Risk Assessment for Wildfire in the Western United States

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Introduction

Wildfire is one of the two most significant disturbance agents (the other being insects) in forest ecosystems of the Western United States, and in a warmer climate, will drive changes in forest composition, structure, and function (Dale et al. 2001, McKenzie et al. 2004). Although wildfire is highly stochastic in space and time, sufficient data exist to establish clear relationships between some fire characteristics and some climatic parameters. An assessment of wildfire risk in response to climate change requires brief definitions of the terms “fire hazard” and “fire risk,” which are often confused in the scientific literature and other applications (Hardy 2005). Fire hazard is the potential for the structure, condition, and arrangement of a fuelbed to affect its flammability and energy release. Fire risk is the probability that a fire will ignite, spread, and potentially affect one or more resources valued by people. The most common means of expressing wildfire risk are (1) frequency, (2) a combination of intensity (energy release) and severity (effects on forests, structures, and other values), and (3) area burned.

Fire Frequency

Fire frequency, which is the number of fires for a particular location and period of time, differs by region as a function of both lightning and human ignitions, with the requirement that fuels are sufficiently dry and abundant to burn. Lightning ignitions dominate mountainous regions with convective weather patterns (e.g., most of the Rocky Mountains), whereas human ignitions dominate regions with little lightning and high human populations (e.g., southern California). Modeling studies (+4.2 °C scenario) (Price and Rind 1994) and empirical studies (+1.0 °C scenario) (Reeve and Toumi 1999) suggest that lightning frequency will increase up to 40 percent globally in a warmer climate. Although no evidence exists to suggest that recent climate change has yet caused an increase in lightning or fire frequency in the West, lightning may increase as the temperature continues to rise (Price and Rind 1994, Reeve and Toumi 1999). Assuming that human population will increase throughout the West, it is reasonable to infer that human ignitions will also increase in most regions. Even if the sources and numbers of potential ignitions do not change, a warmer climate may facilitate increased drying of fine surface fuels (less than 8 cm in diameter) over a longer period (on a daily and seasonal basis) than currently exists (Littell and Gwozdz 2011), allowing more potential ignitions to become actual ignitions that will become wildfires.

Fire Intensity

Fire intensity, or energy released during active burning, is directly proportional to **fire severity** in most forests, and can be expressed as effects on vegetation, habitat, and, in some cases, human infrastructure. Results of modeling based on a doubled carbon dioxide (CO_2) emission scenario suggest that fire intensity will increase significantly by 2070 in the northern Rocky Mountains, Great Basin, and Southwest (Brown et al. 2004). Fire severity and biomass consumption have increased in boreal forests of Alaska during the past 10 years (Turetsky et al. 2010), and large, intense fires have become more common in California (Miller et al. 2008) and the Southwestern United States during the past 20 years. However, interannual and longer term variability in climate-fire relationships can affect trends, making it difficult to infer whether climate change is responsible. Longer time series of fire occurrence, when available, will allow better quantification of the influence of multidecadal climatic variability (e.g., the Pacific Decadal Oscillation or Atlantic

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Multidecadal Oscillation). Fire intensity and severity are a function of both climate and land use history, especially the effects of fire exclusion on elevated fuel loads, and forests with high fuel loading will continue to be susceptible to crown fire in the absence of active management (see below).

Fire Area

Fire area has a stronger relationship with climate in the Western United States than does either fire frequency or severity/intensity. An empirical analysis of annual area burned (1916 to 2003) for federal lands in the West projected that, for a temperature increase of 1.6 °C, area burned will increase two to three times in most states (McKenzie et al. 2004). In contrast, a complex, mechanistic model projected that, for the same temperature increase, area burned will increase by only 10 percent in California (Lenihan et al. 2003). Using the 1977 to 2003 portion of the same data set used by McKenzie et al. (2004), Littell et al. (2009) stratified fire area data by Bailey's ecoprovinces (Bailey 1995) to account for fire-climate sensitivities. On average, the model explained 66 percent of the variability in historical area burned by combinations of seasonal temperature, precipitation, and Palmer Drought Severity Index. In most forest ecosystems and some woodlands, fire area was primarily associated with drought conditions, specifically, increased temperature and decreased precipitation in the year of fire and seasons before the fire season. In contrast, in arid forests and woodlands in the Southwest, fire area was influenced primarily by the production of fuels in the year prior to fire and secondarily by drought in the year of the fire.

Littell et al.[2] projected the statistical models of Littell et al. (2009) forward for a 1 °C temperature increase, calculating median area burned and probabilities that annual fire area would exceed the maximum annual area burned in the historical record (1950 to 2003). Fire area is projected to increase significantly in most ecoprovinces (fig. A2-3); probability of exceeding the historical maximum annual burn area varied greatly by ecoprovince (range 0 to 0.44). For the Pacific Northwest, the projected increases in area burned from Littell et al. (see footnote 2) are consistent with those found by Rogers et al. (2011) using the MC1 simulation model. A weakness of the statistical models is that, if the projected increased area burned were sustained over several decades, then at some point the large areas burned and decreasing fuel loads would result in less area burned than projected by the models. Neither statistical nor process-based models can satisfactorily account for the effects of extreme fire years and biophysical thresholds that may be exceeded in a much warmer climate.

Conclusions

Based on information summarized above and on expert judgment of the authors, the effects of climate change on fire risk are summarized for fire regimes that occur in forests of the Western United States (table A2-1). We estimate risk for a 2 °C increase, which is more likely by mid-21st century than the more conservative temperature scenarios used by McKenzie et al. (2004) and Littell et al. (see footnote 2). All fire regimes in forest ecosystems would experience some increase in fire risk. Low-severity and mixed-severity fire regimes dominate dry forest ecosystems of the West and

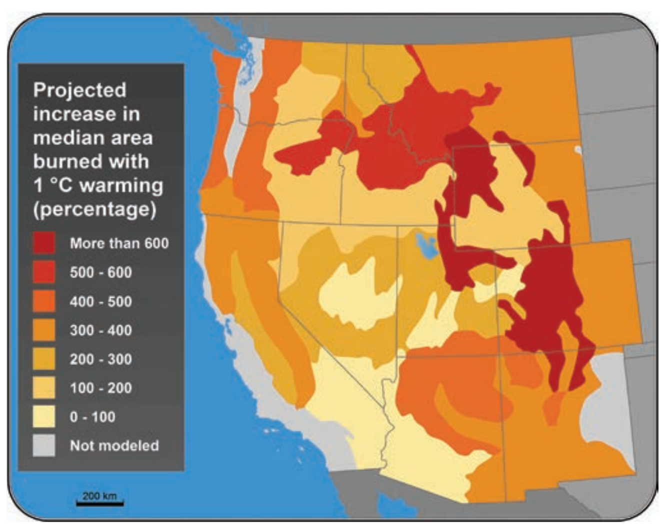

Figure A2-3—Percentage of increase (relative to 1950 to 2003) in median area burned for Western United States ecoprovinces for a 1 °C temperature increase. Color intensity is proportional to the magnitude of the projected increase in area burned.

[2] Littell, J.S. [N.d.]. Relationships between area burned and climate in the Western United States: Vegetation-specific historical and future fire. Manuscript in preparation. On file with: U.S. Department of the Interior, Geological Survey, Alaska Climate Science Center, 4210 University Drive, Anchorage, AK 99508.

Table A2-1—Likelihood and magnitude of increased wildfire risk for fire regimes in forests of the Western United States, based on a temperature increase of 2 °C [a] [b]

Risk parameter	Fire regime: Low severity	Fire regime: Moderate severity	Fire regime: High severity	Rationale for risk ratings
Frequency:				
Likelihood	Moderate	Moderate	Moderate	More fires will occur in all forests because of longer fire seasons and higher human population. In low-severity systems with low fuel loads, more fires will maintain resilience to fire and climate change; in low-severity systems with high fuel loads, more fires will cause more crown fires. In moderate-severity systems, more fires could convert them to low-severity systems. In high-severity systems, even a small increase in fire frequency will have a large effect on forest structure, function, and carbon dynamics.
Magnitude	Low	Moderate	High	
Overall risk and potential action	Low; no action recommended	Moderate; encourage fire prevention in high population areas	Moderate; encourage fire prevention in high population areas	
Intensity/severity:				
Likelihood	Moderate[c]	Moderate	Low	In low-severity and high-severity systems, fire intensity and severity will probably be higher because of more extreme fire weather and elevated fuel loads for the next few decades. In high-severity systems, fuel moisture, not quantity, is limiting, so intensity and severity will not change much; crown fires are always intense and kill much of the overstory.
Magnitude	Moderate[c]	Moderate	Low	
Overall risk and potential action	Moderate; increase fuel treatment area and fuel removal	Moderate; increase fuel treatment area and fuel removal	Low; no action recommended	
Area burned:				
Likelihood	High	High	Moderate	All fire regimes will experience more area burned. This will be especially prominent in drier, low-severity and moderate-severity systems. In high-severity systems, more area will burn, but the percentage increase will be less than in other systems; this will have significant local ecological effects.
Magnitude	High	Moderate	Moderate	
Overall risk and potential action	High; greatly increase fuel treatment area, allow some fires to burn	Moderate; increase fuel treatment area, allow some fires to burn	Moderate; no action recommended	

[a] Risk ratings are qualitative estimates based on information summarized above and on expert judgment of the authors.
[b] Fire regimes are defined as (1) low severity: 5- to 30-year frequency, less than 20 percent overstory mortality (dry mixed-conifer forests and woodlands); (2) mixed severity: 30- to 100-year frequency, patchy and variable overstory mortality (mesic mixed-conifer and drier high-elevation forests); and (3) high severity: more than 100-year frequency, more than 80 percent overstory mortality (low-elevation conifer and wetter subalpine forests).
[c] Fire intensity/severity are expected to increase in the next few decades, but they may decrease if fuel loadings are sufficiently reduced over time.

would incur the greatest overall risk in terms of land area. High-severity regimes cover less land area, so they would have less influence on large-scale ecological changes; however, local effects could be significant, particularly where high-severity fire regimes occur close to large population centers, where socioeconomic exposure could be high even if probability of an event were low.

Management of fire risk is a standard component of fire management in the Western United States. Fire suppression has traditionally been used on both public and private lands to reduce fire area and fire severity. Increasing area burned will provide significant challenges for federal agencies and other organizations that fight fire because of the high cost of suppression and difficulty of deploying firefighters to multiple large fires that may burn concurrently and over a longer fire season. Fuel treatments in dry forest ecosystems of the West can greatly reduce the severity of wildfires (Johnson et al. 2011), although funding is available to treat only a small percentage of the total area with elevated fuel loadings. Fuel treatments that include mechanical thinning and surface fuel removal are expensive, especially in the wildland-urban interface, and in a warmer climate, more fuel may need to be removed to attain the same level of reduction in fire severity as is achieved under current prescriptions (Peterson et al. 2011). Allowing more wildfires to burn unsuppressed is one way to achieve resource benefits while reducing risk, although this approach is often politically unacceptable, especially when fire could threaten human infrastructure and other values. Managing fire risk will be one of the greatest challenges for forest resource managers in the West during the next several decades.

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