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Interactions of climate, fire, and management in future forests of the Pacific Northwest

Michael C. Wimberly *, Zhihua Liu

Geospatial Sciences Center of Excellence, South Dakota State University, Brookings, SD 57007, United States

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ABSTRACT

A longer, hotter, and drier fire season is projected for the Pacific Northwest under future climate scenarios, and the area burned by wildfires is projected to increase as a result. Fuel treatments are an important management tool in the drier forests of this region where they have been shown to modify fire behavior and fire effects, yet we know relatively little about how treatments will interact with changing climate and expanding human populations to influence fire regimes and ecosystem services over larger area and longer time periods. As a step toward addressing this knowledge gap, this paper synthesizes the recent literature on climate, fire, and forest management in the Pacific Northwest to summarize projected changes and assess how forest management can aid in adapting to future fire regimes and reducing their negative impacts. Increased wildfire under future climates has the potential to affect many ecosystem services, including wildlife habitat, carbon sequestration, and water and air quality. Fuel treatments in dry forest types can reduce fire severity and size, and strategically-placed treatments can help to protect both property and natural resources from wildfire. Although increased rates of burning are projected to reduce carbon stocks across the region, research to date suggests that fuel treatments are unlikely to result in significant increases in carbon storage. Prescribed burning combined with thinning has been demonstrated to be effective at reducing fire severity across a variety of dry forest types, but there is uncertainty about whether changing climate and increasing human encroachment into the wildland–urban interface will limit the use of prescribed fire in the future. Most fire research has focused on the dry forest types, and much less is known about the ecological impacts of increased wildfire activity in the moist forests and the potential for adapting to these changes through forest management. To address these knowledge gaps, future research efforts should build on the Pacific Northwest's legacy of integrated regional assessments to incorporate broad-scale climatic drivers with processes operating at the stand and landscape levels, including vegetation succession, fire spread, treatment effects, and the expansion of human populations into wildland areas. An important outcome of this type of research would be the identification of localized "hot spots" that are most sensitive to future changes, and are where limited resources for fire management should be concentrated.

1. Introduction

The Pacific Northwest is renowned for diverse and highly productive forests that are a significant component of the terrestrial carbon sink the United States (Raymond and McKenzie, 2012). Fire was historically a ubiquitous landscape-level disturbance across the region that created a continually-shifting mosaic of forest age classes and structures (Agee, 1993). During the latter half of the 20th century, fire suppression has reduced the frequency of wildfires relative to historical fire regimes while timber harvesting and other forest management practices have increased, causing major changes in forest composition, stand structures, and landscape patterns (Hessburg and Agee, 2003; Wimberly et al., 2004). In the drier parts of the region, these changes have increased fuel loading and connectivity and contributed to the occurrence of uncharacteristically large, high-severity wildfires in recent years (Hessburg et al., 2005). In addition, increased spring temperatures and earlier spring snowmelt have lengthened the fire season across the western U.S., and these changes have been associated with increases in the area burned by large wildfires (Westerling et al., 2006). Projected scenarios of future anthropogenic climate change will further alter fire regimes, with implications for future forest vegetation, habitat for associated species, and forest management practices (Littell et al., 2010; Mote and Salathe, 2010).

Fuel management is an important component of current efforts to restore fire-resilient forest structure and mitigate the negative consequences of wildfires in the dry forests of the Pacific Northwest. It is expected that treatment of hazardous fuels will continue to play a major role in mitigating fire risk and conserving biodiver-

* Corresponding author. Tel.: +1 605 688 5350.
E-mail address: michael.wimberly@sdstate.edu (M.C. Wimberly).

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sity in future climates characterized by more wildfires (Spies et al., 2006, 2010). Although fuel treatments can potentially reduce both fire size (Cochrane et al., 2012) and severity (Prichard et al., 2010), they also have substantial impacts on carbon storage, wildlife habitat, and a variety of other ecosystem services (Stephens et al., 2012). These and other studies (e.g., Raymond and Peterson, 2005; Wimberly et al., 2009; Prichard and Kennedy, 2012) have increased our understanding of how fuel treatments and other forest management activities modify wildfire behavior and effects. However, we still know relatively little about how the direct and indirect effects of fuel treatments will affect fire regimes over large areas and long time periods in the context of a changing climate and expanding footprint of human population growth.

The main objective of this review was to explore the potential interactions between climate, fire, and human activities in future forests of the Pacific Northwest. We summarized recent studies documenting projected climate changes and their likely effects on future fire regimes, and reviewed the literature on fuel treatments to characterize current knowledge about their influences on fire behavior and effects and impacts on a variety of ecosystem services. Our synthesis of these topics highlighted some areas of scientific agreement with strong concordance across multiple studies, but also identified specific relationships and geographic areas where significant knowledge gaps exist. We further explored several novel linkages that have not been emphasized in previous assessments of climate change and fire management in the region, including (1) climatic constraints on the application of prescribed fire that could limit its use for fuel treatment and forest restoration activities, and (2) human population growth and expansion of the Wildland–Urban Interface (WUI) that may both increase fire risk and constrain fire management activities.

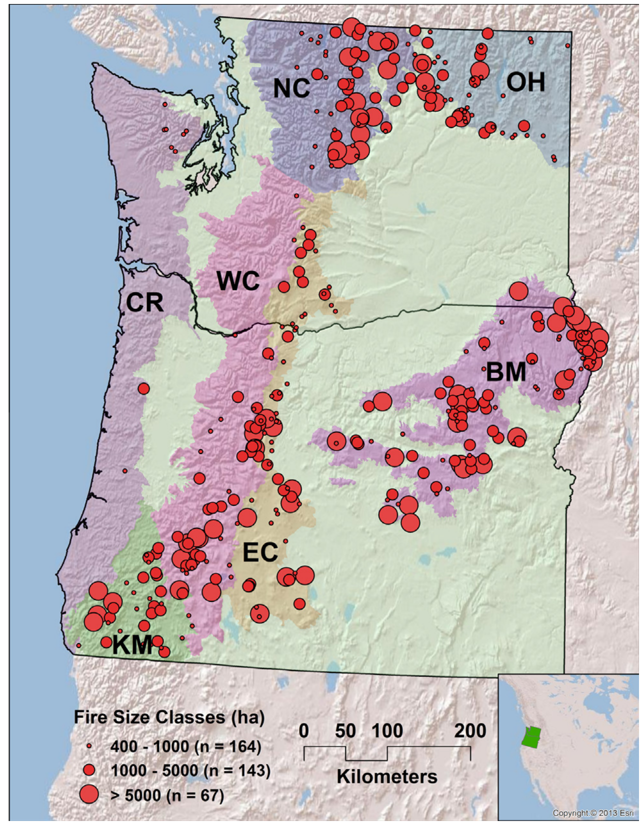

Fig. 1. Map of the Pacific Northwest region encompassing the states of Washington and Oregon along with the Bailey's ecoregion sections referenced in the report. Moist maritime conifer forests occur in the Oregon and Washington Coast Ranges (CR), the Western Cascades (WC), and in the western portion of the North Cascades (NC). Drier forest types predominate in the Eastern Cascades (EC), Okanagon Highlands (OH), Blue Mountains (BM), Klamath Mountains (KM), and the eastern portion of the North Cascades. Circles represent the locations of large historical wildfires (>400 ha) from 1984 to 2008 with size proportional to area burned by the wildfire. Fire data were obtained from the monitoring trends in burn severity (MTBS) project (http://www.mtbs.gov/).

2. Background

The forests of the Pacific Northwest encompass an enormous range of climatic, physiographic, and floristic variability, but can be broadly classified into two geographic regions: a moist zone located west of the crest of the Cascade mountain range, and a dry zone located east of the Cascade crest and in southwestern Oregon (Franklin and Johnson, 2012). The moist zone has a Mediterranean climate characterized by relatively cool wet winters and warm dry summers with most precipitation falling as rainfall except at the highest elevations. The dry zone has a more continental climate generally characterized by colder winters, hotter summers, and lower precipitation with a higher proportion occurring as snow. The historical vegetation and fire regimes of these zones differed, as do current distributions of forest structure conditions, degrees of fire risk, and forest management practices. Consequently, this geographic stratification is important for understanding future responses to climate change as well as the potential for forest management activities to facilitate adaptation to these changes.

Moist maritime conifer forests dominated by Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) occur in the Oregon and Washington Coast Ranges, the Western Cascades, and in the western portions of the North Cascades (Franklin and Dyrness, 1973), (Fig. 1). Sitka spruce (*Picea sitchensis*) is dominant along the Pacific Coast and other species such as noble fir (*Abies procera*), subalpine fir (*Abies lasiocarpa*) and mountain hemlock (*Tsuga mertensiana*) are common at higher elevations. Historical fire regimes in these moist forests were characterized by large, high severity fires with long return intervals (200–500 years) (Agee, 1993; Long and Whitlock, 2002; Weisberg and Swanson, 2003), although fire regimes in some of the parts of the moist forest zone were mixed severity with shorter return intervals (Weisberg, 2004; Perry et al., 2011). In the modern landscape, most wildfires are suppressed and the disturbance regime is dominated by clearcut timber harvests, with much higher rates of stand-replacement disturbance and smaller areas of older forests dominated by large trees and other late-successional forest characteristics than would be expected under the historical disturbance regime (Wimberly et al., 2000; Kennedy and Spies, 2004; Wimberly and Ohmann, 2004). Other important disturbances in western Oregon and Washington typically result from winter storm events with high winds and precipitation and include flooding, debris flows, landslides, and wind-thrown trees. Their impacts can be substantial; the Columbus Day storm of 1962 blew down or damaged more than 10 billion board feet of timber, with most of the damage concentrated in the Western Cascades (Orr, 1963).

Drier forest types predominate in the Eastern Cascades, Okanagon Highlands, Blue Mountains, Klamath Mountains, and the eastern portion of the North Cascades (Fig. 1). Dry middle- and low-elevation forests encompass a variety of tree species, including Douglas-fir, grand fir (*Abies grandis*), Ponderosa pine (*Pinus ponderosa*) and dry-type lodgepole pine (*Pinus contorta*) (Franklin and Dyrness, 1973). In the Klamath region of southern Oregon, rugged mountainous terrain punctuated with serpentine soils supports diverse mixed coniferous-broadleaf forests. Historical fire regimes were highly variable, but were generally characterized by frequent fires (5–35 year fire return intervals) and mixed severities (Heyerdahl et al., 2001; Agee, 2003). Fire suppression, resulting buildup of fuels, and selective harvest of large individual trees since the early