ENVIRONMENTAL FACTORS CONTRIBUTING TO THE EMERGENCE OF SOUTHERN GREAT PLAINS WILDFIRE OUTBREAKS

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1. INTRODUCTION

In order to appropriately assess significant fire potential, a combination of both long-term and short-term (dynamic) factors that influence a location's fire regime should be considered (Snyder et al. 2006). In practice, however, most efforts in operational fire meteorology and predictive services are strongly weighted toward dynamic considerations such as vegetative responses to seasonal variability and the daily state of weather. Faced with the emergence of wind-driven grassland wildfire outbreaks as a preeminent natural hazard during the past decade, meteorologists and fire analysts across the southern Great Plains now strive to understand the long-term trends in climatic and vegetative fuel regimes as well as population and socio-economic conditions that have made the region vulnerable to violent fire episodes. This study will examine long-term changes to the southern Great Plains fire regime that have led to an increased environmental risk of wildfire outbreaks, including the occurrence of a multi-decadal drought coincident with increased population and changes in anthropogenic land usage. An example of how these factors have amplified the wildland fire danger on the southern Great Plains and contributed to the emergence of southern Great Plains wildfire outbreaks (SGPWOs) will be illustrated by events at Cross Plains, Texas, where 120 homes, churches, and businesses were destroyed and two people died during a fire outbreak on 27 December 2005.

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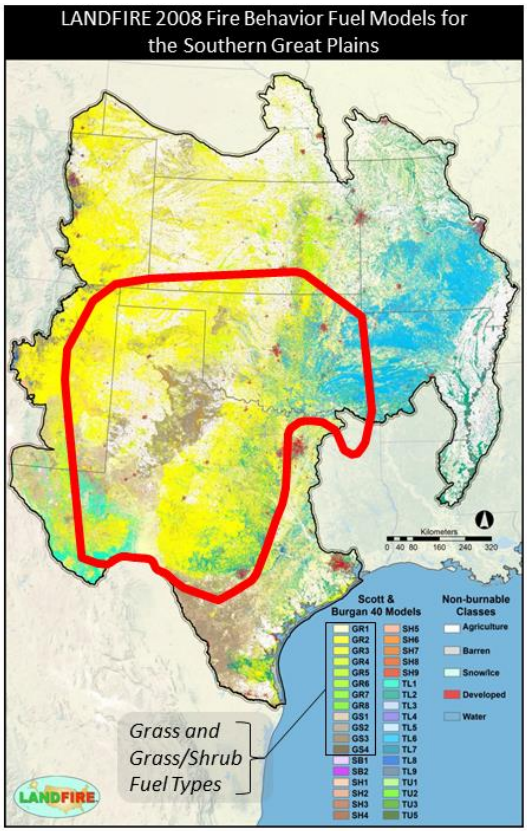
2. HISTORICAL TRENDS

The southern Great Plains physiographic region encompasses the eastern third of New Mexico, much of the western half of Texas, and the western two-thirds of Oklahoma (Fenneman 1917). This Poaceae biome (Licht 1997) is dominated by short and mixed grass prairies comprised of native buffalograss (*Buchloe dactyloides*) and blue grama (*Buoteloua gracilis*) communities (Wright and Bailey 1982). Although these grasses are the dominant vegetative fuels on the southern Great Plains, shrub type fuels also contribute a significant component to the region's fuelscape (Fig. 1). Within the southern Great Plains' fuel environment, grass is the primary catalyst that facilitates fire spread, while the presence of intermixed shrub influences fire intensity and resistance to control (Scott and Burgan 2005). The grass-dominant fuel regime of the southern Great Plains readily supports widespread wildfire outbreaks when sufficiently abundant and dry vegetation is exposed to fire-effective weather patterns such as those identified by the meteorological composite for SGPWOs presented by Lindley et al. (2007).



<u>Figure 1:</u> LANDFIRE 2008 (Reeves et al. 2009) fuel models of the southern Great Plains. Range of 2005-2009 SGPWOs (red).

Reliable historical records of wildland fire on the southern Great Plains are generally not available because of the lack of scar-bearing trees from which to estimate fire frequency (Ford and McPherson 1996). It is known that Native Americans frequently ignited wildland fires on the Plains to modify habitat and to aid in hunting activities before the onset of Anglo-European settlement (Pyne 1982 and Barhre 1985). Later accounts of fire by settlers exist, but are anecdotal and biased towards documenting particularly large and destructive fires (Wright and Bailey 1982 and McPherson 1995). It is widely accepted that settlement substantially altered the fire regime of the Great Plains. Removal of vegetative fuels by grazing domestic livestock and expansion of cultivated croplands reduced the number of fires. Additionally, settlers generally feared the misuse of fire and instituted European philosophies of land management and active fire suppression (Unbanhowar 1996). These conclusions were supported in a dendrochronological study of tree fire scars in the Wichita Mountains, an isolated outcropping of mostly post oak and blackjack oak (*Quercus marilandica* Münchh) (Buck 1964) in an area of elevated and complex terrain of southwestern Oklahoma. This study showed an increase in burn frequency since 1900 (Stambaugh et al. 2009). The study further revealed that while frequent fires have had a long-term presence in the region, burn frequencies as low as 1.7 y (c. 1860) have increased to 5.2 y since settlement (post 1900). Additionally, burn scars associated with the most intense fire activity were shown to occur during periods of drought.

Marlon et al. (2012) also used dendrochronological fire-scar records to document a “fire deficit” in the western United States (U.S.) attributed to the combined effects of human activity, ecological, and climatic changes. This “fire deficit” was shown to be characterized by a slight decline in burning over the last 3,000 years, with the lowest levels attained both during the Little Ice Age (c. 1400-1700) and the 20th Century. It was noted that the current imbalance of the western U.S. fire regime has resulted in an increase of wildfire size and severity, as particularly large and destructive fire episodes have begun to occur within excessive build-ups of unburned vegetative fuels during the 20th and 21st Centuries.

Historical TA&MFS wildland fire records spanning 1925 to 2011 reflect a general decline in the number of annual fires, ranging from a peak of 7,827 wildfires in 1936 to a minimum of only 583 wildfires in Texas during 2004. Four-year running averaged fire occurrences reached a maximum of 6,590 in 1939 and fell to 783 in 2004 (Fig. 2). In spite of this decline in annual wildland fire occurrences, the data show a dramatic increase in the mean size of Texas wildfires in the 21st Century. The four-year running average of mean wildland fire size in the state was consistently <50 acres (20 ha) during the period spanning 1925 to 2005, but increased dramatically to between 200 acres (81 ha) and 500 acres (202 ha) between 2008 and 2011 (Fig. 3). Lindley et al. (2011) noted that recent frequencies of large wildfires have been significantly higher than the expected recurrence interval of 13-27 y for fires ≥10 km^2 (≥2,471 acres or 1,000 ha) as calculated by Malamud et al. (2005). Although this data appears to be consistent with the Marlon et al. (2012) "fire deficit", it may be biased by changes in wildfire sampling practices by Texas officials. Prior to the year 2000, TA&MFS records were heavily weighted toward documentation of wildfires within forested fuel regimes of eastern and central Texas, and were less inclusive of larger grass-dependent wildfires in the western (Great Plains) portion of the state. While this bias in the TA&MFS dataset limits its credibility as evidence of the "fire deficit" documented by Marlon et al. (2012), it does illustrate how the emergence of massive burns associated with SGPWOs have had a balancing influence on the region's fire environment during the past decade.

Grasses are more adaptable to drought than most tree species and the spread of grasslands in the Plains environment occurred at the expense of forested vegetation (Axelrod 1985 and Anderson 1990). The importance of fire in the maintenance of a grassland ecosystem is widely acknowledged, however, and in the absence of periodic fire, grasslands will give way to woody plants (McPherson 1995). This artifact of a decreased fire frequency also appears to have occurred on the southern Great Plains of Texas during the past century, and potentially serves as additional anecdotal physical evidence of changes to the region's fire environment. Aerial photography of the Matador Wildlife Management Area shows an increase of invasive woody species such as mesquite (*Prosopis*) since 1937 (Fig. 4). While many other factors also have influenced environmental changes in the region since settlement (i.e. grazing), increases of woody species within the Plains grasslands may serve as indicators of a long-term decline in wildland fire on the southern Great Plains.

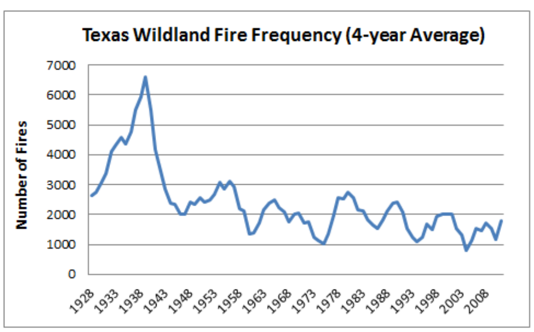


Figure 2: *Four-year running average of yearly wildland fire occurrence in Texas 1925-2011.*

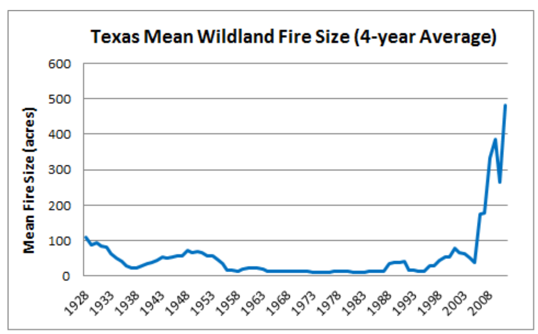


Figure 3: *Four-year running average of mean wildland fire size in Texas 1925-2011.*

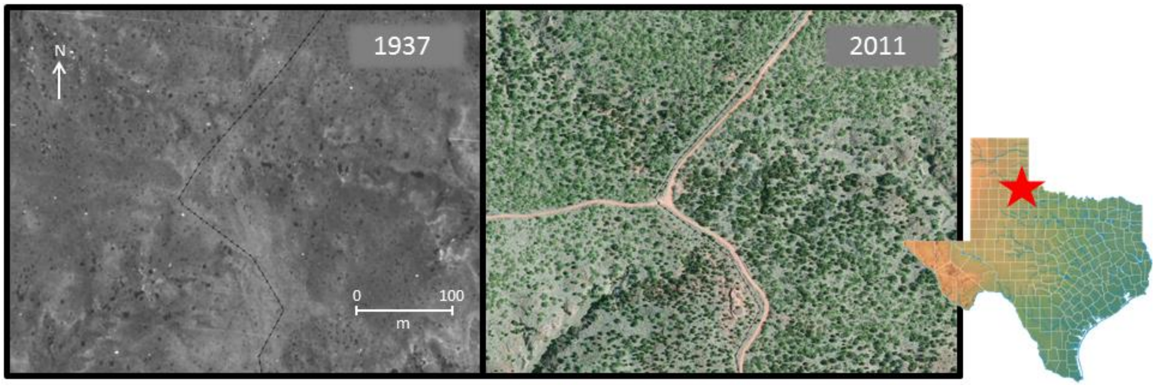


Figure 4: Aerial photos of increased woody vegetative species on the Matador Wildlife Management Area between 1937 and 2011. Images courtesy of Texas Parks & Wildlife Department.

3. POPULATION, LAND USAGE, AND MULTI-DECADAL DROUGHT

Human population and land usage are major determining static environmental factors to influence the continuity of vegetative fuels and the frequency of wildland fire ignitions (Guyette and Dey 2000). Although settlement of the southern Great Plains initially altered the region's fire regime sufficiently to reduce the occurrence of wildland fire, population growth and changes in land management practices have since rendered the fire regime increasingly vulnerable to the occurrence of SGPWOs. The population of the Great Plains has increased at a similar rate to that of the U.S. in general, and has more than doubled since 1950 with the period of largest growth noted between 1990 and 2000 (Wilson 2009). In Texas, a dramatic increase in population was observed during the second half of the 20th Century from approximately 7.7 million in 1950 to 20.9 million in 2000 (U.S. Census Bureau, cited 2013). During the same period, a 35% reduction of agricultural land usage was observed on parts of the Great Plains (Parton et al. 2003). In the past decade alone, an additional population increase to more than 25.1 million (+20.6%) occurred in Texas between 2000 and 2010, and was associated with the loss of 270 acres (109 ha) of agricultural land for each 1,000 new residents (Texas A&M Institute of Renewable Natural Resources, cited 2013). Population growth and the reduction of agricultural lands in Texas, as well as on the southern Great Plains at large, have resulted in the restoration of natural grasslands and an increase of urban-wildland interface. In Texas, 94% of all land is private and managed by individual property owners. Therefore, many formerly grazed or cultivated ownerships now participate in the U.S. Department of Agriculture's Conservation Reserve Program (CRP), a cost-share and rental payment program that encourages farmers to convert crops to native grasslands (USDA, cited 2013). These factors have resulted in an ever-growing population and infrastructure within resurging native grasslands. As of 2013, TA&MFS estimated that 10 million people, or 40% of the state's population, live within an urban-wildland interface.

These changes in population and land usage have combined with long-term climatic trends to influence the current volatility of the southern Great Plains fire environment. Previous studies by Brown (2006) and Stambaugh et al. (2008) have shown evidence of long-term climatic forcing for fire regimes in the Great Plains. On decadal to centennial scales, patterns in wildland fire activity have been linked to ocean/atmosphere interactions associated with low-frequency variations in sea surface temperatures (Trouet et al. 2006 and Kitzberger et al. 2007). Observational data and simulations by Hoerling et al. (2009) suggest that climatic fluctuations on the southern Great Plains, including the occurrence of drought, are particularly sensitive to equatorial Pacific sea surface temperatures.

A long-term plot of the Keetch-Byram Drought Index (KBDI) (Keetch and Byram 1968) averaged at yearly intervals across Texas shows three periods of multi-decadal drought during the last century, and is reflective of climatic trends across a large portion of the southern Great Plains (Fig. 5). The current drought cycle began in the late 1990s. Between 2000 and 2010, statewide average KBDI values were commonly between 580 and 610. This indicator of widespread and long-lived drought was coincident with a continued increase in population. Since the previous episode of long-term drought as indicated by KBDI, generally during the 1940s to 1960s, the population of Texas has increased from ≤10 million to ≥25 million in 2010. While occurrences of drought and wildfires are not mutually exclusive, drought influences fire activity through the prevalence of low precipitation and high temperature which enhances fuel flammability and indirectly controls the risk of wildland fire (Xiao and Zhuang 2007). The emergence of SGPWOs has occurred during this recent period of multi-decadal drought, which is coincident with increased population and infrastructure.

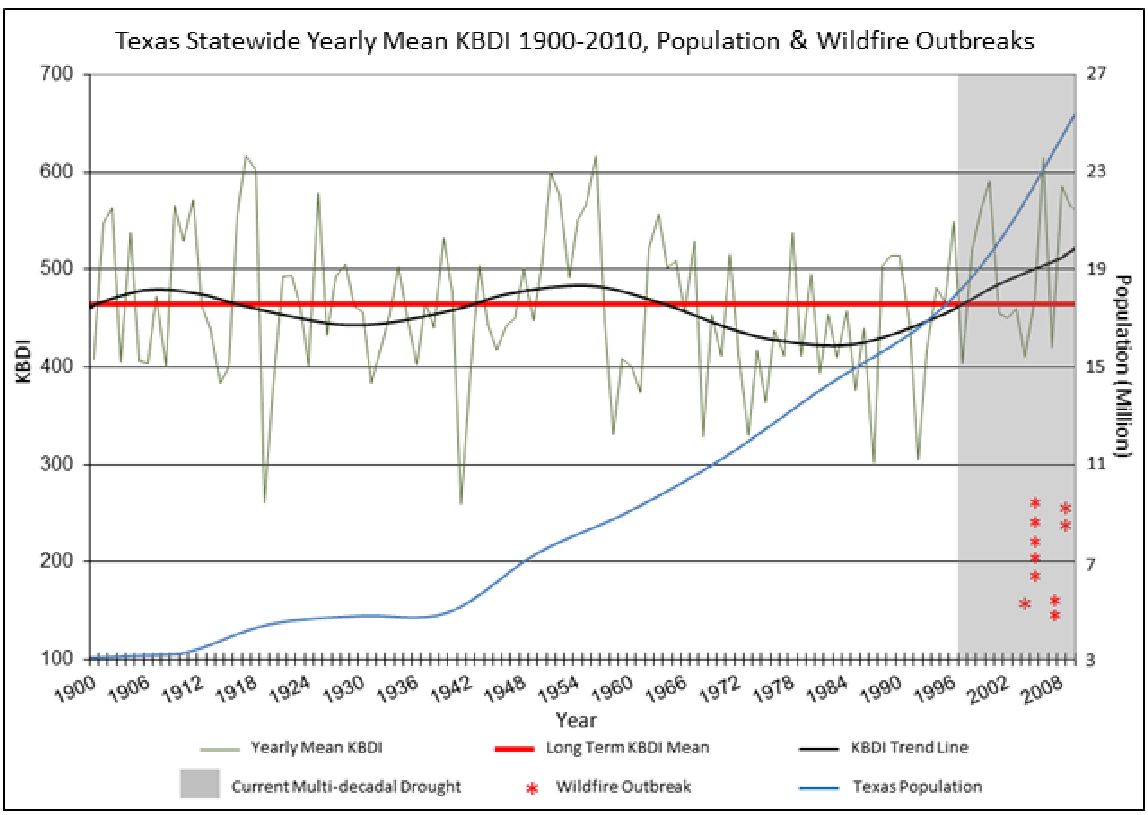
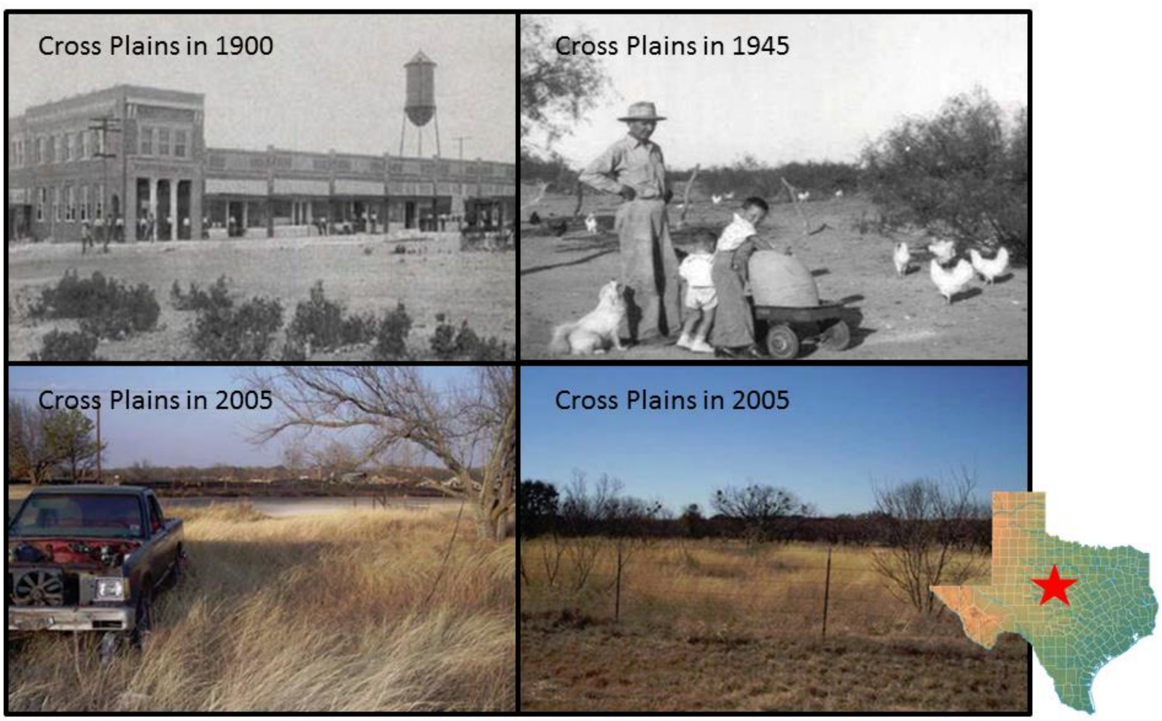


Figure 5: *Texas statewide yearly mean KBDI (1900-2010) plotted with population and SGPWOs. The current period of high KBDI indicative of a multi-decadal drought is shaded.*

4. IMPLICATIONS: CROSS PLAINS, TEXAS – 27 DECEMBER 2005

Given the static environmental variables known to influence an ecosystem's fire regime, it is logical to conclude that the described long-term trends in southern Great Plains population and land usage which preceded the current long-term drought would culminate in an increased risk of wildland fire. An example of how these factors have amplified the danger of wildfire on the southern Great Plains and contributed to the emergence of SGPWOs is evidenced by events at Cross Plains, Texas. Aspects of the following chronology were originally discussed by Gray et al. (2007) and Mutch and Keller (2010).

In the early 1900s, Cross Plains was a small agricultural community surrounded by plowed crops and grazed fields. During the 20th Century, the community grew to become a town of more than 1,000 residents, and the local economy shifted away from agriculture. During the second half of the 20th Century, range and soil conservation programs, such as CRP, changed the way rangelands around Cross Plains were managed. Native grasslands were naturally restored to former farmlands and grazed pastures, and natural grasses became interspersed with occasional shrubs and trees throughout the town (Fig. 6). By the turn of the 21st Century, the modern town was nestled in the midst of a vast open mixed grass prairie. On 27 December 2005, during the first violent SGPWO observed by fire meteorologists in the modern era (Lindley et al. 2007), one of 52 wildfires to plague Oklahoma and Texas that day ignited in the drought-stricken vegetation that surrounds Cross Plains (Fig. 7). Defenseless from the wind-driven flames, the blaze burned through the town. Two residents were killed and at least 120 homes, churches, and businesses were destroyed (Fig. 8).



<u>Figure 6:</u> TA&MFS photo sequence that shows changes in the vegetative environment, particularly an increase in grasslands at Cross Plains, Texas, between 1900 to 1945 and 2005.

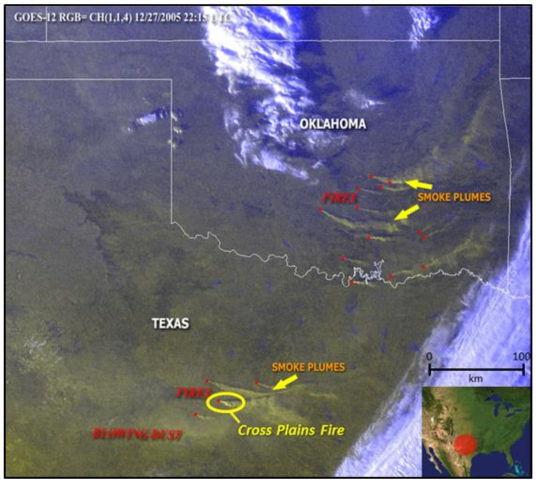


Figure 7: *NOAA satellite image of SGPWO highlighting the Cross Plains, Texas, wildfire at 2215 UTC 27 December 2005.*

Figure 8: *TA&MFS photograph of 27 December 2005 wildfire aftermath in Cross Plains, Texas.*

5. CONCLUSIONS

Although Cross Plains, Texas, was the site of the first community-wide disaster to result from a SGPWO, trends in population and land usage similar to those at Cross Plains exist across the entire southern Great Plains. Population growth and socio-economic changes during recent decades have resulted in an expansion of populace and infrastructure into re-emerging native grasslands (Jones et al. 2013). These environmental factors have amplified the probability of wildland ignitions within a fire regime loaded with renewed and unburned vegetation. An artifact of these concurrent environmental trends is reflected in the modern southern Great Plains fire regime, as evidenced by the emergence of SGPWOs during the past decade. The TA&MFS attributes the escalation of large and destructive fire outbreaks to these unique environmental trends: increased population (heightened likelihood of ignition), land use (increased availability of vegetative fuels), and climate-weather (long-term drought combined with seasonal variability and the passage of fire-effective weather systems) (Fig. 9).

Figure 9: *TA&MFS graphic that shows the combination of environmental factors attributed to an escalating threat of SGPWOs.*

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