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Examining heterogeneity and wildfire management expenditures using spatially and temporally descriptive data

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ABSTRACT

Increasing costs of wildfire management have highlighted the need to better understand suppression expenditures and potential tradeoffs of land management activities that may affect fire risks. Spatially and temporally descriptive data is used to develop a model of wildfire suppression expenditures, providing new insights into the role of spatial and temporal heterogeneity in determining expenditures. Incorporating heterogeneity improves model fit and predictive ability over a model with data based on the point and time of fire ignition. The model is potentially useful for providing expenditure information for simulated fire applications and post-season evaluation of suppression activities.

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Introduction

The escalating costs of wildfire management have been a persistent policy and land management problem for Federal agencies in the United States. Between 1992 and 2014 the proportion of the United States Forest Service's (USFS) annual budget devoted to fire management has risen from 13 to over 50 percent of total annual appropriations (http://www.fs.fed.us/about-agency/budget-performance/cost-fire-operations). In response to this trend, the U.S. Government Accountability Office (GAO) and Department of Agriculture Office of Inspector General (OIG) have criticized

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the USFS and U.S. Department of Interior for their inability to quantify the value of investments in wildfire suppression (USDA OIG, 2006; GAO, 2009).

Much progress has been made toward understanding expenditures on wildland fire management activities, including insights into trends in suppression expenditures (Calkin et al., 2005) and the factors related to incident suppression expenditures (Gebert et al., 2007; Canton-Thompson et al., 2008; Liang et al., 2008; Gude et al., 2013; Donovan et al., 2011; Yoder and Gebert, 2012). Despite this progress, sophisticated expenditure models are increasingly needed to better forecast and manage agency expenditures, support outcome based performance measures, inform land, fire, and fuel management planning efforts, and support incident decision making. For example, prioritizing and planning treatments of hazardous fuels may incorporate the effect of treatment options on expected suppression expenditures (Taylor et al., 2013; Thompson et al., 2013c), and the Wildland Fire Decision Support System (WFDSS) uses a suppression expenditure model to provide information on expected expenditures for an incident under current conditions (Noonan-Wright et al., 2011). As these applications continue to be developed, expenditure models that can provide accurate information at the appropriate spatial and temporal scales will become increasingly important.

An important feature of many of the tools used for planning and decision support is the ability to generate spatially explicit information on biophysical and socioeconomic conditions related to wildfire. In WFDSS, a suite of fire modeling tools can provide detailed spatial information on likely fire behavior under different conditions, as well as the probable exposure of fire-susceptible assets such as built structures (Calkin et al., 2011; Noonan-Wright et al., 2011). Pre-fire analyses similarly consider how variability in environmental conditions can influence wildfire likelihood and intensity, as well as the potential consequences to resources and assets, with potential application for incident response planning and fuel treatment design (Scott et al., 2012a,b; Ager et al., 2013; Thompson et al., 2013a). Many of these fire models explicitly capture temporal variation in fire weather conditions that are driving factors in fire occurrence and behavior (Scott et al., 2013).

However, existing suppression expenditure models have not kept pace with advances in stochastic geospatial fire modeling. The empirical link between landscape and geographic characteristics and wildfire management expenditures has largely relied on geospatial data describing fire conditions at the time and place of ignition (Gebert et al., 2007; Donovan et al., 2011; Yoder and Gebert, 2012). Ignition-point data have to date been the best available data for investigating the determinants of suppression expenditures.[1] With the availability of more detailed geospatial information about wildfires, including the widespread availability of digitized final fire perimeters, expenditure models can potentially incorporate data that provides a richer spatial and temporal description of characteristics that are related to expenditures. If spatial or temporal heterogeneity (or both) of these characteristics is related to expenditures, then ignition-point values will accurately represent this relationship only to the degree that the ignition point and time is representative of characteristics over the entire spatial and temporal extent of the fire. That is, models based on the ignition point alone cannot account for characteristics that exhibit spatial or temporal heterogeneity that may be related to fire behavior (e.g., topography, fuel conditions) or managers' responses to fire (e.g., land designation, proximal human development).

The goals of this study are two-fold: (1) to examine whether information on fire characteristics that vary over space or time can improve the fit and performance of suppression expenditure models over comparable models that use ignition-point data, and (2) to develop a suppression expenditure model that is capable of leveraging spatially explicit information generated by state-of-the-art decision support tools. To this end we develop a suppression expenditure model that can account for spatial and temporal heterogeneity throughout the evolution of wildfire incidents.

The primary empirical hypothesis is that spatially and temporally descriptive data may improve the accuracy and reliability of expenditure predictions by reducing measurement error and accounting for management responses to conditions that change over space and time. We investigate whether incorporating spatially and temporally descriptive data improves model fit and predictive power over

[1] An exception to the ignition-point approach is Liang et al. (2008), who incorporated spatially descriptive data for a sample of fires in western Montana and northern Idaho.