PANEL DISCUSSION: CHALLENGES AND RECOMMENDATIONS FOR THE MAPPING OF FIRE AND POST-FIRE EFFECTS

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ABSTRACT

Scientists are tasked with seeing their science applied, and, in turn, managers rely on the objectiveness of scientists to make defensible decisions. Scientists and managers currently use remote sensing to map, understand, and predict the ecological effects of fire. Although much has been learned, challenges remain; and there is an urgent need to provide science and tools that managers can use to address challenging fire management issues. In order to provide such data and products, scientists must understand the needs and expectations of fire managers. To facilitate bridging this gap between science and application, we brought together an expert panel of both researchers and managers to discuss information needs and challenges and to make recommendations for the mapping of active fire characteristics and post-fire effects. This paper provides a summary of this panel discussion, which highlighted challenges relating to terminology, interpretation, data availability, etc; and suggested recommendations for partnerships and strategies to address these challenges.

BACKGROUND

Fire science is shaped by the needs and expectations of fire managers, who make decisions regarding lives and property with real-world consequences. With the recent focus on accountability by the federal government, there is an urgent need to demonstrate the tangible benefits that research can offer to effectively address challenging fire management issues. Although both fire scientists and fire managers have long worked closely together, their communication, understanding, and collaboration must improve if they are to effectively address these challenges.

Remotely sensed data are an important and widely applied resource for fire science and management. The size and inaccessible nature of many wildfires make remotely sensed data essential for the detection and assessment of conditions before, during, and after fires, in addition to providing a means to quantify patterns of variation in space and time (Morgan et al. 2001). These data can then be used to support management decisions in a timely and cost efficient manner.

Scientists and managers use remote sensing to map, understand and predict the ecological effects of fire. Much has been learned; challenges remain. Many federal funding agencies (e.g., the National Science Foundation, the Joint Fire Sciences Program, etc.) require that scientists emphasize active technology transfer and obtain feedback on data and products from the audiences most likely to apply the science. To this end, we brought together an expert panel of researchers and managers to share their perceptions of the challenges and recommendations for the *Mapping of Active Fire Characteristics and Post-Fire Effects*. The foundation for this panel discussion was a recent article entitled, "Remote Sensing Techniques to Assess Active Fire Characteristics and Post-fire Effects" (Lentile et al. *in press*). This article reviewed current and potential remote sensing methods used to assess active fire behavior, post-fire effects, and ecological responses to fire. This article discussed challenges and future directions of fire-related remote sensing research from the researcher's perspective. This article was circulated to the panellists, who were asked to provide feedback and additional perspectives on the sections relating to challenges and recommendations for fire-related research. Further to these topics, the panel also received questions from the audience. This paper contains a summary of their responses and subsequent discussion.

OBJECTIVES

Scientists and managers may view impediments and opportunities in different ways. Scientists may not wholly understand what tools managers seek and the timeframes and constraints under which they operate. For example, a large wildfire may catalyze a flurry of information gathering, reporting, and strategizing by various resource managers. Information to support decision-making must be readily available and in forms that managers can use. Scientists may view fire events as an opportunity to implement research studies, yet results will likely not be available for many years, and may not be entirely focused on questions that managers actually need answered. Researchers and managers need to actively work closely together to understand the scope of each others' interests and needs. In essence, do more "collaborative" work. Scientists cannot fail to communicate and demonstrate the immediate and long-term value of their research and to seek feedback from managers. Likewise, managers need to understand the limits imposed on many scientists, which control when and who is available to do the research and the ever-present pressure by refereed journals and funding agencies for novel and ground breaking research.

When scientists and managers partner to design and implement studies, it is more likely that results will address applied questions, provide decision support, and lead to the development of appropriate tools and technologies. To this end, our goals were to synthesize the views of scientists and managers on efforts to map active fire characteristics and post-fire effects, to present multiple perspectives on current challenges, and to generate recommendations for partnerships and strategies to address such challenges.

To guide this discussion, a moderator posed several questions to panelists and solicited others from the audience. Panelists were first asked to share their perceptions of current data needs and information gaps relating to the mapping of fire and post-fire effects. Perceptions of data needs may vary depending on the particular expertise and experience of the user. Hydrologists, soil scientists, and forest vegetation managers provided examples of remote sensing technologies that have been used to address applied questions and support time-sensitive decisions. Panelists also provided insight into the challenges for acquiring, interpreting, and applying remotely sensed data and information. Lastly, the panelists and audience discussed ways in which researchers and managers can cooperate to address and overcome these challenges.

MANAGERS' PERSPECTIVE

1) What are the current data needs and information gaps relating to the mapping of fire and post-fire effects?

There are many different information needs—some immediate and localized, others longer-term and broader scale. Monitoring at both high temporal and spatial resolution may help to provide data to evaluate pre- and post-fire treatment effectiveness, including, unintended consequences. However, these data are typically expensive to obtain, and are usually not available when managers need them or in standardized formats so that researchers can conduct cross-site comparisons. Studies are needed that mechanistically link ecological condition to fire behavior and effects as observed both on the ground and via remote sensing systems. Such research would further improve the researchers' assessment of what the imagery is 'seeing' and would provide improved decision support for land managers. As with many remote sensing research disciplines, the current abundant application of Landsat imagery for the production of 'burn severity' maps, coupled with their widespread use by both fire managers and incident commanders, echoes the alarm raised by many scientists surrounding the likely 3 years + data gap in available imagery. Scientists and managers alike are worried about the potential implications if this particularly useful and readily accessible data source is lost, even temporarily. In the following paragraphs, we provide a summary of managers' perspectives on current data needs and information gaps relating to the mapping of fire and fire effects.

There is a need to improve assessment at differing spatial and temporal scales.

Landscape-level ecological effects of fires are not well understood. Predicting where on the landscape fires are likely to cause severe ecological effects and understanding why these effects vary are central questions in fire science and management. Remote sensing can help us to characterize the fuels, vegetation, topography, fire effects and weather before, during and after fires.

Remote sensing can detect immediate ecosystem change, but this change is not necessarily uncharacteristic. Depending on where post-fire assessments are made, portions of the landscape may be traumatically changed, due to prior disturbances such as logging or grazing, or due to fire exclusion, etc. Some landscapes have experienced further departure from historical conditions than others and for different reasons. In some systems, burned forests transition to grasslands or shrublands and follow a very different post-fire successional trajectory. The temporal and spatial scale of change is important. Changes in landscape pattern and process are poorly understood. For example, in some areas of the Southwest, riparian zones that rarely burn or desert systems that have never burned are burning. Managers need information to help guide the planning process, particularly in ecosystems and vegetation types where there is little information or research pertaining to historical or current condition.

There is a need for better assessment of treatment effectiveness and improved monitoring protocols.

The influence of forest structure, topography, and weather on fire behavior and effects is of great interest to managers tasked with deciding where, when and how restoration treatments are most likely to be effective. In general, managers are guided to prescribe treatments that include the restoration of historical fire regime attributes, however, research has provided a limited assessment of the effectiveness of these treatments. This information is in general challenging to acquire, often lacks the robustness of other scientific studies, and to date has been largely anecdotal. Even when treatments appear to reduce the severity of subsequent wildfires, little quantifiable information is available to assess whether historical fire regime attributes have been restored. This confusion has led some managers to question whether restoration treatments are based on viable objectives.

Although efforts are underway, post-fire severity assessment is not standardized. The terminology used to describe fire effects is confused even within the ecological communities, and especially between the ecological and remote sensing communities. The challenges complicate use of quantifiable measures of success in terms of fuels treatment effectiveness, particularly if treatment effectiveness is measured by the reduction in acres burned by severe fire. The broad-scale nature of these questions, as well as the size and remoteness of many wildland fires, warrants the utilization of remotely sensed data.

Studies linking active fire characteristics, post-fire effects and pre-fire stand conditions are limited.

Research is lacking that mechanistically connects current stand and vegetation condition to fire behavior and ecological response. In some cases, managers need real-time data to support suppression and fire management decisions, especially in the wildland urban interface (WUI). Current fire behavior models that are widely used are based on data collected in the laboratory, on prescribed fires, and on limited observations during wildfires. Yet, these models are central to predictions during wildfires for tactics, and for designing successful fuel treatments around communities or elsewhere. Following fire, managers need improved techniques to detect post-fire effects on the surface to prescribe mitigation treatments. Post-fire burn severity assessment via remote sensing may be challenged where residual canopy density is high or where fire consumes only litter. In most fires, the integration of ground-based and remote measures of active and post-fire effects is especially important.

Managers need new or better-calibrated models, as well as increased confidence in the use of these models. Managers make many post-fire decisions based on retrospective causality, and these decisions often have broad implications. Many current post-fire decisions are based on satellite-based interpretation of fire effects, i.e., the visual appearance of green, brown, and black reflectance is translated to low, moderate, and high vegetation burn severity. However, vegetation burn severity may provide very little information for a variety of other important resources. Whereas, a mechanistic understanding of the energy transferred to tree boles, crown, and roots may help managers to make better management decisions regarding the post-fire environment. For example, following fire managers may seek to enhance wildlife habitat with particular objectives for species of interest, such as bats or cavity nesting birds. Understanding fire effects as fires burn will help to support many resource decisions that otherwise are difficult to measure directly. Furthermore, understanding where the greatest amount of energy is transferred during fire may streamline post-fire assessment and assist managers with anticipating the areas of greatest ecological change. The development of remote sensing systems to characterize energy released by fire (e.g., Wooster et al 2002, Riggan et al 2004, Smith and Wooster 2005) is central to developing more mechanistic models of active fire behavior. Similarly, remote sensing methods geared more towards direct characterization of physical post-fire effects will improve understanding more than the current general strategy of relating ground conditions to burn severity indices.

2) What are the current challenges for providing this information?

For some managers the biggest concern with remote sensing technology is that, by and large, the technology is driving the pursuit of information. Managers perceive scientists as looking for applications for use of the technology rather than identifying specific resource questions and developing the technology appropriately. It is however, unlikely that this disconnect can easily be corrected, as the remote sensing scientists conducting the applied fire-related research are not the engineers, designers, or project scientists in charge of developing the sensor systems. In particular, most sensor systems are developed for other research questions, with applications in fire science being an unintended but useful side effect. As a result, such scientists are by virtue of the available data, forced to develop tools with what is available, with few having access to their own sensor systems (exceptions such as FireMapper and HAMCAM are highlighted within this issue). Management needs continue to be rapid field-based applications for short-term coarse-level initial assessment (e.g., Burned Area Emergency Response (BAER) phase) and usable (i.e., low cost, modest complexity) tools for longer range planning and recovery from wildfire. In many cases, remote sensing and field assessments are poorly integrated; as a result, products may not match data needs or be available in the appropriate timeframes.

Managers and researchers often operate in very different timeframes and spatial scales and have a different set of motivating factors.

Managers may often need real-time or immediate answers, while researchers may be more interested in designing longer-term studies and are wary of sharing preliminary conclusions based on relatively few observations or less than thorough analysis. As a result, research products may not match data needs or be available in useful formats and in appropriate timeframes. In general, managers would like to see a better balance of immediate answers provided by studies that have longer-term potential to answer applied questions.

Remote sensing and field assessments are poorly integrated.

The Normalized Burn Ratio (NBR) is one of many remotely sensed spectral indices that have been widely used to measure fire-induced vegetation loss. However, this index of change caused by the fire should be rigorously tested against field data (e.g., canopy scorch, tree mortality, ground char, fuels consumption, fractional cover of char, etc.) across a variety of vegetation biomes and fire regimes to determine where they are most useful and what they actually mean in terms of post-fire ecological effects. For example, further studies comparing remotely sensed data to field data, such as the Composite Burn Index (CBI), could also help us understand whether values of post-fire ecological change arise from fire effects on canopy, understory vegetation, or soil. Insightful combinations of field and remotely sensed data collection, interpretation and analysis, and appropriate application, is important to increase confidence in the ability of remote sensing to address many applied questions.

Terminology is used inconsistently across fire ecology and remote sensing research and within research and management communities.

Confusion about fire intensity, fire severity, burn severity, and related terms can result in the potential misuse of the inferred information by land managers and remote sensing practitioners who require unambiguous remote sensing products for fire management. Even when managers and researchers communicate, they do not always "speak the same language", i.e., use the same terms to refer to similar concepts.

Many managers remark that the terminology used to describe and evaluate fire regimes is confusing and inconsistently applied. Current tools such as the Fire Regime Condition Class (FRCC) were developed to provide a standardized method for determining the degree of departure from reference condition vegetation, fuels and disturbance regimes. FRCC was designed to help guide management objectives and set priorities for treatments; however, some managers find these tools to be overly subjective and only useful to those with extensive local knowledge of the evaluation area. For example, stand-replacing fires are often referred to as "high severity"; however, lethal fire effects may be characteristic for these regimes. High severity fires may not have the same effects in all forests, giving high severity components a negative connotation in some forests where lethal fire effects may be beneficial or natural.

The term ***burn severity*** has been used to describe the effects of fire on a variety of resources (e.g., vegetation mortality, soil erosion, soil nutrition etc.) (Jain et al. 2004). Burn severity is a value-laden term, and assessments may vary according to objectives. Burn severity is often defined as the magnitude of ecological change, yet this change may not be apparent immediately following fire or may be difficult to gauge if pre-fire information is lacking. High burn severity implies significant ecosystem change, which may be true in the relatively short term; yet, actual ecosystem processes may be unchanged 100 years later. For example, the 2002 Hayman Fire in Colorado was described as an uncharacteristically severe wildfire. Fire effects were more severe and found in patches larger than recorded in the previous century, and > 3 years post-fire, most of the burned landscape is still in FRCC 3, which relates to a high degree of departure from the historical ecological condition of the landscape. An abnormally severe fire may result from a variety of causal factors leading to conditions that are outside the range of historical conditions. Causal factors may be fire exclusion, or some other change to the disturbance regime to which the biota is not adapted, (e.g., clearcut harvest and subsequent thick forest regrowth), decreasing the likelihood that one fire will return a landscape to historical condition. Some managers question how pre- and post-fire landscapes can both be accurately described as severely departed, yet burned at high severity. In many cases, it is probably unrealistic to describe the consequences of individual fires without a good understanding of cumulative effects, particularly under changing climatic regimes.

Another example of potential confusion that may arise from terminology, relates to fuels treatments and restoration treatments. Fuels treatments to mitigate fire hazard (as supported by the Healthy Forest Restoration Act) and restoration treatments are two very different concepts and should be guided by different objectives—often treatments do not meet either objective, but increase fire hazard with potentially negative fire effects that are unsustainable. Managers need to be clear about objectives and motivating factors. Researchers need to provide defensible information with a transparent list of assumptions and limiting factors, so that managers can move forward with treatments. It is important to be clear about the language and objectives to enhance public trust and so that lessons can be learned. Not all ecological systems are created equal—in systems that have been modified to the point that they are unhealthy, we need research to improve our understanding of historical conditions and restoration treatments likely to achieve sustainable processes, and not just properties. Public, as well as research and management communities, need to understand that restoration is not a static goal, and plan accordingly.

There is insufficient time and resources to conduct ground-based monitoring.

There is a lack of fiscal resources to monitor treatments, and even less to monitor untreated (control) sites to assess the effectiveness of the treatments; remote sensing research can help monitor both. Managers need more research to help us understand the consequences of management activities, as well as the no-management option. There is insufficient time and resources to conduct ground-based monitoring, and managers need ways to monitor post-fire treatments using remote sensing. Remote sensing can be used to monitor indicators of severe fire effects, such as the occurrence of white ash or highly iron-oxidized orange soils, which can be perhaps spectrally detected with sufficient reliability to guide mitigation treatments. Severe fire effects and unintended consequences of management actions can follow both prescribed and wildland fires.

Reliance on the Landsat sensor is high, yet the future is uncertain.

As highlighted earlier, we are unlikely to see a replacement US Landsat-type sensor before 2010 (http://www.space.com/spacenews/archive05/Broad_103105.html.,10/31/05). Therefore, it is urgent researchers investigate the potential of different data sources to refine remotely sensed measures of active fire and post-fire ecological measures. However, scientists need to provide managers with clear and consistent reasons as to why this research is necessary, as the managers are likely unaware of the impending data shortfall. There are a wide variety of different sensors and techniques available to assist fire mangers in their decisions, which will ultimately depend on the objective of the particular study. For example, requirements to assess post-fire recovery in chaparral will differ from managers trying to assess watershed-level erosion potential near homes in southern California. Landsat TM and ETM data are most frequently used to assess post-fire ecological effects in North America. The application of alternative sensors to Landsat (e.g., ASTER, MODIS, Quickbird, IKONOS, airborne hyperspectral sensors, etc.,) with varying spectral, spatial, and temporal resolutions warrants further investigation. Additional research is also needed to explore the potential of airborne sensors, which provided funds exist, can be tasked on demand to study high temporal, spatial and spectral variations.

Many post-fire managers currently prefer Landsat-derived Burned Area Reflectance Classification (BARC) products to traditional sketch maps of burn severity. Many managers have serious concerns with timing and availability of products to map burn severity if the Landsat sensor becomes unavailable. Managers need short-term response information to plan mitigation treatments and to ensure public safety. Managers need efficient ground-truthing protocols for remotely sensed products. These protocols need to be transparent and standardized. Some seasoned post-fire planners have a lot of confidence in adjusting BARC products, but less experienced managers need to build confidence and expertise. Immediate, post-fire ground-truthing tools such as the CBI may be useful, especially if employed before wind and water further disturb the burned area.

The *political will* may outweigh the best ecological and remote sensing science.

When it comes to restoration of ecological processes, fire is not the only one. Invasive plant species may have forever changed the function of these systems. Restoration of ecosystems that developed under different climate or soil regimes is particularly challenging. Beyond these considerations, the social context is also very important; the way we perceive and manage most ecosystems is likely more dynamic than the ecosystems themselves. Currently there is strong political will to do *something* to restore systems. In many cases, the effect(s) of these restoration treatments are unknown. Several studies have documented the dramatic effects of seeding and various post-fire rehabilitation treatments on vegetation response (e.g., Beyers 2004, Robichaud et al. 2000). However, it may not matter how good remotely sensed intelligence is when the political will is stronger. Some managers consider themselves to be forest physicians and adopt the "do no harm" approach. For example, if seeding might be beneficial, and harmful effects are unknown, then many managers will go ahead and treat.

3) How can these data needs and challenges be addressed?

Researchers and managers need to work together to overcome challenges.

Researchers and managers need to actively work together to understand and appreciate each other's interests, i.e., do more "collaborative" work. Resources are limited to monitor post-fire treatments and effects. There are many opportunities for researchers and managers to work together to share data and to answer questions of interest to both groups. Coordination and collaboration can be improved across agencies and across manager and researcher communities. Research proposals based on local manager input are likely to provide more useful products to managers. Applied research objectives must be appropriate to managers' questions. In a similar vein, managers need to provide inputs to funding agencies on their needs, which may involve re-assessments of prior methods rather than seeking a new fix to an old problem. Overall, studies must mutually benefit researchers and managers.

Be aware of different needs and temporal constraints.

Management needs continue to be: rapid field-based applications for short-term coarse-level initial assessment (e.g., BAER phase) and usable (i.e., low cost, modest complexity) tools for longer range planning and recovery from wildfire. Researchers, especially those based within universities, are in contrast driven by the need to fund students (who actually conduct the research) and publish peer-reviewed articles. This typically requires a minimum of a 2-year commitment, plus the need to conduct novel research. Managers and researchers should work together to design and implement studies that meet both these short and long-term needs.

Researchers need to be aware of various audiences and how conclusions might be interpreted or misinterpreted. Researchers need to retain their objectiveness and be clear about where their conclusions apply and where they do not. Researchers should be careful about statements they make because managers have to deal with public perceptions. Research publications quickly become the state-of-the-art knowledge. Managers may have to defend why the same results are not applicable everywhere. Managers understand differences between systems and that not all places are created equal, but the public may not readily understand these differences (e.g., the recent controversy surrounding the publication by Donato et al. 2006). Managers are making better predictions and prescribing better treatments based on good research, but the best intended treatments may have unforeseen consequences. Many bad ideas, predictions and treatments can be precluded if only researchers and managers work together.

Develop simple and standardized monitoring techniques.

Managers need more research on treatment effectiveness, especially as treatments relate to 1) fire behavior and effects in the wildland urban interface (WUI), 2) post-fire erosion risk, flooding, and landslide potential, and 3) vegetation response to fire, particularly, non-native invasives and weeds. Currently most fuels treatment projects are focused in the WUI and most of the research is being done by social scientists. Predicting fire effects and reassuring feelings of angst among people living in the WUI is an applied science research need. Weeds are an emerging issue that warrants development of high spatial and spectral resolution remote sensing technology. Lastly more post fire research is needed on basic hydrologic response at the watershed scale, and effects of post-fire salvage on watershed processes. Managers realize that treatment effectiveness may be largely dependent on factors that are out of their control (e.g., weather).

Conduct more studies that link ecological condition to fire behavior and effects.

Mechanistically linking surface processes to imagery is the goal of remote sensing science. However, until we understand the underlying ecological and fire processes and link them directly to remotely sensed measures, we are relegated to developing empirical relationships for many different environments. Fire effects are often "symptoms" of fire's impact on an underlying process. Remote sensing data are too often considered as qualitative 'pictures' but are more fundamentally quantitative, to be more usefully treated as quantitative measures to improve the understanding and interpretability of landscape ecological processes. As such the characteristics and scale of both the patterns and the inferred processes must be clearly defined. Further, the methodological approach must be transparent, repeatable, and robust if we are to compare results from one geographical area to another or among sensors.

Many fire effects are driven by the heat pulse below the soil surface and subsequent impacts on belowground processes, in particular nutrient cycling and soil water infiltration. Understanding how post-fire effects relate to pre-fire conditions (forest structure and fuels) and fire behavior will facilitate the development of improved tools for predicting and mapping the degree of ecosystem change induced by the fire process (e.g., heat penetrating soil, consumption of organic materials, change in soil color). This information can improve understanding of the role of fire in creating conditions that drive sustainable ecosystem structure and function.

Develop more accurate models and useful tools.

Most post-fire management questions relate to potential risks and outcomes. Many management decisions are influenced by professional instincts and politics, and not strictly by science. Managers need more tools like the Erosion Risk Management Tool (ERMiT)/WEPP site (http://forest.moscowfsl.wsu.edu/fswepp/). For example, the

ERMiT model provides estimates of soil erosion for five years post-fire, based on biophysical and climatic parameters for a burned area and compares the effect of several rehabilitation treatments. Managers have a need for this same kind of tool to predict post-fire vegetation pathways and different outcomes based on alternative rehabilitation treatments. Managers need to have a better understanding of the short and long term impacts of various treatments and be ready to incorporate this information into planning.

CONCLUSION

Remote sensing has great potential for scientists and managers seeking to map, understand, and predict the ecological effects of fires. Remote sensing has made great strides in terms of providing data to address operational and applied research questions, beyond the scope and feasibility that ground-based studies can provide. Efficient and time-sensitive ground-based monitoring protocols will improve the utility of remote sensing products. Standardization will enable cross-site comparison and improve the potential to address both short-term information needs and longer-term ecological understanding. Using consistent terminology is an important step in developing a better understanding of the causes and consequences of spatial variability of fire effects. Mechanistic understanding of fire behavior and effects will provide decision support and better predictive models.

The goal of this panel was to highlight information needs and to provide recommendations for better coordination among remote sensing researchers and managers working in applied fire science and management. There are many opportunities for improved communication and collaboration, and forums like these can be especially informative for sharing different perspectives and overcoming challenges.

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