FIRE POTENTIAL EVALUATION IN SUPPORT OF PRESCRIBED FIRE RISK ASSESSMENT

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ABSTRACT

Increased use of prescribed fire requires an expansion of the current capabilities of decision support systems. In this paper we describe influencing factors that must be included to assess potential fire severity and risk of escape of prescribed fire, capabilities and shortcomings of current fire danger rating and fire behavior prediction systems for risk assessment in support of prescribed fire, and system development work that is underway to meet changing fire management needs.

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INTRODUCTION

The final report of the Federal Wildland Fire Management Policy and Program Review (USDI/USDA 1995) begins: "The challenge of managing wildland fire in the United States is increasing in complexity and magnitude." A key point of the report is, "Wildland fire, as a critical natural process, must be reintroduced into the ecosystem. This will be accomplished across agency boundaries and will be based upon the best available science." That science is often made available for field application in the form of decision support systems (DSS). Existing systems need to be strengthened and augmented to meet the needs of an expanding prescribed fire program. The title of this conference spotlights a shift in fire management from emphasis on suppression to emphasis on both suppression and prescription.

Today, the U.S. Forest Service uses prescribed fire on about 450,000 acres (182,110 hectares) per year to reduce fuel loadings. There is a need to treat an estimated 3 million acres (1.2 million hectares) per year in long needle pine types alone to better approximate a more natural, less severe fire cycle (USDA Forest Service 1995). However, the use of prescribed fire, especially on a landscape scale, presents managers with the challenge of conducting those burns in a safe manner, with a low risk of escape. Managers must be able to recognize and avoid high-risk prescribed burning treatments. Escape thresholds and factors that trigger or contribute to escaped prescribed fires need to be identified.

One of the eight guiding principles that are the basis for the Federal Wildland Fire Management Policy and Program Review is, "Sound risk management is a foundation for all fire management activities. Risks and uncertainties relating to fire management activities must be understood, analyzed, communicated, and managed as they relate to the cost of either doing or not doing the activity" (USDI/USDA 1995).

In this paper we discuss influencing factors that should be included in assessing potential fire severity and risk of escape of prescribed fires, capabilities and shortcomings of current fire danger rating and fire behavior prediction systems for this application, and decision support system development work that is underway to meet prescribed fire risk assessment needs.

INFLUENCING FACTORS

A successful prescribed burn meets management objectives and remains under control. Many factors are involved in assessing the risk of escape of a prescribed fire. We focus here, however, on only those factors that influence fire behavior.

Williams and Rothermel (1992) used the diagram shown in Figure 1 to illustrate that potential fire severity develops differently according to the type of vegetation. This has important implications for successful prescribed burning programs. The diagram compares ponderosa pine (*Pinus ponderosa*) and subalpine fir (*Abies lasiocarpa*) vegetation types in terms of prescribed burning windows of opportunity. In open mature ponderosa pine stands, wide prescribed burning windows are often available. In subalpine fir stands, on the other hand, the rapid transition to crown fire potential that occurs when the stand is dry enough to burn results in a narrow window of opportunity and a

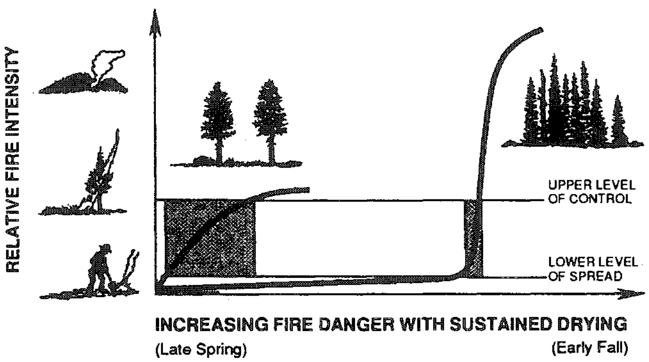

Figure 1. Fire dynamics diagram showing the change in fire potential as a function of sustained drying. A comparison of prescribed burning windows between a ponderosa pine type and a subalpine fir type (from Williams and Rothermel 1992).

high risk of escape for prescribed burning. What are the factors that influence this change in fire behavior? If the potential can be recognized, the risk of escaped prescribed fire will be lessened.

In examining the influencing factors we must go well beyond the familiar fire fundamentals triangle (Figure 2). The fuel, oxygen, and heat elements represented in the triangle must be in place for a fire to exist; if a leg of the triangle is broken, combustion ceases. There is, however, much more to wildland fire than combustion, which takes place in a burning match as well as in a crown fire.

The fire environment triangle (Figure 3) (Countryman 1972) represents the influence of fuel, topography, and weather on a wildland fire. These three factors, the fire itself in the center of the triangle, and the interaction among them compose the fire environment. These are the influencing factors that must be examined, as they change in space and time, in assessing the risk of escaped prescribed fire.

When a small area is burned, the elements of the fire environment triangle are essentially constant. Large landscape burns will likely involve significant changes in space, and if the burn is conducted over several burning periods, changes in time must also be considered. This added complexity means that burning techniques that have been successfully used on small burn blocks may not apply to larger landscape burns.

Variation in fuel, topography, and weather may result in a higher risk of escape but might also be used as a mitigation strategy. Moist areas with green fuels

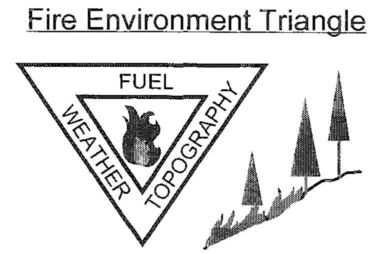

Figure 3. Fire environment triangle illustrating the factors that influence fire behavior. These factors and their interaction should be examined, as they change in space and time, in assessing the risk of escaped prescribed fire.

might be used to reduce escape potential. The influence of the moisture-temperature gradient with respect to the vegetation that grows there (Figure 4) should be recognized and utilized in an assessment of fire potential.

Although change in topography over time is not a consideration, changes in fuel and weather certainly are. We use a fire pyramid to illustrate change over time (Figure 5). Longer term changes are at the base, with fast-occurring changes on the top. Changes in time are grouped into five categories: successional, annual, seasonal, diurnal, and abrupt. Successional changes occur on the order of decades or centuries; vegetation and fuel change due to normal succession patterns, declines in forest health, and dead fuel buildup and decay. Annual changes occur on the order of years; the effects of drought may accrue over several years, for example. Seasonal changes occur weekly or monthly during a year; examples are the greenup and curing of live fuels and changes in the moisture content of large dead fuels and duff. Diurnal changes occur throughout the 24-hour cycle; fine dead fuel moisture and windspeed change throughout the day and night. Abrupt changes are immediate; examples are ignition due to a lightning strike or the sudden increase in winds that precede a fast-moving frontal system.

In looking at the influencing factors involved in the risk of escaped prescribed fire, the foundation is often set with changes at the bottom of the pyramid that result in a decline in forest health, fuel buildup, and development of ladder fuels. The risk can increase as a result of long- term drought that causes deep soil drying and stressed vegetation. A season that results in dry heavy fuels and duff and in cured live fuel adds

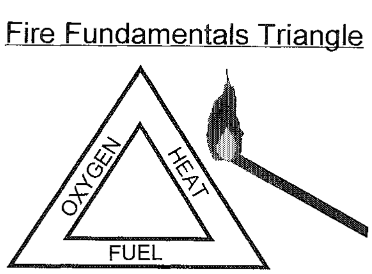

Figure 2. Fire fundamentals triangle illustrating the factors that must be in place for combustion to occur. This applies to a burning match as well as a crown fire.

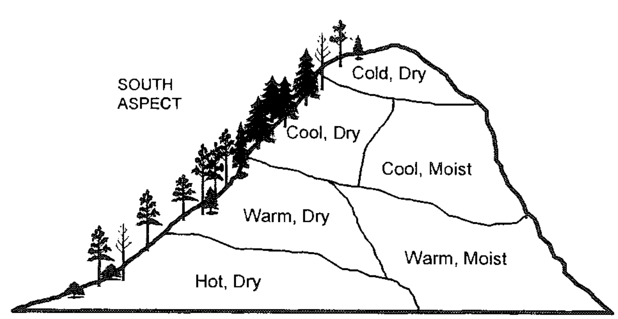

Figure 4. The temperature-moisture gradient influences the vegetation that occurs across the landscape.

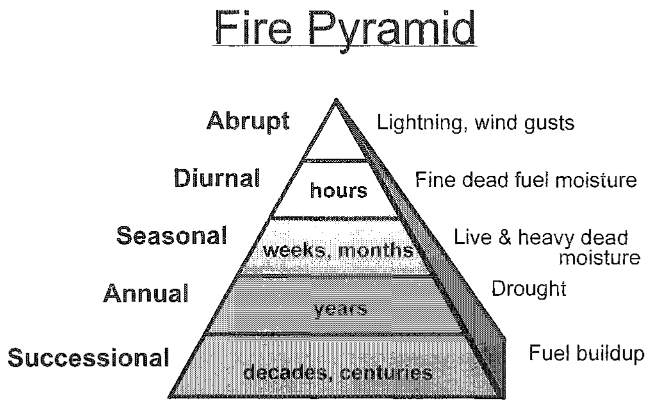

Figure 5. Fire pyramid illustrating how factors that influence fire behavior change over time scales from hundreds of years to hours.

to the potential for extreme fire behavior and for escaped prescribed fires due to holdover fire. The stage is set as the pyramid is built. Yet even with those conditions in place, days with high fine fuel moisture and no wind might preclude a burn when conditions are at the low end of the burning window.

Mitigating hazards at the bottom of the pyramid, though, are more certain of reducing risks in time and space. The quickly changing conditions that occur at the top of the pyramid rapidly change risks.

The question of what causes the shift in fire potential illustrated in Figure 1 will not be answered by a single indicator. Rather, the answer will come from an assessment of a combination of factors that vary across the landscape and that change at different time scales.

DECISION SUPPORT SYSTEM (DSS) GOALS

The goal is to develop decision support systems that address the influencing factors discussed here and that support risk assessment for prescribed fire. The DSS should include elements of the fire environment triangle and how they change in time (fire pyramid) and in space across the landscape. Although it is unlikely that a system would be able to predict exactly when threshold conditions would be reached, it is an appropriate goal to expect that such a system be able to identify increasing risk in the potential for extreme fire behavior.

People working on fires need to be able to recognize factors that indicate changes in fire behavior and fire dynamics. A person may not notice nor recognize the implications of change that occurs over long periods. On one hand, most people will recognize the change in fire behavior caused by an increase in windspeed. But a slow change in fuel type, or a hard-to-observe change in fuel due to drought, may go unnoticed. In addition, those changes may result in conditions that are beyond an individual's experience.

Decision support systems (DSS) are just as the name implies, they support decisions. Humans, not systems, make decisions. A DSS is not a substitute for experience, education, or training; but it can certainly supplement experience. A younger person may not yet have experienced a wide range of conditions. An older, more experienced person may not have encountered extreme conditions.

We, of course, want DSS with capabilities beyond those offered by current systems. We also want these systems to be easier to use, interpret, and apply. The systems need to be integrated for a range of applications. We are addressing prescribed fire here, but most of the considerations we have described also apply to suppression, planning, preparedness, initial attack, and other fire and land management applications.

A prediction of fire potential for the upcoming year is too much to expect, given the state-of-the-art in weather forecasting. But the fundamental influences of successional stage or drought can be assessed. It is not unreasonable to expect a DSS to provide notice of early bottom-of-the-pyramid indicators, giving warning that the risk of escape is increasing. This would lead to closer attention being paid to the shorter term factors near the top of the pyramid.

DEVELOPMENT OF FIRE POTENTIAL ASSESSMENT TOOLS

In this paper, we address only the fire potential aspects of the risk assessment process. We therefore examine the capabilities and limitations of current fire behavior and fire danger rating systems. We discuss system development work that is underway to meet changing fire management needs, as well as research that is needed to extend the capabilities of those systems.

The BEHAVE fire behavior prediction system (Andrews 1986, Andrews and Chase 1989) and the FARSITE fire growth simulation (Finney 1996) reflect conditions at the upper levels of the fire pyramid. Diurnal changes in moisture are emphasized. Changes in live fuel throughout the season can be included. There is no influence of heavy dead fuels in these systems. Abrupt changes such as spotting and probability of ignition are incorporated. Only surface fuels are included in BEHAVE, but FARSITE includes the overstory and a crown fire model. FARSITE accounts for changes in space. Fire behavior is calculated as it is influenced by changes in fuel, weather, and topography across the landscape and by weather changes throughout the time of the burn.

The National Fire Danger Rating System (NFDRS) (Deeming et al. 1977) reflects influencing factors in the center of the pyramid. Calculations are based on daily weather observations. The fuel and topography legs of the fire environment triangle are essentially held constant. There is no consideration of the diurnal changes in fine fuel moisture, and windspeed is a once-per-day observation. NFDRS was designed to reflect seasonal changes and includes the moisture of the larger dead fuels and changes in live fuel. The Keetch Byram Drought Index is provided by

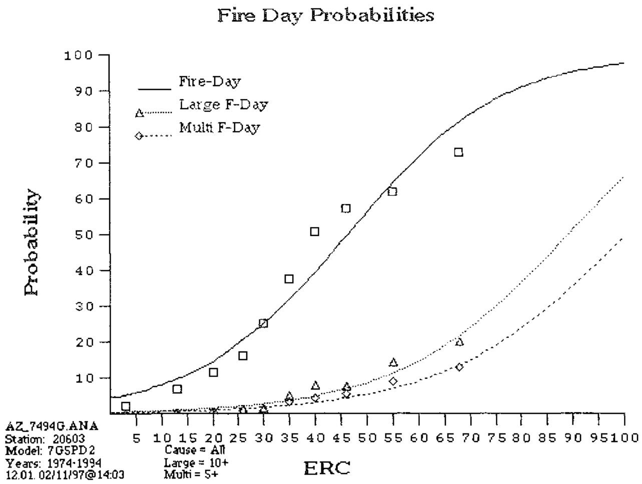

Figure 6. Probability of a fire-day, large-fire-day, and multiple-fire-day as a function of Energy Release Component (ERC) for the Tonto National Forest in Arizona, output from the FIRES: Fire Information Retrieval and Evaluation System. An analysis of the relationship between fire activity and fire danger rating indexes can be used to define critical fire danger levels to support an assessment of the risk of escaped prescribed fire.

the NFDRS. Fire danger rating assessments apply to large areas without accounting for variation across that area. They do not reflect differences in fire potential that result from aspect and elevation gradients and from vegetation type changes. These factors are critical for successful application of prescribed fire. NFDRS provides a way to compare the current year to historical maximums, averages, and percentiles and to other specific years of memory.

The Fire Information Retrieval and Evaluation System (FIRES) (Andrews and Bradshaw 1997) allows NFDRS to be used to full advantage. By doing an analysis of the relationship between fire danger indexes and wildfire activity, critical levels of fire danger can be identified. Figure 6 shows probability of a fire-day, large-fire-day, and multiple-fire-day as a function of index. Logistic regression analysis is based on 0/1 data (Loftsgaarden and Andrews 1992). A day is either a fire-day or it is not. It is either a large-fire-day or it is not. A similar analysis could be done with prescribed fire data if they were available. A day would be classified as 1 if one or more prescribed fires escaped on that day, and 0 of none of the prescribed fires on that day escaped. (A day on which there were no prescribed fires would not be included in the analysis.)

The Wildland Fire Assessment System (WFAS) (Burgan et al. 1997) includes spatial components that are not available in NFDRS. Maps of fire danger are produced for the United States giving an indication of fire potential for large areas. In addition, maps reflecting the state of live fuel are made available on a weekly basis. They are based on satellite data and are at 1 kilometer resolution (Burgan and Hartford 1993). Changes in vegetation type and elevation differences are apparent.

WFAS is being developed in phases. The goal is that it will be an integrated fire behavior and fire danger rating system that will be expanded to include improved research models and methods.

In addition to system development needs, there are research problems yet to be solved and models that need to be improved or developed. Examples include a better assessment of long-term drought as it affects various vegetation types throughout the country; better links between vegetation type and fuel description for fire models; inclusion of the whole fuel complex, including ladder fuel as well as ground, surface, and crown fuels; stronger links between fire behavior and fire effects and smoke production models; vegetation succession models linked to fuel and fire potential; and improved models for the transition to extreme fire behavior.

SUMMARY

This paper lays the conceptual groundwork for a more comprehensive fire potential evaluation model in support of prescribed fire risk assessment. An improved decision support system will better account for factors that change in both time and space. Fire managers, particularly those engaged in long-duration landscape-scale prescribed fire treatments, are encouraged to weigh the cumulative influence of the factors illustrated in Figure 5 to better evaluate fire potential in an assessment of risk.

The need for more prescribed burning requires better support from decision support systems. Although many of the influencing factors are addressed by current systems, the cumulative effects of one upon another are not always well understood. And some influencing factors remain unknown. System development work is in progress to meet some of those needs, and research is being conducted to solve some of the fundamental problems. The goal is to provide for better, safer, and more cost-effective use of fire based on a firm foundation of science.

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