# Daily Fire Weather and Environmental Factors Influencing Burn Severity for 42 Forest Fires of Central Idaho and Western Montana, 2005-2011

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Donovan S. Birch[1], Penelope Morgan[1], Crystal A. Kolden[2], John T. Abatzoglou[2], Gregory K. Dillon[3], Andrew T. Hudak[4], and Alistair M.S. Smith[1]

[1] Dept. of Forest, Rangeland, and Fire Sciences, College of Natural Resources, University of Idaho, Moscow, ID; [2] Dept. of Geography, College of Science, University of Idaho, Moscow, ID; [3]USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, MT; [4] Rocky Mountain Research Station, USDA, Forest Service, Moscow, ID


## INTRODUCTION

- Extent and frequency of wildland fires in the western United States have increased with recent climate changes (Littell et al. 2009; Spracklen et al. 2009)
- High severity fires consume large amounts of vegetation (Keeley 2009) and have long-term ecological effects (Holden et al. 2009; Lentile et al. 2007)
- Burn severity is the degree of ecological change one year post fire (Lentile et al. 2006)
- Burn severity varies even when large areas (105– 5200 ha) burn in a day (Birch et al. 2013) which may be due to variations in topography and vegetation
- Differenced Normalized Burn Ratio (dNBR) can be used to infer burn severity in forested ecosystems (Hudak et al. 2007) despite limitations (Roy et al. 2006)
- Multiple environmental factors may interact to produce burn severity (Schoennagel et al. 2004; Dillon et al. 2011)

We expand on the work of Dillon et al. (2011) by examining how climate, weather, vegetation, and topography influence burn severity. Using daily fire IR perimeter maps we know what areas of 42 large forest fires of central Idaho and western Montana burned on given days. Using this information we are able to test how daily weather, including winds, and other factors influence dNBR. We expect local "bottom-up" factors to be more important than "top-down" influences on burn severity as hypothesized by Dillon et al. (2011).

### Question

**How do environmental factors, such as topography, fuels, climate, and daily weather, influence burn severity in forested systems?**

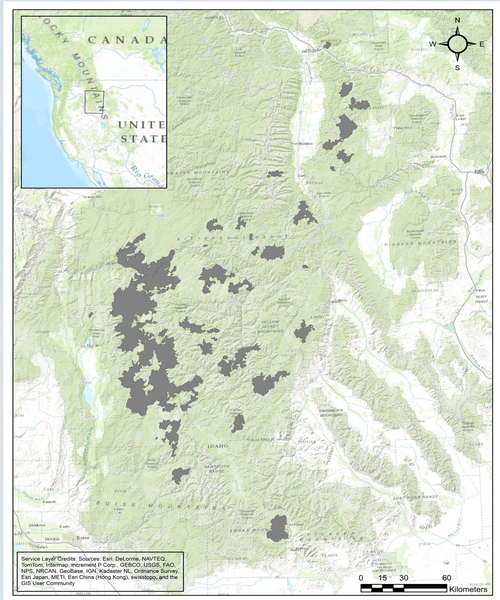



**Figure 1.** 42 fires from central Idaho and western Montana, 2005, 2006, 2007, and 2011. Fires selected based on availability of burn severity mapping and daily infrared perimeter maps. Total area burned: 532,000 ha.

## CONCLUSION AND FUTURE WORK

- Higher percent vegetation cover on steeper-northern aspects of cold forests had the greatest impact on changes of dNBR (Figure 4)
  - Holden et al. (2009) found similar influences of cold-wet-north facing slopes for the Gila Wilderness of the southwest
- Air (RH) and fuel (Duff and Fine Fuel) moistures as measured by daily weather and climate predictors also influence dNBR
  - Due to moisture of extinction these may limit smoldering combustion (Ferguson 2002) which has a large influence on burn severity (Sackett et al. 1993)
- Wind is not a large part of burn severity, though it influences fire intensity and spread (Bessie and Johnson 1995)
  - Dillon et al. (2011) found similar results
- Local "bottom-up" factors, including vegetation and topography, have more influence on burn severity than climate and weather even when large area burns in a day
- Limitations: Different scales of environmental variables
- Future Work:
  - Use a Model Improvement Ratio (MRI) to better select fewer predictor variables
  - Examine weather that occurs multiple days before specific areas burned
  - Use similar approach for non-forested areas, as predictor variables likely differ

**Value of this work**

- Use of fire progression mapping to better model fire growth using daily weather information
- Fire perimeter maps are regularly obtained for firefighting operations but seldom used in research; with them we know when areas burned
- Accuracy has not yet been established. We used a 30 m buffer to try to guarantee the area burned on a specific day

## METHODS

**Study Area**

- Central Idaho and western Montana, 2005 to 2007, 2011
- Fires with both 5 consecutive days of Infrared (IR) perimeter mapping data and burn severity (dNBR) mapped by the Monitoring Trends in Burn Severity project (MTBS)
- 42 large multi-day forest fires, sizes ranged from 128,000 to 280 ha (Figure 1)

**Data Selection**

- 47 preliminary variables, 12 correlated variables removed using Spearman's Rho > 0.75
- 35 predictor variables that might influence burn severity
  - 9 - Weather
  - 11 - Topography
  - 6 - Vegetation
  - 9 - Climate
- 10,819 randomly sampled points across 111,397 ha of burned forest area within the known daily IR perimeters (Figure 2)
- Modeled (4km) daily weather observations (Abatzoglou 2011) (http://nimbus.cos.uidaho.edu/METDATA/)
- Climate data (4 km) were calculated as the percentile from daily weather observations for summer fire months July, August, and September from 1979 to 2013
- Vegetation characteristics obtained from Landfire data layers (30m)
- Topography from 30 m DEM

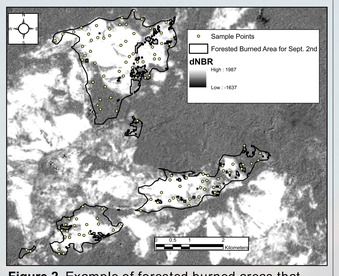



**Figure 2.** Example of forested burned areas that occurred on Sept. 2nd on the 2005 Burnt Strip Mountain Fire of central Idaho and randomly selected points.

**Analysis**

- Random Forest machine learning algorithm (Bremen 2001)
- Continuous dNBR as response variable (values ranged from -431 to 1218)
- 5 replicates of 1500 regression trees
- Initial model run then Optimum model
  - Optimum model was model with smallest number of predictor variables that was within 1 standard error of the initial model error
- Provides a "pseudo" $R^2$ [1 – Mean-Square-Error/ Variance (dNBR)]
- Importance rankings of predictor variables based on MSE
- Partial dependence plots
  - Show how values of each predictor variable influence burn severity

## RESULTS

- Pseudo $R^2$ = 0.42
- Optimum Random Forest model of 20 predictor variables
- Mix of Vegetation, Topography, Daily Weather, and Climate variables influence burn severity (Figure 3)
  - 3 - Vegetation variables
  - 5 - Topography variables
  - 5 - Weather variables
  - 7 - Climate variables
- Bottom-up variables more important than top-down variables

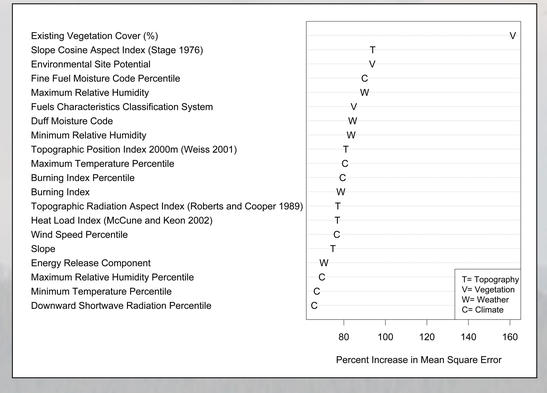
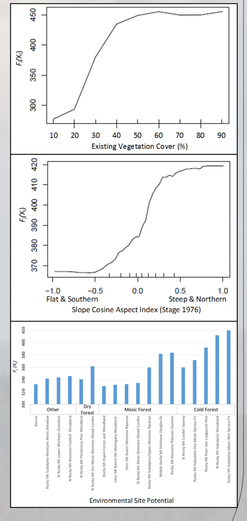



**Figure 3.** Importance ranking for 20 predictors of burn severity as measured by percent increase of Mean-Square-Error for optimum Random Forest model.

**Figure 4.** Partial Dependence Plots for top three predictor variables. Plots show how individual values of a predictor affect changes in dNBR while holding all other variables at their mean.

*Use relative range of Y values to compare between predictors.




## REFERENCES


Abatzoglou, J.T. 2011. Development of gridded surface meteorological data for ecological applications and modeling. International J. Climatology DOI: 10.1002/joc.3413.

Bessie, W.C., and E.A. Johnson 1995. The relative importance of fuels and weather on fire behavior in subalpine forests. Ecology 76: 747-762.

Birch, D.S., P. Morgan, C.A. Kolden, J.T. Abatzoglou, G.K. Dillon, Z.A. Holden, A.T. Hudak, and A.M.S. Smith. 2013. Burn Severity And Areas of Daily Fire Growth for 42 Forest Fires In Idaho and Western Montana, 2005 – 2011. Master Thesis. University of Idaho, Moscow, Idaho.

Bremen, L. 2001. Random forests. Machine Learning 45: 5-32.

Dillon, G.K., Z.A. Holden, P. Morgan, M.A. Crimins, E.K. Heyerdahl, and L.H. Charles. 2011. Both topography and climate affected forest and wood land burn severity in two regions of the western US, 1984-2006. Ecosphere 2(12): 130.

Ferguson, S.A., J.E. Ruthford, S.J. McKay, D. Wright, C. Wright, and R. Ottmar. 2002. Measuring moisture dynamics to predict fire severity in long leaf pine forests. Int. J. of Wildland Fire 11(4): 267-279.

Holden, Z.A., P. Morgan and J.S. Evans. 2009. A predictive model of burn severity based on 20-year satellite-inferred burn severity data in a large southwestern US wilderness area. Forest Ecology and Management. 258(11): 2399-2406.

Hudak, A.T., P. Morgan, M.J. Bobbitt, A.M.S. Smith, S.A. Lewis, L.B. Lentile, P. R. Robichaud, J. T. Clark, and R.A. McKinley. 2007. The relationship of multispectral satellite imagery to immediate fire effects. Fire Ecology 3(1): 64-90.

Keeley, J.E. 2009. Fire intensity, fire severity and burn severity: a brief review and suggested usage. International Journal of Wildland Fire 18: 116-126.

Lentile, L.B., P. Morgan, A.T. Hudak, M.J. Bobbitt, S.A. Lewis, A.M.S. Smith, and P.R. Robichaud. 2007. Post-fire burn severity and vegetation re sponse following eight large wildfires across the western United States. Fire Ecology 3(1): 91-108.

Littell, J.S., D. McKenzie, D.L. Peterson, and A.L. Westerling. 2009. Climate and wildfire area burned in western U.S. ecoprovinces, 1916-2003. Ecol. Appl. 19: 1003-1021.

Roy, D. P., L. Boschetti, and S.N. Trigg. 2006. Remote sensing of fire severity: assessing the performance of the normalized burn ratio. Geoscience and Remote Sensing Letters, IEEE 3(1): 112-116.

Sackett, S.S., S.M. Haase, and M.G. Harrington. 1996. Lessons learned from fire use for restoring southwestern ponderosa pine ecosystems, in WW Covington and PK Wagner eds., Conference on adaptive ecosystem restoration and management: restoration of Cordilleran conifer land scapes of North America: June 6-8, 1996, Flagstaff, Arizona. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Gen. Tech. Rep. RM-278, p. 54-61.

Schoennagel, T., T.T. Veblen, and W.H. Romme. 2004. The interaction of fire, fuels, and climate across Rocky Mountain forests. BioScience 54(7): 661-676.

Spracklen, D.V., L.J. Mickley, J.A. Logan, R.C. Hudman, R. Yevich, M.D. Flannigan, and A.L. Westerling. 2009. Impacts of climate change from 2000 to 2050 on wildfire activity and carbonaceous aerosol concentrations in the western United States. J. of Geophysical Res.: Atmospheres (1984 –2012) 114: D20. DOI:10.1029/2008JD010966.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University of Idaho
College of Natural Resources