CANADIAN FOREST FIRE INFORMATION SYSTEMS*

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ABSTRACT

This paper provides an overview of four national forest fire information systems currently used in Canada. The Canadian Forest Fire Danger Rating System (CFFDRS) is a non-spatial system, which provides the science framework for fire danger rating in Canada. The Spatial Fire Management System (sFMS) is a geographic information system based fire management information system that implements two core subsystems of the CFFDRS, along with other models and systems. The sFMS is the spatial engine that has been used to implement both of Canada's national forest fire information systems, the Canadian Wildland Fire Information System (CWFIS) and the Fire Monitoring, Mapping and Modeling System (Fire M3). The CWFIS is Canada's national fire information system; it presents daily information on fire weather, fire behavior potential and selected upper atmospheric conditions. Fire M3 integrates the use of satellite technology for monitoring and mapping large fire occurrence in Canada. Fire M3 also incorporates information from CWFIS to model the impacts of large forest fires based on fire weather and fire behavior conditions.

1.0 INTRODUCTION

The Canadian Forest Service has a history of over 75 years of forest fire science research. Two major contributions from this work have been the development of a national system for forest fire danger rating and accompanying forest fire information systems. This paper provides an overview of four fire information systems currently in use in Canada.

Canada has 244 million ha of productive forest that produced $27 billion in forest product exports in 1994 (amounting to more that agriculture, mining and fisheries combined) (Canadian Council of Forest Ministers, 1994). Ninety percent of Canada's forests are owned by the public, represented mainly by the 10 provincial and three territorial governments. Forest fire management is the responsibility of each province and territory and huge areas fall under the jurisdiction of a single fire management agency.

Wildfires are a significant agent of change in Canadian forest ecosystems. On average, 10,000 fires burn 2.5 million ha of wildland areas in Canada each year. The variation in number of fires and area burned varies widely from year to year (Fig. 1). Not all fires are suppressed. There are two distinct causes of forest fire in Canada: people and lightning. On average, lightning causes one-third of the fires in Canada, yet results in 90% of the area burned. Typically these lightning caused fires occur in remote areas of Canada where detection is more difficult.

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The systems described in this paper have been developed to provide a systematic approach to the assessment of forest fire danger rating in Canada. These systems have been successfully adopted by Canadian fire management agencies to help mitigate the impacts of fire both regionally and nationally.

2.0 CANADIAN FOREST FIRE DANGER RATING SYSTEM

Fire danger rating constitutes the process of systematically evaluating and integrating the individual and combined factors that determine the ease of a fire starting, spreading, the difficulty of control and the resultant impacts based on an assessment of ignition risk, the fire environment (i.e., fuels, weather, topography) and values at risk. Fire danger rating systems produce qualitative and/or numerical indexes of fire potential that are used as a guide in a wide variety of fire management applications involving both wildfires and prescribed fires.

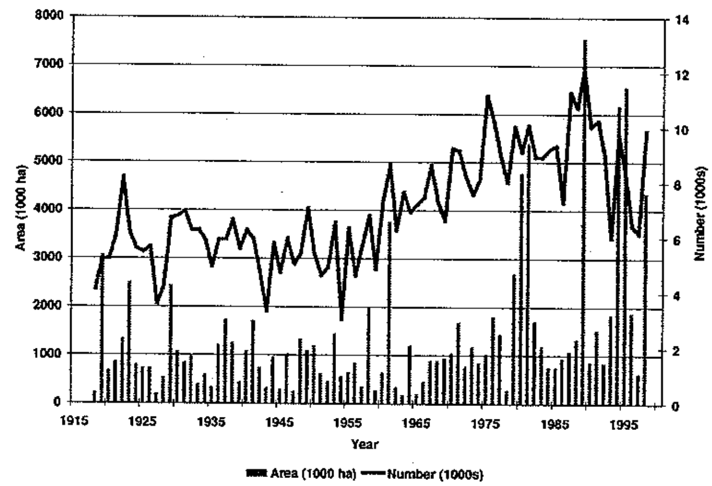
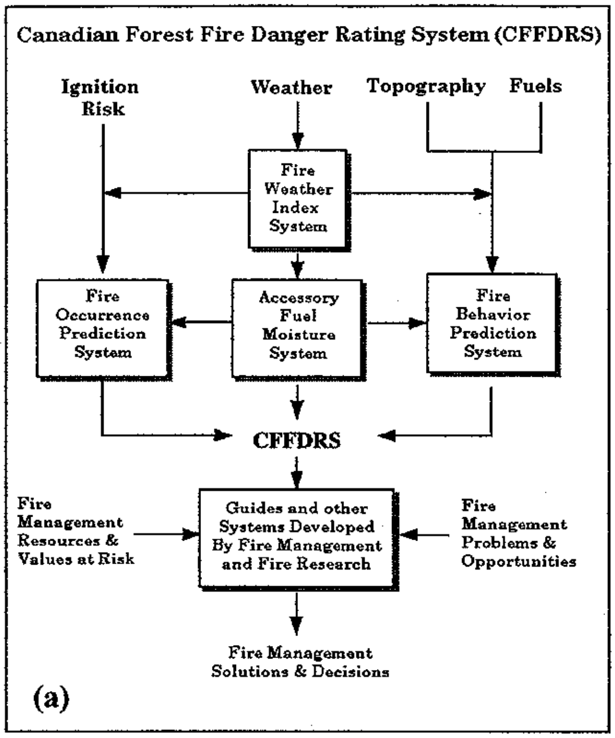


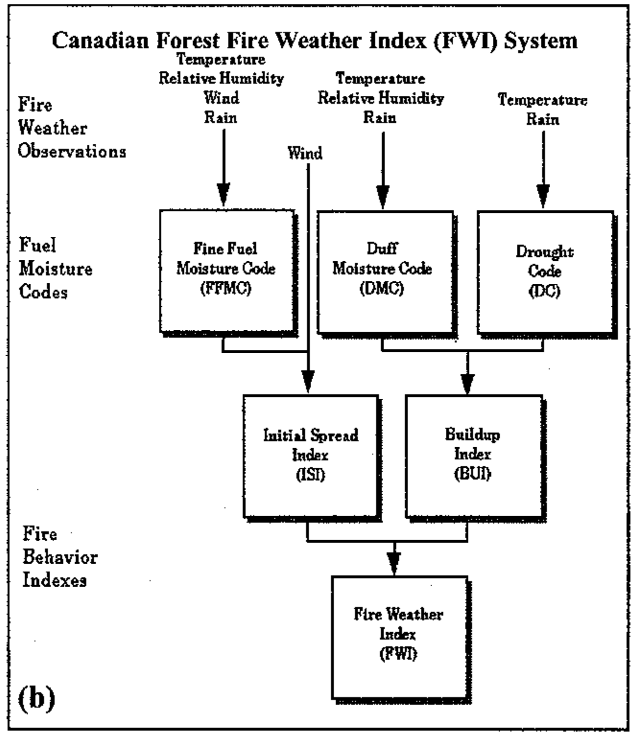
Figure 1. Forest fire occurrence in Canada.

The Canadian Forest Fire Danger Rating System (CFFDRS), as developed by the Canadian Forest Service, is the national system of fire danger rating used in Canada (Stocks et al., 1989; Alexander et al., 1996). The CFFDRS actually comprises two primary subsystems or modules (Fig. 2a) -- the Canadian Forest Fire Weather Index (FWI) System (Canadian Forestry Service, 1984; Van Wagner, 1987) and the Canadian Forest Fire Behavior Prediction (FBP) System (Forestry Canada Fire Danger Group, 1992; Taylor et al., 1997). The other two elements of the CFFDRS are the Accessory Fuel Moisture System and the Canadian Forest Fire Occurrence Prediction (FOP) System have not been entirely developed for national use. The latter subsystem is intended to predict the number of lightning and human-caused fires while the purpose of the latter is to support applications of the other three subsystems of the CFFDRS.

The output of the FWI System consists of six relative numerical ratings for various aspects of fire danger for a reference fuel type (i.e., mature pine stand) on level terrain based on a continuous record of four weather observations taken daily at 1300 hours daylight time (Figs. 2b and 2c). The FBP System on the other hand provides for actual quantitative estimates of certain physical fire behavior characteristics (e.g., head fire rate of spread in m/min or km/h and head fire intensity in kW/m) for selected fuel types and topographic situations based on certain components of the FWI System (Fig. 2d).

Conceptually, the CFFDRS deals with the prediction of fire occurrence and behavior from point-source weather measurements (i.e., a single fire weather network station). The CFFDRS deals primarily with variation in weather from day to day, but it can also account for diurnal variation in fire danger as well. The system does not account for spatial variation in weather elements between points of measurement. Models and other systems external to the CFFDRS must handle such interpolation. Spatial variation in fuels and terrain is a fire management information problem not easily handled by the CFFDRS or any fire danger rating system for that matter unless linked by computer technology to a geographic information system (GIS), which stores, updates, and displays such land base information in ways directly usable to wildland fire managers.





Canadian Forest Fire Weather Index (FWI) System Codes and Indices

FFMC – A numerical rating of the moisture content of litter and other cured fine fuels. This code is an indicator of the relative ease of ignition and flammability of fine fuel.

DMC – A numerical rating of the average moisture content of loosely compacted organic layers of moderate depth. This code gives an indication of fuel consumption in moderate duff layers and medium-size woody material.

DC – A numerical rating of average moisture content of deep, compact, organic layers. This code is a useful indicator of seasonal drought effects on forest fuels, and amount of smouldering in deep duff layers and large logs.

ISI – A numerical rating of the expected rate of fire spread. It combines the effects of wind and **FFMC** on rate of spread without the influence of variable quantities of fuel.

BUI – A numerical rating of the total amount of fuel available for combustion that combines **DMC** and **DC**.

FWI – A numerical rating of fire intensity that combines **ISI** and **BUI**. It is suitable as a general index of fire danger.

(c)

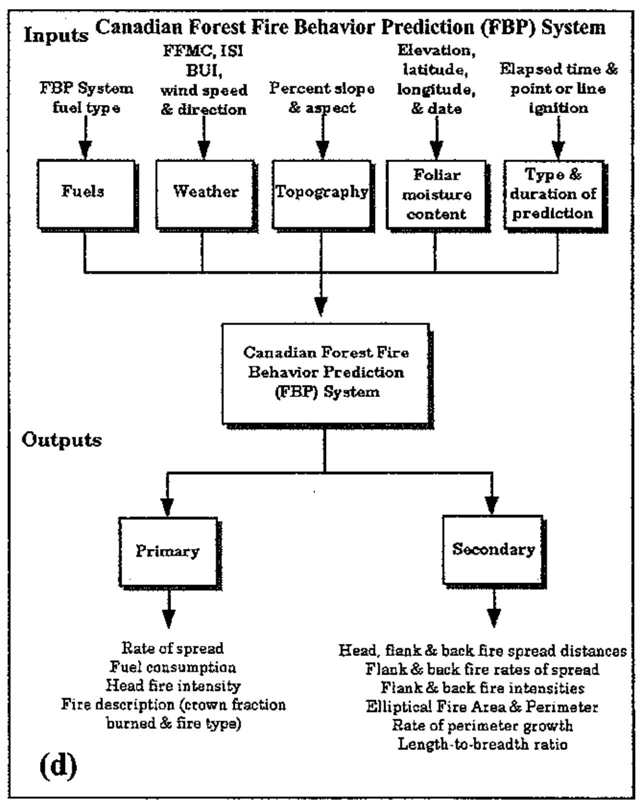


Figure 2. Simplified structure diagram for the Canadian Forest Fire Danger Rating System illustrating (a) the linkages to fire management actions; (b) structure diagram for the Canadian Forest Fire Weather (FWI) System and (c) component definitions; and (d) structure diagram for the Canadian Forest Fire Behavior Prediction System.

3.0 SPATIAL FIRE MANAGEMENT SYSTEM

Computer based fire management systems have been used in Canada since the early 1970s. All regional fire management agencies in Canada employ some form of computer-based fire information systems in their operational fire management programs. The minicomputer based Fire Management System (Kourtz, 1984) and personal computer based Intelligent Fire Management Information System (Lee and Anderson, 1989), both designed and developed by the Canadian Forest Service, provide the bases for most of these systems.

In 1992, the Canadian Forest Service began investigating the use of geographic information systems as an enabling technology for constructing fire management information systems. These efforts culminated in the development of the Spatial Fire Management System (sFMS). The sFMS is a spatially referenced forest fire management information system that builds on previous systems, while incorporating the latest enabling technologies. The comprehensive list of information management functions possible with sFMS include data capture and update, data management, data modeling, user interface and information presentation.

3.1 sFMS ARCHITECTURE AND SYSTEM INTEGRATION

The sFMS can operate either as a stand-alone system or be integrated into existing information systems. Enabling technologies include a geographic information system, a mathematical optimizer and one or more relational data base management systems (Fig. 3). The sFMS data model is flexible and consists of a variety of spatial, temporal, and non-spatial data.

The fire management business functions are supported by an integrated set of system modules. An extensive list of modules can be selected as required, depending on the task. Extensive parameterization has also been incorporated into the overall design of sFMS to ease implementation.

3.2 sFMS BUSINESS FUNCTIONS

Fire management systems must be functional over a range of interrelated business functions from policy formulation through fire suppression actions. The sFMS has been designed to support a range of executive, strategic, management, and operational business functions.

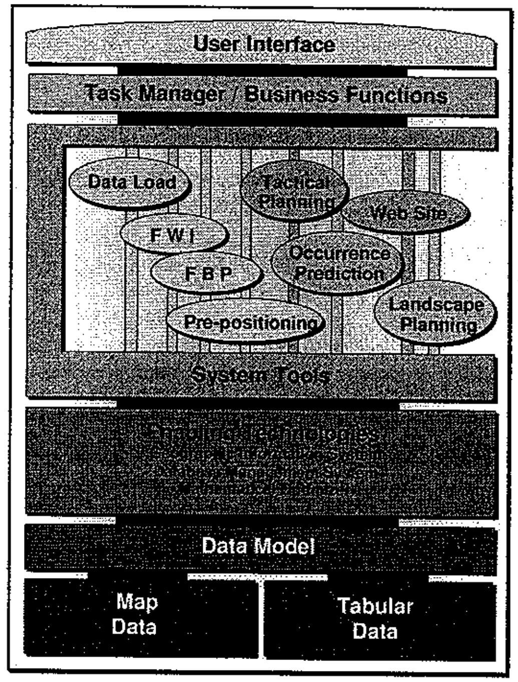


Figure 3. Spatial Fire Management System architecture.

At the executive level, sFMS can provide information to support the setting or review of policy. The range of policy issues may include the allocation of national or regional priorities, establishing suppression goals, altering fire response guidelines to consider the ecological role of fire, or establishing budgets.

At the strategic level, sFMS can assist in making decisions such as the regional distribution of budgets, personnel and equipment, as well as the establishment and maintenance of initial attack bases, weather monitoring and fire detection systems.

At the management level, sFMS provides the structure and data processing to operate and maintain fire weather monitoring, fire behavior potential, and fire occurrence prediction systems.

Operationally, sFMS provides decision support for initial attack response, logistical and tactical planning, and the operations of sustained action when and where necessary.

The sFMS can be used at any spatial scale from global to local. It has been adopted for use by many regional fire management agencies in Canada and internationally. It is also the engine used behind Canada's national forest fire information systems.

4.0 CANADA'S NATIONAL FOREST FIRE INFORMATION SYSTEMS

Natural Resources Canada currently operates two national forest fire information systems: the Canadian Wildland Fire Information System (CWFIS) and the Fire Monitoring, Mapping and Modeling System (Fire M3). Both of these systems incorporate components of the CFFDRS and use the sFMS spatial engine for data capture, management, modeling, analysis and presentation.

4.1 CANADIAN WILDLAND FIRE INFORMATION SYSTEM

The CWFIS is Canada's national level fire information system. The CWFIS has been operated by the Canadian Forest Service since 1994 and was developed to provide a national overview of daily wildland fire conditions and for national reporting (Lee, 1995). The system is used by regional fire management agencies, fire interagency coordination centers, the public, researchers, and the media. The system employs sFMS as the underlying technology and operates in a fully automatic mode from the Northern Forestry Centre, located in Edmonton, Alberta, Canada.

The CWFIS collects hourly weather data from more that 650 weather stations located across Canada. These data are processed using sFMS to produce daily FWI and FBP systems maps (Fig. 4). Weather data is interpolated between weather stations to produce surfaces for each FWI system input (temperature, relative humidity, wind speed, wind direction and 24 hour precipitation amount). Procedures include adjustments to compensate for changes in elevation. Cartographic modeling is then performed on these weather data surfaces to compute both FWI and FBP system values at a 1-km cell resolution.

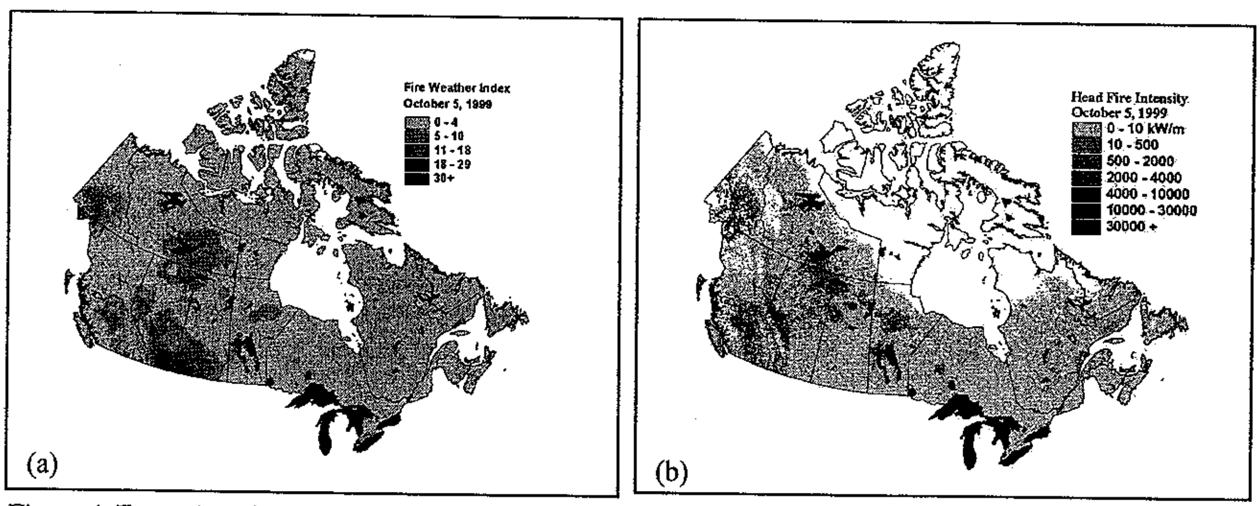


Figure 4. Examples of (a) daily fire weather index, and (b) head fire intensity maps for Canada, for October 5, 1999 (produced by the Canadian Wildland Fire Information System).

4.2 FIRE MONITORING, MAPPING AND MODELING SYSTEM

Fire M3 is a joint initiative of two sectors of Natural Resources Canada, the Canada Centre for Remote Sensing and the Canadian Forest Service. The primary objectives of Fire M3 are to use satellite technology to automatically monitor fire activity on a daily basis, to produce end-of-season fire maps, to model the impacts of fire, and to disseminate this information daily via the Internet.

About 3% of the wildfires in Canada grow larger than 200 ha in size; however they account for almost 97% of the annual area burned (Stocks et al., 1996). In an average year, 300 fires attain a size greater than 200 ha. This provides an excellent opportunity to monitor active large fires using low-resolution sensors.

The monitoring component of Fire M3 uses 1-km resolution National Oceanographic and Atmospheric Administration (NOAA) Advanced Very High-Resolution Radiometer (AVHRR) satellite data to detect active burning forest fires. Using an algorithm developed by the Canada Centre for Remote Sensing (CCRS) (Li et al., 1997), AVHRR images are processed daily from May through October to monitor large fire activity in Canada. The images effectively identify hot spots and smoke plumes from large fires (Fig. 5a).

The mapping component of Fire M3 serves to get better estimates of area burned using both low and high-resolution sensors. Initial estimates of area burned are possible using AVHRR and SPOT VGT (Fig. 5b). Medium- to high-resolution sensors such as Landsat Thematic Mapper and SPOT-HRV are being used in the Fire M3 project to calibrate and verify area estimates from AVHRR and SPOT VGT. These sensors are also being used to demonstrate the advantages of using medium to high-resolution sensors over traditional fire mapping approaches.

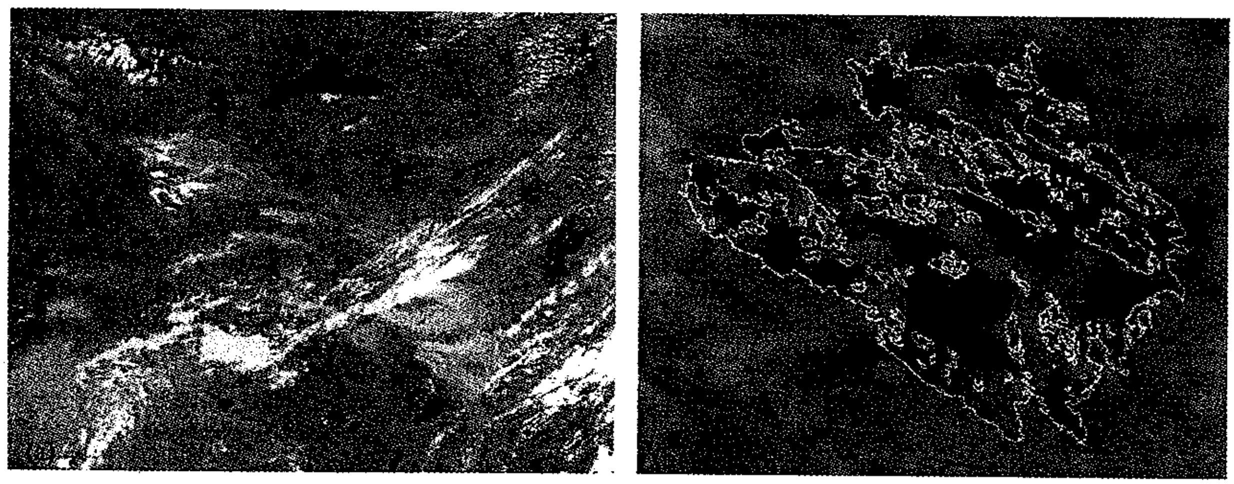


Figure 5. Sample monitoring and mapping products from Fire M3. Figure 5a is a NOAA-AVHRR derived monitoring product showing hotspots, smoke and cloud. Figure 5b is a SPOT VGT derived mapping product for the 1998 Virginia Hills fire in Alberta, Canada. (Images courtesy of the Canada Centre for Remote Sensing.)

Fire M3 also integrates data from CWFIS to provide estimates of fire behavior parameters for individual fires. Map production includes images (Fig. 6) for public web site access along with an Internet map server that allows interacting panning, zooming and querying of satellite images and hotspot maps.

4.3 CANADA'S FIRE MANAGEMENT SYSTEMS' WORLD WIDE WEB SITE

Both the CWFIS and Fire M3 system are available publicly via the World Wide Web. Further information on both of these two systems, as well as the CFFDRS and sFMS can be found on the Internet at: http://fms.nofc.cfs.nrcan.gc.ca

5.0 BENEFITS OF FOREST FIRE INFORMATION SYSTEMS

Over the past 30 years, Canadian forest fire management agencies have demonstrated that information technology has an essential place in tracking fire weather, predicting fire behavior and monitoring fire occurrence. During this period, decision support systems have been successfully integrated into daily fire operations of all Canadian fire management agencies. These systems have enhanced the utility of the CFFDRS by exploiting the ability to turn data into information in near real time. Better information has resulted in more effective and efficient decision making.

While the CFFDRS conceptually deals with the prediction of fire potential from a point source (i.e., a single fire weather station), it is the integration of a fire danger rating system with information management/ information technology that accounts for spatial variation across the landscape. Systems such as sFMS provide a mechanism for the fire manager to deal with spatial variation in weather, fuels, and terrain.

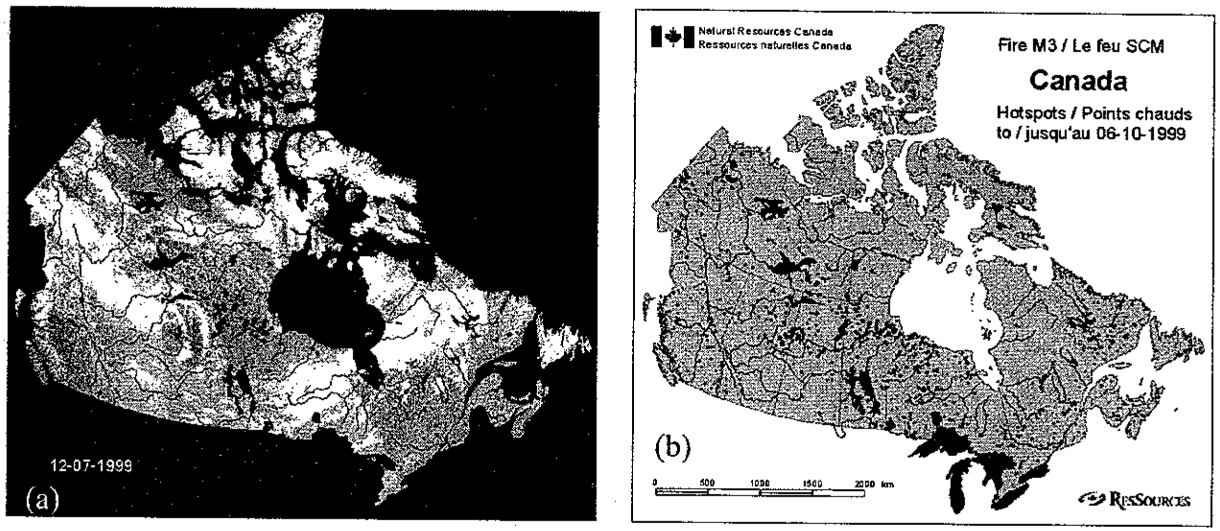


Figure 6. (a) Fire M3 AVHRR satellite image for July 7, 1999 (image courtesy of the Canada Centre for Remote Sensing) and (b) a map of all hotspots detected by Fire M3 as of October 7, 1999.

At the national level, systems like CWFIS and Fire M3 have a much broader role. These systems are not designed for operational fire management, but for national monitoring and reporting. The Canadian Interagency Forest Fire Centre use CWFIS and Fire M3 to monitor national fire danger on a daily basis. This information contributes to decision making with respect to interagency transfers of fire suppression resources. A developing role for CWFIS and Fire M3 is in the area of national and international reporting. At the national level, both of these systems contribute data to the Canada Forest Inventory, Canada Forest Statistics Data Base and the State of Canada's Forests annual report. These data can also been further abstracted to meet international reporting requirements for criteria and indicators of sustainable forestry and for global change reporting.

A final benefit of Canada's forest fire information systems is in the area of knowledge management. The CWFIS and Fire M3 constitute the fire data warehouse component of Canada's National Forest Information System. The fire data warehouse creates a permanent data archive for the national fire weather and large fire occurrence databases. Through formal data exchange protocols, the fire data warehouse provides expanded opportunities for collaborative research and management between a wide range of knowledge domains including forest policy, forest inventory, forest management, forest fire science, forest health, forest inventory, global change, forest economics and remote sensing.

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