Defining Extreme Wildland Fires Using Geospatial and Ancillary Metrics

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INTRODUCTION

Fires result in immediate, short-, and long-term impacts on terrestrial vegetation, soils, hydrology, atmospheric cycles, and social systems. As society expands into the natural landscape the effects of wildland fire on social-ecological-systems has become more pronounced. Mega-fires, conflagrations, extreme, and catastrophic are descriptors that are interchangeably used to increasingly describe fires in recent decades in the US and globally. Of particular concern are individual fire events that have uncharacteristically large negative impacts on social-ecological-systems. Statistically, such "extreme" fires should be rare events; but they may become more common under future conditions.

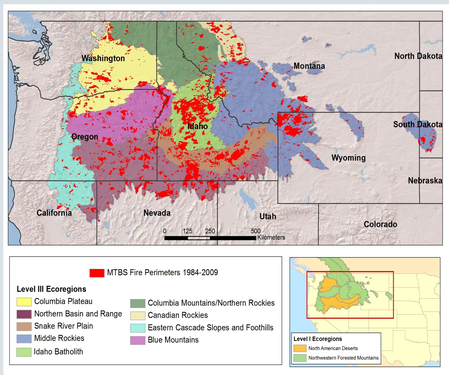
It is necessary to have consistent, meaningful, and quantitative metrics to define these perceived "extreme" fires, given studies predict an increased frequency of large and intense wildfires in many ecosystems as a response to climate change.

This study explored four metrics to describe both widespread fire years and potentially extreme individual fires from a case study of wildland fires during 1984-2009 in the northwestern United States. A combination of percentile-based thresholds was used for each of the metrics to define individual fires as extreme events. The metrics included distributions of fire size, fire duration, burn severity, and distance to the wildland urban interface.

METHODS

Study Area

Our research focused on a 91.2 million-ha area of the northwestern United States. We analyzed fires within the Blue Mountains, Middle Rockies, Canadian Rockies, Columbia Mountains/Northern Rockies, Eastern Cascade Slopes and Foothills, and Idaho Batholith Level III ecoregions.



MTBS Data

The Monitoring Trends in Burn Severity (MTBS) program maps burn severity (as defined using the Differenced Normalized Burn Ratio (dNBR) family of spectral indices) and perimeters of wildland fires > 404 ha in the western United States and 202 ha in the eastern United States that burned between 1984 and present. MTBS fire perimeters for 3,085 fires (1984-2009) and severity classifications for 2,916 fires (1984-2007) were evaluated within the study area.

Geospatial Metrics

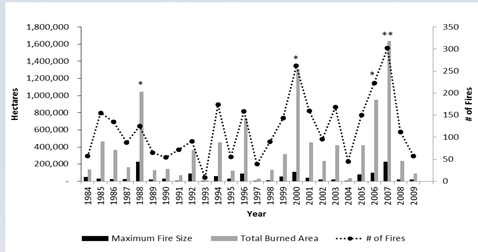
- To **identify widespread fire years** we used the Tukey's 75th percentile + 1.5 * interquartile-range (IQR) rule of annual total burned area across all years.
- To **identify the individual extreme fires** we evaluated four criteria: size, severity, duration, and distance to the Wildland Urban Interface (WUI).
  - Criteria were evaluated for independence between the separate extreme criteria.
  - The 90th, 95th, and 99th percentile of individual (1) fire burned area, (2) MTBS % area high severity, (3) distance to WUI, and (4) fire duration were calculated (along with 1st, 5th, & 10th %).
  - **Fires meeting three or more of these criteria** at the different percentile thresholds were characterized as potentially **"extreme."**
- **To examine the relationships to regional scale climatic variability,** inter-annual variability in the biophysical metrics of extreme fires were compared to climate variables, including temperature, fire danger indices (ERC-G, Energy Release Coefficient), and water balance metrics (PDSI, Palmer Drought Severity Index) scaled over the study area.
- **We evaluated trends in the data from 2,916 fires over the 24-year period from 1984-2007** using the Time Series Modeler (SPSS, IBM. Version 20) and calculated stationary R^2, the Ljung-Box statistic. The autocorrelation function of each metric was evaluated for lags of 1-24 years.

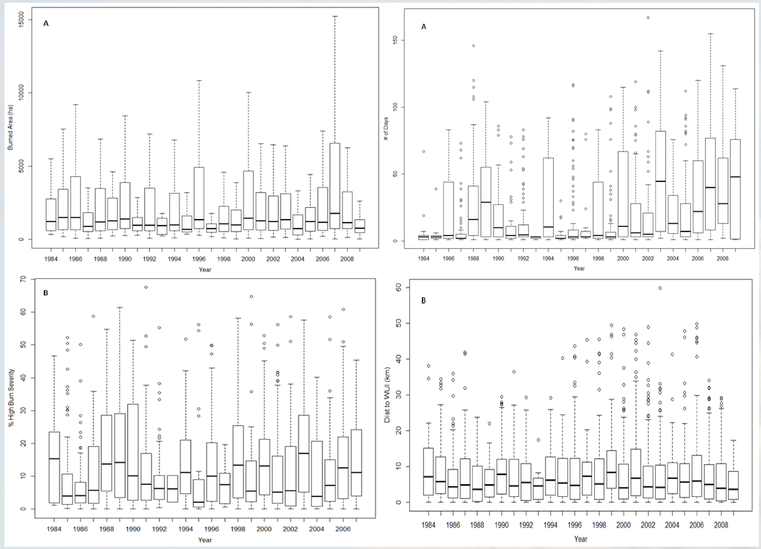
RESULTS

Widespread Fire Years

Four years were identified as widespread fire years: 1988, 2000, 2006, and 2007

- These years experienced above average summer temps, mid-summer drought (PDSI<-1.5), fire-season (1 Jul-16 Sep) ERCs, and DMCs in the upper quintile relative to 1979-2012 observations.





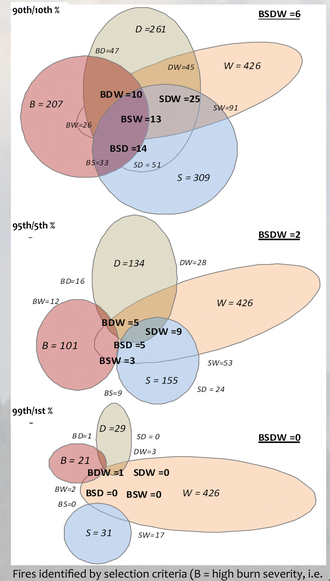
Individual Extreme Fires

39 individual fires were identified as potentially extreme fires

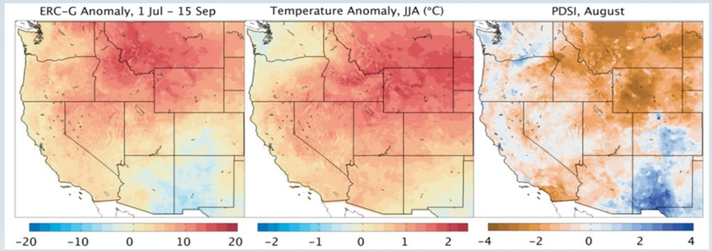
- *At the 90th/10th percentile, 6 fires met all four criteria.*
- *At 95th/5th percentile, 2 fires met all four criteria.*
- *At 99th/1st percentile, zero fires met all four criteria.*
- Only 426 fires had at least one pixel in which the fire burned into the WUI.
- *The 39 identified fires represent approximately 15% of the total area burned within the studied temporal series.*

Influence of Regional Scale Climatic Variability

- *Widespread fire years experienced above average summer temperatures, mid-summer drought (PDSI<-1.5), fire-season (1 Jul-16 Sep) ERCs, and DMCs in the upper quintile relative to 1979-2012 observations.*
- Area burned and inter-annual area burned at high severity were correlated with drought (August PDSI) and June-July temps (R=-0.60 and R=0.69, and R=-0.69 and R=0.80).
- Area burned was correlated to 1 Jul-15 Sep ERC (R=0.83), 1 Jul-15 Sep DMC (R=0.84), and 1 Jun – 15 Sep PET (R=0.83).
- % area burned at high severity was correlated with summer ERC (R=0.91) and PET from summer (R=0.92).

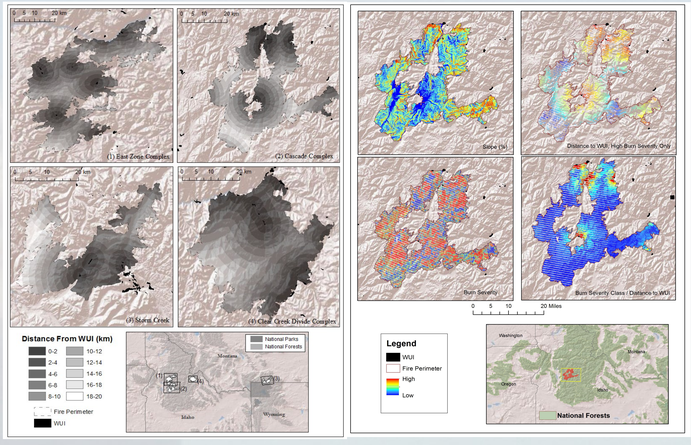


Fires identified by selection criteria (B = high burn severity, i.e. high mortality; S = size, i.e. burned area; D = duration; W = burning into WUI). Overlap areas represents fires meeting multiple criteria at different threshold.



Composite climate variables of the four identified widespread fire years (1988, 2000, 2006, and 2007) expressed as departure from the 1981-2010 climate normal.

- No discernible temporal trends were observed with percentage area burned with high severity, area burned, or minimum distance to WUI as a function of time.
- A notable trend was observed for the mean fire duration over time (stationary R2335 =0.826, Ljung-Box p=0.709).
- A correlation between annual mean duration of the individual fires and the average percentage area burned at high severity was observed (R=0.64, n=24, p<0.001).



Moving Forward: Indices that marry social and ecological factors, such as the combination of high burn severity and distance to WUI may be useful in finding a concise metric to evaluation.

Conclusions

- **Potentially extreme fire events can occur within any year** when fires ignite under sufficiently hot, dry and windy conditions that they exceed initial attack fire suppression efforts.
- Although our data could not be used to evaluate trends of extreme fires within climate because of the short temporal series, **the occurrence of the widespread fire years did occur during years that significantly departed from historic climate norms**.
- Fire size, proximity to WUI and either long duration or high rates of spread could identify them as **potentially extreme events to manage**.
- Our list of criteria should be expanded for both biophysical and social parameters, e.g. identifying areas of shifting plant communities, rate of fire growth, more direct and indirect social impacts of wildfire, etc.
- Work is needed to explore new metrics that better integrate biophysical and social information and approaches for weighting and visualizing the importance of different metrics.

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