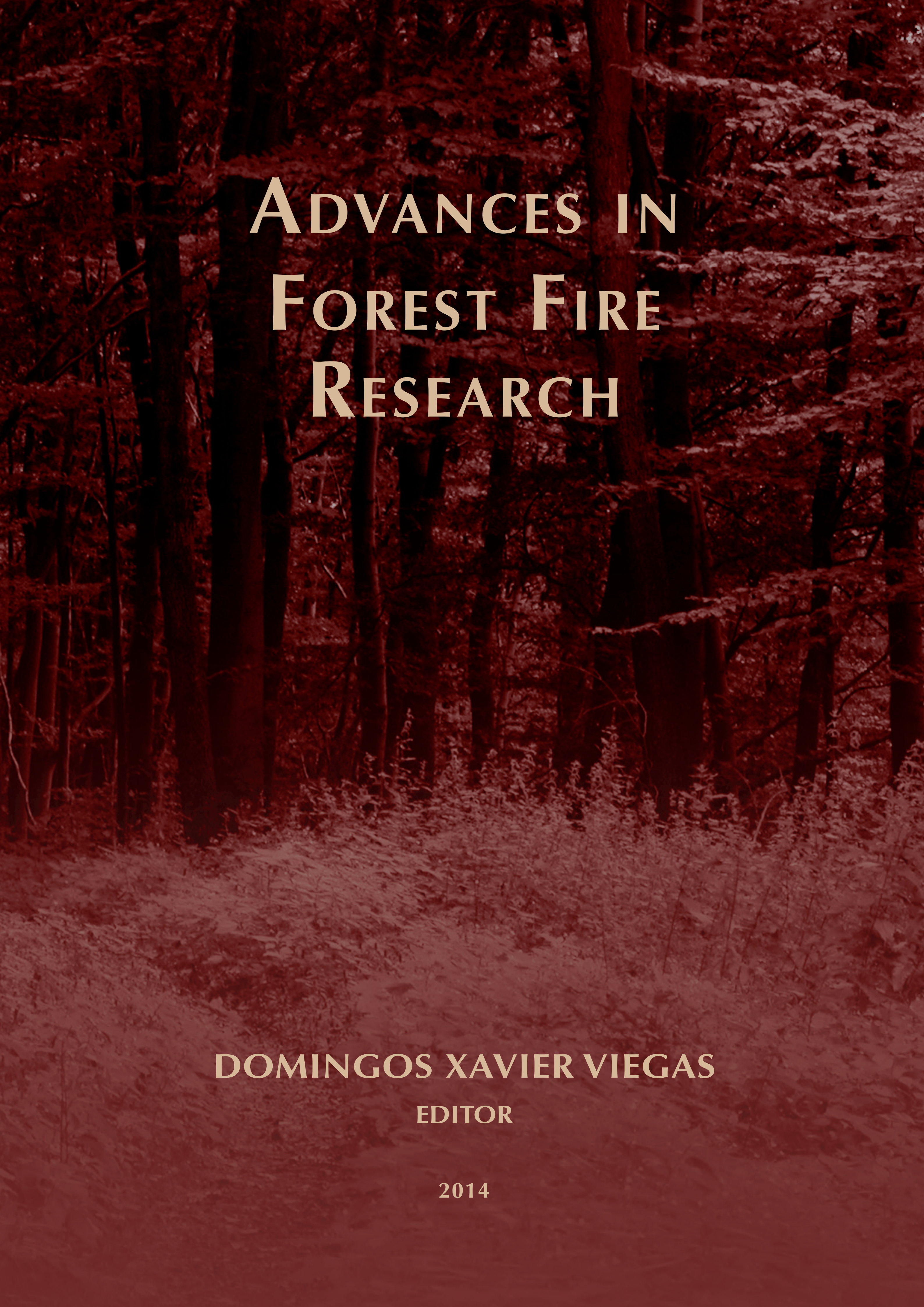

Advances in Forest Fire Research

Domingos Xavier Viegas

Editor

2014

The impacts of treated landscapes on suppression cost effectiveness

Matthew P Thompson[a], Michael S Hand[a], Jon Rieck [a], Jessica R Haas [a], and David E Calkin [a]

[a]*Rocky Mountain Research Station, US Forest Service, Missoula, MT, USA,*
mpthompson02@fs.fed.us, *mshand@fs.fed.us*, *jrieck@fs.fed.us*, *jrhaas@fs.fed.us*, *decalkin@fs.fed.us*

Abstract
In this paper we will focus on the role of treated landscapes on suppression costs and suppression effectiveness. We will begin with a framework outlining the pathways through which treatments could influence wildfire management decisions and fire outcomes, rooted in treatment impacts on fire behaviour. We will then synthesize several emerging research threads seeking to characterize treatment impacts on suppression costs and effectiveness: (1) a simulation-based approach combining stochastic fire modelling with statistical cost modelling; (2) an econometric approach analysing historical suppression costs; and (3) a case study approach using spatial fire perimeter and fire line construction data to quantify fire line effectiveness. To conclude we will outline how these threads can be woven with improvements in fire and fuels modelling to better characterize spatiotemporal trends and trade-offs related to fuel treatment and suppression.

Keywords: *wildfire management, spatial analysis, simulation analysis, econometric analysis*

The views expressed here are the authors', and do not necessarily represent the views of the USDA

1. Introduction

High-quality wildfire suppression decisions require information on the conditions under which alternative strategies and tactics would be safe and cost-effective. Incident management decisions are premised on the acquisition, analysis, and application of timely and accurate fire information (Zimmerman 2012), and recur within a dynamic, uncertain environment (Thompson 2013). Important pieces of information that fire managers must consider include weather forecasts, fire behaviour and fire growth potential, firefighting resource availability and productivity, and the exposure and susceptibility of values-at-risk (Calkin *et al*. 2011). Accurate spatial data on current landscape conditions are essential to predict fire behaviour and identify management opportunities.

A critical component of landscape condition is the location of areas previously treated by wildland fire (i.e., wildfire and prescribed fire) and/or with mechanical methods. Post-fire analyses and simulation modelling demonstrate the potential for treated areas to alter fire behaviour, size distributions, and spatial patterns of burn probability, and to mitigate fire effects (Ager *et al*. 2010; Stephens *et al*. 2012; Parks *et al*. 2014). Less well understood are whether or how these fire-specific changes can meaningfully or measurably lead to changes in incident decisions, expenditures, or effectiveness.

A conceptual model for treatment impacts on suppression cost-effectiveness is presented in Figure 1. The impacts of treated areas have two main pathways. First, altered fuel composition and continuity can directly influence fire behaviour, which can also indirectly influence incident response. Second, the presence of treated areas on the landscape can directly inform the design of incident strategies and tactics, although this is premised on sufficient knowledge regarding the location, age, and type of treatment. In a post-fire environment, the degree and magnitude of treatment impacts may be discerned through interviews with incident management personnel, statistical analyses, and/or retrospective modelling (Moghaddas and Craggs 2008; Wimberley *et al*. 2009; Cochrane *et al*. 2012). In a pre-fire environment, however, treatment impacts are more uncertain and modelling is necessary. Importantly, recognizing the relative rarity of wildfire occurrence and the commensurate low likelihood of treated areas interacting with fire, evaluation of treatment impacts needs to occur within a probabilistic framework (Thompson and Calkin 2011). Pre-fire risk assessment results can then be shared with fire managers to help inform incident response planning (Scott *et al*. 2012).

Building from this conceptual model, we synthesize several emerging research threads on the effects of treated landscapes on suppression costs and suppression effectiveness: (1) a simulation-based approach combining stochastic fire modelling with statistical cost modelling; (2) an econometric approach analysing historical suppression costs; and (3) a case study approach using spatial fire perimeter and fire line construction data to quantify fire line effectiveness. In concert with improvements in fire and fuels modelling, we believe these research efforts will enable significant advancements in spatiotemporal evaluation of trends and trade-offs related to fuel treatment and suppression.

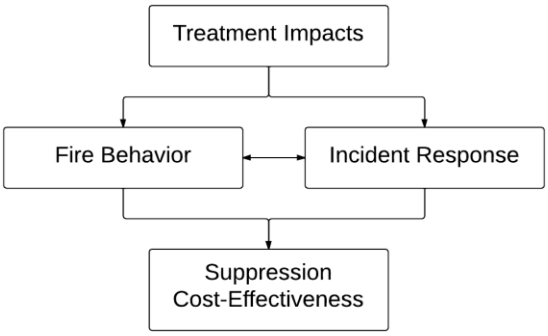

Figure 1. Conceptual model linking treatment impacts to suppression cost-effectiveness

2. **Emerging Research on Suppression Cost-Effectiveness**

Interest in whether treated landscapes can measurably influence suppression costs has been around for more than a decade, although only recently have researchers begun to rigorously quantify these potential impacts with geospatial analysis and fire behaviour modelling. Some of these modelling advancements came with the advent of the Collaborative Forest Landscape Restoration Program (CFLRP) in the United States, intended in part to facilitate the reduction of wildfire management costs. In a pilot study, Thompson *et al*. (2013) demonstrated the pairing of stochastic wildfire simulation with suppression cost modelling on landscape in the Deschutes National Forest, using models developed and used by the U.S. Forest Service (Gebert *et al*. 2007; Finney *et al*. 2011). Results indicated the possibility for significant savings given wildfire-treatment interactions, although after considering the likelihood of wildfire occurrence annual savings of any kind only occurred in 1 out of every 4 years.

Simulation of wildfire occurrence and behaviour across the landscape under existing and post-treatment conditions allows for the isolation of fuel treatment impacts on fire metrics and subsequent changes to cost distributions. The spatially-explicit modelling approach captures heterogeneity in fire likelihood and behaviour across the landscape, the size and location of treatments with respect to fire spread direction, and the location of ignitions with respect to factors influencing cost such as land designation and proximity to human development. These techniques are now being systematically applied to evaluate the cost impacts of landscape fuel treatment strategies funded under CFLRP throughout the U.S.

Concurrently with advancements in the coupling of fire and cost models and risk-based evaluation of treatment impacts, researchers have made advancements in the spatiotemporal resolution and predictive power of suppression cost models (Hand *et al*. 2014). One key improvement is the use of spatially descriptive data within the entire perimeter of the fire rather than information based off the ignition location alone, which is made possible by the compilation of a large dataset of spatial fire perimeters from recent fire seasons. The use of perimeters enables, for instance, a more accurate characterization of the diversity of vegetative and topographic conditions. Additionally, the model can better capture variation in fire weather throughout the course of the incident. With these improvements, cost models will be able to better capture potential treatment impacts by considering not just changes to fire size distributions but also changes in the location and orientation of their footprints with respect to factors known to influence costs.

These improvements further open the door for novel retrospective analysis of historical wildfire-treatment interactions. By leveraging comprehensive, geospatial fire history databases (Short 2013), and possibly agency fuel treatment databases, we will be able to identify the degree to which our dataset of fire perimeters overlaps with previous treatments. Geospatial analyses will allow us to characterize the extent and severity of re-burned areas, and econometric analyses we will allow us to quantify the impact, if any, on observed suppression costs. Figure 2 compares and contrasts these two approaches, both of which should add to the knowledge base of potential treatment impacts on suppression costs.

Better understanding the cost component however does not by itself yield insights into treatment impacts on suppression cost-effectiveness. A third thread of research therefore relates directly to the characterization and quantification of suppression effectiveness. Though theoretical frameworks exist for efficient suppression (Mendes 2010), in practice significant data limitations and knowledge gaps present challenges for identifying factors influencing successful suppression and for characterizing conditions under which alternative strategies and tactics would be safe and effective (Finney *et al*. 2009; Holmes and Calkin 2013). One key challenge is the acquisition and alignment of incident management data from disparate sources such as firefighting resource ordering systems, incident status reporting systems, and operational fire management decision support systems, in addition to data generated and managed at the incident-level. As a result, on-site data collection during an actual wildfire incident is often the best option, despite being time and resource intensive. Specifically, we have been able to collect data on daily assignments by mission type, fire line construction productivity, and daily spatial fire perimeter growth.

With these data, case study analyses can yield new insights into the role of previously treated areas on suppression effectiveness. One initial approach is to query incident decision documentation to qualitatively ascertain the degree to which knowledge of treated areas influenced strategies and tactics. An extra layer of analysis can quantify fire line effectiveness in terms of percent of line held, and can statistically analyse fireline effectiveness within and outside of previously treated areas. The goal of these analyses is to improve our understanding of how suppression resources are used on wildfires and which factors contribute to effectiveness.

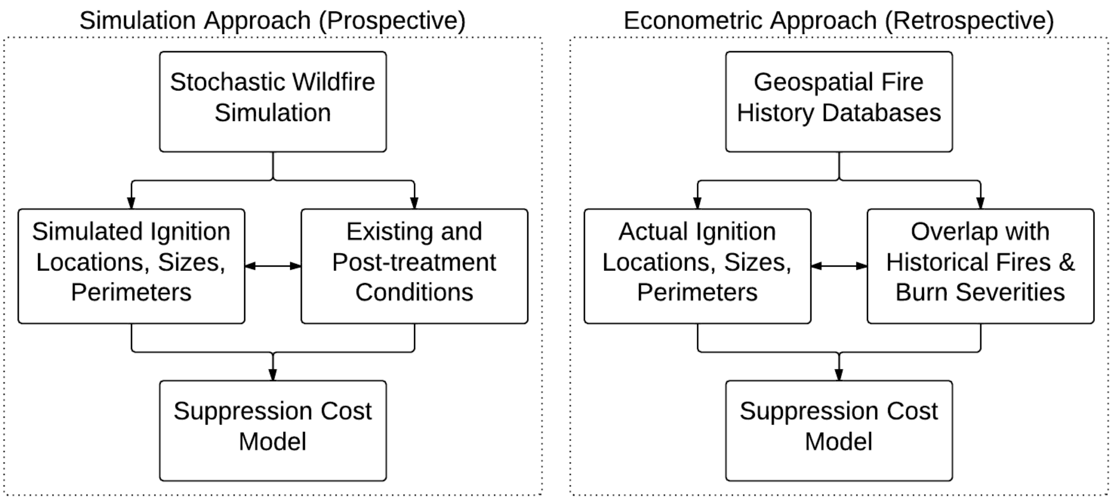

Figure 2. Prospective and retrospective approaches for characterizing potential influences of treated areas on suppression costs

3. Future Research Directions

The emerging research threads presented in the previous section will set the stage for a wide spectrum of integrated research opportunities. First and foremost we aim to leverage our research with advances in fire and fuels modelling as well as advances in decision support for fuel planning and incident response. Landscape-scale simulation of the spatiotemporal dynamics of wildland fire occurrence, spread, and resulting fuel and vegetation changes will set the stage for life cycle economic analysis of fuel treatment strategies, as well as the costs and benefits of different fire suppression policies. The analytical process can be designed to specifically target salient questions regarding how the spatial and temporal scales of fuel treatment (and retreatment) influence treatment costs and subsequent cost effectiveness. Ultimately the aim of this research is to support evaluation and prioritization of fuel treatment investments at programmatic and landscape scales, and to support risk-informed, forward-looking suppression strategy development.

4. Acknowledgements

The Rocky Mountain Research Station, the National Fire Decision Support Center, and the Joint Fire Science Program supported this effort.

5. References

Ager, A. A., M. A. Finney, A. McMahan, and J. Cathcart (2010), Measuring the effect of fuel treatments on forest carbon using landscape risk analysis, Natural Hazards and Earth System Sciences 10, 2515-2526.

Calkin, D. E., M. P. Thompson, M. A. Finney, and K. D. Hyde (2011), A real-time risk assessment tool supporting wildland fire decisionmaking, Journal of Forestry, 109(5), 274-280.

Cochrane, M., C. Moran, M. Wimberly, A. Baer, M. Finney, K. Beckendorf, J. Eidenshink, and Z. Zhu (2012), Estimation of wildfire size and risk changes due to fuels treatments, International Journal of Wildland Fire, 21(4), 357-367.

Finney, M. A., C. W. McHugh, I. C. Grenfell, K. L. Riley, and K. C. Short (2011), A simulation of probabilistic wildfire risk components for the continental United States, Stochastic Environmental Research and Risk Assessment, 25(7), 973-1000.

Finney, M., I. C. Grenfell, and C. W. McHugh (2009), Modeling containment of large wildfires using generalized linear mixed-model analysis, Forest Science, 55(3), 249-255.

Holmes, T. P., and D. E. Calkin (2013), Econometric analysis of fire suppression production functions for large wildland fires, International Journal of Wildland Fire, 22(2), 246-255.

Gebert, K. M., D. E. Calkin, and J. Yoder (2007), Estimating suppression expenditures for individual large wildland fires, Western Journal of Applied Forestry, 22(3), 188-196.

Hand, M. S., K. M. Gebert, J. Liang, D. E. Calkin, M. P. Thompson, and M. Zhou (2014), Modeling Fire Expenditures with Spatially Descriptive Data, in Economics of Wildfire Management, edited, pp. 37-48, Springer New York.

Mendes, I. (2010), A theoretical economic model for choosing efficient wildfire suppression strategies, Forest Policy and Economics, 12(5), 323-329.

Moghaddas, J. J., and L. Craggs (2008), A fuel treatment reduces fire severity and increases suppression efficiency in a mixed conifer forest, International Journal of Wildland Fire, 16(6), 673-678.

Parks, S., C. Miller, C. Nelson, and Z. Holden (2014), Previous Fires Moderate Burn Severity of Subsequent Wildland Fires in Two Large Western US Wilderness Areas, Ecosystems, 17(1), 29-42.

Scott, J., D. Helmbrecht, S. Parks, and C. Miller (2012), Quantifying the threat of unsuppressed wildfires reaching the adjacent wildland-urban interface on the Bridger-Teton National Forest, Wyoming, USA, Fire Ecology, 8(2), 125-142.

Short, K. (2013), A spatial database of wildfires in the United States, 1992–2011, Earth System Science Data Discussions, 6(2), 297-366.

Stephens, S. L., J. D. McIver, R. E. Boerner, C. J. Fettig, J. B. Fontaine, B. R. Hartsough, P. L. Kennedy, and D. W. Schwilk (2012), The effects of forest fuel-reduction treatments in the United States, BioScience, 62(6), 549-560.

Thompson, M. P., and D. E. Calkin (2011), Uncertainty and risk in wildland fire management: a review, Journal of Environmental Management, 92(8), 1895-1909.

Thompson, M. P., N. M. Vaillant, J. R. Haas, K. M. Gebert, and K. D. Stockmann (2013), Quantifying the potential impacts of fuel treatments on wildfire suppression costs, Journal of Forestry, 111(1), 49-58.

Wimberly, M. C., M. A. Cochrane, A. D. Baer, and K. Pabst (2009), Assessing fuel treatment effectiveness using satellite imagery and spatial statistics, Ecological Applications, 19(6), 1377-1384.

Zimmerman, T. (2012), Wildland Fire Management Decision Making, Journal of Agricultural Science and Technology, B(2), 169-178.