**0726-B1**

# Considerations in Developing a National Forest Fire Danger Rating System

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## Abstract

Effective forest-fire management is based on sound knowledge of the potential for ignition, behavior, difficulty of control, and impact of fire in a given situation. Forest-fire danger-rating systems provide a framework for organizing and integrating scientific knowledge and operational experience, and they are a cornerstone of modern fire management.

The Canadian Forest Fire Danger Rating System (CFFDRS) is one of the most well developed and widely applied schemes. This paper suggests how experience with the CFFDRS can inform the development of danger-rating systems in other forest or wildland environments.

There are four key elements to developing and realizing a national forest-fire danger-rating system:

- A sustained program of scientific research to develop a system based on relationships between fire weather/fuels/topography and fire occurrence/behaviour/impact that are appropriate to the fire environment.
- Development of the technical infrastructure to gather and process fire weather data and to disseminate fire weather forecasts, information about fire-danger, and predictions of fire behavior within operational agencies.
- Technology transfer, and training in the use of fire-danger information in fire operations, which are appropriate to the needs and capabilities of operational agencies.
- Development of institutional mechanisms to foster cooperation and communication between fire-management and research agencies; to share resources; and to set common standards for information, resources and training.

Most important, a common vision and a sense of common cause are needed. Where the CFFDRS has been implemented in other countries, technological aspects are often over-emphasized, while the importance of human and institutional factors is overlooked.

# Introduction

An adequate fire-intelligence system is the cornerstone for effective management of wildland fire. A major component of any fire-intelligence system is a fire-danger rating system. The purpose of fire-danger rating systems is that where the fire environment (i.e., weather, fuels, and topography) varies in space and time, and where fire-management resources are costly and limited, a means is needed to allocate the available resources across a region or country from day to day or place to place, on the basis of fire danger. The process of systematically evaluating and integrating the individual and combined effects of the factors influencing fire potential is referred to as fire-danger rating. Fire-danger rating systems provide for one or more qualitative and/or numerical indices of ignition potential and probable fire behavior.

# Canadian Experience in Forest-Fire Danger Rating

The Canadian Forest Fire Danger Rating System (CFFDRS) is one of the few systems in the world that is implemented across an entire country (Alexander et al. 1996). It has two primary subsystems (Figure 1)-the Fire Weather Index (FWI) System and the Fire Behavior Prediction (FBP) System (Stocks et al. 1989). The CFFDRS is the principal source of fire intelligence in Canada and is fundamental to fire-management operations at strategic and tactical levels, from prevention to fire-fighter safety. The development of a national forest-fire danger-rating system for Canada faced many challenges. Canada is a large country with fire environments that range from rain forest and taiga to grassland and semi-desert. Land-management objectives, the importance of fire, and the resources available for fire management, vary widely across the country. The national government has a limited role in forest management and must work cooperatively with provincial and territorial agencies to implement national programs, rather than act unilaterally.

**Figure 1. Left: Structure of the Canadian Forest Fire Danger Rating System (CFFDRS).**

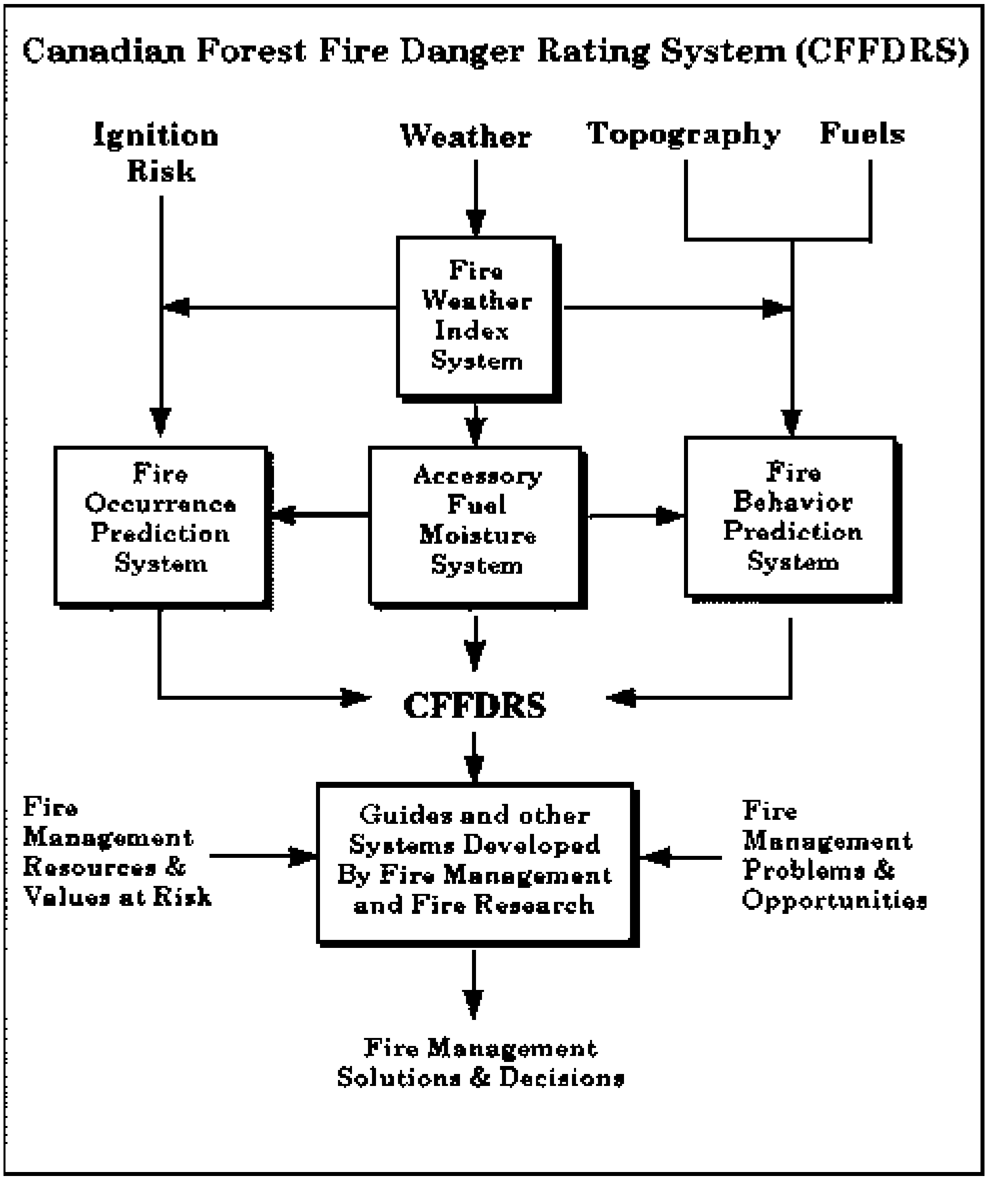
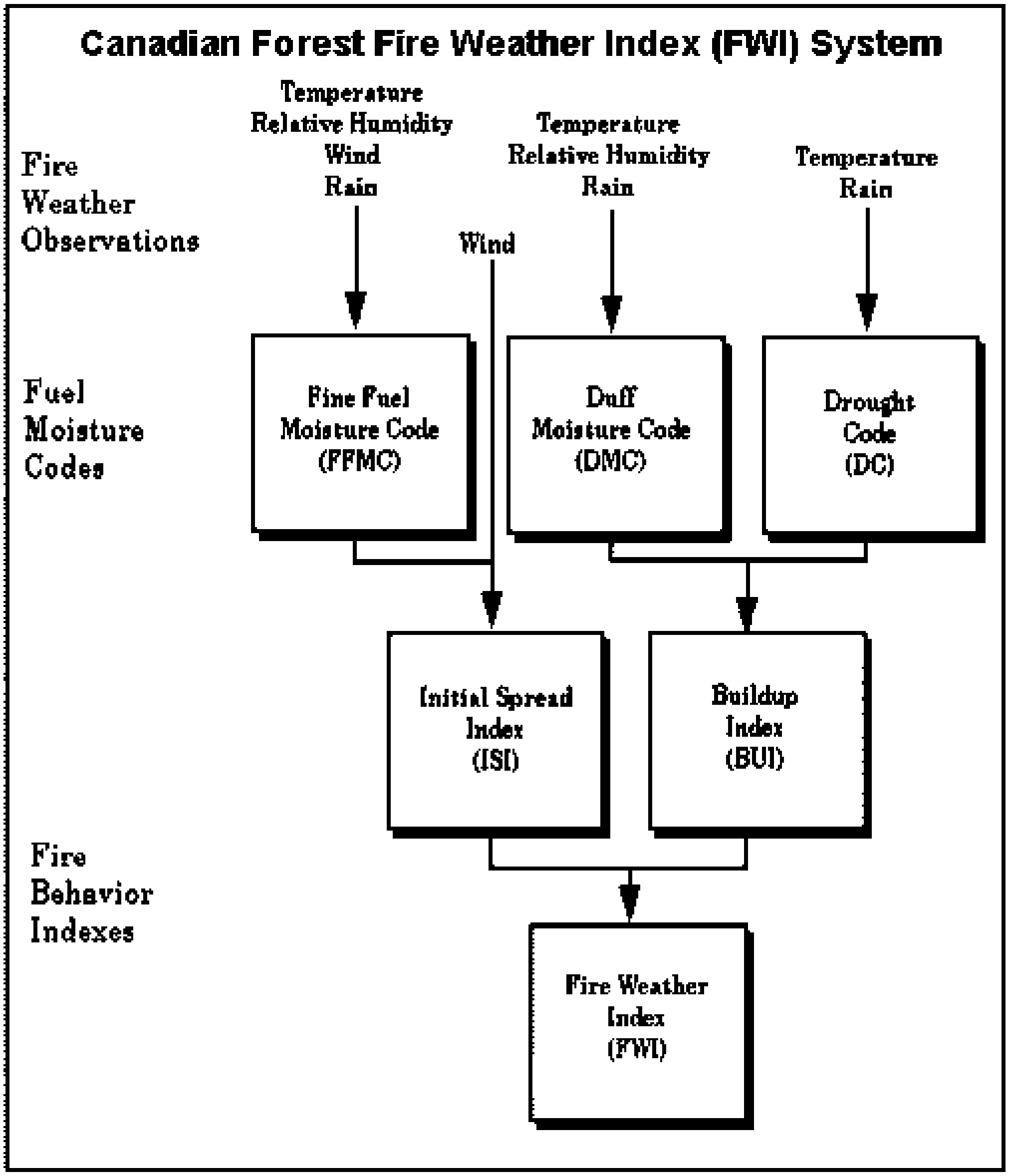



**Figure 1. Right: Structure of the Fire Weather Index (FWI) System of the CFFDRS.**




Research on fire danger began in Canada in the 1930s and resulted in the development of a number of regional fire-danger tables. Fire research was greatly expanded during the 1960s, and in 1967 a modular, national, fire-danger rating system was proposed to replace various regional systems. The Fine Fuel Moisture Code (FFMC) was developed to represent the moisture content of surface litter, which is important to ignition and fire spread. The Duff Moisture Code (DMC) and Drought Code (DC) were developed to represent the moisture content of shallow and deep organic layers, respectively. These organic layers are important to surface fire intensity, crowning potential, and difficulty of control in temperate and boreal coniferous forests. Three fire-behavior indexes-the Initial Spread Index (ISI), Buildup Index (BUI, and Fire Weather Index (FWI)-were developed and scaled in relation to fire behavior observations of small-scale test fires in a standard, jack pine fuel type (Van Wagner 1987), but can be correlated with fire behavior in other fuel types. All of the FWI System values are calculated from four simple weather observations-temperature, relative humidity, wind speed, and 24-h precipitation at noon local standard time; however, the values represent conditions at around 1600 hours, which is the peak fire danger period (Van Wagner 1987).

As soon as the FWI System was released in 1970, work began on a system to predict quantitative characteristics of fire behaviour (McAlpine et al. 1990). Primary relationships were developed between FWI System components such as ISI and rate-of-spread, and BUI and fuel consumption. These relationships were based on measurements from experimental fires carried out over a range of burning conditions, and on observations of wildfires for major Canadian fuel types including coniferous, deciduous and mixed forests, grasslands, and logging slash. An interim edition of the FBP System was released in 1984 and the first complete edition of the FBP System was published eight years later (Forestry Canada Fire Danger Group 1992).

The FWI System was originally designed so that simple observations from manual weather stations could be used and so that the FWI System values could be calculated from look-up tables (Canadian Forest Service 1984). However, the development of electronic computing, automatic weather stations, and communications technology in the 1980s and 1990s has enabled weather data to be collected from remote locations and CFFDRS values to be calculated on a provincial and even national basis in almost real-time. Sophisticated fire-management systems such as the Spatial Fire Management System (SFMS) (Lee et al. 2002) have evolved to process and display these data in concert with fuel and topographic data. Internet-based map displays such as the Canadian Wildland Fire Information System (CWFIS)[2] have also been developed. Nonetheless, users in remote locations without access to sophisticated technology can still use basic weather instruments and look-up tables to determine the fire danger in their particular location.

After its release, the FBP System was implemented in several provincial fire-management systems and in commercial software. In 1995 a fire-behaviour field guide was released (Taylor et al. 1997) that is widely used by operational staff. Previously, tools for fire-behavior prediction were readily available only to specialists. Canadian Forest Service staff also helped develop two national fire-behavior training courses.

Fire-management agencies have had an important role in developing and testing equipment and information systems, and they have the lead role in implementing the CFFDRS through training and operational practices. Implementation of the CFFDRS has been aided by institutional mechanisms developed to foster cooperation between federal and provincial agencies in forest-fire management and research. These have included, most importantly, the Canadian Committee on Forest Fire Control (later the Canadian Committee on Forest Fire Management) which operated between 1952 and 1997, and its successor the Canadian Interagency Forest Fire Centre (CIFFC) which has operated from 1981 to the present. Representatives of the Canadian Forest Service, provincial and territorial fire-management agencies, universities and technical schools, and the forest industry have contributed to these groups. CIFFC, for example, delivers two national fire-behaviour courses.

# Use of the CFFDRS Outside of Canada

The CFFDRS has been implemented in whole or in part in a number of countries, and these experiences have provided useful lessons.

New Zealand and Fiji adopted the FWI System for use in exotic pine plantations in 1978 and 1989, respectively. The plantation fuel model of the FBP System has potential application in pine plantations in much of the southern hemisphere (Pearce and Alexander 1994). However, in subsequent years the FWI System was used for fire-danger rating in a wide range of vegetation types in New Zealand, including shrublands, for which it was not intended. In 1992 a research program began to develop new models for indigenous fuel types, mainly shrublands, and to improve technology transfer (Fogarty et al. 1998).

From 1981 to 1991, the Ontario Ministry of Natural Resources carried out a project to develop a model forest-fire management system, including a fire-danger rating system, in northeastern China (White and Rush 1990). Many of the issues that the Canadian staff encountered in China were cultural. Decisions related to fire suppression had been reactive and were often made at a very senior level. Also, the use of Canadian-made electronics and weather instruments posed maintenance problems.

The Alaska Fire Service adopted the CFFDRS in 1990, mainly because of the capability of the FBP System to predict crown behaviour, and because of the similarity between fuel types in Alaska and northern Canada. Since then, other northern American states such as Minnesota and Michigan have adopted the system. Despite similar environments, there is a need to make adjustments for particular conditions in Alaska, such as the effect of permafrost on wetting and drying processes in the DMC and DC, and to develop local interpretive guidelines tied to FWI System component values. However, the use of the CFFDRS in some states may have reduced the national fire-danger rating capability because the National Fire Danger Rating System is used in most of the United States.

The CFFDRS has been used, in part, in broad-scale, fire-management systems in Mexico, southeast Asia, and Florida largely because of its simplicity and its strong interpretive products (Lee et al. 2002). In Argentina the National Fire Management Plan began to implement the FWI System in three pilot areas in 2001. In a review of the project, Taylor (2001) recommended that institutional mechanisms should be created and/or strengthened to enhance communication and cooperation between national and provincial agencies before implementing the system nationally.

Several European countries, including Portugal and Spain, have also adopted parts of the CFFDRS. Viegas et al. (1999) found the FWI System components were well correlated with fire activity in southern Portugal, Spain, France, and Italy although the vegetation and dry mediterranean climate are much different than in Canada.

# Discussion and Conclusions

Experience with the CFFDRS within and without Canada over the past 80 years has revealed some important lessons for any country developing a national fire-danger rating system.

*1. Through a program of scientific research, develop relationships between fire weather/fuels/topography and fire occurrence/behaviour/impact that are appropriate to the particular fire environment.*

The CFFDRS was designed for Canadian fuel and weather conditions. In other countries where environmental conditions may be quite different, all components of the CFFDRS may be neither necessary nor appropriate. However, because fuel wetting and drying processes are the same all over the world, and because fires respond to variation in the same physical influences of fuel, weather, and topography, elements of existing fire-danger systems can often be used. The key is to identify the fuel types of most importance to the fire problem, the fuel elements within them that are important to ignition, spread, difficulty of control, and impact, and moisture models that represent these fuel elements.

Fire-danger rating systems must be based on factors that are fairly easy to measure accurately, and they must give consistent measures of fire danger from place to place and from time to time with approximately the same antecedent conditions. Fire-danger rating systems must also integrate a large number of factors in a simple, easy-to-use, and yet still soundly based system. There is a strong tendency to apply fire-danger rating systems beyond their useful range. The assumptions on which they are based, and the range of conditions under which the fire-danger rating system is valid, need to be carefully defined and frequently rechecked.

It takes many dedicated researchers working together for a long time to develop a national fire-danger rating system. In adapting an existing system, it is important for the adapting country to carrying out their own research and evaluation, to develop local interpretive products, and to participate in the international fire research community. This requires a long-term commitment to fire research and training by fire-management and science agencies. Timelines and expectations must be realistic.

Developing a national fire-danger rating system is also an evolutionary process-improvements occur gradually in the light of continued research and operational experience, changes in the sophistication of fire-management organizations, changing problems and opportunities, and technological advances.

*2. Based on research and operational experience, develop guidelines, decision aids, and training for fire managers that are appropriate to the needs and capabilities of operational agencies.*

A fire-danger rating system should not only be appropriate for the fire environment, but also for the human environment, institutional structures, culture, economic circumstances, and technological capability of the implementing fire-management agencies.

Fire-danger rating systems will be useful only where fire managers have authority to make pro-active resource-allocation decisions on the basis of fire danger. A fire-danger rating system is of little use where decisions are reactive or where resources are allocated at a political level. Of course no decision aid can replace an individual's knowledge of the local fire environment, knowledge of the local influences on fire behavior, or experience with fire suppression and prescribed burning, nor an individual's skill and common sense.

A national system should be flexible enough to be implemented at varying degrees of intensity and complexity in different regions, depending on the local importance of the fire problem and the capability of fire-management agencies. Various interpretive tools, from posters and look-up tables to web displays, can all play a useful role in providing fire-danger information, depending on the background, literacy/numeracy, and culture of fire-management staff.

*3. Using appropriate technology, develop the technical infrastructure to gather, process, and disseminate fire weather data and forecasts and fire-behavior predictions (weather instruments/stations, standards, communication) within operational agencies.*

Fire-danger indexes are usually calculated from one weather observation per day to represent a large administrative area which might include many different fuel types and variable topography. This is a very difficult thing to do well. Spatial fire-management systems have been developed to integrate fuel, weather, and topographic data. These systems need sophisticated data inputs, valid fire behavior relationships, and a well-developed technical infrastructure. While useful in the appropriate setting, this technology is not core to the operation of the CFFDRS or any fire-danger rating scheme¾it is an interpretive tool. Much useful information can be obtained using simple weather instruments and look-up tables. However, whatever type of technology used, it is important to collect continuous, quality weather data and fire records.

*4. Develop cooperative relationships between agencies in order to set common standards for information and training, and to facilitate resource sharing and allocation between agencies.*

To fully realize a national system, institutional mechanisms are needed to coordinate implementation across agencies and between regions, and to facilitate communication between researchers and operations staff. Formal agreements, and working groups of federal and provincial research and operations staff, have an important role in setting policy, direction, and standards, and in sharing information and resources.

Perhaps the most important lesson, though, is the need for a common vision and sense of common cause.

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