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Fire-Danger Rating: The Next 20 Years[1]

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Abstract: For the next 10 years, few changes will be made to the fire-danger rating system. During that time, the focus will be on the automation of weather observing systems and the streamlining of the computation and display of ratings. The time horizon for projecting fire danger will be pushed to 30 days by the late 1990's. A close alignment of the fire-danger rating system with the fire-behavior and fire-planning systems will occur with the release of the second-generation fire model in the late 1990's. Improved utilization of all of these systems will be delayed until more structured approaches to decision making are adopted by management. By 2007, expert systems utilizing real-time direct and remotely sensed weather and fuel moisture data will be on line.

Research to develop a means of evaluating wildland flammability began in the United States more than 60 years ago. Coert du Bois, S.B. Show, E.I Kotok, and H.T. Gisborne dominated the early fire research scene. Six fire-danger rating "meters" were developed between 1930 and 1946 by Gisborne for use in the Northern Rockies. Programs patterned after that of Gisborne were pursued in many sections of the United States in the 1940's and 1950's. John J. Keetch worked on a national fire-danger rating system from 1958 to 1963. By the late 1960's, researchers M.J. Schroeder (U.S.), A. McArthur (Australia), and C.E. Van Wagner (Canada) were setting the pace in fire-danger rating research and development.

Mark J. Schroeder organized the U.S. national program at Fort Collins. Colorado in 1968; I joined the unit in 1970. James W. (Wally) Lancaster, Michael (Mike) Fosberg, R.W. (Bill) Furman, and I worked together until the 1972 version of the National Fire-Danger Rating System (NFDRS) was completed (Deeming and others 1972) and the computerized version (AFFIRMS) on line (Helfman and others 1975, 1978).

From 1973 to 1975, Wally Lancaster and I continued with the NFDRS program at the National Interagency Fire Coordination Center (formally the Boise Interagency Fire Center) with the able help of R.J. (Bob) Straub. R.E. (Bob) Burgan, Jack D. Cohen, and I were the key players from 1975 through 1978. We made the 1978 update of the System (Deeming and others 1977). That work was done at the Intermountain Fire Sciences Laboratory (formally the Northern Forest Fire Laboratory) (Bradshaw and others 1983).

Having "been in the business" for 17 years, looking 20 years into the fire-danger-rating future for this meeting seemed like a reasonable undertaking. However, I sought the views of others with fire-danger rating backgrounds in Canada and the United States, hopefully to balance my own biases. A number of those distinguished people responded and I have "pooled" their "visions" in this 20 year outlook.

For this exercise, I made a sincere attempt to avoid the "Starwars" syndrome; limiting my futuring to the "probable," and tried not to be distracted by the "possible." That was not easy in this bells and whistles era of dial-up color radar, pull-down menus, 80-megabite PC hard disks, satellite data relay, and so on. Neither

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did I intend to restate any of the issues highlighted in my 1983 "Reflections" paper on the development, application, and future of NFDRS (Deeming 1983).

This paper is divided into sections that address:

- The current state of fire-danger rating R&D.
- The need for fire-danger ratings.
- Understanding the character of fire danger.
- The fire-danger rating system of 2007.
- The practice of rating fire danger in.
- Communication and display of ratings.

CURRENT STATE OF FIRE-DANGER RATING R&D

No work has been done on the NFDRS since the research project at Missoula was disbanded in 1978. Forest Service researchers at East Lansing Michigan, however, have completed a number of validation studies (Haines and others 1983, 1985; Main and Haines 1983). At the Forest Services's Intermountain Fire Sciences Laboratory, Andrews (1987) is developing a technique for matching fire-danger ratings with different measures of fire business.

NFDRS users meetings were held in 1985 at Salt Lake City, Utah, and in 1986 at Harper's Ferry. Virginia, to assess the need for additional research (and development). An outgrowth of those meetings is the impending transfer of R.E. Burgan from Missoula to Macon, Georgia. His assignment is to resolve NFDRS shortcomings identified by eastern users.

A 4-year contract for AFFIRMS has recently been awarded to the General Electric Company. (AFFIRMS was developed on GE and GE provided the service until 1980.) A multiyear program to develop a replacement system for AFFIRMS will begin later this year. That system will be called the Weather Information Management System (WIMS).

Dick Rothermel and his staff at the Intermountain Fire Sciences Laboratory are planning a program of research to develop the second-generation mathematical fire model. His project has also been given an assignment to develop an integrated fire management system inclusive of needs ranging from fire-behavior prediction to fire planning (Rothermel and Andrews 1987).

Dr. Mike Fosberg is embarking on a 5-year program at the Riverside Fire Laboratory to develop medium and long range weather forecasts for fire management (Fosberg and Fujioka 1987).

And we are here talking about fire-danger rating ......

THE NEED FOR FIRE-DANGER RATINGS

The need for a fire-danger rating system will not become less during the next two decades. The range of fire management tasks is expanding and those tasks require greater understanding and skill; they are increasingly complex (measured suppression response, fire effects); and the consequences of making poor decisions are more costly and politically sensitive.

The time horizon for projecting fire-danger ratings will certainly be pushed beyond the current 24 to 30 hours, a lead time sufficient for making decisions that affect local and subregional presuppression activities. The need to share increasingly expensive and scarce suppression resources among widely separated cooperators, however, has caused managers to ask for weather and fire-danger forecasts well beyond a couple of days.

The need for 15- and 30-day fire-danger projections has been documented. Thirty days is a goal for submission of emergency funding requests to the Congress and some state legislatures. The Washington Office of the Forest Service requires Forest Service Regions to give 2 weeks notice of a requirement for supplemental presuppression funding. Since May 1985, the National Interagency Fire Coordination Center (Boise, Idaho) has issued an "experimental" regional-scale, 30-day projection of wildfire activity (U.S. Department of Agriculture, Forest Service 1986).

By the mid 1990's the formats of both short and extended range fire-danger predictions will include estimates of uncertainty. The uncertainty resulting from the stochastic nature of the environmental drivers of fire danger, as well as the uncertainty inherent in the forecasting process, will be quantified. The current practice of making single value, deterministic predictions are not providing users with a complete picture of the actual fire-danger situation.

Though it will not happen in the near future, fire managers will develop and employ structured decisionDmaking [sic] systems based in the management sciences, including decision theory. Only then will management be able to properly consider the natural variability and stochastic character of fire danger.

UNDERSTANDING THE CHARACTER OF FIRE DANGER

Improvements to the performance and use of the NFDRS during the next several years will be modest. One reason is our poor understanding of the temporal and spatial scales of fire-danger. Getting more to the point, we don't know what scales of fire danger are possible to characterize and/or predict.

For instance, it is impossible to characterize, with a single rating, the fire danger near the ocean where there is a twice-per-day passage of a sea-breeze front. In such situations, the extreme diurnal variability of burning conditions require an approach more akin to that of predicting fire behavior.

Another shortcoming is our poor understanding of the temporal components of regional fire danger. Once those components are identified each can be tracked and integrated into a set of meaningful and useful ratings.

The components of a regions's fire danger are the result of the interactions of a region's fuels and weather cycles--diurnal, synoptic, seasonal, and climatic. Here is an example:

The spring fire season in the Lake States is nearly as predictable as spring itself. Its severity does vary, but there are few surprises. The typical spring fire burns in cured grass and reed-like plant debris, hence the key fuels are predominantly in the 1-hour and 10-hour timelag classes. The spring fire danger is determined by the highly transient weather elements, wind and relative humidity.

On the other hand, severe fire seasons such as 1976 are anything but routine. They are typically preceded by one to several years of below normal precipitation resulting in low water tables and exposure of normally saturated organic soils to the atmosphere. The 1976-class of fire season poses a completely different fire-danger rating problem than does the spring fire season. Its cause is a subclimatic shift of precipitation-producing weather events, and organic soils lie at opposite end of the fuel moisture response spectrum from dead grass. It is not possible for any single fire-danger index to do a good job in both of these situations.

FUTURE FIRE-DANGER RATING SYSTEM

The fire-danger system of 2007 will be complicated. Fire danger is a complex, multi-dimensional concept; its physical character varies tremendously across the range of conditions for which ratings are needed. I am confident that the fire-danger rating system of 2007 will look a great deal like the 1978 NFDRS.

The NFDRS offers the user a choice of six indexes and components. That number could certainly be reduced to four: ignition, fuel energy, burning, and occurrence.

Fire problems and the needs of the responsible agencies vary so greatly that a range of options must be provided. The menu of choices must include options that index the factors that affect ignitability, fireline intensity, composite fuel moisture (fuel energy), and occurrence.

The fire-danger rating system of 2007 will not be integrated with the fire-behavior and fire-planning systems to the degree that it will lose its identity.

Fuels

The Rothermel fire spread model (Rothermel 1972, Albini 1976) provided the basis for the NFDRS, the Forest Service's National Fire Management and Analysis System (NFMAS) (U.S. Department of Agriculture, Forest Service 1985), and the Fire-Behavior Prediction System (FBPS) (Rothermel 1983).

The spread model was modified to meet the special requirements of NFDRS and NFMAS. Though the modifications were minor, a unique sets of stylized fuel models had to be developed for each processor. This has, unfortunately, confused many users of the three systems.

The standard fire-danger rating fuel models will be a subset of the fuel models used for fire-behavior predictions and fire planning. The most significant change will be the licensing of users to develop their own fire-danger rating fuel models much as they can now do for the fire-behavior prediction system (Burgan 1984).

The fire-danger rating system of the future will account for the variation in fuel moisture responses to weather and plant life processes. Consider the Lakes States example in the preceding section and picture the tundra of Canada and Alaska. Contrast the character of those fuels with a common Great Basin fuel--a pure stand of annual grasses and forbs.

At least one additional fuel class will be added to represent organic soils, tundra, and deep duff and litter. The moisture-response model for this fuel class will account for transpiration as well as evaporation. Drawdown from transpiration may continue long after organic soil moisture reaches equilibrium with the atmosphere.

Live-fuel moisture models will certainly be improved as will dead-fuel moisture models (Rothermel and others 1986). More importantly for some areas of the country, will be a better understanding and modeling of the effects of living plants on fire danger.

A drought index will not be needed if satisfactory moisture models for organic soils and live fuels are developed.

Fire Danger for Extended Periods (2 to 30 Days)

What I have discussed, thus far, has been fire-danger rating in the traditional time realm--out to 30 hours. In this section the stickier issue of rating fire danger out to 30 days is addressed.

The capability to produce useful 6 to 10 day fire-danger rating products will lag behind yet-to-be-realized advances in extended range weather forecasting. No breakthroughs are expected for the next 20 years (Harnack 1986), but there is every reason to expect significant progress in the 2 to 6 day range by the mid to late 1990's.

More to the point of this paper, within 10 years it will be feasible to calculate daily, worst-case fire-danger ratings out to 6 days. I'm talking here about ratings that account for wind, the most elusive and challenging weather element to predict. The National Weather Service is now running its most sophisticated predictive models out to 10 days. They are showing great promise.

Beyond 6 days, an entirely different approach and fire-danger rating format will be needed. The reasons are: (a) the list of predicted weather parameters will not include relative humidity and wind, and (b) the predictions will be expressed as "departures from normal." Weather information of this type is adaptable for fire-danger rating purposes, but it will be usable only if there is a good historical record of fire-danger ratings from which "normal fire danger" can be determined. The required data has been collected and archived since the early 1970's (Furman and Brink 1975, Main and others 1982).

Integration With Fire-Behavior and Fire-Planning Systems

Dick Rothermel is looking ahead to a second-generation fire model that will account for the effects of large fuels on fire behavior and, possibly, model the behavior of fires burning in organic soils. That model (or family of models) should satisfy the specific requirements of all the NFDRS, NFMAS, and FBPS. That will make it much easier than now for users to change from one system to another.

The data demands of the second-generation fire model(s) will make them unsuitable for direct application in the fire-danger rating "beyond 6 days" time frame discussed in the previous section. I foresee a technological discontinuity at that transition point that will likely persist well beyond 2007.

THE PRACTICE OF RATING FIRE DANGER

GOES and remote automatic weather stations are changing the way fire-weather data is being collected. Since 1978, several hundred stations have been deployed by state and federal agencies, and more are planned. Almost all are now located in the far West and Alaska, but they will be common in the East before 2007.

Before the next 20 years has passed, fire weather will be collected from specially designed networks of automatic and manual stations. The numbers and locations of stations making up those networks will be determined by requirements passed down by management. Management will have finally determined how good the "answers" must be.

Some users will locate stations in the "woods," a practice commonly followed by our

Canadian colleagues. This will be an improvement for some. The "worst case" standard for taking the basic weather observation will be continued. More attention will, however, be given to the time the "worst" conditions actually occur.

More use will be made of weather data taken at non-wildland sites such as airports. Factors will have been developed to convert a 1- and 3-minute, 10-meter windspeed to an equivalent 10-minute, 20-foot windspeed. Neither will there be a need to weigh fuel sticks.

COMMUNICATION AND DISPLAY OF FIRE-DANGER RATINGS

Automated fire-weather stations will replace more than half of the manual stations by 1997. The replacement system for AFFIRMS will be in place by 1992. That will just about do it for the first half of the 20-year outlook.

No one knows what WIMS will look like; that will, however, be known before the year is out. Because of a consulting agreement with a private company I will not discuss my vision of WIMS, except that it will very likely make good use of micro-computers and will have limited "expert system" capabilities.

During the second half of the 20-year outlook, local data bases will allow each fire management unit to do its own planning, calculate and interpret its own fire danger, and make detailed fire behavior predictions for large, multiperiod fires. Uncertainty of both fire-danger and fire-behavior predictions will be quantified and that information incorporated in sophisticated computer-generated decision aids.

By 2007, the moisture contents of tundra, organic soils, and the full range of vegetation will be monitored from satellites and those data sent directly to the primary users. High resolution precipitation data from the weather radar network will be automatically integrated, along with the satellite moisture data, into operational fire-danger rating and fire-behavior prediction systems.

SUMMARY

--The need for fire-danger ratings will not disappear.
--Only modest technical improvements will be made to the NFDRS during the next 10 years.
--The 2007 NFDRS will look much like the 1978 NFDRS.
--A better understanding of the character of each region's fire danger will be the key to improved fire-danger rating system usage.
--Detailed, 6-day projections and regional trends of fire-danger ratings will be feasible by the mid 1990's.
--The format of predicted fire danger, beginning in the late 1990's, will include ranges of uncertainty.
--Fire-behavior, fire-danger rating, and fire-planning systems will be closely integrated, but not fully integrated.
--Satellite observations of vegetation and soil moisture conditions will be integrated into the fire-danger rating process.
--Weather radar will be the source of high resolution precipitation data for rating fire danger.

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