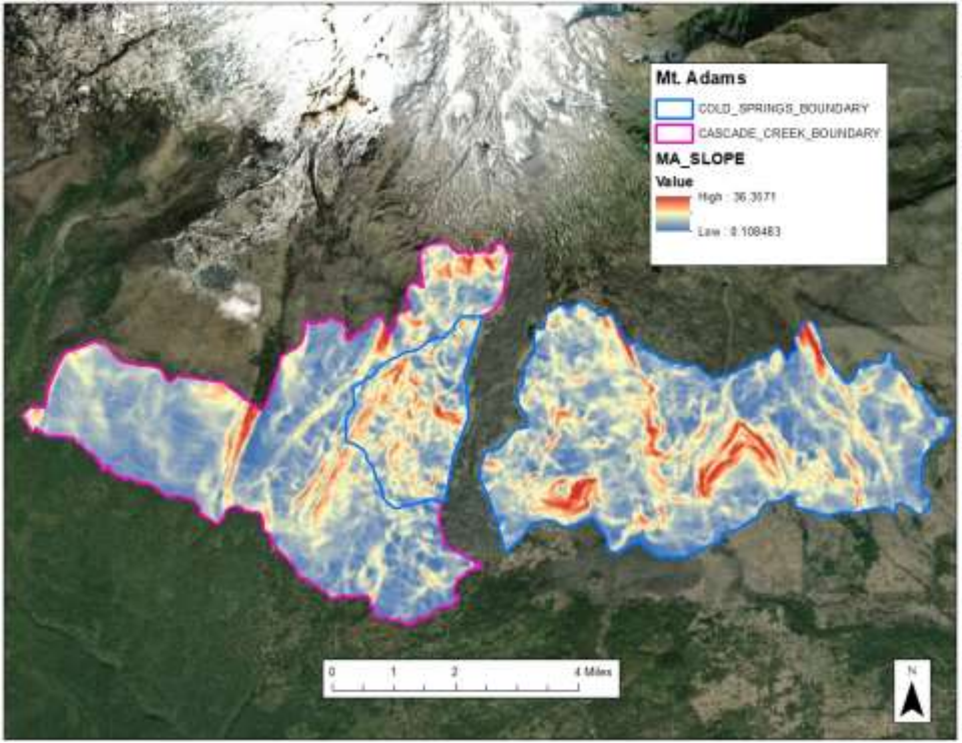
(Eidenshink et al. 2007)

Elevation (m)

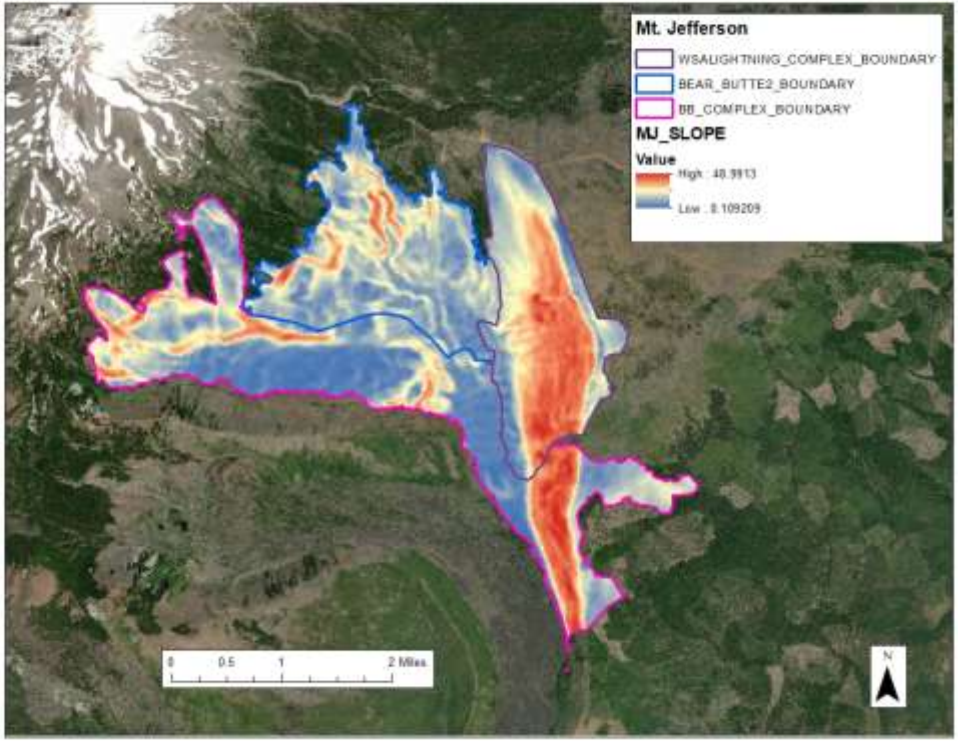

Mt. Adams
COLD_SPRINGS_BOUNDARY
CASCADE_CREEK_BOUNDARY
MA_ELEVATION
Value
High : 1910
Low : 1010
0 1 2 4 Miles
N


Mt. Jefferson
WSALIGHTNING_COMPLEX_BOUNDARY
BEAR_BUTTE2_BOUNDARY
BB_COMPLEX_BOUNDARY
MJ_ELEVATION
Value
High : 2003
Low : 1075
0 0.5 1 2 Miles
N

Slope (°)

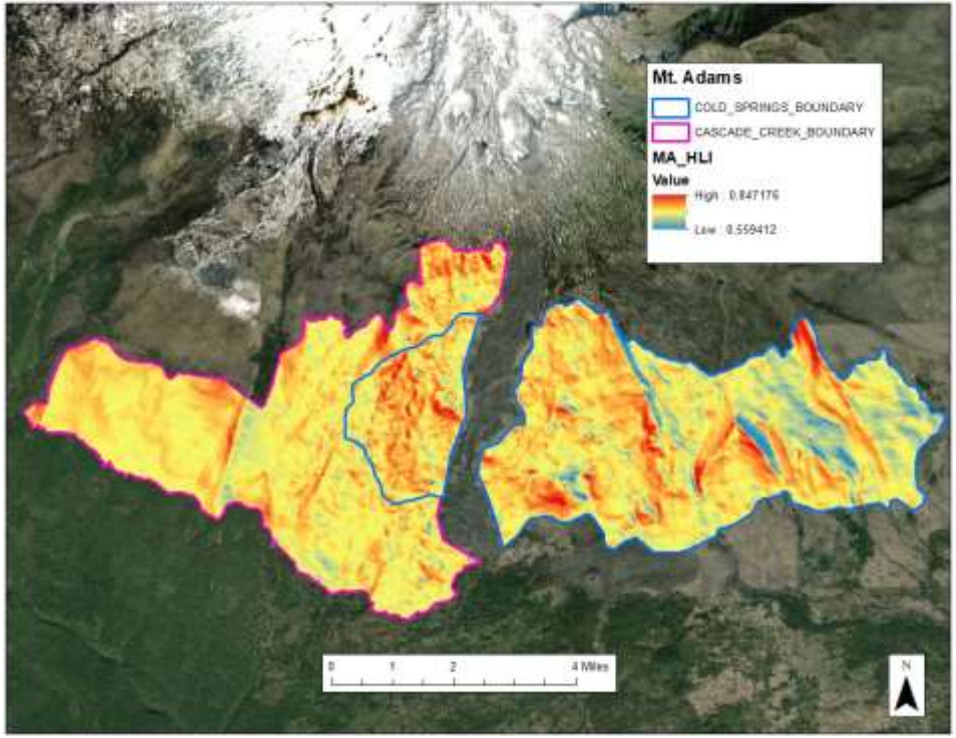


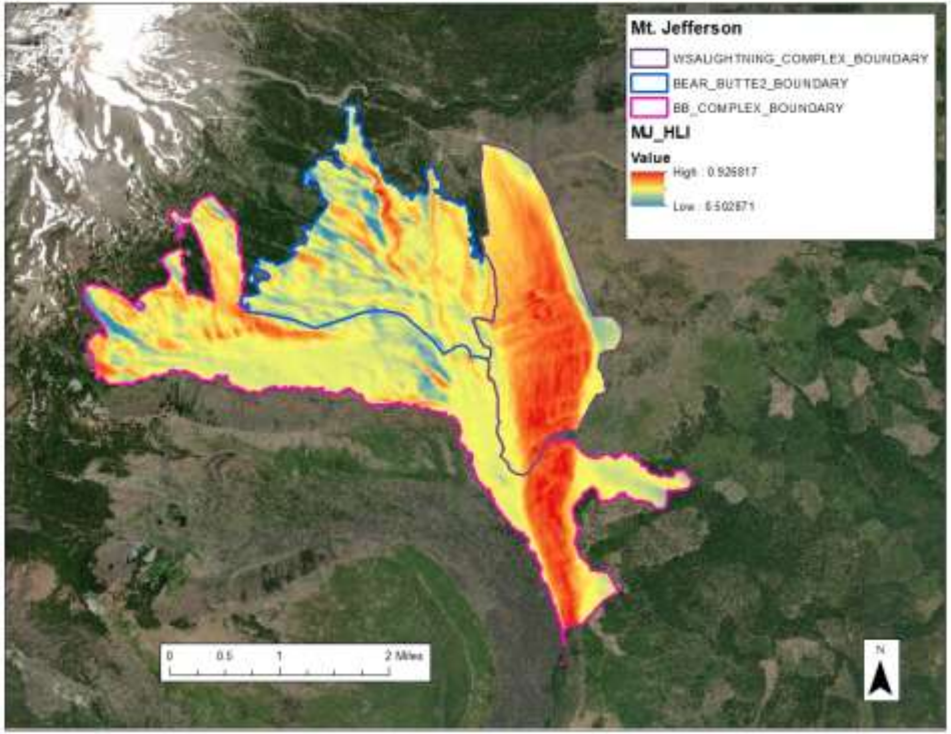
Mt. Adams
COLD_SPRINGS_BOUNDARY
CASCADE_CREEK_BOUNDARY
MA_SLOPE
Value
High : 36.3571
Low : 0.108483
0 1 2 4 Miles
N



Mt. Jefferson
WSALIGHTNING_COMPLEX_BOUNDARY
BEAR_BUTTE2_BOUNDARY
BB_COMPLEX_BOUNDARY
MJ_SLOPE
Value
High : 48.9913
Low : 0.109209
0 0.5 1 2 Miles
N

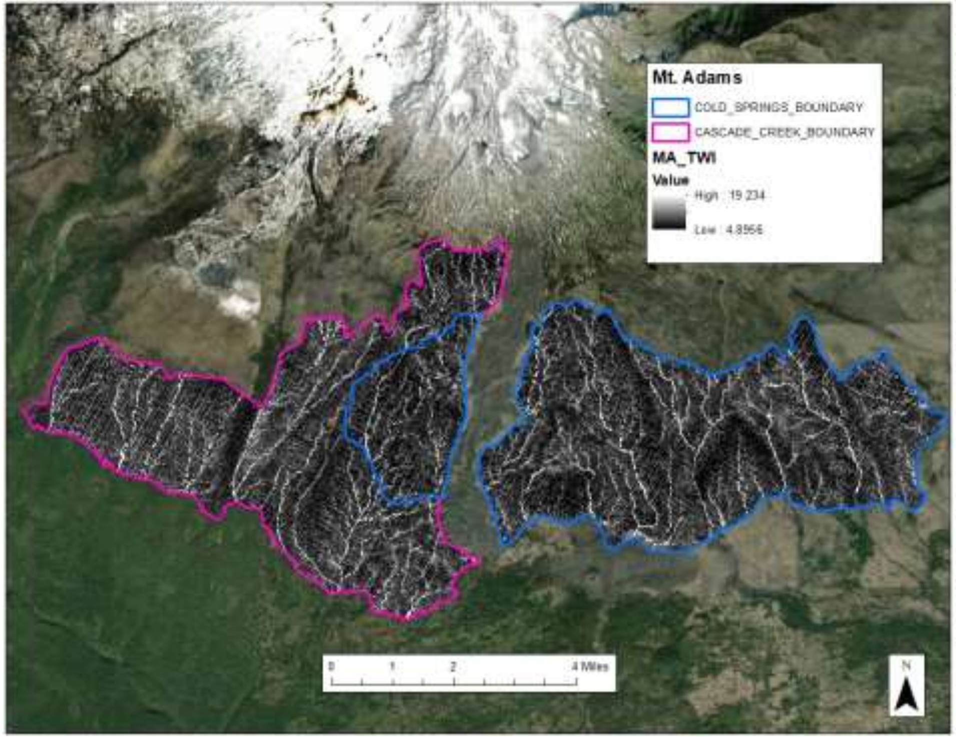
Heat Load Index (HLI)

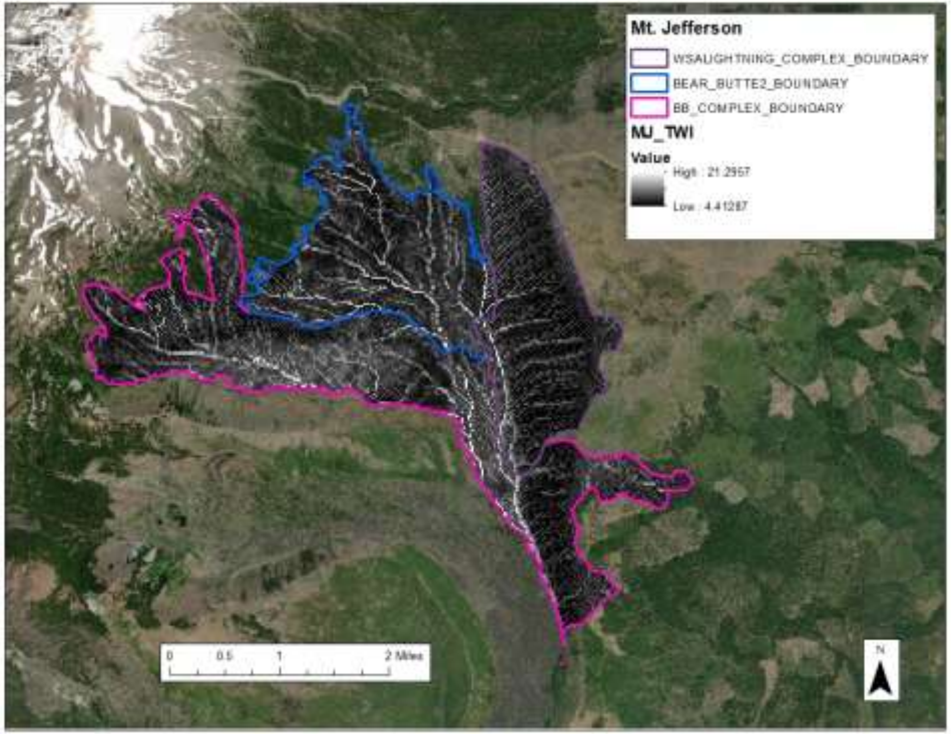




(McCune and Keon 2002)

Topographic Wetness Index (TWI)

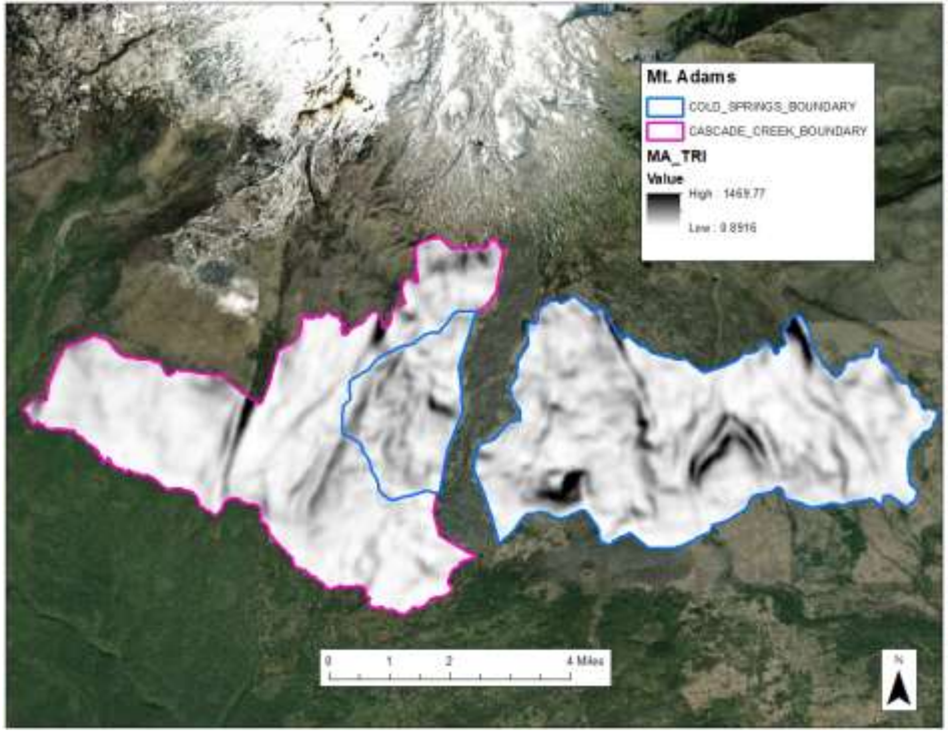


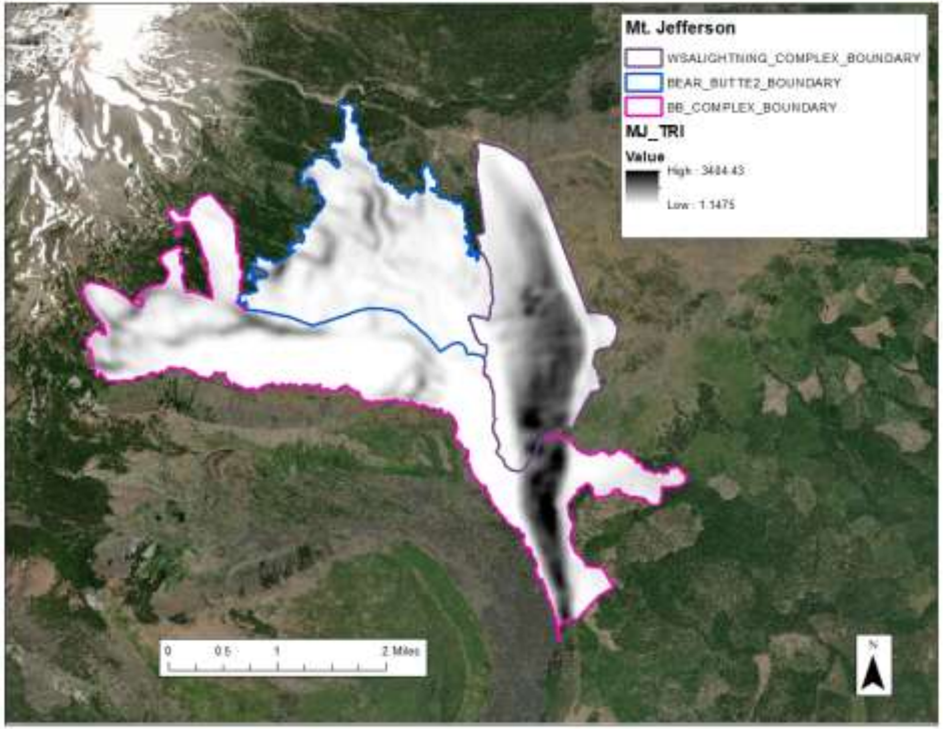


(Beven and Kirkby 1979)

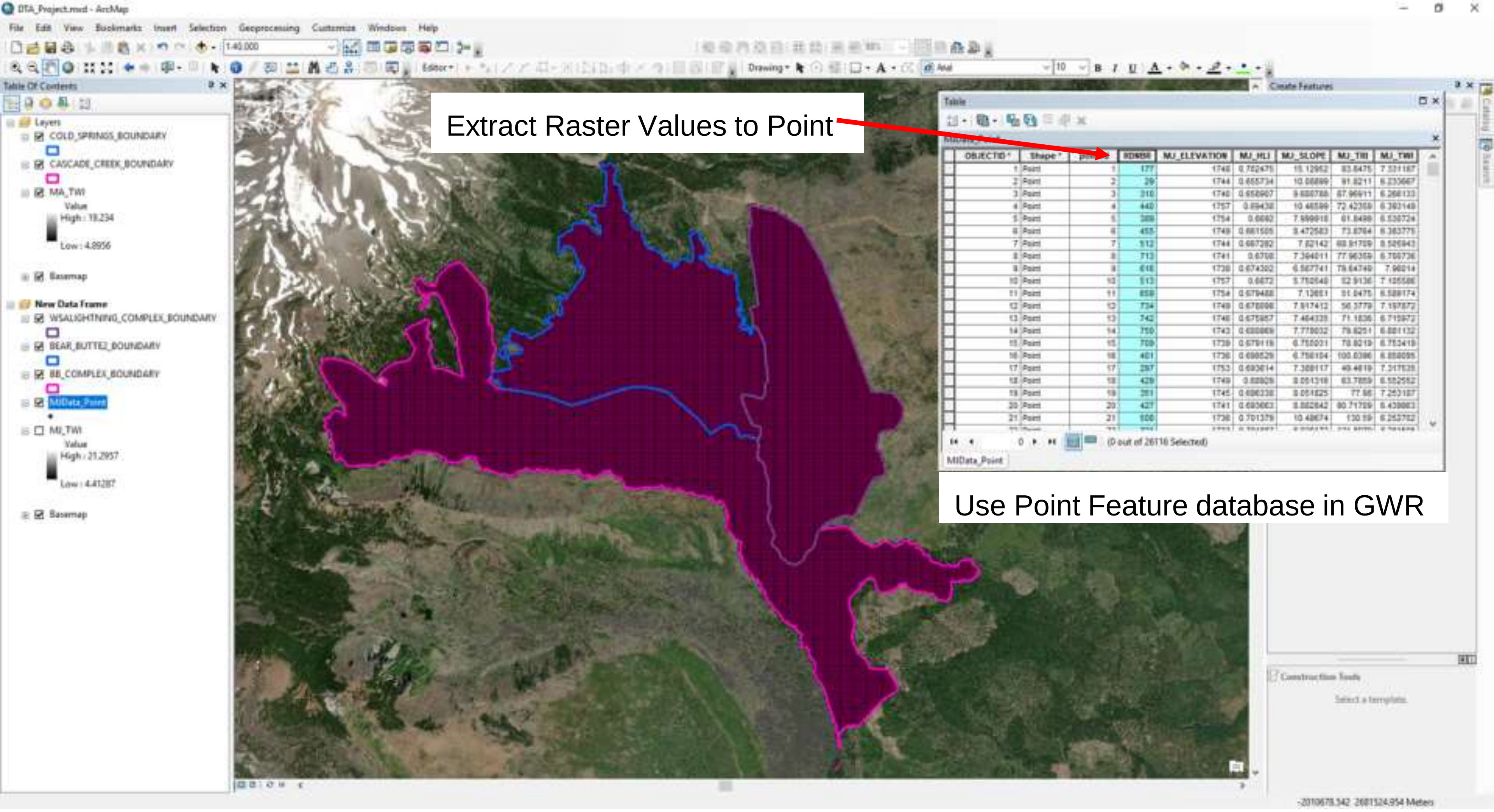
Topographic Roughness Index (TRI)

10x10 window (9ha)





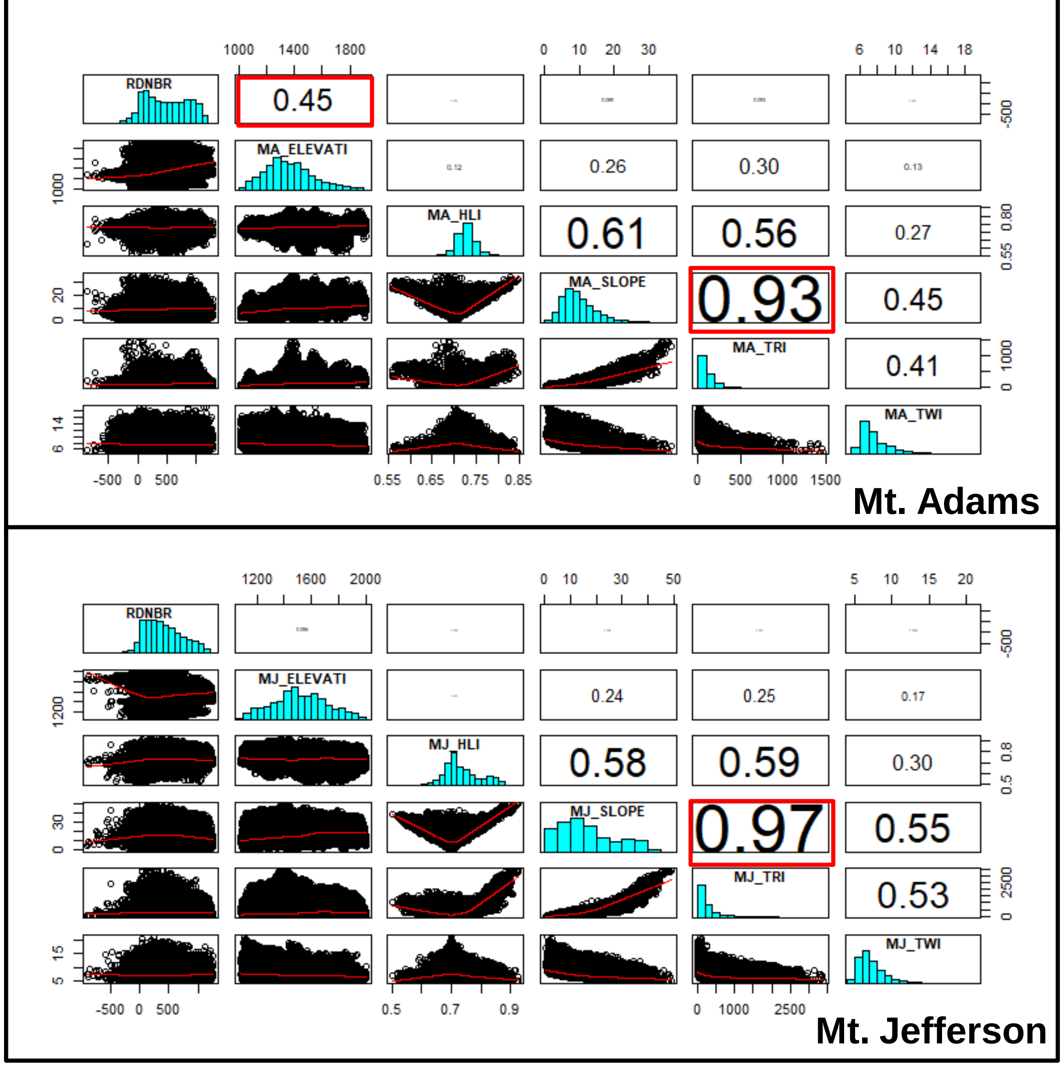
(Riley et al. 1999; Krawchuk et al. 2016)


Extract Raster Values to Point
Use Point Feature database in GWR
DTA_Project.mxd - ArcMap
Table Of Contents
Layers
COLD_SPRINGS_BOUNDARY
CASCADE_CREEK_BOUNDARY
MA_TWI
High : 19.234
Low : 4.8956
Basemap
New Data Frame
WSALIGHTNING_COMPLEX_BOUNDARY
BEAR_BUTTE2_BOUNDARY
BB_COMPLEX_BOUNDARY
MIData_Point
MI_TWI
High : 21.2957
Low : 4.41287
Basemap
Table
OBJECTID
Shape
MJ_ELEVATION
MJ_HLI
MJ_SLOPE
MJ_TWI
(0 out of 26116 Selected)
MIData_Point
Create Features
Construction Tools

Correlation Matrix

- Elevation has a weak correlation with RDNBR on Mt. Adams, not Mt. Jefferson
- No other variables seem to have a correlation with RDNBR
- Slope and TRI are highly collinear
- Other topographic variables have moderate collinearity

➔ Collinearity not surprising, all measures of topography



Geographically Weighted Regression

Issues:

- GWR would not run with some of the predictor variables; Elevation, HLI, Slope
- Poor performance of the multiple regression models is likely due to collinearity of variables

Mt. Adams	Performance	Response	Predictor(s)	Sigma	AICc	R2	R2 Adj	Residual Squares
Model 1	#2	RDNBR	TRI	150	741,677	0.84	0.83	1,253,251,222
Model 2	#1	RDNBR	**TWI**	**115**	**715,833**	**0.92**	0.9	624,967,802
Model 3	#3	RDNBR	Slope	163	750,778	0.81	0.8	1,487,800,704
Model 4	#4	RDNBR	TWI + TRI	167	754,106	0.8	0.79	1,562,712,827
Mt. Jefferson	**Performance**	**Response**	**Predictor(s)**	**Sigma**	**AICc**	**R2**	**R2 Adj**	**Residual Squares**
Model 1	#2	RDNBR	TRI	207	353,019	0.58	0.58	1,115,989,903
Model 2	#1	RDNBR	**TWI**	**139**	**334,100**	**0.83**	0.81	439,417,900
Model 3	#3	RDNBR	TWI + TRI	213	354,415	0.56	0.55	1,170,892,586

Results:

- Across both field sites, the Topographic Wetness Index (TWI) produced the best GWR model and explained the most variance (R2) in wildfire burn severity.

Do These Results Make Sense?

Yes!

- TWI is a steady-state wetness index.
- Shows where water topographically is most likely to be funneled to and pool in.
- Forests stands with a high moisture content during a fire are much less likely to burn!
- Therefor high TWI values should relate to a lower RDNBR values.
- Take results with a grain of salt, non-topographic factors are important and can overpower influence of TWI.

References

- Beven, K.J.; Kirkby, M. J. (1979). "A physically based, variable contributing area model of basin hydrology". Hydrolological Science Bulletin. 24 (1): 43–69.
- Birch, D. S., P. Morgan, C. A. Kolden, J. T. Abatzoglou, G. K. Dillon, A. T. Hudak, and A. M. S. Smith. 2015. Vegetation, topography and daily weather influenced burn severity in central Idaho and western Montana forests. Ecosphere 6 (1):art17.
- Eidenshink, J., B. Schwind, K. Brewer, Z.-L. Zhu, B. Quayle, and S. Howard. 2007. A Project for Monitoring Trends in Burn Severity. Fire Ecology 3 (1):3–21.
- Riley, S. J., S. D. DeGloria and R. Elliot (1999). A terrain ruggedness index that quantifies topographic heterogeneity, Intermountain Journal of Sciences, vol. 5, No. 1-4,1999.
- Rogeau, M.-P., Q. Barber, and M.-A. Parisien. 2018. Effect of Topography on Persistent Fire Refugia of the Canadian Rocky Mountains. Forests 9 (6):285.
- Higuera, P. E. 2015. Taking time to consider the causes and consequences of large wildfires: Fig. 1. Proceedings of the National Academy of Sciences 112 (43):13137–13138.
- Krawchuk, M. A., S. L. Haire, J. Coop, M.-A. Parisien, E. Whitman, G. Chong, and C. Miller. 2016. Topographic and fire weather controls of fire refugia in forested ecosystems of northwestern North America. Ecosphere 7 (12):e01632.
- McCune, B., and D. Keon. 2002. Equations for potential annual direct incident radiation and heat load. Journal of vegetation science 13 (4):603–606.

Datasets

1. Burn Severity (RdNBR): Monitoring Trends in Burn Severity (MTBS)
2. 10m DEM: University of Washington (WA); Oregon Spatial Data Library (OR)