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Wildfire exposure and fuel management on western US national forests

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ABSTRACT

Substantial investments in fuel management activities on national forests in the western US are part of a national strategy to reduce human and ecological losses from catastrophic wildfire and create fire resilient landscapes. Prioritizing these investments within and among national forests remains a challenge, partly because a comprehensive assessment that establishes the current wildfire risk and exposure does not exist, making it difficult to identify national priorities and target specific areas for fuel management. To gain a broader understanding of wildfire exposure in the national forest system, we analyzed an array of simulated and empirical data on wildfire activity and fuel treatment investments on the 82 western US national forests. We first summarized recent fire data to examine variation among the Forests in ignition frequency and burned area in relation to investments in fuel reduction treatments. We then used simulation modeling to analyze fine-scale spatial variation in burn probability and intensity. We also estimated the probability of a mega-fire event on each of the Forests, and the transmission of fires ignited on national forests to the surrounding urban interface. The analysis showed a good correspondence between recent area burned and predictions from the simulation models. The modeling also illustrated the magnitude of the variation in both burn probability and intensity among and within Forests. Simulated burn probabilities in most instances were lower than historical, reflecting fire exclusion on many national forests. Simulated wildfire transmission from national forests to the urban interface was highly variable among the Forests. We discuss how the results of the study can be used to prioritize investments in hazardous fuel reduction within a comprehensive multi-scale risk management framework.

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1. Introduction

The growing incidence of catastrophic fires in the US and elsewhere is forcing public land management agencies and private landowners to re-examine strategies to reduce human and ecological losses (USDA Forest Service, 2010). Mega-fires in the western US (Williams, 2013) overwhelm suppression efforts and burn through large areas of wildlands, destroying infrastructure and homes, and damaging scenic and ecological values. These trends continue despite significant changes in wildland fire policies, including the National Fire Plan, Healthy Forest Restoration Act (HFRA) and most recently, the Federal Land Assistance, Management and Enhancement Act (FLAME, USDA-USDI, 2014) that call for strategic investments in fuel management, wildfire preparedness, and suppression. For federal land management agencies such as the USDA Forest Service, this sequence of legislation has provided a moving window of policy direction for the national forest system (henceforth NFS) faced with a growing suppression budget and the task of reducing risk to people and minimizing adverse wildfire impacts to an array of ecosystem services. Implementing these policies has required prioritizing funding to the 155 national forests and grasslands, and downscaling the policy intent to field units where site-specific fuel treatment projects are designed and

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implemented. The annual budget for these activities within the NFS is between 200 and 300 million USD (USDA, 2012), resulting in treatments on an average area of 1.0 million ha per year between 2002 and 2011 (USDA Forest Service, 2011b). A substantial portion of the budget and treatment area is targeted to the wildland urban interface (WUI), where for instance, between 2004 and 2008 some 45% of the investments were made (USDA Forest Service, 2011a).

Despite many demonstrated instances where Forest Service fuel management projects have reduced fire severity and facilitated suppression efforts (Safford et al., 2012; USDA-USDI, 2014), the program has been critically reviewed by oversight agencies (GAO, 2007). This is not surprising given that predicting the effects of fuel modifications on risk posed by future, highly stochastic and large (e.g., 100,000 ha) wildfire events is a complex problem. While a growing body of literature has advocated increased use of risk science and risk assessment methods to cope with uncertainty issues (GAO, 2004, 2009; Miller and Ager, 2012), developing consistent and standardized performance metrics for field implementation is a complex process. However, without formal risk-based protocols and assessments, it is not possible to track changes in risk from fuel management programs designed to reduce it. At the same time, developing a standardized measure of wildfire risk across 155 US national forests, each having unique ecological settings and social context, is a challenging and perhaps intractable problem.

In this paper we draw on a number of empirical and modeled data sources to systematically describe variation in wildfire exposure among the fire prone national forests in the western US with the broad goal of creating a strategic understanding of how wildfire potentially impacts each of the Forests, and how those impacts are related to current investment in federal fuel management programs. Wildfire exposure concerns the general description of potential wildfire activity in relation to values of concern, and is a precursor to more detailed risk analyses where losses are predicted with associated probabilities (Finney, 2005). Exposure analyses are a necessary step in risk assessments and typically reveal much of the same spatial patterns without the complexity of predicting fire effects on specific human and ecological values. Our exposure analysis mined data from historical records and used simulation modeling to examine five interrelated questions that all have a direct bearing on fuel management strategies aimed at reducing risk on the western national forests: 1) what is the relative magnitude in wildfire exposure both within and among the Forests, 2) what are the major trends among pre-settlement, recent, and simulated fire activity in terms of burned area, 3) to what extent do wildfires ignited within the NFS contribute to wildfire exposure to surrounding lands and the wildland urban interface (WUI), 4) what is the future probability for a "mega fire" event in each of the Forests, and 5) how do recent fuel management investments among the national forests compare with recent burned area? We used the outputs from the above analyses to rank the national forests for selected exposure metrics to illustrate the magnitude of the differences and understand regional trends. Finally, we discuss potential improvements to the current budget allocation process for the fuel treatment program within the NFS, and propose a long-term goal of developing an adaptive risk protocol that connects funding priorities with monitoring activities to fine tune fuel management investments in relation to their performance in terms of reducing risk.

2. Methods

2.1. Study area

The study area included the 82 national forests, grasslands, and scenic areas west of the Mississippi River (henceforth Forests, Fig. 1, Sup-Table 1), and the adjacent wildland urban interface (WUI) as mapped by the SILVIS project (Radeloff et al., 2005). The Forests cover over 67 million ha and contain a diverse array of forest and rangeland ecosystems. About 64 million ha are classified as burnable from LANDFIRE data (Rollins, 2009). The Forest network is dissected by many mountain ranges including the Rockies, Sierra Nevada, Cascade, and numerous sub-ranges creating pronounced gradients in vegetation, climate, and fire regimes.

2.2. WUI boundaries

The SILVIS polygon-based spatial data (Radeloff et al., 2005) were used to create a WUI layer to examine exposure to private property adjacent to Forests as described below. We removed polygons that had 1) less than 50% vegetation, thus very low levels of wildfire spread and severity; 2) low population density (<6.17 housing units km^{-2}), with lower concern of transmission; and 3) polygons <100 ha in size due to the scale of the simulation data. Each polygon was subsequently assigned to the nearest Forest based on the distance from the WUI centroid to the Forest boundary. The selection of thresholds to remove polygons preserved the larger, higher density WUI areas around Forests, and created a layer that was more suitable for large scale comparisons of exposure across the Forests included in the study.

2.3. Recent fire occurrence data

We obtained a recent fire history (1992–2009) database that was developed for fire simulation research (Finney et al., 2011) from federal and state agency fire suppression records (Short, 2013). The data consisted of ignition location and date, final fire size, and a number of other attributes and were initially derived from the National Interagency Fire Management Integrated Database (NFMID) at the National Information Technology Center in Kansas City, Missouri (accessed 11/14/2011). The data extracted covered wildfires over the period 1992–2009 and provided information on the size and ignition location of approximately 130,000 fires for the 82 western Forests. Of those, approximately 91% of fires were reported as originating on Forest lands with federal protection responsibility. After initiating the study, we re-queried the NFMID database to specifically obtain attributes not included in the Short (2013) database pertaining to the percent of different ownerships burned by individual wildfires. These latter data were required for analysis of empirical transmission as described below, and spanned the time period 1990–2011 (FIRESTAT, 2011).

2.4. Fuel investment data

Data on fuel treatment budgets for the Forests were obtained from administrative reports as compiled by Fire and Aviation Management in the USFS Pacific Northwest Region office in Portland, Oregon (L Mayer, Region 6 Forest Service Fuel Planner). The data consisted of hazardous fuels (Forest Service budget code WFHF) allocations to individual Forests over the period 2006–2011. We adjusted allocations for inflation using the 2009 annual average from the Consumer Price Index (ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt) and used the budget data to compare total fuel investments to recent and simulated fire occurrence. The data were adjusted on a Forest by Forest basis to remove allocations to Forests that were contained within the hazardous fuels budget but not targeted for fuels projects. The budget allocation to each Forest was the outcome of national and regional funding processes within the agency and broadly represents fuel management priorities at the scale of individual Forests.