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Fire Behavior System for the Full Range of Fire Management Needs[1]

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Abstract: An "integrated fire behavior/fire danger rating system" should be "seamless" to avoid requiring choices among alternate, independent systems. Descriptions of fuel moisture, fuels, and fire behavior should be standardized, permitting information to flow easily through the spectrum of fire management needs. The level of resolution depends on the application, but the same central processor can be used. Three tasks must be carried out to reach the goal: (1) determination of fire management needs, (2) development of a central processor to be used as the core of the system, and (3) development of the individual subsystems with a framework for moving between them.

One of nine research initiatives proposed by the director of Forest Fire and Atmospheric Sciences Research staff in the Forest Service's Washington office is an "Integrated Fire Behavior/Fire Danger Rating System" (Philpot 1985). The initiative states: "A single, integrated system that can accommodate the full continuum of spatial/temporal resolution requirements--from National, long-range fire severity forecasting to real-time suppression strategy decisions on actual fires--is needed to meet the varying fire behavior information needs of wildland managers."

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The need for an integrated fire behavior system designed for the full range of fire management needs has come about for several reasons:

1. Proliferation of systems based on fire behavior has resulted in confusion in the choice of the appropriate system for a specific fire management need.
2. It is difficult to make the transition from one system to another when moving from the planning to operational phases.
3. Requirements placed on tire managers for analysis and planning are much more demanding than in the early 1970's when the current fire behavior and fire danger systems were formulated. We expect this trend to continue.
4. There have been significant advances in fire research.
5. The technology available for reaching fire managers and assisting them is increasing dramatically.

A fundamental concept of the system envisioned in the initiative is that it be "seamless." or integrated, to avoid requiring choices among alternate, independent systems. Descriptions of fuel moisture, fuels, and fire behavior should be standardized, permitting information to flow easily through the spectrum of fire management needs.

We see three tasks as necessary to carry out the initiative:

Task 1. Determine the needs of fire managers for systems centered around fire behavior. Develop a plan that specifies the necessary subsystems, such as long-range planning, prescribed fire planning, fire danger rating, and dispatch. The plan should outline the span of operations for each subsystem with emphasis on their interaction.

Task 2. Develop a central processor containing the mathematical fire behavior prediction models that will serve as the core for all subsystems.

Task 3. Develop the subsystems using the new central fire behavior processor according to the plan defined in task 1. Develop a framework for accessing subsystems and moving between them.

The first two tasks can be carried out in parallel. There is a long lead time and there will be ample time for coordination. Planning for the third task can begin when the subsystems are identified, but actual development of the subsystems will depend upon completion of the central processor.

Developing a plan for the systems needed by operating agencies (task 1) should be the responsibility of those agencies with support from research. Developing a central processor for the systems identified in the plan (task 2) should be the responsibility of research with support from the operating agencies. Responsibility for developing the subsystems (task 3) will probably fall upon both research and the operating agencies. This third task is several years away.

NEED FOR THE INITIATIVE

Number of Systems/Confusion in Application

Since 1972. many systems have been developed to meet the expanding needs of fire management. Although fire behavior and fire danger rating are specifically mentioned in the title of the initiative, those are only two of the systems involved. Another system that is used nationwide by the Forest Service is the National Fire Management Analysis System (NFMAS) (USDA Forest Service 1983). Other examples are FIRECAST (Cohen 1986), RXWTHR and RXBURN (Bradshaw and Fischer 1981), HAZARD (Brown and others 1977), the National Fuel Appraisal Process (Radloff and others 1982), and the Initial Attack Management System (IAMS) (German 1985).

The National Fire Danger Rating System (Deeming and others 1977) was designed as a prefire planning tool. It is basically a seasonal weather processor. The indexes it produces are relative values that rate fire danger over broad geographic areas.

The fire behavior prediction system (FBPS) is based on concepts described by Rothermel (1983). It was designed to predict actual fire behavior and allows the user to tailor the resolution of the input to meet the application. The FBPS is available through a number of computing methods as summarized by Andrews (1986a). One of the most widely used methods is the BEHAVE fire behavior prediction and fuel modeling system (Andrews 1986b, Burgan and Rothermel 1984).

NFMAS is used to evaluate long-term consequences of alternative fire protection programs for relatively large planning writs. It is essentially a hybrid of NFDRS and FBPS. NFMAS uses the danger rating equations and fuel models. However, it uses site-specific input and interprets output in terms of actual fire behavior.

In addition to national systems, individual administrative units have designed their own systems for assisting them in both long-term planning and day-to-day operations. A specific example i3 the Mt. Hood Field Guide for Appropriate Suppression Response (USDA Forest Service 1985). It is based on tables of predictions generated by BEHAVE.

it is understandable that there is confusion on proper application of the many fire management systems. However, there is a positive aspect to the large number of systems based on fire behavior. The utility of deterministic mathematical models structured into decision processing systems has proved to be a highly effective and readily adaptable method of assessing fire management problems.

Difficult Transitions

Almost all current fire management systems are based on a mathematical model designed to predict the spread of a steady-state surface fire (Rothermel 1972, Albini 1976). There are, however, significant differences in the equations as they are used in NFDRS. Developers of other systems (e.g., NFMAS) have had to decide which set of equations to use. The difficult transition from one system to the next is caused by the difference in equations (the central processor).

The most visible aspect of this problem is the fact that there are two sets of fuel models. Fuel models are designed to work with a specific set of equations. If a fuel map is produced for use by NFMAS, it has NFDRS fuel models, and cannot be easily used for fire behavior prediction applications.

Changing Needs

If the National Fire Danger Rating System and the Fire Behavior Prediction System satisfied all of the needs of fire managers, there would not be the need for the initiative. Fire management, however. has become more complex since those systems were developed. The following are examples of the changing needs of fire managers:

--Managers now have options other than strict fire control. Unplanned ignitions may be declared prescribed fires rather than wildfires if they meet criteria set up in a tire management plan. In addition, there are options on the level of suppression action that might be taken on a wildfire; in Forest Service terminology, Contain/Confine/Control.

--Smoke production is becoming an overriding concern in connection with prescribed fire. The window of acceptable burning conditions may be quite narrow, making it critical that an acceptable day not be missed.

--Restricted budgets make it important that correct decisions be made on fuel treatment options using the best information available on expected consequences.

--The encroachment of homes into forest areas is causing a major problem for forest protection agencies.

--Prescribed fire is much more than the attainment of "black acres." More emphasis is being put on fire effects.

--Fire is just one aspect of the total resource management job and is becoming more integrated into the overall planning process.

--Forest managers often have duties that include more than fire. Fire behavior systems that are compatible and easy to use can help them make the best use of their time and help assure careful consideration of options without excessive tedium.

Available Research

Even if there were no compatibility problems with the current systems, it is time to begin planning a major change. The existing fire spread model is 15 years old and should be updated. Models are also needed for crown fires and smoldering ground fires. Other models are needed to supply inputs to these new fire models.

Advances in Technology

A trend that is most likely to continue and one that will have a large effect on the form of our product is the explosive advancement of technology. When the current fire danger rating and fire behavior prediction systems were developed, they were offered on mainframe computers using punch cards, and as publications of tables and nomograms. We have since progressed to using interactive programs on in-house computers, desk-top computers, and micro chips developed for handheld calculators. New systems will be able to take advantage of satellite mapping of fuels for large areas, geographic information systems, graphic output of results, telecommunications linking all levels of management, personal computers, and far more.

DEVELOPMENT OF THE CENTRAL PROCESSOR

The structure of a system is based on a flow of information from inputs through the central processor to outputs. It is the fire behavior models and their related input and output models that we refer to as the central processor. This basic structure is altered to meet specific management needs by specifying methods for obtaining inputs required for certain operations. Inputs for planning may come from historical data bases, while real-time fire prediction requires up-to-the-minute data. Similarly, output is tailored for certain applications. This may involve maps that display levels of fire danger or suppression cost-plus-net-value-change analysis.

The use of mathematical models to predict fire behavior, fuel moisture, etc., has proved to be such a powerful technique and adaptable to so many fire management activities that the development of these models will continue to be the primary goal of our research.

Our knowledge of fundamental fire behavior and the factors controlling fire is still limited. A long list of items needing attention can be made quickly. Among the more challenging in the list are the nonuniform fuel problem, crowning, spotting, combustion of living fuels, burnout of large fuels, smoke production, and wind flow in rough terrain. Research results are available on some of these problems and research must continue, particularly in regard to arriving at general solutions that can be adopted in national systems.

Development of the central processor is not expected to be a crash program. The research emphasis for the next 3 to 5 years will be on fundamental research and model development. Because there are so many areas needing investigation and because of limited scientific staff, we must concentrate on the areas of highest priority.

Crown Fires and Spotting

Crown fires have aroused renewed interest. The Canadians have incorporated good field data in their system for quantitative fire behavior prediction (Lawson and others 1985). Albini (1986) made a strong effort at modeling the spread of crown fires, but the model is far from being ready for field application. We currently think that the biggest question is whether a surface fire will develop into a crown fire, i.e., identifying the conditions for the onset of crowning. Van Wagner (1977) has characterized the types of crown fires and their dependence on the surface fire. We believe that a detailed examination of the ignition-moisture relationship, especially as influenced by drought, needs further explanation.

Spotting is not restricted to crown fires, but is usually associated with severe fires of some type. It is one of the most intractable problems we face. Methods for predicting the distance firebrands will travel and still be burning are already in use (Albini 1979, Albini 1981, Albini 1983, Chase 1984). However, the ability to estimate the number of spot fires actually started remains a difficult problem.

Surface Fire Model

Research under way for several years is designed to increase our capability for predicting the behavior of fire in surface fuels. One of these efforts has been to define the limits of combustion. Better information about the probability of whether a fire will be sustained in a steady state condition is vitally needed. This research, begun originally to define the moisture of extinction, has gone well beyond that and will form the basis of a new fire spread model. It is being couched in stochastic form so that the probability of fire spread can be defined (Wilson, in press). The concepts have been developed using data from a much wider range of fuel sizes and loading conditions than were used in the original fire spread model. The research must be expanded to include the effect of wind, slope, and green fuels.

Significant progress has also been made in the area of fuel chemistry. We now have analytical instrumentation capable of determining the heat required to bring fuel up to ignition and for determining the heat available from both flaming and glowing combustion (Susott 1981). This information will form the basis for all new combustion models. We have a considerable amount of data, and a library of fuel particle properties is being developed.

Ground Fires

We need the characterization of smoldering in forest duff to estimate fire effects, the probability of holdover fires, and the probability of detection. Ground fires often occur in highly compacted fuel for which the surface fire spread model is not suited.

In addition to field work on duff consumption (Sandberg 1980, Brown and others 1985), a carefully designed laboratory study (Frandsen 1980) is closely examining combustion of duff and will provide the basis for models of the phenomenon.

Related Models

Input to the ground, surface, and crown fire models will often be the output of other mathematical models. Fuel moisture and fuel models are examples.

Although fuel moisture is sometimes determined from direct sampling and drying, it is more often calculated. Some recent significant results (Anderson 1985) indicate that we will probably have to abandon the idea that all fine fuels have 1-hour time constants for moisture response.

Description of the fuel geometry and load as an input to the surface fire spread model is currently put in terms of a fuel model. The fact that there are two sets of fuel models, 13 for FBPS and 20 for NFDRS, has caused considerable confusion. The spread model works under the assumption that fuels are uniform and continuous. In the field, however, that is the exception rather than the rule. The contribution of large fuels to fire problems must be included in future models and systems. In addition, we will have to learn to describe fuel for the ground and crown fire models as well as surface fires. The whole fuel issue needs to be reexamined closely and a fresh approach actively pursued.

SYSTEMS DEVELOPMENT

Simultaneously with work by research on the central processor, the operating units should be examining their needs and developing specifications for the systems envisioned for the future. Good coordination should be maintained between research and the operating agencies to assure realistic goals. One step in examining fire management needs should be a survey of applications that are based on the current fire spread model and definition of the needs they fill.

Careful consideration should also be given to an overall framework to tie the subsystems together. It is not expected that one computer program would contain all of the subsystems; it would be too large and unwieldy. A user-friendly interactive computer system using expert system techniques may help fire managers identify and access the subsystem appropriate to specific needs.

Although the equations in the new central processor may be more complex than those in current systems, the complexities will be invisible to the user. At present, much energy is put into explaining the differences in the central processors and fuel models of the NFDRS and FBPS. Basing all subsystems on the same central processor will eliminate this problem. In addition, the system of the future will be easier to use and understand due to more user-friendly interfaces, interactive exchange between the computer and the fire manager, and presentation of results in graphic formats.

SUMMARY

It is time to look at an integrated fire behavior/fire danger rating system that can meet the whole range of fire management needs. The large number of systems in use sometimes leads to confusion in proper selection and application. It is often difficult to make the transition from one system to another. The situation could be simplified by basing all subsystems of the integrated system on the same central processor and by providing a framework for accessing subsystems.

Development of the mathematical models that go into the central processor will be the primary responsibility of research. Operational agencies should take the lead in assessing needs and in developing a plan that specifies the necessary subsystems to fill those needs. This work will require careful coordination among researchers, system developers, and fire managers to ensure that the system meets fire management needs of the future.

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