Exploring Use of Climate Information in Wildland Fire Management: A Decision Calendar Study

Thomas W. Corringham, Anthony L. Westerling, and Barbara J. Morehouse

ABSTRACT

We conducted surveys of fire and fuels managers at local, regional, and national levels to gain insights into decision processes and information flows in wildfire management. Survey results in the form of fire managers' decision calendars show how climate information needs vary seasonally, over space, and through the organizational network, and help determine optimal points for introducing climate information and forecasts into decision processes. We identified opportunities to use climate information in fire management, including seasonal to interannual climate forecasts at all organizational levels, to improve the targeting of fuels treatments and prescribed burns, the positioning and movement of initial attack resources, and staffing and budgeting decisions. Longer-term (5–10 years) outlooks also could be useful at the national level in setting budget and research priorities. We discuss these opportunities and examine the kinds of organizational changes that could facilitate effective use of existing climate information and climate forecast capabilities.

Keywords: climate, forecasts, western United States, wildfire management

Devastating wildfires flaming across large expanses of the United States in recent years have galvanized politicians, fire managers, and ordinary citizens alike in an effort to understand the processes driving catastrophic fire and to develop ways to anticipate when and where severe fire is likely to occur over time and space. Properly designed and used scientific knowledge and information, including climate information and forecasts, can contribute to better fire prediction and management. An essential first step in this process involves identifying optimal points in the decision networks of agencies charged with wildland fire management where such information may be inserted into decision processes. This, in turn, requires understanding the annual cycle of decisionmaking within the multiagency wildland fire management structure. The study reported here developed monthly decision calendars for National Forest Service and Park Service management units in California and the Southwest. These were used to identify points where scientific knowledge about climate–fire interactions are or may be productively introduced and to discuss the potential value of such information in strategic fire planning processes.

Background

Since the 1970s there has been a dramatic rise in the area burned by wildfires in the western United States. The average annual reported area burned in forest wildfires

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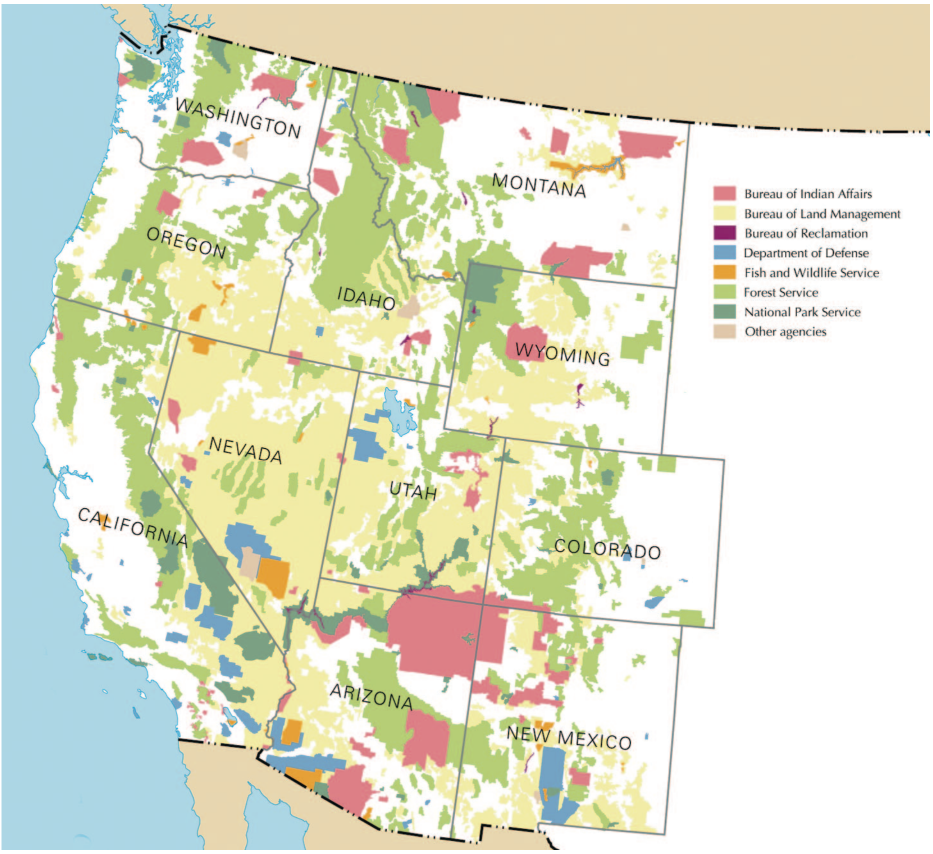

Figure 1. Federally managed land in the Western United States.

increased by about 300% in the 11 contiguous western states in this period (Westerling et al. 2006). Concomitantly, real average annual suppression costs for the US Forest Service alone have increased by a factor of 2.6 over the last 20 years and have exceeded $1 billion in 3 of the years since 2000, while costs for the Department of the Interior agencies also have increased, exceeding $300 million/year in the four years since 2000, more than double the average of the preceding 6 years (Krista Gebert, Rocky Mountain Research Station, pers. comm., 2005).

In the same period, the variance in annual area burned also has increased; the variance in the last 10years is more than 30 times higher than in the 1970s. Increases in variability in annual area burned and in fire suppression costs pose a serious challenge for federal and state land and resource managers because, although budgets have increased recently, funding still reflects what would likely be spent in an "average" year. Given that average years seldom occur, actual costs tend to fluctuate between low and high extremes. Consequently, the US Forest Service's suppression expenses regularly exceed the annual suppression budget.

Federal and state land and resource managers must be prepared for the worst possible scenarios in every fire season. Thus, increased uncertainty about the scale of the western fire season each year imposes high costs on public agencies to sustain appropriate levels of preparedness. Recent progress in our understanding of the links between climate and wildfire and in our ability to forecast some aspects of both climate and wildfire season severity offers some hope that these costs might be reduced through the increased integration of climate information into strategic planning for fire and fuels management (Westerling 2007). In this article we identify actual and potential uses of climate information and forecasts by wildland fire managers, based on the results of a decision calendar survey of fire and fuels managers in the western United States.

Organization of Fire Management

Wildland fire management in the United States is integrated across agencies by the National Interagency Coordinating Center (NICC) located in Boise, Idaho, and by 10 Geographic Area Coordination Centers (GACC). At the same time, a variety of other national, state, and local agencies continue to perform their own wildland fire suppression and preparedness activities. Federal, state, and local entities charged with wildland fire management include the US Forest Service, US Department of the Interior (USDOI) National Parks Service (NPS), USDOI Bureau of Land Management (BLM), USDOI Bureau of Indian Affairs, USDOI Fish and Wildlife Service (FWS), and state land and resource management agencies. Their wildland fire suppression efforts are supported by the US Department of Commerce National Oceanographic and Atmospheric Administration (NOAA) and National Weather Service (NWS, within NOAA), and the National Association of State Foresters.

More than one-half of the land in the 11 contiguous western United States is managed by federal agencies, encompassing most of the West's wildlands (Figure 1; USDOI 2006). Each agency works at different organizational levels, ranging from federal agency offices in Washington DC and the National Interagency Fire Center in Boise, Idaho, to regional agency offices, GACCs, and local administrative units managing the crews and equipment needed to actually perform fire suppression and fuels management. We use the US Forest Service within the US Department of Agriculture and the NPS within the USDOI as examples to describe the organization of fire management across multiple agencies.

At the local level, federal fire managers, fuels managers, and fire chiefs work within national parks and forests; these units are overseen by regional offices of the NPS and the US Forest Service. The local and regional units report, in turn, to national offices of the NPS and the US Forest Service, which are located, respectively, within the Departments of the Interior and Agriculture.

National parks and forests also coordinate their fire suppression and fuels management activities under the auspices of regional interagency fire management organizations and administrative bodies: the GACCs mentioned previously, and Multi-Agency Coordination Groups, which operate during the peak fire season to coordinate all the resources available in the different agencies to maximize efficiency in fighting wildland fires. Outside of the fire season, most interaction between the national parks and forests and their regional and national offices involves budgeting and planning activities. Some planning and fuels treatment work is also coordinated with the GACCs and National Interagency Fire Center (NIFC). A simplified flow chart shows the organizational levels and links of interest in this study (Figure 2).

Fire weather and climate information and forecasts feed into the decision processes at different levels from several sources. At the national level the NWS provides a variety of weather and climate products for use by fire managers. NIFC offices in Boise, Idaho, house the national offices for the center's Intelligence and Predictive Services functions. The NWS regional office in Boise provides a specific Fire Weather Service. At the regional level, the GACCs' Intelligence and Predictive Service functions include gathering and disseminating weather and climate information provided by regional NWS offices, as well as from several of the NOAA-funded Regional Integrated Science and Assessment (RISA) projects; the Program for Climate, Ecosystem, and Fire Applications (CEFA); and from their own fire meteorologists. At the local level, climate and weather information is obtained from the GACCs and the NWS, and, at some parks and forests, from staff fire meteorologists.

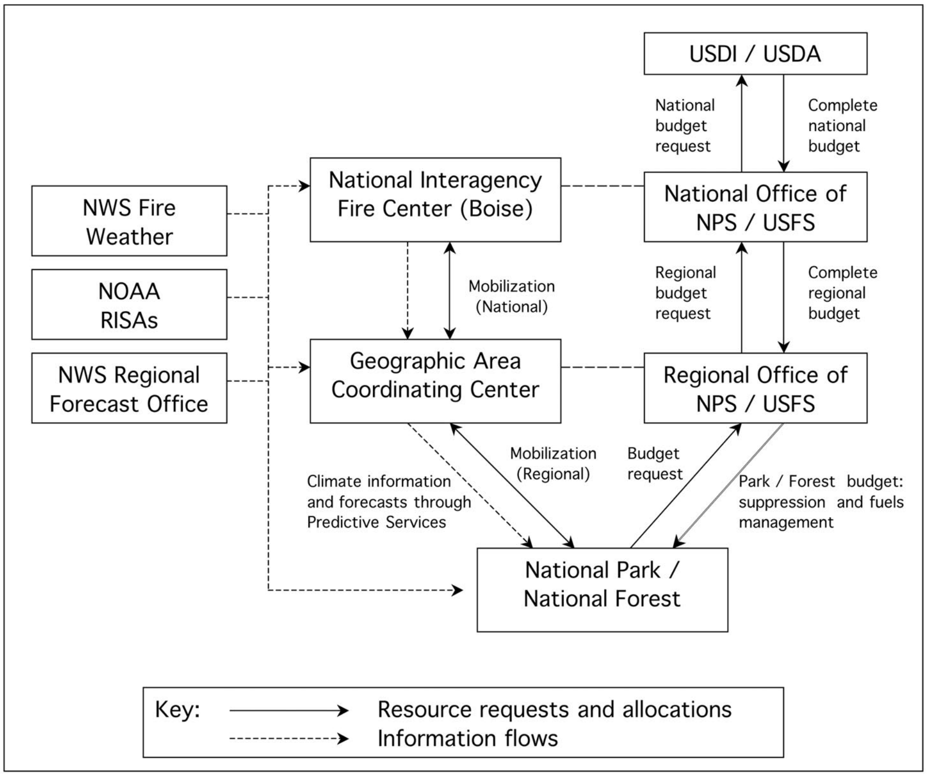

Figure 2. Wildland fire management organizational flow chart.

Climate Science and Climate Forecasts

Over the past several decades, there has been increasing interest in developing a better understanding of the use of scientific and forecasting information by decisionmakers (Hansen et al. 1998, Stern and Easterling 1999, Morehouse 2000, Sarewitz et al. 2000, Jacobs and Pulwarty 2004). Scientific information and forecasts can provide important guidance to decisionmakers who are concerned about reducing risks to vulnerable populations, ecosystems, and the built environment, reducing their operational costs, diminishing the potential for lawsuits or other challenges to their decisions and activities, and managing in a more rational manner the resources for which they are responsible. For example, information about past climatic conditions can prompt decisionmakers to change their assumptions about what constitutes "normal" climatic conditions (Swetnam and Betancourt 1998, Miles et al. 2000, Grissino-Mayer and Swetnam 2000, Westerling and Swetnam 2003); this, in turn, can influence the degree and nature of extreme conditions they include in their infrastructure and emergency planning activities.

Wildfire management is no exception to this recent trend. Traditionally, short-term weather information has been used to great effect operationally in wildland fire suppression during the fire season. With increasingly long and severe fire seasons and with an increased emphasis among federal agencies to restore natural fire regimes to ecosystems through use of fuels treatments such as mechanical thinning, prescribed fires and wildland fire use, seasonal and longer-term climate information products are finding use to support longer-term planning decisions. In this article we identify more opportunities as well as obstacles to further incorporate climate science and forecasts into wildfire management, using decision calendars.

Survey Methods

Decision calendars, as we define them here, are temporally organized structures that reflect the timing of planning and decisionmaking in the course of a regular fire year. Decision calendars have been used previously in integrated climate assessments. We based our calendar format on that used by Wiener (2004). Using this approach allowed us to determine what sorts of plans and decisions were important at which times of the year. This in turn allowed us to associate the timing of decisions, historical climate conditions during those periods, and forecasts for those time periods.

To construct fire management decision calendars showing the use of climate information, we conducted a survey (in 2002–2003) of nine fire management officers and decisionmakers based in the Southwest and California and of several dozen members of wildland fire management groups. We focused on two of the primary federal agencies responsible for wildland fire management, the US Forest Service and the NPS. We structured our selection of interviewees to assure representation of the three most important organizational levels of management: the local level, the regional level, and the national level. Conversations with several key decisionmakers responsible for interagency coordination provided supplemental background information.

The survey was designed to gather a range of information. First, we asked respondents to complete a decision calendar, specifying when during the fire year key prevention and suppression decisions are made and indicating the extent to which climate information and climate forecasts are used to support these decisionmaking processes. We asked informants to specify what climate information and climate forecasts are used, where these products are obtained, and what additional climate products managers would find useful. We asked respondents about their perceptions of the limitations of these products, in terms of the accuracy of forecasts and in terms of other constraints in the decision processes. We asked if agencies kept records of yearly management goals and of postseason evaluations and if respondents could provide examples of climate information successes and failures. Finally, we asked respondents to rank a set of wildland fire management objectives in terms of importance and to list additional objectives not listed in our survey.

We recognize that the small number of parks and forests we surveyed in the Southwest and the Pacific Southwest happen to have high levels of prescribed fire activity. However, the framework we use could readily be extended to generate a more complete picture of climate information use for fire and fuels management throughout the United States. We also recognize that the number of respondents was too low to conduct a statistical evaluation of responses; however, qualitative analysis produced valuable insights from key informants as well as information that could be generalized across all fire management groups in the US Forest Service and Park Service.

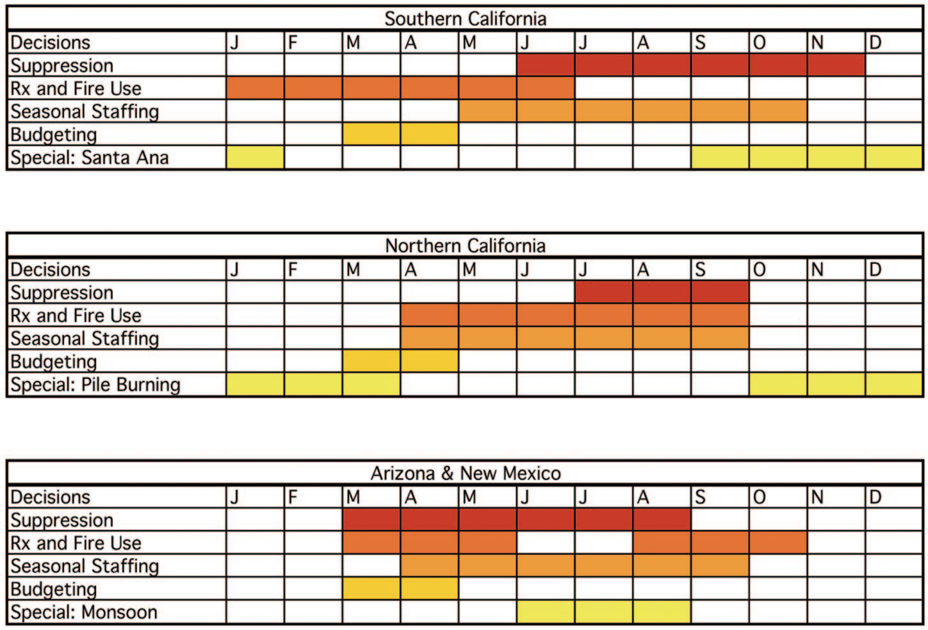

Figure 3. Aggregated decision calendars.

Survey Results

Decision Calendars. The decision calendars (Figure 3) developed from information provided by our respondents show several interesting patterns. The timing of activities varies over the geographical extent of our study areas. In particular, the peak suppression season differs in length and actual time of year from region to region. Southern California has a long season with a special concern in the late fall/early winter season when strong Santa Ana winds are dominant (Keeley 2004, Westerling et al. 2004). The Sierra Nevada in central and northern California has a relatively short season in comparison, while the severity and length of New Mexico and Arizona fire seasons depend heavily on the prefire season precipitation, during-season temperatures (Crimmins and Comrie 2004), and on the timing and wetness of the June–August monsoon season. Of particular concern is the probability of dry lighting igniting fires in the premonsoon period. Monsoon rains typically end the spring/summer fire season (Swetnam and Betancourt 1990), although a second fire season may occur in the fall after the end of the monsoon season. Similarly, optimal windows for prescribed fire and fuels management activities also vary greatly across the study areas.

The decision calendars also differ across organizational levels. At the local level, staffing decisions involve seasonal staffing, training, and determination of hiring and layoff dates. Budgeting involves the internal allocation of funds, annual funding requests, and peak season severity funding requests. Presuppression activities include fuels treatments, prescribed fire, broadcast burns, pile burning, and mechanical thinning projects. Suppression activities include the prepositioning of local resources, movement of resources, mutual aid decisions, severity requests, large fire management and fire use (planning and implementation), fire prevention, restrictions, and area closures. Other local activities reported by survey respondents include outreach, public education, special staffing, training, 5-year planning and analysis, and geographic information system (GIS) analysis.

Regional- and national-level activities include suppression support for large fires or multiple fire events or widespread high fire danger or preparedness levels, strategic prepositioning and movement of resources (again, generally when high danger conditions are present), planning and budgeting work, and the dissemination of information. Research and changes in overall organizational structure are managed at the national level.

Priorities. In accordance with national firefighting policy, risks to lives was consistently ranked as the highest priority by all respondents. Risks to property generally ranked second, although occasionally these risks ranked below smoke management requirements. The priority ranking of other issues, such as the Endangered Species Act (ESA), urbanization, population growth, exotics, and the protection of cultural resources, varied among the respondents. Budget generally placed fairly low on the list of priorities. This owes mainly to the fact that managers view their planning budgets as fixed for a given fire season and that for suppression purposes, severity funding (emergency funding distributed independently of annual budget allocations) ensures that the most important suppression objectives will be met.

Climate Information and Forecasts. The general use of climate information and forecasts to support fire and fuels management activities was described by one respondent as a "funnel approach" with historic data, real-time information, and short-term forecasts (spot forecasts, 1- to 5-day-ahead forecasts) of weather conditions at the narrow end of the funnel, and seasonal and annual outlooks and assessments at the wide end. Longer-term forecast products are used in strategic planning for a wide range of decision processes, including fuels treatment programs, staffing decisions, resource requests, and budgeting. Throughout the course of the fire season, outlooks and assessments are updated with more accurate shorter-term forecast products. Year-to-date conditions are compiled and compared with historical climate averages. When climate and fuels conditions exceed certain thresholds relative to historic conditions, more active monitoring and management activities are initiated.

According to interviewees, real-time climate information and short-term forecasts used include temperature, humidity, precipitation, fuel moisture, and wind patterns. Forecasts for more than 1 week ahead include drought indices (e.g., Keetch-Byram Drought Index and Palmer Drought Severity Index) soil moisture, live moisture, relative greenness (Normalized Difference Vegetation Index), precipitation, snowpack, fuel moisture, 1,000-hour fuel, live woody fuel (chaparral), Energy Release Component, wind patterns, 30-day outlooks, 90-day outlooks, and 3-year cumulative comparisons. Long-term forecasts used for planning include long-term outlooks for pest management, forest health projects, drought indices, and snowpack.

Sources of climate information identified by respondents included NOAA/NWS regional offices, GACCs websites and meteorologists, BLM's weather site, Desert Research Institute (CEFA), the Remote Automated Weather Stations network for up-to-date readings in the field, and the NICC's Predictive Services websites. The variety of sources reported suggests that fire and fuels managers could potentially benefit from one centralized clearinghouse for information; the clearinghouse could include specialized forecasts and information products for specific geographic areas.

Forecasts a week to a month ahead are used in broad project implementation. They are used in prescribed fire project planning and in burn plan implementation. Such forecasts also are used to support decisions about mutual aid, determining how many resources can be sent to other areas, staffing decisions, prepositioning decisions, and in the request and provision of additional resources. They are used in prevention efforts (e.g., in park or forest closure decisions) and also in severity funding requests.

Responses concerning longer-term seasonal, annual, and interannual forecasts were mixed. Some respondents reported that long-term climate forecasts are used to predict fire season start and end and are considered when planning the next year's projects, e.g., in determining the number of stations to be covered and staffing levels. Many, however, reported that longer-term forecasts still were not accurate enough to be used in decision support. One respondent claimed the use of long-term forecasts was "very rare," another said they "would use, but no product is available," and one respondent voiced concern that "the accuracy [of such products] is just not there yet." Several respondents said they would use long-term climate forecasts if good products were available and, indeed, were generally enthusiastic about the development of such products. Respondents reported that trends are considered in decisionmaking, but also noted that specific long-range forecasts still are not useful to fire and fuels managers. As an example, one respondent mentioned that El Niño Southern Oscillation (ENSO) forecasts that give reasonable information about whether the winter will be wet or dry are not sufficient for management purposes, that what is needed is an indication of how wet the season will be and the timing of the onset of precipitation.

Potential for Improved Use of Climate Information: Planning, Budgeting, Staffing, and Fuels Treatment

Based on survey responses, we have identified a number of decision processes that would benefit from enhanced use of climate information. All the decision activities described below at some point require plans and action with regard to assembling and allocating resources. Hiring, training, and staffing decisions are made leading up to the fire season; the number of fire fighters and support personnel needed are identified for each fire event, vendors are contracted to provide support services, and aircraft and other equipment needs are addressed. These types of activities within an annual decision calendar highlight decision nodes and the entry points where climate and related scientific information may be most readily and effectively introduced. Climate information and forecasts provided in advance of these points are most likely to improve district and forest-level fire management planning, budgeting, and decisionmaking.

National Level. At the national level (i.e., at the NIFC and Washington DC offices of the NPS and US Forest Service), national annual and interannual budget requests and allocations are conducted in the late winter and early spring. Budgeting procedures could be improved by explicitly taking seasonal to interannual climate forecasts into consideration, as could communications with Congress throughout the fiscal year. Forecasts of wildfire season area burned can be made with reliable confidence a year or more in advance in parts of the Southwest, up to a year in advance in some interior basins, and up to a season in advance in many other parts of the western United States (Westerling et al. 2002, 2003, 2006). Thus, forecasts and other information can provide support for annual budget requests for fire management and at the seasonal level for emergency funding requests.

As the fire season approaches, shorter-term climate information provides decisionmakers with information that is useful for refining plans for suppression activities, for identifying opportunities for fire use (i.e., allowing already-ignited fires to burn in areas where such burns would be beneficial to the landscape), and for allocating resources. Fiscal-year suppression-expenditure estimates, which are based on observed and forecasted climate and are updated on a regular basis throughout the fire season, also are used to keep the US Department of Agriculture and Congress apprised of funding needs.

For longer time horizons, instrumental and paleo records can provide analogous scenarios that can be used to explore the possible extent in space, time, and impact of extreme conditions that might affect fire regimes in wildlands. Such information can be incorporated into long-range forest and fuels planning, such as the National Fire Plan, which requires planning out 10 years (US Departments of Agriculture and Interior 2001), and Fire Management Plans, which are revised on a 5-year cycle in conjunction with land-management plans.

Also, in considering long-term objectives, at the national level the Joint Fire Science Program Board sets the national wildland fire research agenda. A greater emphasis on climate information systems and the role of climate forecasts in wildland fire management decisions could lead to improvements in the quality of forecasts available to wildland fire managers.

Regional Level. At the regional level (regional offices of the NPS, US Forest Service, and the GACCs), regional budgeting and resource allocation activities occur before and during the fire season. Annual hiring, training, and staffing decisions are made leading up to the fire season, as are decisions concerning the prepositioning of initial attack resources. External budget requests at the local level are made annually a year in advance, to regional offices, and could be set more accurately with the aid of annual climate forecasts, potentially reducing the need to rely on severity funds during the peak season. These decision processes could benefit from increased use of seasonal and annual climate forecasts.

The allocation of resources to fire suppression and prescribed fire activities occurs throughout the year, and regional mobilization decisions and mutual aid decisions are made during the peak fire season. Climate information for the past several years and for the upcoming season or year can help managers determine the relative risk of performing prescribed burns, based on current and predicted conditions. For example, managers can compare existing conditions with those of analogous years in the past, based on analyses of the instrumental and proxy records of fire occurrence and climate conditions in the region. Forecasts provide insights into the likelihood of anomalous wet or dry conditions, as well as of "normal" conditions (i.e., those that were statistically prevalent over recent decades).

Institutional Barriers to Using Seasonal Forecasts in Fire Management

The complex set of priorities faced by decisionmakers at each level of wildland fire management suggests that those designing and disseminating climate products need to take into account the different priorities of decisionmakers. In addition to having multiple objectives, decisionmakers also face several constraints. By looking closely at the constraints of decisionmakers, which we identify here, climate scientists can do a better job of developing products that match decisionmakers' needs.

Several important institutional barriers exist to the use of seasonal forecast information by fire managers. First, the 2-year budget cycle for the US Forest Service allows little latitude for shifting funds targeted to forest treatment activities, based on climatic conditions that arise after budgets are submitted and approved. For example, given the high probability of La Niña conditions producing anomalously dry conditions during the winter in the Southwest (Gershunov and Barnett 1998), a reasonably confident La Niña prediction the winter before a fire season should prompt a new analysis of budget allocations to address the emerging fire risk for that season. However, current policies afford little room for such adjustments to allocations of funds to avert or suppress fires in the region.

Second, and related to the first constraint, is the lack of flexibility in authorizing legislation, at the federal level, to make regional or local-level modifications in policies that reflect ground-level realities. For example, fire managers argue in their survey responses that it should not be so cumbersome to obtain permission from the USFWS to treat areas protected by the ESA.

A third barrier to effective use of available climate information and forecasts lies in the lack of flexibility in the fire planning process itself. Organizational inertia is partly to blame. As Lach et al. (2003) have shown for water managers, changes only tend to be made when extraordinary conditions result in the inability of existing practices and policies to address the problems. For example, seasonal staff can only be hired for 6 months in a given year, while in some regions, under certain climatic conditions, the fire season extends beyond 6 months, e.g., Southern California in dry years.

The fourth area of constraints involves the mismatch between decision calendar needs and forecast time horizons. A recurring theme that arose in the surveys and in the interviews was the lack of forecast products specifically targeted to fire and fuels managers. Several respondents stressed the importance of their local topography and its interaction with climate, fire history, and value at risk, and argued strongly for integrating climate forecasts with GIS products that map their region and highlight the condition and location of fuels of particular interest. Local fuels managers reported that 2-week-ahead forecasts would be most useful for planning prescribed burn activities.

Finally, even good forecasts will not be correct every time. Although there are clear benefits to taking early action (e.g., mobilizing resources in advance of a fire event) on the basis of a correct forecast, such benefits often are difficult to measure. The costs of mobilizing resources on the basis of an incorrect forecast, however, are very clear and easy to quantify. As a result, fire and fuels managers are understandably wary of taking proactive measures based on forecast products, unless the accuracy of the forecasts has been proven. Keeping detailed records of forecasts, actions, and outcomes would expedite the development and adoption of new forecast products.

Conclusions

Climate information is currently widely used by fire managers, but there is potential for greater and more effective use of available information, especially if institutional barriers could be loosened. For example, climate forecasts could be used to set more realistic fuels management goals at the unit level and to strategically set priorities for fuels management and prescribed fire treatments. Additional research concerning wildland fire budgeting procedures at the local, regional, and national levels, to identify changes that would facilitate more effective use of climate information would be useful. If congressionally allocated funds could be spent for prescribed burns and other treatments over multiyear time horizons or if tradeoffs in funding could be made over larger regions, it would be easier for managers to adjust their fire and fuels management plans to reflect forecasts and impacts of ENSO conditions, including multiyear combinations of wet and dry conditions. Determining a feasible way of implementing such changes could generate significant efficiency gains.

The National Fire Plan notes that "Critical to fire science program success are mechanisms to ensure that the information is transferred to land and fire managers in a usable form" (US Departments of Agriculture and the Interior 2001). The National Wildfire Coordinating Group's (NWCG) Fire Environment Working Team has been charged in part with assessing current and projected requirements for fire weather products. In this task, continued collaboration between the NWCG and the GACCs with Regionally Integrated Science Assessment project members and other scientists having expertise in climate and wildland fire will be important over the coming decades. Additional training in the use of climate information could be provided through the National Advanced Fire and Resource Institute at the national level (where climate is an explicit topic in the advanced fire danger course), and Predictive Services at the GACCs is ideally suited for disseminating information and skills into operations and planning.

For the climatology community, we expect continuing collaborations with the fire community to result in the development of better and more useful products to stakeholders. Recent efforts to establish annual fire-climate-fuels assessment processes for the US West and the US Southeast, e.g., included the development of specific consensus climate forecasts for the time periods of most concern to fire and fuels managers, particularly those associated with preseason planning for resource allocation (Garfin and Morehouse 2001, Garfin 2002, Garfin et al. 2003). The National Seasonal Assessment Workshops initiated by the Climate Assessment for the Southwest RISA, CEFA, and Predictive Services offer an annual venue for sustaining communications between producers and users of fire-climate information. (Crawford et al. 2006, Heffernan et al. 2007)

Realizing the full potential of climate information and forecasts will require the collaborative effort of several agencies and the climate science community. The potential gains from such an effort would be significant, however, and can be facilitated by a detailed understanding of the decision-making processes involved in wildland fire agencies, the timing of such decision processes, and the kinds of information requested by fire managers across the United States.

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