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Towards Efficient Large Fire Management: Monitoring, Modeling, and Accountability

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Introduction

Context and Purpose

This extended abstract summarizes six interrelated presentations organized together under a special session on wildland fire management in the U.S. The objective of the special session is to synthesize recent and ongoing research focused on quantifying and improving the efficiency of incident response, with a focus on the rare but large fires that typically account for the majority of socioeconomic and ecological impacts. This body of work embraces a primary focal area of the National Cohesive Wildland Fire Management Strategy – safe and effective wildfire response – and is premised on the idea that how fires are managed, not just how landscapes are managed before and after fires occur, is a key determinant of long-term landscape resiliency (Thompson et al. 2015).

In recent decades, the risks and complexities of the U.S. wildland fire management environment have increased dramatically, driving increased losses and elevated response costs (Calkin et al. 2015). A multitude of factors are likely responsible, including historical forest and fire management practices resulting in increased forest density and fuel loads, climatic changes resulting in warmer, drier, and longer fire seasons, and significant expansion of the wildland urban interface resulting in increased exposure of communities and homes. It is becoming increasingly apparent that a business-as-usual approach to fire management is unsustainable (Olsen et al. 2015). Suggested alternative management paradigms identify a need to learn to live with fire, and deemphasize fire exclusion while promoting expanded application of prescribed and managed natural fire (Moritz et al. 2014; North et al. 2015).

While the need to transition to a new fire management paradigm is well-recognized, significant knowledge gaps constrain our ability to clearly and comprehensively describe how changes in the way agencies plan for and respond to fires may lead to improved outcomes. Hence a need to better monitor fire management actions and outcomes, to better model and evaluate alternative management strategies, and to ensure agencies are accountable for acquiring and basing decisions on best-available information. These three concepts – monitoring, modeling, and accountability – are essential elements of risk analysis and management, and are the primary topics of our special session and of this extended abstract.

Organization

The remainder of this extended abstract is organized into three sections that tie back to our main concepts. Each section contains simply the title, lead author, and abstract for all individual presentations. Monitoring is the first topic we address, as a critical element for performance measurement and program review, as well as for ensuring models are accurately parameterized and calibrated. Both presentations in this section focus on aerial firefighting, which is dangerous and costly, and which remains the subject of analysis and deliberation regarding fleet modernization strategies. We next turn to modeling, presenting descriptive as well as prescriptive approaches that focus on the ordering, use, and movement of ground and aerial firefighting resources. Models such as those presented are critical for helping managers better evaluate alternative management strategies across a range of decision contexts. Lastly, we briefly review the notion of accountability, how it relates to monitoring and modeling efforts, and how it relates to risk management principles. While by no means exhaustive, we note that the topics discussed here are representative of the breadth and depth of analyses necessary to improve fire management efficiency.

Monitoring

Large airtankers in US fire management: describing historical use and discussing implications related to efficiency
Crystal Stonesifer

Airtankers are widely used in suppression of wildfires in the United States. While Federal guidance suggests that they are best reserved for initial attack (IA) of new wildfire ignitions, our past work analyzing drop records from 2010-2012 has shown that the Federal large airtanker (LAT) fleet was used in IA approximately half of the time. Further, nearly three-quarters of IA drops were on fires that escaped containment efforts during the first operational period, suggesting that LATs are used on fires that are inherently difficult to contain, and that there are often potential objectives at play beyond basic incident containment (e.g., point protection). Additionally, our analysis demonstrated frequent LAT use in conditions where their effectiveness may be limited by a combination of environmental factors conducive to extreme fire behavior (e.g., late afternoon, steep slopes, timber fuel models). These patterns demonstrating widespread use under conditions when all suppression resources are known to be less effective suggest that LATs may be viewed as a resource of last resort. Here, we briefly summarize our previous findings, and then discuss the implications of utilizing LATs under fire conditions when all else fails. We present ideas for an alternative system that emphasizes targeted use of LATs under conditions where they are known to be most effective through thoughtful preplanning, efficient deployment, and utilization of the best available fire activity and behavior forecast tools. The Aerial Firefighting Use and Effectiveness (AFUE) study currently underway will provide valuable additional information regarding environmental conditions of use, drop intent as it relates to the larger strategic fire suppression plan, and associated outcomes, which will greatly enhance our ability to improve the efficient use of the federal LAT fleet in the future.

Meaningful translation of aerial firefighting objectives, context and outcomes into effectiveness across the range of fire sizes for the Aerial Firefighting Use and Effectiveness Study
Keith Stockmann

A 2013 Government Accountability Office (GAO 2013) report critiqued interagency inability to characterize use, effectiveness and needs for aerial assets in wildfire suppression, which justified a long-term study to improve our understanding of the role and contribution of planes and helicopters in firefighting efforts. The current project takes a leap of complexity past previous investigations by designing a study that untangles the wide range of aircraft uses, focusing on expensive aircraft delivering suppressants and retardant to assist fire managers. The Forest Service's Technology and Development Centers are working with partners in fire and aviation management, USFS Research, National Interagency Fire Center information technology and the BLM. The AFUE Study has four operational modules across the western US, each with three experienced firefighters, a field coordinator, a data manager and an analyst. Collectively they developed an ESRI Collector instrument that classifies use into one of various objectives, captures drop tactics, plans, terrain, weather, and complementary resource availability/actions and also assesses outcomes at multiple scales. After refining this approach for several seasons and observing thousands of drops, it is time to translate the combinations of objectives and outcomes into a meaningful assessment of effectiveness. This is an inside look at the mechanics of this translation, anchored in firefighter perspective, but flexible enough to scale across the range of fire sizes and supported with limited quantitative analysis of fire growth and retardant survival modeling. This translation of outcomes to effectiveness is a key step towards classification and regression tree diagnosis of factors explaining success and future cost effectiveness analyses, both of which should lead to more informed and efficient use of aircraft in wildfire suppression.

Modeling

Firefighting Resource Use and Movement in the United States
Erin Belval

Examining the efficiency and effectiveness of wildland firefighting resource use is becoming increasingly crucial in light of rising suppression expenditures; however, there has been little research to date that has been designed to understand and quantify the patterns of resource ordering and movement in the US. Archived records from the Resource Ordering and Status

System (ROSS) provide data that support the task of quantifying national fire suppression resource use for large fire suppression. An initial analysis of ROSS data compares team assignments recorded in ROSS to the team type recorded in the set of incident status summary reports; this analysis found differences between the two sets of data and indicates that additional efforts may be needed to more accurately track team use. We also used ROSS data to study suppression resource utilization and resource movements between geographic regions during fire seasons. These analyses used linear regression techniques to examine crew, engine, dozer, and helicopter utilization on large fires. The results indicate significant variation in resource assignment frequency and assignment length on large fires based upon fire complexity and the region of fire occurrence. Additional multinomial regression analyses are used to model crews responding to fires outside their home region. The results demonstrate that the probability of a crew response from a specific home region to fires outside of its home region is significantly correlated with factors such as the region in which the crew is based, fire activity and resource scarcity in crew's home region, the region in which the incident occurs, national level resource scarcity, seasonality, and the proximity of the crew's home region to the region in which the incident occurs.

Develop a simulation/optimization procedure to study the daily suppression resource reassignments during a fire season in Colorado
Yu Wei

Sharing fire engines and crews between fire suppression dispatch zones over a fire season improves the utilization of these resources and allows managers to meet suppression demand in each zone during time of high fire activity. Using data from the Resource Ordering and Status System (ROSS) and the Predictive Service 7-day Outlook from 2010 through 2013, we studied daily fire crew and engine demand in Colorado's six dispatch zones and designed a simulation/optimization procedure to transfer crews and engines into Colorado and to move them between these zones. Management assumptions and policies may influence resource assignment patterns and related efficiencies; we compared the effect of several different assumptions and policies using our model. We also compared several model-suggested crew and engine reassignment patterns with historical ROSS records to identify potential improvements in efficiency.

A framework for optimal incident management: safe and effective response in a new fire management paradigm
Christopher Dunn

Transition to the new fire management paradigm will require adaptation and innovation from fire management organizations so they can manage risk and uncertainty while minimizing decision biases. This requires alignment of a hierarchy of decisions beginning with pre-suppression planning and continuing through the development of optimal response tactics. In this talk, we propose a new dynamic, multi-response optimization model of large fire management that considers uncertainty in land management objectives, environmental conditions and suppression resource availability, safety and efficiency. The most pressing and potentially important decision for large-fire incident response is the establishment of means-based objectives that are specific, measureable, achievable, realistic and time-constrained. Without means-based objectives there is limited opportunity to utilize modern analytical methods for decision support. Identified control lines, resources and assets requiring point protection, and logistical-features requiring construction should be included as part of the tactical response objectives utilized by incident managers that ultimately lead to the objective function and constraints within the dynamic optimization model. The next step in the dynamic optimization model is to integrate long-term fire behavior simulations with resource production models to determine the likelihood of controlling a fire at the identified control boundary. Following identification of intended control lines, three umbrella decisions are necessary to manage large-fire incidents and therefore need to be accounted for in the dynamic optimization model: resource acquisition, resource allocation, and resource demobilization. Each umbrella decision includes several sub-level decisions specific to individual resources and tasks, and all interact to determine the final solution. These large-fire management decisions are constrained by interactions between the operational environment and resources assigned to the incident, including variables related to operational standards and environmental constraints, which largely relate to interactions between fire behavior and firefighter safety. The framework we have described integrates decisions made at multiple levels within land and fire management organizations. Pre-suppression planning and use of modern analytical tools with expert knowledge has the potential to improve the large-fire management decision making process, provide the opportunity to develop optimal incident response tactics, and improve the safety and efficiency of large fire management. The dynamic optimization model requires improved data and modeling capacity, both of which require investment and support from agency leadership. Integrating these modeling efforts with expert knowledge will help fire management organizations more effectively adapt to the new fire management paradigm.

Accountability

Infusing Accountability and Risk Management Principles into the Fire Management System
Matthew Thompson

Adoption of core risk management principles is important to improve wildland fire management decisions and outcomes. Embracing risk management for instance means investing time and resources in upstream assessment and planning to reduce the uncertainties and time-pressures of the incident decision environment. It also means embracing various facets of accountability: committing to generating and using the best available information, developing robust systems to monitor performance, and using that information to facilitate continual improvement. Absent a data-driven system of accountability, fire management organizations have no basis for tracking or correcting behavior, even when such corrections would help better attain objectives. Similarly, without accountability organizations have difficulty connecting decisions to outcomes and evaluating how alternative courses of action may lead to improved outcomes. The analyses related to monitoring and modeling presented in this special session highlight pathways forward for improved adoption of risk management and accountability principles.

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