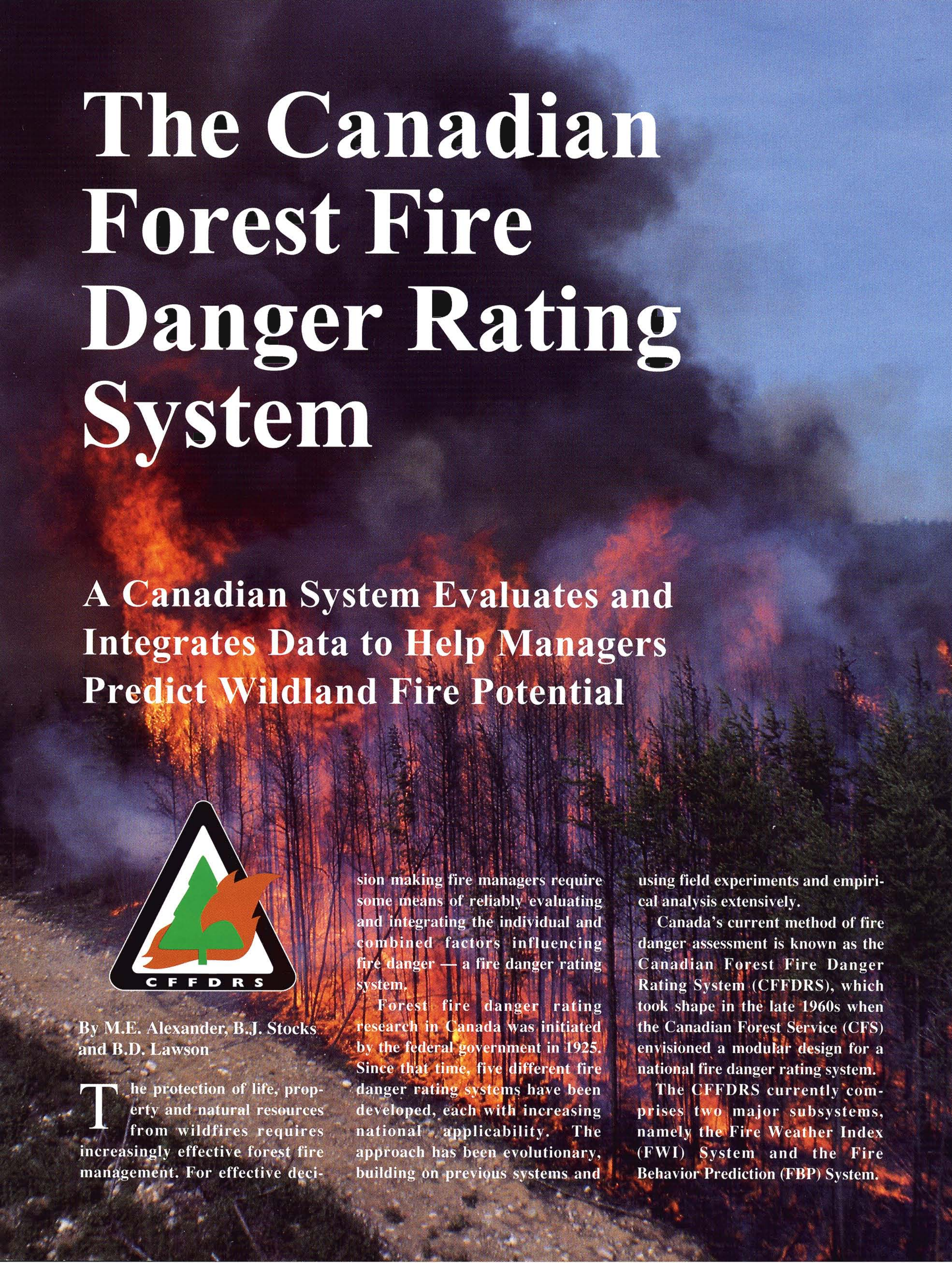


The Canadian Forest Fire Danger Rating System

A Canadian System Evaluates and Integrates Data to Help Managers Predict Wildland Fire Potential

CFFDRS

By M.E. Alexander, B.J. Stocks and B.D. Lawson

The protection of life, property and natural resources from wildfires requires increasingly effective forest fire management. For effective decision making fire managers require some means of reliably evaluating and integrating the individual and combined factors influencing fire danger — a fire danger rating system.

Forest fire danger rating research in Canada was initiated by the federal government in 1925. Since that time, five different fire danger rating systems have been developed, each with increasing national applicability. The approach has been evolutionary, building on previous systems and using field experiments and empirical analysis extensively.

Canada's current method of fire danger assessment is known as the Canadian Forest Fire Danger Rating System (CFFDRS), which took shape in the late 1960s when the Canadian Forest Service (CFS) envisioned a modular design for a national fire danger rating system.

The CFFDRS currently comprises two major subsystems, namely the Fire Weather Index (FWI) System and the Fire Behavior Prediction (FBP) System.

Weather input in fire danger rating

The first phase in the development of the national fire danger rating system, the FWI System, provides for the assessment of relative fire potential based solely on weather observations. This has now been in operational use for 25 years.

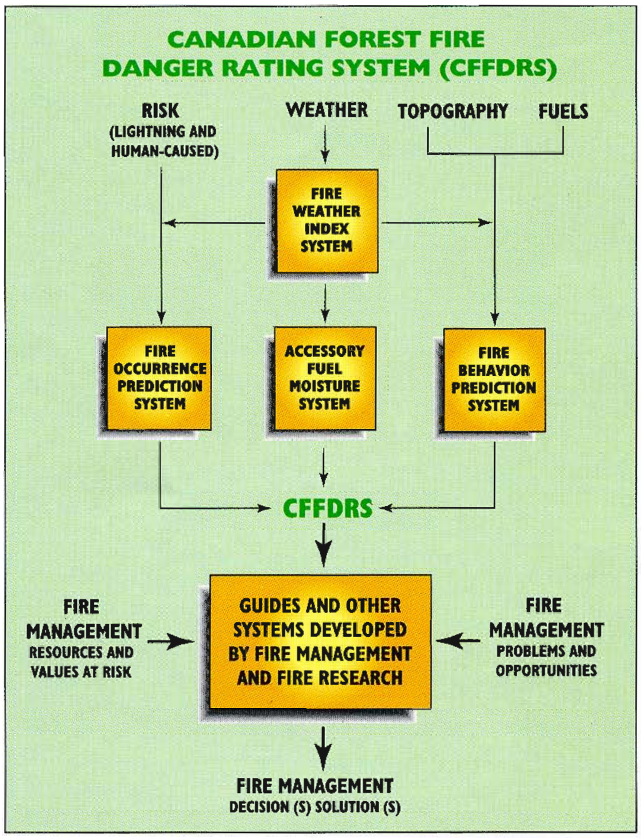
The FWI System's six components individually and collectively account for the effects of fuel moisture and wind on ignition potential and probable fire behavior in the form of relative numerical ratings.

Three fuel moisture codes reflect the fuel moisture content of fine surface litter (Fine Fuel Moisture Code — FFMC); loosely compacted duff of moderate depth (Duff Moisture Code — DMC); and deep compact organic matter (Drought Code — DC), respectively. The codes are in fact dynamic bookkeeping systems that account for each day's precipitation and drying.

The fuel moisture codes plus wind are linked in pairs to form two intermediate and one final index of fire behavior. The Initial Spread Index (ISI) combines the effects of wind and fine fuel moisture content (FFMC). It represents a numerical rating of fire spread rate, without the influence of variable fuel quantity. The Buildup Index (BUI — based on the DMC and DC) represents a measure of the total fuel available for combustion.

The Fire Weather Index (FWI) component itself combines the ISI and BUI to indicate the potential intensity of a fire on level terrain in a stand of mature pine. Because jack pine and lodgepole pine forests form a more or less continuous band across Canada, the concept of a standardized fuel type is reasonable.

FWI System components depend solely on daily measurements of: dry-bulb temperature, relative humidity, a 10-metre open wind speed and 24-hour accumulated precipitation, recorded at noon local standard time. Because calculation of the components depends solely on weather readings, they can just as easily be calculated from forecast weather to yield a fire danger forecast.



Simplified CFFDRS structure diagram illustrating the linkage to fire management actions.

The FWI itself is a good indicator of several aspects of fire activity and is best used as a measure of general fire danger for administrative purposes. However, it is impossible to communicate a complete picture of daily fire potential in a single number. The subsidiary components need to be examined as well for proper interpretation of past and current weather effects on fuel flammability.

Each component of the FWI System conveys direct information about certain aspects of wildland fire potential. For example, the FFMC is a useful indicator of human-caused ignition probability, as is the DMC for lightning-caused ignitions. The DC and the BUI are excellent indicators of smouldering combustion or fire persistence in deep compact organic layers and hence of mop-up difficulty.

Quantitative fire behavior prediction

The relative numerical values of the FWI System components have different meanings in different fuel types because the system was developed to rate fire potential in a generalized standard fuel type on a relative basis as opposed to an absolute sense. Fire behavior variation with fuel type is addressed, in quantitative terms, by the FBP System.

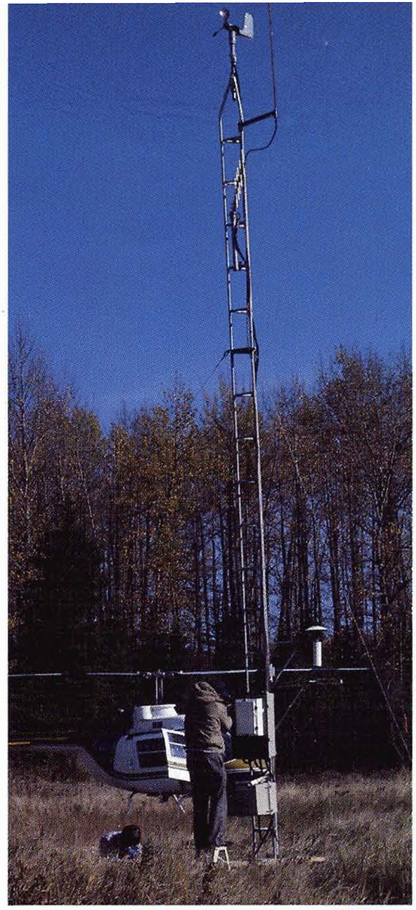
An incomplete interim edition of the FBP System was released for field testing and evaluation in 1984, although information from experimental burning projects and wildfire investigations was issued as it became available. Formal publication of the system was completed in 1992 and represents the latest achievement by the CFS in the practical application of fire behavior knowledge and research experience for the general improvement of forest fire management in Canada.

The technical derivation of the FBP System rests on a sound scientific basis developed from real-world observation and measurement of numerous experimental fires, coupled with many well-documented wildfires and operational prescribed fires, correlated against the weather-based fire danger indices of the FWI System or weather parameters for discrete fuel types. The FBP System is unique in that it incorporates the most extensive crown fire data set available anywhere.

The FBP System allows the user to predict the rate of spread (metres/minute), fuel consumption (kilograms/square metre) and intensity (kilowatts/metre) at the head, back or flanks of fires that are still accelerating following ignition or which have reached a steady-state condition with their environment. These characteristics are determined by the prevailing fire weather severity (based on wind velocity and certain FWI System components), fuel type, slope steepness, geographical location, elevation and calendar date. A general description of the type of fire is also given (for instance, surface fire, intermittent crowning or continuous crowning). A simple elliptical fire growth model is employed in estimating the size and shape of fires originating from a single ignition source as opposed to an established line of fire.

The FBP System's operation is based on a small number of readily available inputs. At present, 16 major Canadian benchmark fuel types are recognized in the system, a reflection of the empirical fire behavior data available in Canada.

The FBP System incorporates the best available information on forest fire behavior in Canada. Canadian fire managers are therefore in a good position to predict certain fire behavior characteristics with reasonable assurance for a wide range of burning conditions and excellent results have been reported with the system. The general response to the FBP System has been very positive as reported by nation-



Input from both manual and electronic fire weather network stations is used in the calculation of the FWI System components.

wide surveys conducted in 1992 and 1994 by the Canadian Committee on Forest Fire Management, the national body responsible for advising the federal government on wildland fire research needs.

Other subsystems

The development of a Canadian Forest Fire Occurrence Prediction (FOP) System is currently under consideration. This subsystem is envisioned as a national framework of both lightning- and human-caused fire components. Several approaches to predicting area-specific numbers of lightning-and human-caused fires (employing one or more of the FWI System components) are now being used on an operational or experimental basis in several Canadian provinces and territories. Research studies on the fundamentals of ignition and prediction of fire occurrence have been completed or are nearing completion.

The primary role of the CFFDRS's Accessory Fuel Moisture System (AFMS) is to supplement or support special applications and requirements of the three major subsystems. This subsystem includes fuel-specific moisture codes not represented by the standard codes in the FWI System. Other adjustments for land-form characteristics, latitude, season, time of day and other factors will also be included. Given the variety of fuel situations and fire danger rating requirements in Canada, development of the AFM System is a continuing process.

Applications

The CFFDRS remains one of the few nationally implemented fire danger rating systems in the world. This fact is testimony to the quality of fire research and the technology transfer efforts of the CFS. Daily calculations of system components are made from data recorded at more than one thousand weather stations across Canada. Some current uses of the danger rating system include:

- fire behavior training;
- prevention planning (e.g., informing the public of impend ing fire danger, regulating access and risk associated with public and industrial forest use);
- preparedness planning (level of readiness and pre-positioning of suppression resources);
- detection planning (e.g., lookout manning and aircraft routing);
- initial attack dispatching;
- suppression tactics and strategies on active wildfires;
- escaped fire situation analysis; and
- prescribed fire planning and execution.

The CFFDRS is also being used increasingly by other wildland fire researchers and environmental scientists for applications ranging from fire suppression effectiveness and fire growth modelling to analyses of fire regimes and potential impacts of climate change.

Although the CFFDRS was designed for Canadian use, several other countries have adopted system modules and/or its research philosophy as the basis for their own system of fire danger rating, most notably New Zealand, Fiji and the State of Alaska (U.S.). Evaluations of the System have also been undertaken recently in Croatia, China, Russia, Chile and the State of Michigan (U.S.).

Information gathered from both experimental fires and wildfires was used in developing the FBP System.

Decision support systems

Fire management information systems exploit advances in computerized information handling, automatic remote collection and transmission of fire weather data, and automatic lightning detection and recording networks. The value of such technologies depends, in part, on the CFFDRS to integrate the information and provide fire managers with near-real-time fire occurrence and behaviour prediction capability.

Conceptually, the CFFDRS deals with the prediction of fire potential from point-source weather measurement (i.e., a single fire weather network station). The system deals primarily with day-to-day variations in the weather, but will accommodate variations through the day as well. The system does not account for spatial variation in weather elements between points of measurement; such interpolation must be handled by models and guidelines external to the CFFDRS.

In operational practice, fire weather and fire danger forecasting procedures have been devised to integrate point-source measurement of the system's components over time and space. Spatial variation in fuels and terrain is a fire management information problem not easily handled by a fire danger rating system unless it can be linked to a computer-based geographic information system which stores, updates and displays land base information in ways directly usable by the fire manager. Geographic information systems for fire management are in use in nearly all regions of Canada. For example, the Intelligent Fire Management Information System (IFMIS), developed by the CFS, is employed by provincial fire management agencies in Alberta and Saskatchewan.

Outlook

Fire management agencies will expand their application and training programs based upon advances in the CFFDRS. The responsibility for its continued development rests with the CFS, which maintains liaison with a variety of agencies to ensure research, development and application of the system continues in a timely and relevant manner. Further additions and improvements will require continued research, testing and feedback from the field.

Effective use of fire occurrence and fire behaviour prediction systems requires improvements in fire weather forecasting, data collection and information handling capability. Com-puterized decision aids which include advances in artificial intelligence and expert systems will become prominent in fire management with outputs from the CFFDRS forming an integral part of any new knowledge-based system. This much is certain – Canada's national forest fire danger rating system will evolve in future years to reflect the needs of fire management agencies. The result will be demonstrable improvement in the effectiveness of forest fire management in Canada.

Further information on the CFFDRS is available on the Internet at http://www.nofc.forestry.ca/fire/cwfis.html

Marty Alexander, Brian Stocks and Bruce Lawson are members of the Canadian Forest Service's fire management science and technology network, located in Edmonton, Alta., Sault Ste. Marie, Ont. and Victoria, BC respectively. The authors acknowledge the contributions made by other CFS fire research staff in the development of the CFFDRS.