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A STATISTICAL ANALYSIS OF ENERGY RELEASE COMPONENT FOR LARGE WILDLAND FIRES ON THE SOUTHERN GREAT PLAINS

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1. INTRODUCTION

The wildland fire environment is a complex system within which weather and ambient vegetative fuels combine to parameterize potential fire intensity and spread. This is particularly true in the grass-dominated fuelscape of the southern Great Plains, where dramatic biophysical responses of herbaceous-type vegetation to both short-term meteorological and seasonal climatic variation is a critical influence on significant fire potential.

This study provides a statistical analysis of Energy Release Component (ERC) for fuel model G (Bradshaw et al. 1983) associated with two southern Great Plains fire databases. These data are comprised of: 1) 201 fires (≥121 ha) within the West Texas Mesonet (WTM) (Schroeder et al. 2005) domain between 2006 and 2011, and 2) maximum daily fire size for Texas A&M Forest Service (TA&MFS) reported fires within the High Plains predictive service area (PSA) between 2000 and 2011.

To provide operational relevance, a spectrum of wildland grassfire is introduced. In this context, the data suggest that thresholds of ERC based upon local critical percentile values have utility in defining significant fire potential. As such, matrices for combining the state of weather and fuels are proposed to have utility in improving red flag warning services.

2. WILDLAND FIRE IN THE SOUTHERN GREAT PLAINS GRASSLANDS

Rates of fire spread up to 2.5 m s^{-1} have been observed (Smith 2011) within the fine short- and mixed-grass prairies on the southern Great Plains. These prairies are dominated by native buffalograss (*Buchloe dactyloides)* and blue grama *(Bouteloua gracilis)* communities (Wright and Bailey 1982). These fuels are the primary catalyst for extreme rates of spread. The presence of intermixed shrub within the Plains fuelscape, however, additionally influences fire intensity and resistance to control (Scott and Burgan 2005). Fine fuel characteristics of the Plains' grass-dominant ecosystem, such as fuel moisture and temperature, are variable and highly dependent on local weather conditions which may change dramatically on the order of a few hours. Yet a common misperception in land management and firefighting operations is that

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an ever-present high fire danger exists in dormant grasses (Fig. 3). This perspective is proliferated by inappropriate interpretation of weather-dependent adjective measures such as the National Fire Danger Rating System's Fire Danger Rating (Deeming et al. 1977, Burgan 1988, and Beierle 2012). In reality, the influence of inter-mixed shrub on potential fire intensity and lingering effects of moisture in soil and duff result in variations of ambient grassland fire danger. If the former assumption were true, significant wildland fire would occur on the southern Great Plains during each dormant season. Instead, Texas wildland fire records illustrate a high degree of seasonal variation (Fig. 4) and demonstrate how relatively infrequent combinations of weather and fuel are prerequisite to significant wildland fire (Brotak and Reifsnyder 1977).

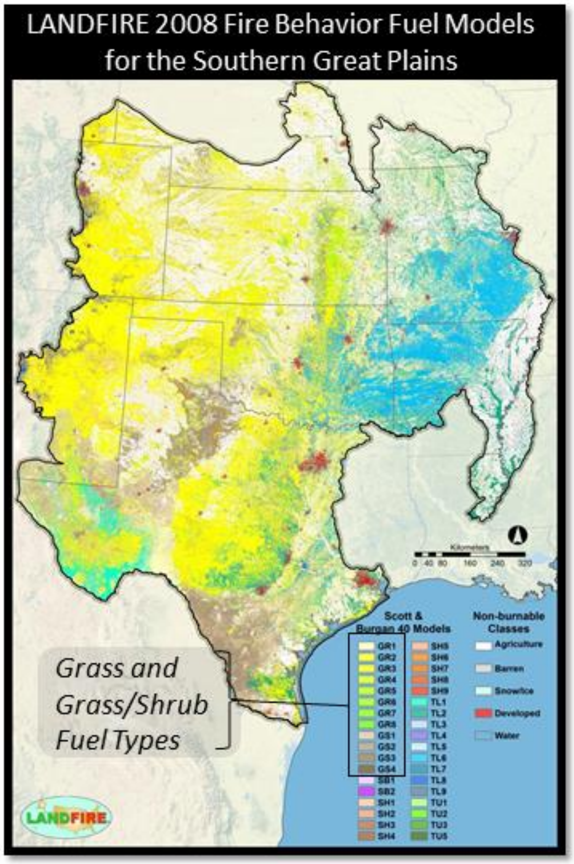


Figure 1: Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) 2008 (Reeves et al. 2009) fuel models for the southern Great Plains.

Figure 2: Southern Great Plains grassland with intermixed shrub in the Texas Panhandle.

Recognizing and communicating wildland fire risk is a difficult challenge for both fire weather forecasters and predictive services. In order to assess utility of this study's ERC analysis as a predictive indicator for significant fire potential, a spectrum of wildland grassfire is introduced (Fig. 5). This spectrum differentiates wildland grassfires into three categories: initial-attack fires, large fires, and significant wildfires. Each category is associated with ranges of National Wildfire Coordinating Group fire size classes (National Wildfire Coordinating Group, cited 2015), but in practice overlap and gray thresholds exists in quantifying transitional fire types between categories. Wildland fires burn at various temperatures, spread at varying rates, and have differing fireline intensities. These physical characteristics are functions of the weather and fuel environment within which a fire occurs. Such fire-specific attributes determine a fire's resistance to control and, ultimately, influence burn area and duration. Application of this concept to Oklahoma wildfires that occurred between 2000 and 2007 (Reid et al. 2010 and Weir et al. 2012) indicate that more than 90% of fires occupy the initial-attack or lower bound of the large fire portion of the spectrum. Differentiating wildland grassfire threats within this spectrum is important in both quantifying and effectively communicating significant fire potential.

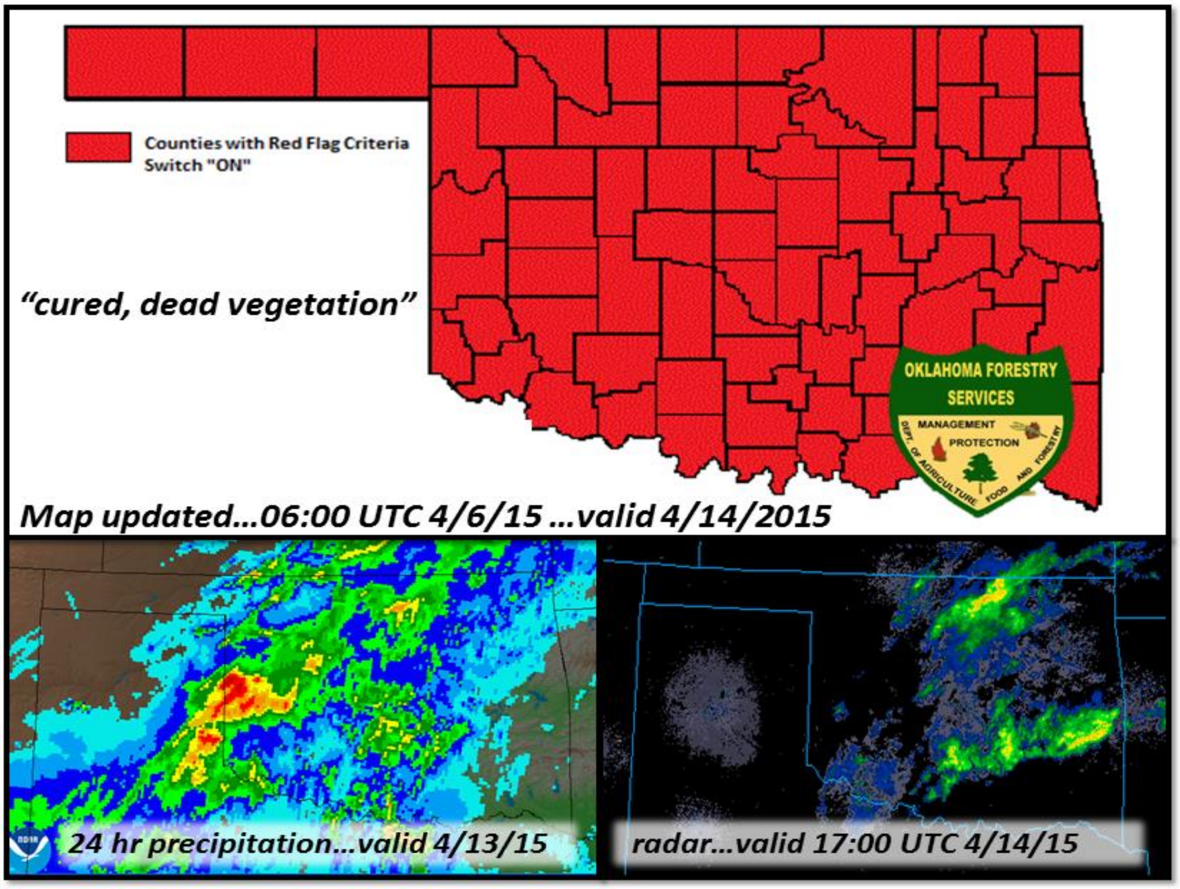


Figure 3: Oklahoma Forestry Services' red flag criteria switch map citing "cured, dead vegetation" valid 14 April 2015 shown with 13 April 2015 24-hour precipitation and 14 April 2015 17:00 UTC radar.

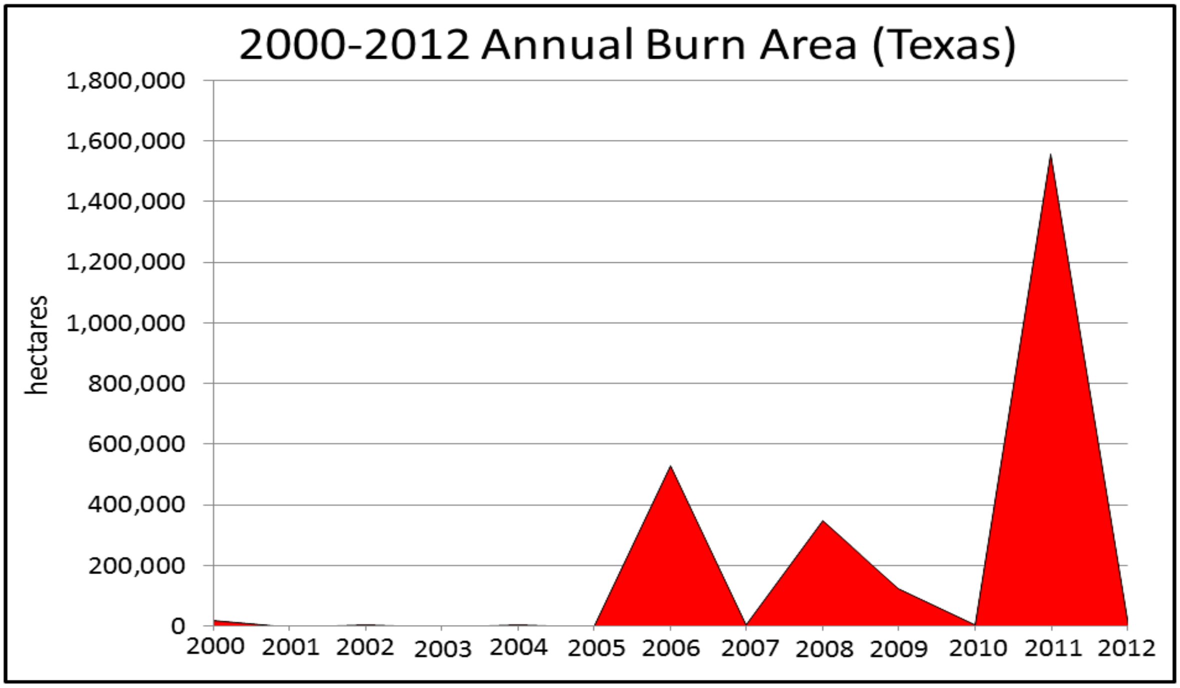


Figure 4: Annual area burned by wildland fire in Texas between 2000 and 2012.

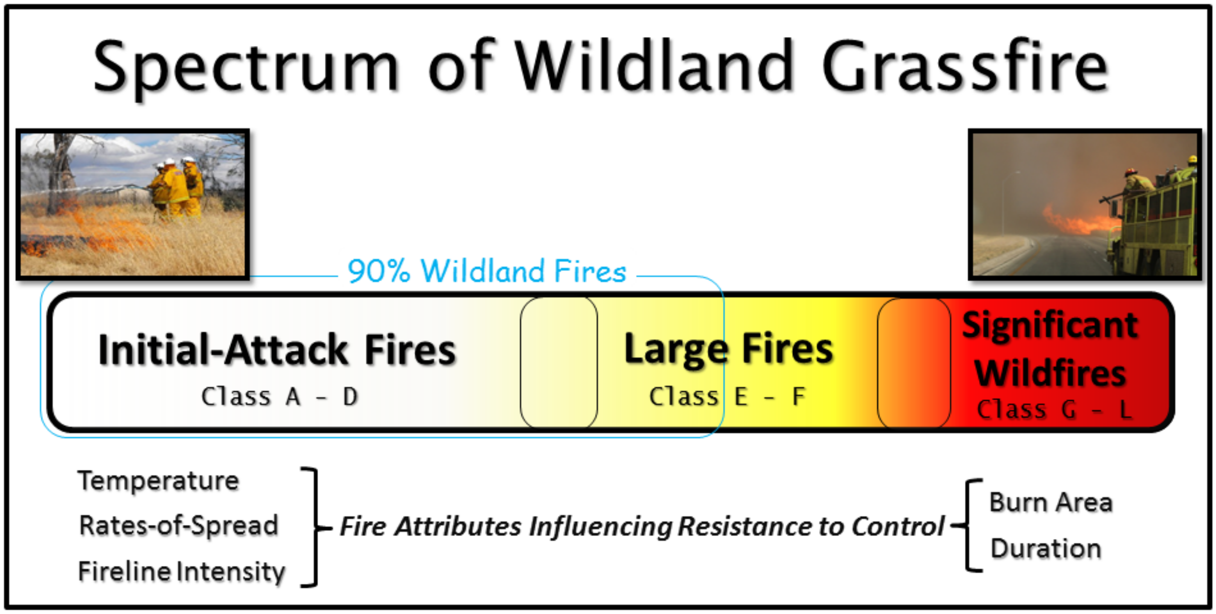


Figure 5: Proposed spectrum of wildland grassfire categorizing initial-attack fires, large fires, and significant wildfires along with NWCG fire size class and contributing physical fire attributes.

3. ERC & ANALYSIS

In order to identify operationally useful measures of vegetative fuel state which can be combined with meteorological parameters to quantify the total weather and fuel environment and resultant significant fire potential, this study uses ERC (fuel model G). ERC is a quantity directly related to the total energy (BTU) per unit area of vegetative fuel, or the potential heat release available for burning in the flaming zone of a fire for a specific fuel model (Bradshaw et al. 1983). Variables of ERC include weighted fuel loading (surface area-to-volume ratio) as well as a composite of live and dead large-fuel moistures (Cohen and Deeming 1985). The ERC is a cumulative index, and applies values from each of the previous seven days to successive calculations. The effects of day-to-day weather and fuel loading accumulate over time as live fuels cure and dead fuels dry. Therefore, in the absence of widespread fire mitigating moisture or wetting rainfall, ERC has low day-to-day variability during steady-state drying conditions, and is an excellent indicator of intermediate to long-term drying of vegetative fuels and (by extension) potential fire behavior.

a. Dataset 1

An analysis of 201 large fires and significant wildfires (≥121 ha) within the West Texas Mesonet domain between 2006 and 2011 reveals the range of ERC values which supported class E or larger fires. This dataset indicated that such fires occurred when ERCs ranged from 44 to 93 (Fig. 6). Half of all fires (inner quartile range) occurred when ERC values were within a relatively narrow range of vales between 60 and 71. Median and mean ERC values were 64 and 66 respectively. A significant majority (84%) of the fires occurred when ERC values exceeded local 75th percentile values of 56, and nearly half (43%) were associated with ERCs greater than the local 90th percentile ranking of 67.

b. Dataset 2

A second dataset of TA&MFS reported wildland fires (class A-L) within the High Plains PSA from 2000 to 2011 was analyzed. Fires in this database were filtered to include fire-related ERC values during the pronounced southern Great Plains' dormant fire season spanning January through April, when the region's largest and most dangerous wildland fires occur

(Lindley et al. 2011). To best sample fire potential within each vegetative fuel environment, maximum daily fire size was referenced for days which had multiple reported fires. Therefore, the original dataset of 243 fires was utilized to investigate ERC environments for 78 individual wildland fire days on the High Plains of west Texas.

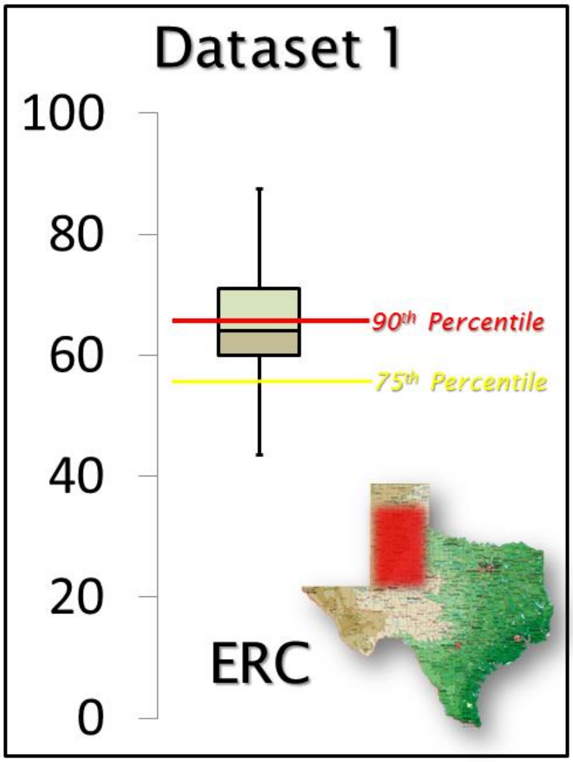


Figure 6: Box and whisker plot of ERC for 201 fires ≥121 ha within the WTM domain between 2006 and 2011.

This analysis shows a stratification of minimum ERC values for each escalating category along the wildland grassfire spectrum (Fig. 7). This trend is reflected in the 3rd percentile of fire-specific ERC and is especially evident in differentiating significant wildfire environments, with 97% of all initial-attack fires associated with ERCs ≥45, large fires ≥47, and significant wildfires ≥60. The inner quartile range of ERC values in each category of the wildland grassfire spectrum generally occurs at or above the local 75th percentile ERC ranking of 56 and the median ERC for significant wildfire (class G-L) environments of 66 approximated the climatological 90th percentile ERC of 67.

4. SIGNIFICANT FIRE POTENTIAL

Significant fire potential, typically categorized as “Low”, “Moderate”, or “High”, describes the projected risk of wildland fires requiring mobilization of remote resources through an assessment of the total fuel and weather fire environment (National Interagency Coordination Center, cited 2015). The National Weather Service’s (NWS) red flag warning program consists of various criteria across the country, but is generally dictated by locally critical fire weather thresholds with minimal or inadequate considerations toward ambient vegetative fuel measures. The analysis provided here suggests that operational utility of ERC-derived matrices may improve red flag warning services relative to significant fire potential.

Examples of assimilating weather and ERC-based fuel measures to derive significant fire potential include the use of nomograms which combine ERC with Burning Index (BI, Deeming et al. 1977) and Red Flag Threat Index (RFTI, Murdoch et al. 2012) (Fig. 8a-b). Applying the product of ERC and RFTI+1 to dataset 2 shows skill in predicting minimal combinations of weather and fuel required to support varying classes of fire size correlated via polynomial regression (R^2=0.96) (Fig. 9).

These methods, used experimentally in operational predictive services, provide context to weather and fuel environments supportive of varying degrees of significant fire potential. The authors propose that “Low”, “Moderate”, and “High” significant fire potential represent combinations of weather and fuel associated with initial-attack fires (class A-D), large fires (class E-F), and significant wildfires (class G-L) on the wildland grassfire spectrum respectively. Further, these categories have the potential to serve as benchmarks for a tiered advisory/warning red flag paradigm analogous to other hazardous weather headlines issued by the NWS.

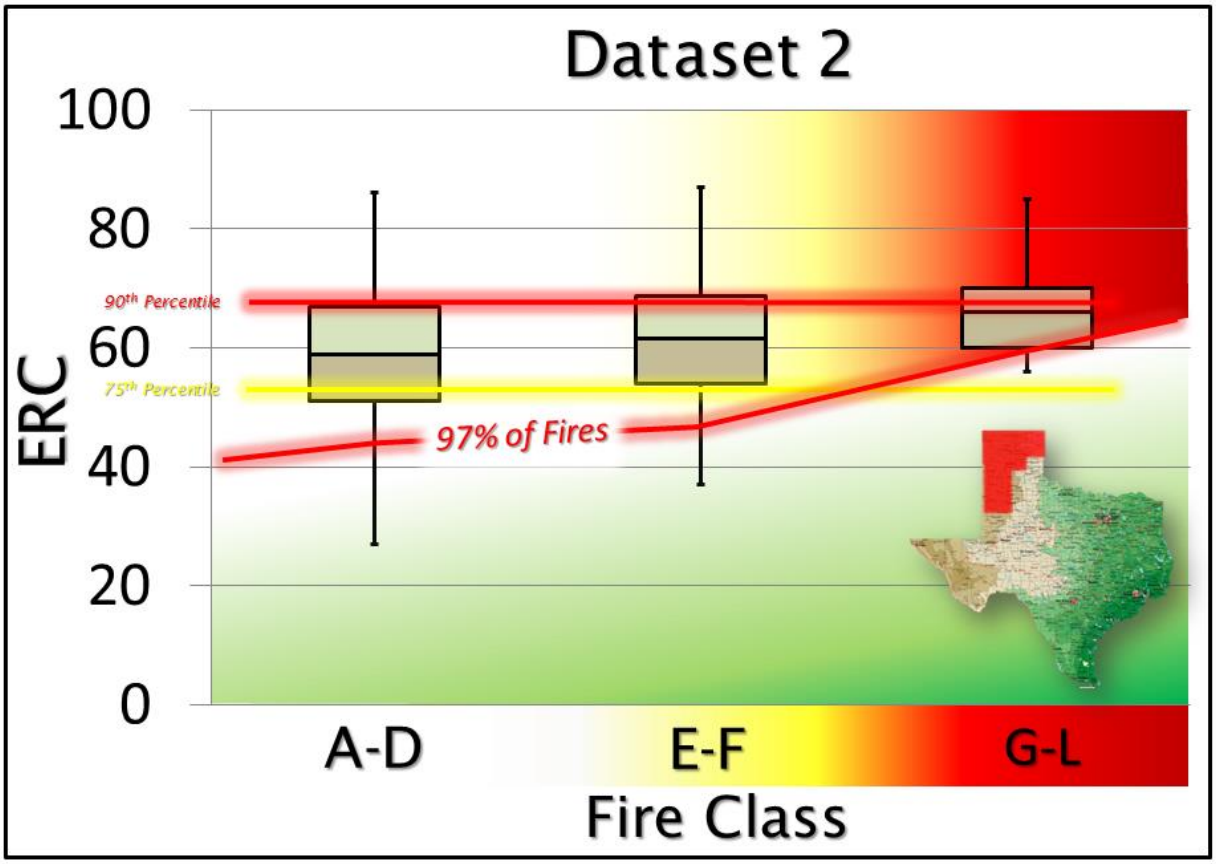
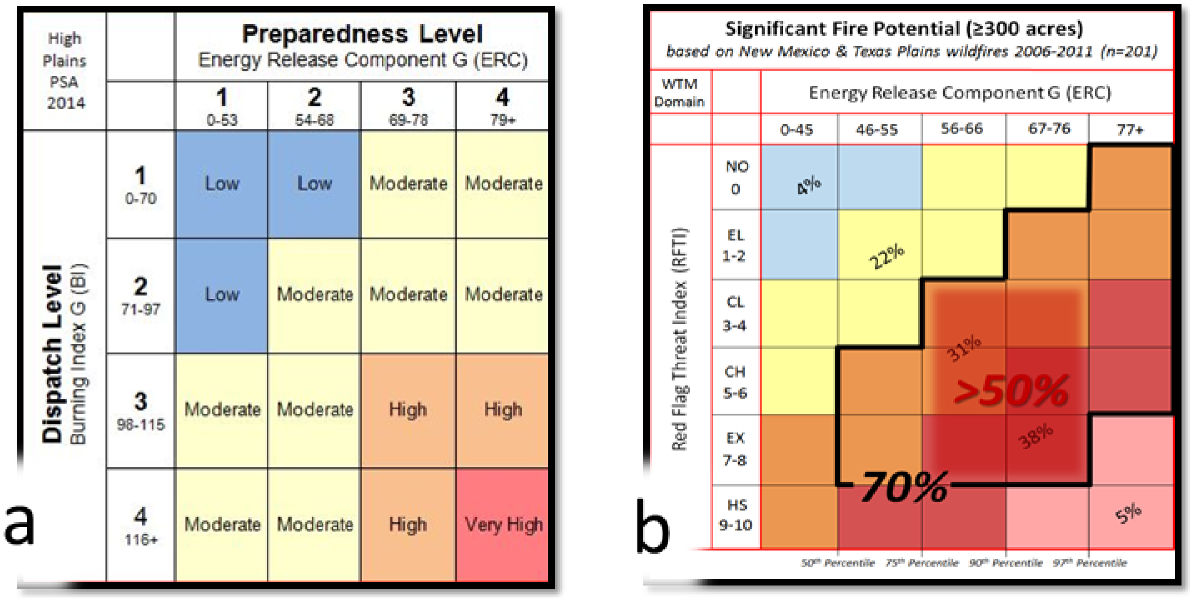


Figure 7: Box and whisker plots for ERC associated with class A-D fires, E-F fires, and G-L fires within the High Plains PSA between 2000 and 2011.



High Plains PSA 2014		Preparedness Level Energy Release Component G (ERC)			
		1 0-53	2 54-68	3 69-78	4 79+
Dispatch Level Burning Index G (BI)	1 0-70	Low	Low	Moderate	Moderate
	2 71-97	Low	Moderate	Moderate	Moderate
	3 98-115	Moderate	Moderate	High	High
	4 116+	Moderate	Moderate	High	Very High

Figure 8a-b: TA&MFS and NWS nomograms that combine ERC with more weather-dependent variables including a) BI and b) RFTI to provide operational guides for significant fire potential.

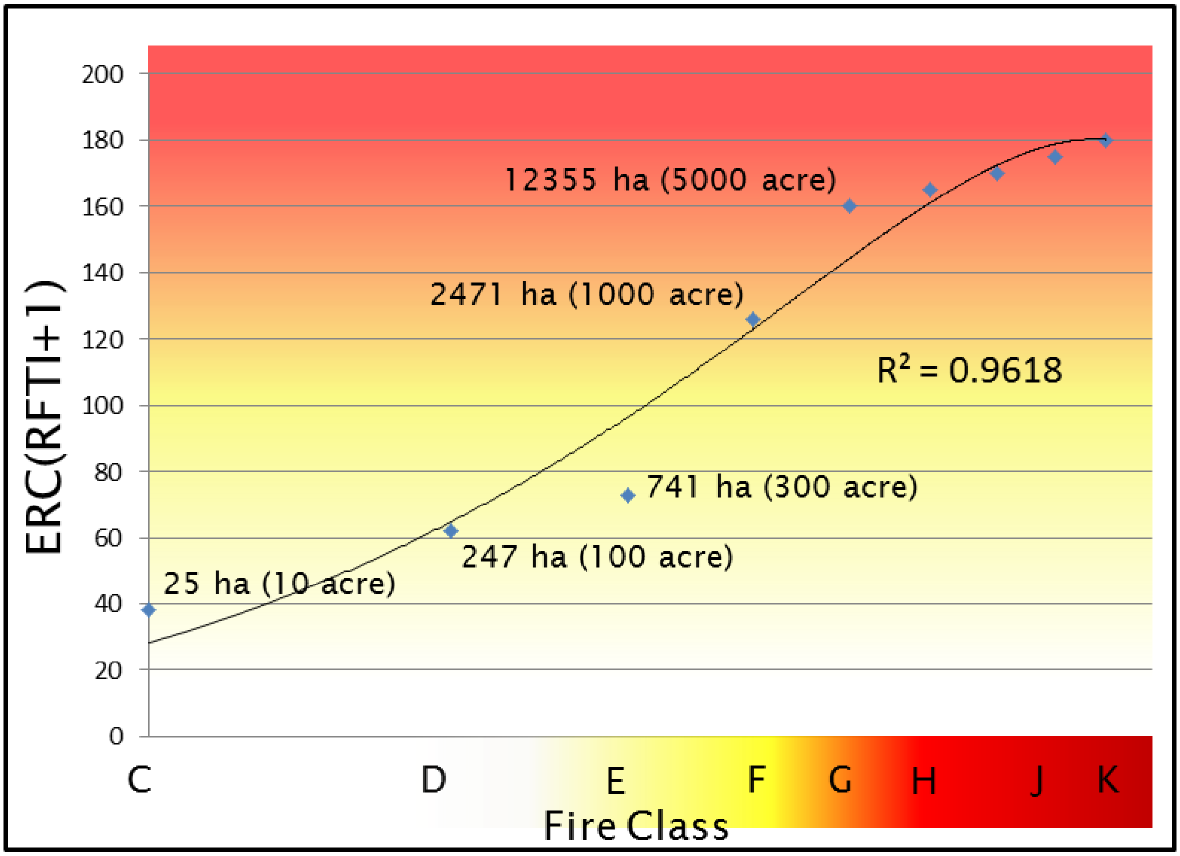


Figure 9: Polynomial regression for minimal values of the ERC(RFTI+1) for fire size classes C-K derived from dataset 2.

5. CONCLUSION

This study presented a statistical analysis of ERC associated with two wildland fire databases on the grasslands of the southern Great Plains. Operational relevance of the analysis was provided through differentiating ERC associated with specific fire size classes along a wildland grassfire spectrum. The analysis showed that typical ERCs for large fires and significant wildfires (class E-L fires ≥121 ha) ranged between 44 and 93, with 84% of such fires occurring when ERC exceeded the climatological 75th percentile value of 56. The lower bound of inner quartile ranges (75% of all fires) for initial-attack fires (class A-D), large fires (class E-F), and significant wildfires (class G-L) were generally near or in excess of the 75th percentile ERC, and median ERC for significant wildfires approximated the local 95th percentile ranking. Fire-specific ERCs for 97% increased from 47 to 60 between large fires and significant wildfires. This signal appears particularly useful in recognition of antecedent vegetative fuel conditions supportive of class G-L wildfires, or “High” significant fire potential environments. Thus, matrices for combining the state of both weather and fuels as a measure of significant fire potential were introduced. These matrices provide context and a preliminary benchmark for transitioning the NWS’s red flag warning program toward a significant fire potential paradigm.

The authors recommend that more extensive studies consider the utility of deterministic fuel quantities combined with critical weather thresholds in red flag warnings. Other possible measures, including BI, may better discriminate lower fire class environments given rapid responses to day-to-day weather. In the future, it is essential for both fire weather forecasters and predictive service fire analysts to develop more comprehensive knowledge of the total weather and fuel wildland fire environment. These disciplines are not exclusive in operational predictions of significant fire potential.

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