FIRE DANGER RATING AND FIRE BEHAVIOR PREDICTION IN THE UNITED STATES

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SUMMARY

For the seven year period from 1998 to 2004, an average of almost 79,000 fires per year on U.S. Federal and State land burned a yearly average of over 22,000 km^2. An average of 1 billion US dollars was spent on suppression each year by the Federal agencies alone. Variation in climate, vegetation, and population across the U.S. leads to significant differences in the timing of the fire season and in predominate fire cause. Fire danger rating and fire behavior prediction systems are used to support fire management decision-making in fire prevention, fire suppression, and fire use. The U.S. National Fire Danger Rating System is based on current, historical, and forecast weather data. Selection of the most appropriate index can be based on the relationship to fire occurrence. The WFAS Wildland Fire Assessment System is an Internet system that provides maps of fire potential based on a network of fire weather stations and on remote sensing. Fire behavior prediction systems use additional information on fuel, terrain and weather. Specific fire danger and fire behavior systems are described. Ongoing research and development is briefly discussed.

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1. INTRODUCTION

The Wildland Fire Management Program in the United States combines elements of fire prevention, fire suppression, and fire use. Fire danger rating systems and fire behavior prediction systems are used to support decision-making by managers at national, regional, and local levels. In the terminology used in the U.S., there are three kinds of *Wildland Fire*: wildfire, wildland fire use, and prescribed fire. *Wildfire* is unplanned, unwanted wildland fire; the objective is to put the fire out. *Wildland Fire Use* is the application of the appropriate management response to naturally ignited wildland fires to accomplish specific resource management objectives in predefined designated areas outlined in Fire Management Plans. *Prescribed Fire* is a fire ignited by management actions to meet specific objectives. A written, approved prescribed fire plan must exist.

Wildland fire occurrence is inevitable in all North American ecosystems. Most wildland fire is suppressed to meet resource and social objectives. Unprecedented expenditures on wildland firefighting over the past several years have brought federal wildland fire management to the forefront of political debate [1, 2]. Federal expenditures on emergency fire suppression exceeded $1 billion (USD) in each of 2000, 2002, and 2003 (Table 1). In addition to aggressive wildfire prevention and suppression, fire is used to achieve various objectives including restoration of ecosystem health and reduction of the risk of damaging fire. In 2003 a record area was burned by wildland fire use and prescribed fire.

The U.S. National Fire Danger Rating System (NFDRS) provides an indication of seasonal fire potential for large administrative areas such as National Forests where weather, fuel, and topography can vary greatly. NFDRS is a climatology-based system, and as such, analysis of historical fire danger is required for proper interpretation and application of indices. The Wildland Fire Assessment System (WFAS) includes spatial fire danger products. Fire behavior prediction systems, including BehavePlus, FlamMap, and FARSITE, are designed to model time and site-specific fire characteristics such as rate of spread, intensity, flame length, and fire growth.

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Variation in climate, vegetation, and population across the U.S. leads to significant differences in the timing of the fire season and in predominate fire cause. I begin with a description U.S. wildland fire activity to show the challenge of developing systems that can be applied over the wide range of conditions in the country.

2. WILDLAND FIRE IN THE U.S.

Fire and land management in the U.S. is the responsibility of a variety of federal, state, and private agencies and organizations. As a result, there is significant variation in quantity and quality of archived fire occurrence data [3, 4]. In this paper I present summaries from two sources. I give a national view of fire activity for 1998-2004 based on fires reported to the National Interagency Coordination Center (NICC). And I use 35 years (1970-2004) of U.S. Department of Agriculture (USDA) Forest Service wildfire data to illustrate differences in season and fire cause across the U.S.

2.1 National Interagency Coordination Center Reports

The National Interagency Coordination Center (NICC) is the focal point for coordinating the mobilization of national resources for wildland fire and other incidents throughout the United States. Located in Boise, Idaho, NICC also provides Intelligence and Predictive Services related-products designed to be used by the internal wildland fire community for wildland fire and incident management decision-making. The fire danger products described in this paper are used by NICC in their assessments and briefings.

Wildland fire statistics are gathered by NICC to provide a national perspective of annual fire activity. Individual agencies keep a more specific and detailed record of fires. An annual statistics and summary report is produced for operational purposes by NICC. The following is taken from the 2003 and 2004 reports [5, 6].

Figure 1 shows the location and timing of large fires reported to NICC in 2003 and 2004. 'Large' is defined as 40+ ha (100+ ac) for timber fires and 121+ ha (300+ ac) for grass fires. Differences between the years are evident. In 2003 there were many large fires in the Northern Rocky Mountains; in 2004 there were many in the southeastern U.S. The fire locations are marked to indicate four month periods. Regional differences in fire seasons are readily apparent. In the eastern U.S. the majority of fires occur January through April, while in the west the majority occur from May through August.

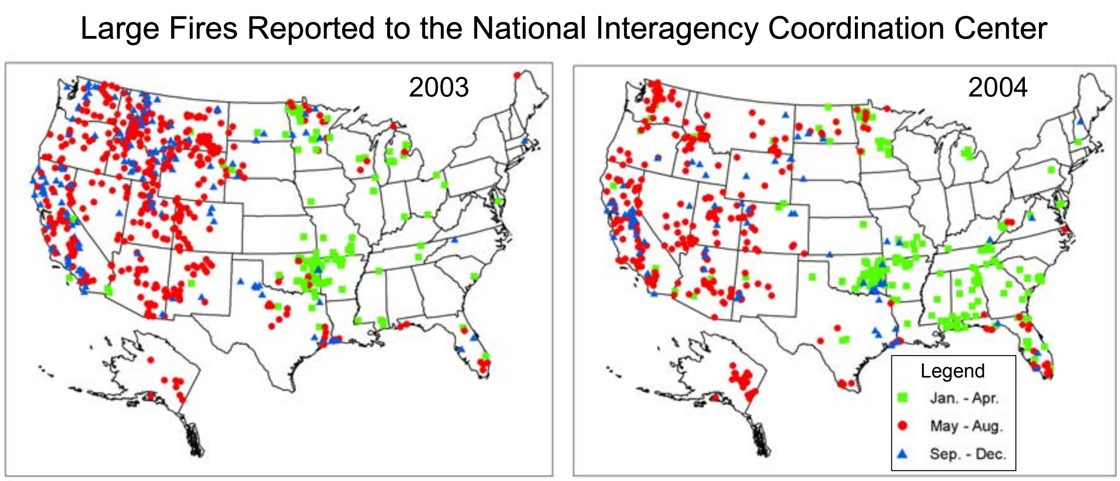

Figure 1--Large fires reported to the U.S. National Interagency Coordination Center (NICC) in 2003 and 2004. This includes fires on Federal, State, and other land. Large fires are defined to be over 40 ha (100 ac) for timber fires and over 121 ha (300 ac) for grass fires. Symbols and colors indicate the time of year that the fire burned according to four month periods.

Table 1 and Figure 2 show wildland fire activity for the years 1998 to 2004, as reported to NICC. This period was selected because national prescribed fire reporting began in 1998. For the seven year period, over a half million wildfires were reported to NICC, for an average of almost 79,000 fires per year. Over this time period, there was a decreasing trend in the number of wildfires, with variation in the area burned. The area of high wildfire activity in 2003 was in the northern Rockies and in California. In 2003 4,090 homes were burned by wildfire, 89% of those in California. It is noteworthy that in the midst of the busy 2003 fire season, agencies successfully managed a record area burned by wildland fire use and prescribed fire. In 2004 wildfire activity was moderate in most of the lower 48 states, and very heavy in Alaska, which experienced that state's busiest fire season on record. In 2004 nearly 82% of the national total area burned was in Alaska.

Table 1 -- Wildfires, wildland fire use, and prescribed fires reported to the National Interagency Coordination Center from 1998 to 2004. This includes fires on Federal, State, and other land.

Year	Wildfires		Wildland Fire Use		Prescribed Fire		Suppression costs for Federal Agencies, billion USD
	Number	Area burned, km^2	Number	Area burned, km^2	Number of projects	Area burned, km^2	
1998	81043	9,428	358	251	4,277	3,554	$0.3
1999	92487	22,768	335	306	5,937	8,068	$0.5
2000	92250	29,921	107	162	4,697	4,825	$1.4
2001	84079	14,451	273	379	5,909	6,674	$0.9
2002	73457	29,076	408	252	29,776	10,796	$1.7
2003	63629	16,029	342	1,339	22,868	11,477	$1.3
2004	65461	32,771	309	504	8,840	9,965	$0.9
Total	552,406	154,444	2,132	3,195	82,304	55,359	$7.0
Average	78,915	22,063	305	456	11,758	7,908	$1.0

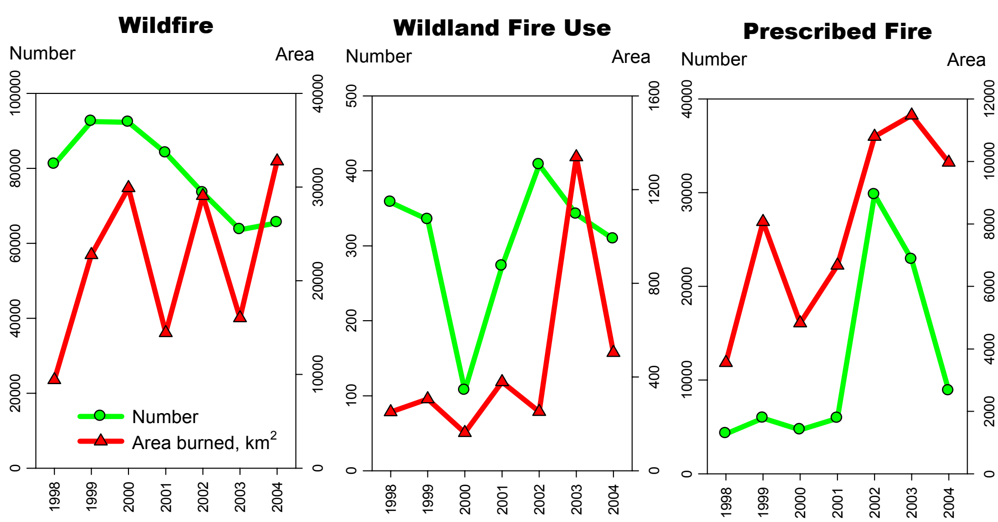

Figure 2 -- Yearly trends in number of wildfires, wildland fire use, and prescribed fires and associated area burned reported to the National Interagency Coordination Center from 1998 to 2004. This includes fires on Federal, State, and other land. Data are taken from Table 1.

The NICC summaries include all fires reported to the national center. Federal fires include USDA Forest Service and the U.S. Department of Interior agencies Bureau of Land Management, National Park Service, Bureau of Indian Affairs, and Fish and Wildlife Service. Table 2 and Figure 3 show the number of fires and area burned for 2003 and 2004 segregated according to Forest Service, other Federal, and State and Other. Forest Service fires accounted for 16% and 13% of the fires reported to NICC in 2003 and 2004, respectively. In 2003, 36% of the reported area burned was by Forest Service fires, significantly more than the 6.8% in 2004. Following is a summary of only Forest Service wildfires.

Table 2--Fires reported to NICC for 2003 and 2004 according to reporting agency.

Agency	Number of Wildfires				Area burned by Wildfires			
	2003		2004		2003		2004	
	Number	Percent	Number	Percent	Area, km^2	Percent	Area, km^2	Percent
Forest Service	10,258	16.1%	8,608	13.1%	5,780	36.1%	2,234	6.8%
Other Federal	7,870	12.4%	7,530	11.5%	4,632	28.9%	14,228	43.4%
State and other	45,501	71.5%	49,413	75.4%	5,617	35.0%	16,309	49.8%
Total	63,629	100%	65,551	100%	16,029	100%	32,771	100%

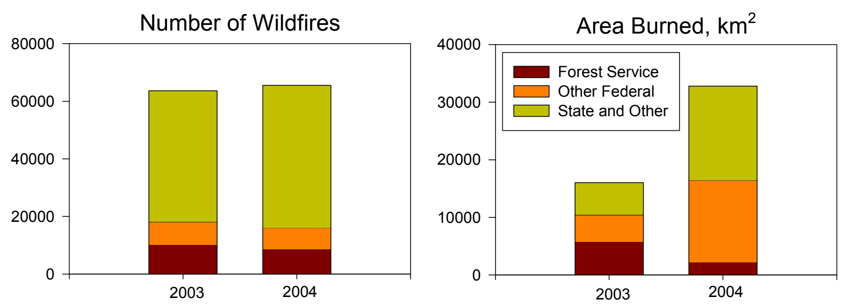

Figure 3--Number and area burned for fires reported to NICC in 2003 and 2004, by reporting agency. Data from Table 2.

2.2 Forest Service Reports

U.S. Forest Service fire data are available for 1970-2004 on the Internet [7]. I present a summary by Forest Service Region to illustrate differences in fire season timing and fire cause across the country. Figure 4 is a U.S. map showing the nine Forest Service Regions and the National Forest land included in each. Although the U.S. Forest Service is responsible for fire protection on some land outside of National Forest boundaries, this map gives an indication of the land represented in the Forest Service fire occurrence database. Note that there is more Forest Service land in the Western U.S. than in the East. Note also that Forest Service land in Alaska (R10) is in the 'panhandle'. The large fires of 2004 were primarily in interior Alaska on Bureau of Land Management (BLM) land.

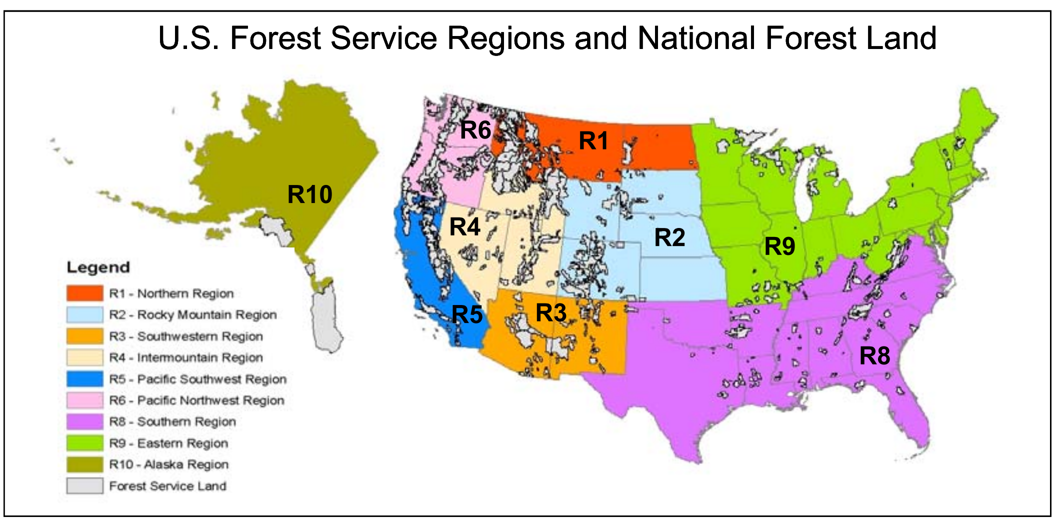

Figure 4--The U.S. Forest Service is managed according to Regions. The National Forest Land is indicated on the map.

Table 3 -- Summary of U.S. Forest Service wildfires by Region for the 35 year period from 1970 to 2004.

Forest Service Region	Number of fires				Area burned, km^2				Percentage of fires for 35 years			
	Total 1970-2004	per year			Total 1970-2004	per year			Size class*		Cause	Time
		Mean	Min	Max		Mean	Min	Max	A	E+	Ltng.	Jul-Aug
R1	42,830	1,224	398	2,900	16,582	474	3	6,903	71%	1.5%	73%	72%
R2	21,474	614	348	980	7,196	206	5	1,956	65%	1.3%	62%	55%
R3	78,072	2,231	1,400	3,256	11,423	326	18	1,136	69%	0.9%	70%	51%
R4	37,882	1,082	533	1,792	20,400	583	6	4,252	72%	2.0%	71%	67%
R5	79,847	2,281	1,394	3,664	28,023	801	47	3,085	76%	1.3%	47%	49%
R6	59,309	1,695	909	3,203	13,740	393	11	3,626	79%	0.8%	62%	64%
R8	54,018	1,543	561	2,738	5,697	163	25	562	21%	1.0%	9%	9%
R9	22,364	639	268	1,702	1,528	44	8	160	29%	0.6%	5%	12%
R10	1,051	30	0	108	61	2	0	34	77%	0.4%	5%	52%
FS all	396,847	10,256	6,498	13,926	104,650	2,407	300	10,328	63%	1.2%	52%	49%

*Size class A is <0 .10 ha (25 ac); E+ is >121 ha (300 ac)

Table 3 summarizes Forest Service wildfire activity by Region for the 35 year period from 1970 to 2004 according to number of fires, area burned, fire size, cause, and timing. There are significant differences by location, especially from East to West.

The magnitude of fire season activity varies considerably from year to year. The area burned in the Northern Region (R1), for example, ranged from 3 km^2 in 1975 to 6,903 km^2 in 1988.

Of the 396,847 fires in the 35-year Forest Service database, 63% were very small, less than 0.10 ha (0.25 ac). Only 1.2% were larger than 121 ha (300 ac), but those fires accounted for 93.2% of the total area burned.

For the 35 years of data summarized here, about half (52%) of all Forest Service fires were lightning caused and the rest human caused. Human caused fires are the result of equipment, smoking, campfires, debris burning, railroad related, arson, children, etc. The percentage varies significantly by Region, from 73% lightning fires in the Northern Region (R1) to only 5% in the Eastern Region (R9). Although only 5% of the Forest Service Alaska Region (R10) fires are lightning caused, 71.5% of Alaska fires managed by the Bureau of Land Management were lightning caused (1980-2004).

The percentage of fires reported in July and August is given in Table 3 for each Region, with the extremes represented by the Northern Region (R1) at 72% and the Southern Region (R8) at 9%. Figure 5 shows for each Region the percentage of fires by each month, categorized by cause. The western Regions have a summer fire season with the peak in July or August. The Southern and Eastern Regions (R8 and R9) have a bimodal fire season with very few fires in the summer.

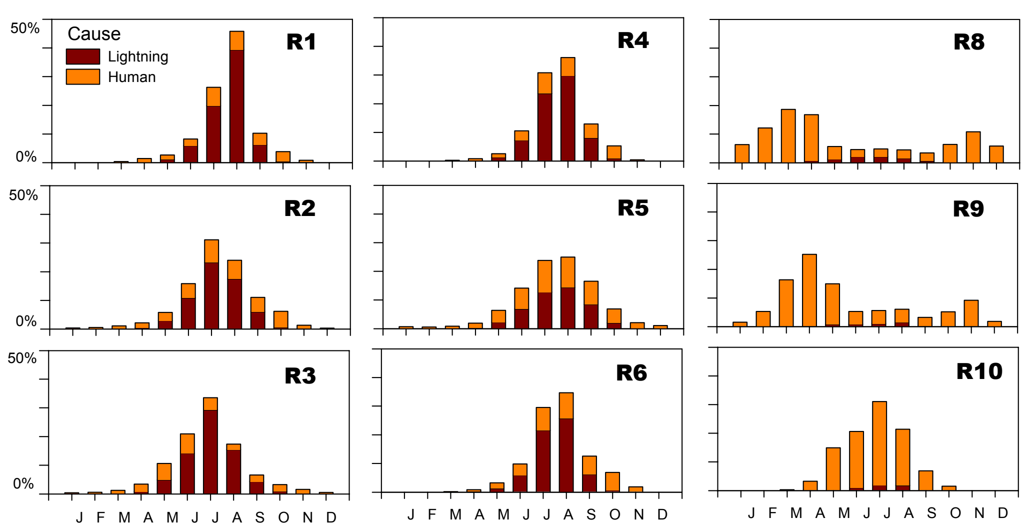

Figure 5 -- Percentage of wildfires by month for each Forest Service Region, with indiction of cause (lightning or human). Forest Service managed wildfires for 1970-2004. See Figure 4 for Region locations.

3. DECISION SUPPORT

Figure 6 gives examples of fire management activities that take place at various time and space scales. Time is referenced with respect to a fire event. As the time scale moves from left to right, additional information on weather and fuel conditions becomes available. At the spatial scale labeled 'site', specific information is available on fuel, terrain, and other local conditions. The regional level encompasses a wide range of conditions, but represents a general fire climate [8]. A national view is made up of regional components. This chart can be used to indicate the scope of application for fire danger rating and fire behavior prediction systems.

Fire danger rating supports operational decision-making during the fire season, before a fire start. Seasonal fire danger indices can be useful at all spatial scales, from site to national. Site applications are generally served by fire behavior prediction systems that incorporate variation of terrain, fuel, and weather across the landscape and allow consideration of changing conditions throughout the 24 hour day. Fire behavior prediction systems are used in support of fire management decision-making at all time scales, for planning, operations, and monitoring activates.

TIME →

SPACE ↓	PLANNING	OPERATIONS			MONITORING
	YEAR OR YEARS BEFORE A FIRE	PRE-SEASON	DURING SEASON, PRE-FIRE	FIRE	AFTER A FIRE
SITE	Fire prescription development	Fuel treatment	Assessment of conditions for fire use	Fire suppression	Suppression tactics assessment
REGION	Fuel hazard assessment	Resource requests	Fire prevention, Resource readiness	Situation assessment	Economic impact
NATION	Budget needs assessment	Resource allocation	Resource movement to areas of high fire potential	Situation assessment	Season assessment for future planning

Figure 6--Examples of wildland fire management activities that take place at various temporal and spatial scales. Fire danger rating is generally used during the fire season, pre-fire (center column). Fire behavior prediction is generally used for site applications at all time scales (top row).

Fire managers use fire danger systems to track seasonal conditions to support fire management activities in prevention, suppression, and fire use. *Fire prevention* is education and other actions that reduce unwanted wildfires. When the index reaches a given level, additional public awareness messages are presented, burning restrictions are put in place, and logging operations are limited or halted. Fire danger systems are used to help make the difficult decisions to close public lands to recreation and to stop fireworks sales or use. *Fire suppression* is action taken on wildfires to protect life, and to reduce damage to resources and property. In support of fire suppression, fire danger is used to determine staffing levels and dispatch levels. In times of high fire activity, there are requests for more resources than are available; fire danger can be used to set priorities in filling requests and to determine the need to move resources such as fire suppression crews and air tankers to areas of higher fire potential. Fire danger indices are also used to communicate the status of regional fire potential to fire fighters for awareness and safety [9]. *Use of wildland fire* is the application of wildland fire to meet specific management and resource objectives. Fire danger is used in support of fire use in the planning stage; prescriptions and fire management plans identify conditions under which fire use is appropriate and safe. In the operational stage, the current fire danger level is part of the information used in determining whether a new lightning-ignited fire is identified as a wildfire and suppressed or put in the wildland fire use category.

Fire behavior prediction is also used in support of fire prevention, suppression, and use. Calculation of potential fire behavior under various weather scenarios and fire start locations can be used to develop a fire prevention program with focus on areas of highest need. A Fire Behavior Analyst serving on an Incident Management team uses fire behavior systems to project the growth of a wildfire to assist with defining safe and effective fire suppression tactics. Calculated fire behavior is used to define a prescription for management ignited prescribed fires. Long-range projections of fire growth are used for wildland fire use to project whether the fire will remain within the Maximum Manageable Area (MMA) without suppression action.

4. FIRE DANGER RATING

The following fire danger products are described in this section:

- NFDRS (National Fire Danger Rating System) is the algorithm for calculation of indices from weather and site descriptors such as fuel model. There is not a computer program called NFDRS.
- FFP (FireFamily Plus) is a computer program for historical analysis. Archived weather data files are used to do the NFDRS calculations.
- WIMS (Weather Information Management System) is the communication system for gathering fire weather data from around the country and for doing NFDRS calculations each day during the fire season. Weather data entered into WIMS is archived for later analysis by FFP.
- WFAS (Wildland Fire Assessment System) is an internet-based system that produces national maps from WIMS weather and fire danger data. WFAS also includes other products including those generated from satellite data.

The current version of the U.S. National Fire Danger Rating System (NFDRS) was implemented in 1978 [10]. Computation details are given by Bradshaw et al. [11]. Additional options are described by Burgan [12]. A simplified diagram of NFDRS is given in Figure 7. NFDRS provides a systematic way to integrate and interpret seasonal weather trends; fuel and terrain factors are essentially held constant. NFDRS uses daily weather observations and next day forecasts to produce indices that are indicators of fire danger or seasonal fire potential for large areas. Weather readings are taken daily at the same time and location. Fuel moisture values are calculated for live grasses and shrub foliage and several size classes of dead fuel. The fuel moisture values are then used to calculate the indices. Note that the calculation of Spread Component (SC) is influenced most by the moisture content of fine dead fuel (1-h) and that wind speed is included in the calculations. On the other hand, calculation of Energy Release Component (ERC) is weighted toward heavy dead fuels (100-h and 1000-h), and wind is not part of the calculation. SC therefore reflects daily variations in fine fuel moisture and wind, and ERC reflects longer term drying (if there are heavy fuels in the selected fuel model). Burning Index (BI) is a function of SC and ERC.

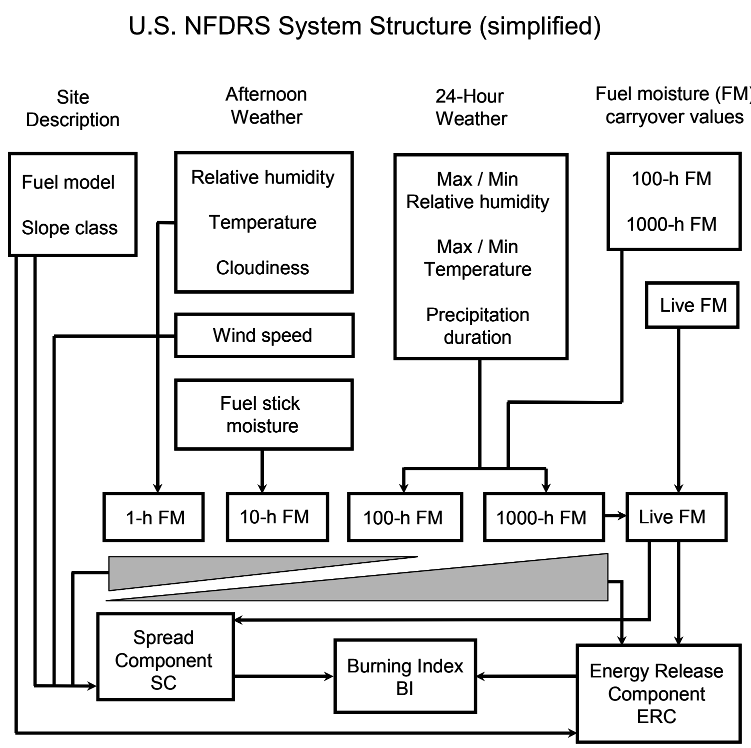

Figure 7--Simplified information flow for the U.S. National Fire Danger Rating System. Weather data and site descriptors are used to calculate fuel moisture values, which are used to calculate indices. The wedges indicate the weighting of the dead fuel moisture size classes in the calculation.

NFDRS is a climatology-based system. It is necessary to do historical calculations in order to properly interpret and apply indices. The computer program FireFamily Plus (FFP) is designed for analysis of historical fire danger and weather data [13, 14]. (In addition to NFDRS, it includes calculation of Canadian fire danger indices and allows input of a file of any index.). Figure 8 is an example using weather data from the West Fork fire weather station (242907) and fires from the Bitterroot National Forest in Montana. Seasonal plots can be produced with the maximum, minimum, and average values by day for the period of record (Figure 8a). FireFamily Plus matches fire data to index data and does analysis of the relationship of fire activity to index using methods described by Andrews et al. [15]. Figure 8b shows the probability of a fire-day, a large-fire-day, and a multiple-fire-day as a function of ERC. In addition to graphics, reports can be printed or exported for further analysis. Index analysis gives local managers guidance on selection of the index, fuel model, and other options that best reflect fire activity in an area.

(a) (b)

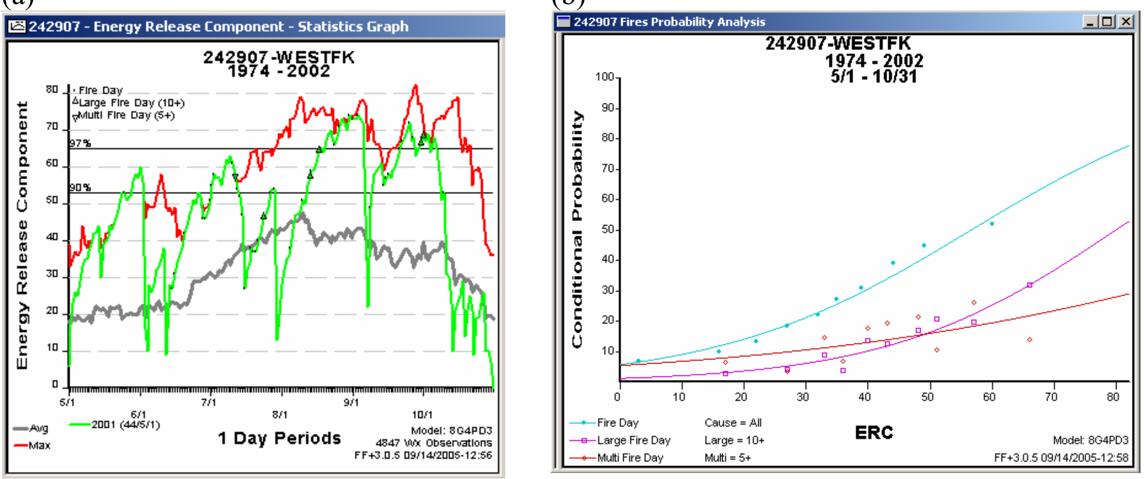

Figure 8-- Sample output from the FireFamily Plus program for historical fire danger rating analysis. Seasonal trends of a selected year compared to average and maximum values. Logistic regression gives probability of fire occurrence as a function of index.

The Weather Information Management System (WIMS) [16] is used for daily calculation of fire danger throughout the fire season. WIMS collects weather data daily from over 1200 fire weather stations around the U.S. Fire danger indices are calculated according to station catalogs (fuel model, index, threshold levels, etc.) which have been set up by local managers. Summaries of weather and fire danger values are made available in a tabular form. Weather data are archived and made available for later analysis by programs such as FireFamily Plus.

The Wildland Fire Assessment System (WFAS) [17, 18] is an internet-based system that collects weather and fire danger data from WIMS and produces national maps. Simple interpolation is used between stations (Figure 9a). Experimental products use weather for each pixel to do NFDRS calculations (see Figure 12). WFAS also includes products derived from satellite data designed to reflect changes in live vegetation throughout the year (Figure 9b) [19, 20].

Evaluation of fire danger rating is difficult because it is a somewhat nebulous concept as compared to the more well-defined fire behavior prediction, which is used to calculate observable fire characteristics such as rate of spread and flame length. A fire danger rating index is not meant to describe the characteristics of a specific fire, but rather to be an indication of fire potential for a management area. Various approaches have been taken in evaluation of fire danger rating systems. Andrews et al. [15] summarize other methods and propose the use of percentiles and logistic regression. Various efforts are underway to accomplish the important and difficult task of developing comparable methods of evaluating spatial fire danger products.

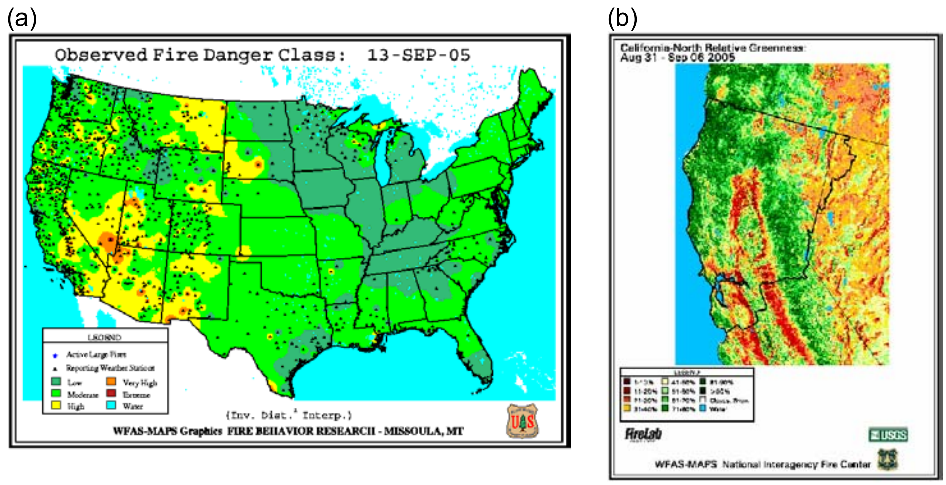

Figure 9--Sample Wildland Fire Assessment System (WFAS) products. (a) Fire danger class, interpolation of values from indicated fire weather stations. (b) Relative Greenness for Northern California from NDVI AVHRR satellite data.

5. FIRE BEHAVIOR PREDICTION

The following set of three related fire behavior prediction systems is described in this section:

- BehavePlus fire modeling system
- FlamMap fire behavior mapping and analysis system
- FARSITE fire area simulator

These systems are based on essentially the same mathematical fire models, including, for example, the surface fire spread model [21], spotting distance model [22], and transition to crown fire model [23]. They differ in the spatial and temporal variations that they address. BehavePlus is a point model. FlamMap is a spatial model, doing calculations for each pixel independent of its neighbors on the landscape. FARSITE uses the same spatial data as FlamMap, but includes a temporal component, calculating fire behavior and growth over time under changing weather and fuel moisture conditions.

The BehavePlus fire modeling system is a computer program that is a collection of models that describe fire and the fire environment [24, 25]. It is a flexible system that produces tables, graphs, and simple diagrams. Conditions are defined interactively by the user; selected conditions are generally examined over a range of values. Figure 10 shows calculated surface fire rate of spread for a range of wind and dead fuel moisture conditions. The fire modeling capabilities in BehavePlus include spread and intensity of a spreading surface fire, transition from surface to crown fire, crown fire spread, size of a point source fire, fire containment, safety zone size, crown scorch, tree mortality, probability of ignition, and others.

FlamMap uses spatial fuel and terrain data and user-defined weather and fuel moisture conditions to calculate fire behavior elements for every pixel on the landscape. Figure 11a shows calculated surface fire rate of spread for an area. This map shows areas with differing fire spread potential. FlamMap is used for fuel hazard assessment and other planning applications.

FARSITE is a fire growth simulation program, using the same spatial data layers as FlamMap. But rate of spread is calculated for the fire perimeter based on changing weather conditions [26]. Figure 11b shows modeled fire perimeter for a specified ignition point. FARSITE is used to project the growth of fires in both planning and operational settings.

Fuel model 2, 120% live fuel mois.
Surface Rate of Spread (maximum) (m/min)

Midflame Wind Speed km/h	Dead Fuel Moisture % 3	6	9	12
0.0	0.9	0.7	0.6	0.5
3.0	3.0	2.4	2.1	1.5
6.0	8.4	6.8	5.9	4.3
9.0	16.7	13.5	11.8	8.6
12.0	27.6	22.4	19.5	14.2

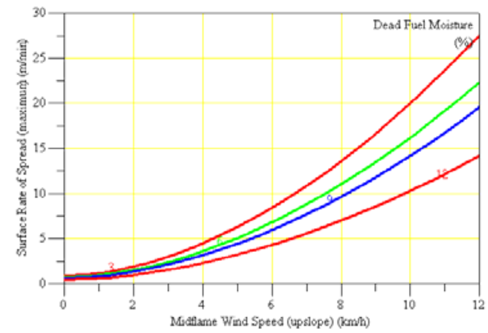

Figure 10—Example table and graphic output from the BehavePlus fire modeling system. Calculated surface fire rate of spread for fuel model 2, live fuel moisture 120%, and a range of dead fuel moisture and windspeed values.

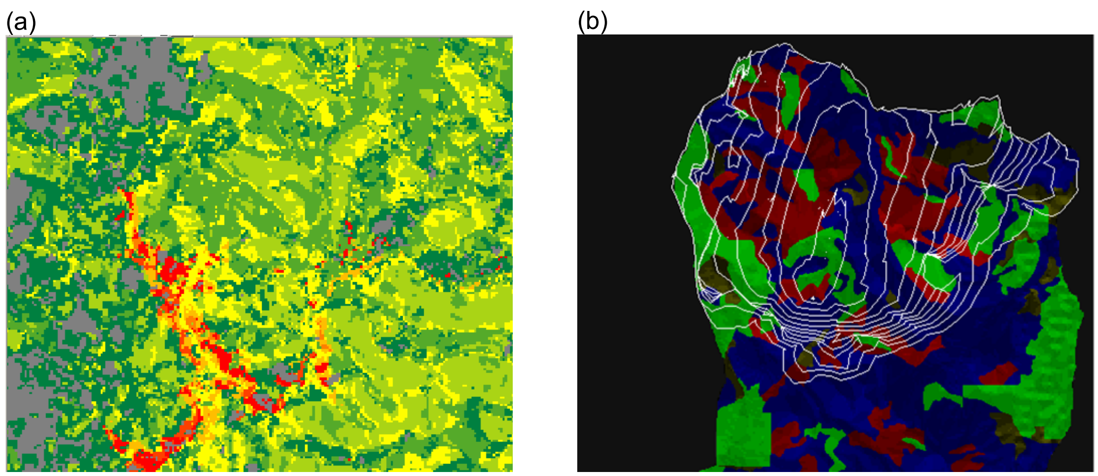

Figure 11--Sample output from FlamMap and FARSITE (for different landscapes). (a) FlamMap display of surface fire rate of spread calculated for each pixel on the landscape under constant conditions. (b) FARSITE projected fire perimeters. The underlying map is colored according to fuel type.

6. FUTURE RESEARCH AND DEVELOPMENT

The fire danger rating and fire behavior prediction systems described in this paper are successfully used throughout the United States for many aspects of wildland fire management. Research and development efforts are aimed at improving the systems and strengthening the links among them.

6.1 Simplification of NFDRS

The U.S. National Fire Danger Rating System is complex, in terms of the number of options that are available to a user. There are several indices which can be calculated for 20 fuel models, as well as other options. The 1988 update more than tripled the number of options. Preliminary evaluations have shown that the system can perform well with most of the options being eliminated or ignored. We will continue our analysis to show that a simplified version of NFDRS can be effective across the broad range of conditions represented in the U.S.

In addition to daily weather observations, NFDRS requires user input of a 'state of the weather' code and a subjective specification of greenup date or a greenness factor as the season progresses. The goal is to eliminate this need through more effective modeling. In that way we will assure that the fire danger calculations done for the historical analysis are the same as those done during the ongoing fire season.

Changes to the widely-used, well-established NFDRS will require a convincing analysis that the improvements are worthwhile.

6.2 WFAS expansion

The Wildland Fire Assessment System will be expanded to include additional weather and fire danger products. We will continue development of spatial fire danger products, using additional sources of weather data and making use of gridded weather models and forecasts (Figure 12). We will incorporate MODIS satellite data into WFAS. WFAS has focused on broad-scale national products. We are beginning to develop regional products specifically designed to support decision-making at that level. We hope to be able to use the FlamMap structure to present local fire potential for selected areas, several times per day. This will be an important bridge between fire danger rating and fire behavior prediction.

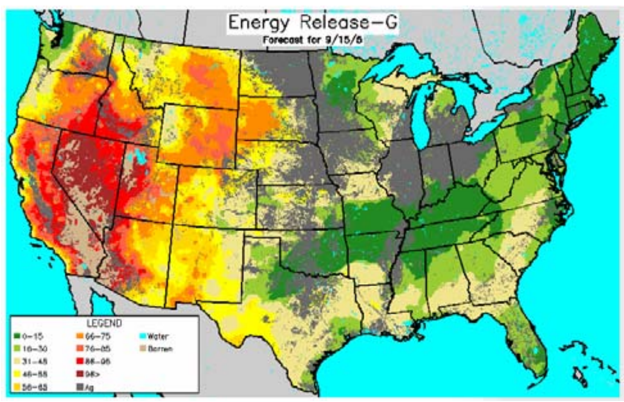

Figure 12--Experimental 24-hour forecast of ERG, fuel model G, based on gridded weather.

6.3 Fire danger and fire behavior linkages

In this paper I have described some of the relationships among fire danger and fire behavior systems. We are working on a conceptual design that is effectively an umbrella over all of these systems. The goal isn't one huge computer program that will do everything. We envision a structure that defines more specific links among components in terms of fire models, fuel descriptions, fuel moisture values, data files, and so on. This will make it easier for fire managers to know which system is best suited to the application at hand. And it will be easier for system developers to incorporate improved mathematical fire models developed by research.

Table 4--Web sites referred to in this paper.

Topic	URL
WFAS: Wildland Fire Assessment System	http://www.fs.fed.us/land/wfas/
BehavePlus, FlamMap, FARSITE, FireFamily Plus programs and supporting documentation	http://www.fire.org
U.S. Federal agency fire and weather data	http://famweb.nwcg.gov/weatherfirecd/
NICC yearly statistics and summary reports	http://www.nifc.gov/nicc/predictive/intelligence/intelligence.htm
NICC official wildland fire statistics	http://www.nifc.gov/stats/index.html
Coarse Assessment of Federal Wildland Fire Occurrence Data report	http://www.cefa.dri.edu/Publications/

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