

The Development and Implementation of Forest Fire Management Decision Support Systems in Ontario, Canada¹

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Abstract

The Ontario Ministry of Natural Resources in Canada has supported forest fire management systems research for more than 30 years. It has worked closely with researchers to develop, field test, and implement many decision support systems that have enhanced forest fire management in Ontario. A comprehensive overview is presented of the work that has been carried out in Ontario and some of the lessons that have been learned.

The Aviation Flood and Fire Management Branch (AFFMB) of the Ontario Ministry of Natural Resources (OMNR) is responsible for forest fire management on publicly owned crown land in the Province of Ontario, Canada. Since the late 1960's, the OMNR and its predecessor, the Ontario Department of Lands and Forests, have worked closely with government and university researchers to develop, test, and implement decision support systems to enhance forest fire management in Ontario. Glenn Doan, Project Officer with the Fire Control Unit of the Ontario Department of Lands and Forests, convinced his colleagues they should explore the possibility of using Operations Research (OR) in Ontario in the 1960's. Martell (1982) and Martell and others (1997) review forest fire management operational research studies including many of those carried out in Ontario. Kourtz (1984) discusses the relationship between centralized control and the use of information technology, and Kourtz (1994) summarizes much of the work he did in Ontario and other jurisdictions.

Forest Fire Management in Ontario

Ontario's Fire Management Program provides fire protection to more than 85 million hectares of crown land. The forest fire protection requirements of resource management clients, other stakeholders, and the public are identified through fire management strategies that specify land management objectives, values at risk, protection requirements, and strategic investment requirements. Those plans include a zoning system and fire management objectives that specify area burned targets and initial attack strategies by area. Wilderness parks and some areas in the far north, for example, receive a different level of protection than the parts of the province that are committed to industrial forestry. The government of Ontario currently spends an annual average of \$85 million (in Canadian dollars) directly on fire management (10-year average costs, adjusted for inflation, 1987-1996).

Ontario's fire program responds to an average of 1,200 to 2,000 fires per year. Fewer than 5 percent of the fires in the intensively protected area escape initial attack to cause significant damage. An average of two to four escaped fires become large fires and require a significant suppression effort each year. Fire management strategies stipulate an annual burned-area target of 80,000 ha in the commercial forest zone, and the average area burned there has remained below this target over the past decade. An average annual burned area of about 200,000

¹An abbreviated version of this paper was presented at the Symposium on Fire Economics, Planning, and Policy: Bottom Lines, April 5-9, 1999, San Diego, California.

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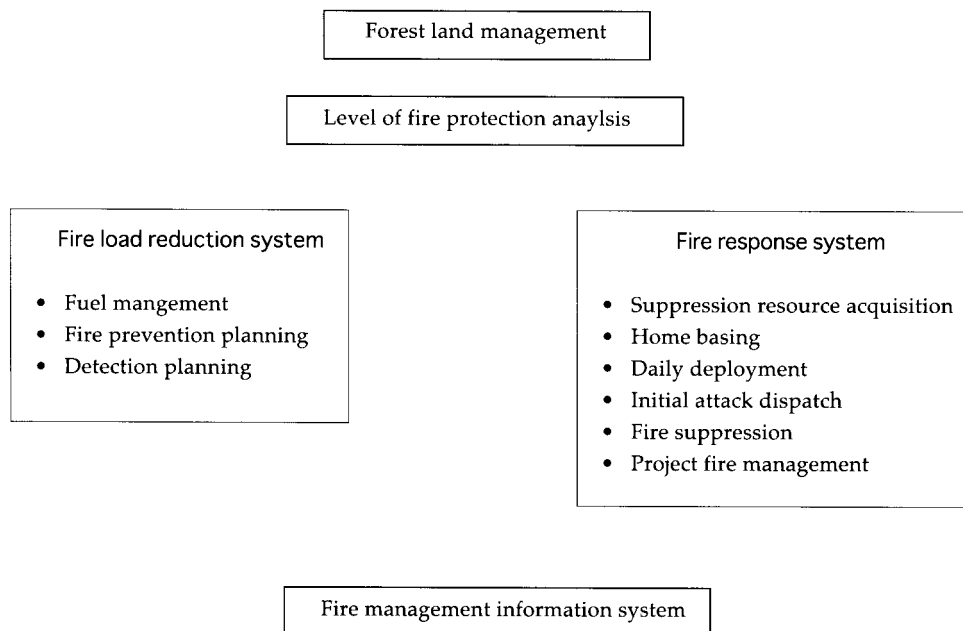
hectares is the target in the extensively protected area north of the industrial forest. Sixty percent of the fires are caused by people, but lightning causes more than half the fires in the province's West Fire Region. As in other Canadian provinces, lightning caused fires burn a disproportionate amount of the total area burned because they tend to occur in more remote areas and are therefore more difficult and more costly to access and attack.

The OMNR operates a large integrated fire prevention, preparedness, detection, response, suppression, and support system. A permanent staff of 220 is augmented seasonally by 640 firefighters and other seasonal staff. The OMNR operates a fire fighting airfleet of nine large amphibious airtankers (CL-215's are presently being converted to CL-415's), five smaller Twin Otter airtankers, and five light helicopters. Fourteen helicopters, fifteen detection aircraft and seven bird-dog aircraft are contracted on a seasonal basis, and additional firefighters and support resources are contracted from the private sector on a short term basis during periods of high fire activity. The fire program is able to draw on additional OMNR staff and resources in the event of a severe fire situation, and it participates in Canada's national resource sharing agreements through the Canadian Interagency Forest Fire Centre.

A Fire Management Systems Framework

Fire management decision support systems in Ontario can be illustrated by the framework presented in *figure 1*. Forest management planning systems use fire management outcomes. Some fire management alternatives are evaluated by using a strategic level of protection planning system that simulates the behavior of the fire management system given specified fire suppression resources and strategies and tactics that govern their use. The fire management system can be divided into two major groups of subsystems: the fire load reduction systems and the fire response systems. The fire load reduction systems can reduce the number and intensity of fires that occur and response systems reduce the cost of containing and limiting the damage that results from fires that do occur. The OMNR has developed a comprehensive Fire Management Information System (FMIS) that provides the crucial infrastructure required to deliver basic weather, fire, and planning information for decision support systems and fire managers. Ontario's FMIS contains components that support both fire load reduction and fire response planning and operations.

Figure 1
A fire management systems framework.



Fire Load Reduction Systems

Fuel Management

With the exception of a small number of projects in blow-down areas and the spring burning of grass along railway corridors and other areas, there is very little fuel management activity in Ontario. However, Ontario does not have the type of fuel build-up problem that is important in the drier climates of the southern United States, parts of the Mediterranean, and Australia. The OMNR did undertake a cooperative research project with Laurentian University to study the feasibility of "green-stripping"-using sowing or planting high-moisture content vegetation types along rights-of-way and other high-hazard or high-value areas to reduce fire ignition potential and spread (Hogenbirk and Sarrazin-Delay 1995).

The OMNR's use of prescribed fire, primarily for silvicultural purposes and to a much lesser extent for wildlife habitat management, waxes and wanes depending upon budget levels, cost recovery policies, and land management objectives. Martell and Fullerton (1988) completed a decision analysis of site preparation strategies, and Martell (1978) developed a prescribed burn fire weather prescription analysis software package (PBWX) that can be used to estimate the likelihood that a specified fire weather prescription might occur on the basis of analyses of historical fire weather data. Kourtz explored the use of the Kourtz and others' (1977) contagion fire spread model for prescribed burn planning purposes. He recently developed an understory prescribed burn expert system for white pine management (UPBX), a large rule-based/neural network expert system that guides managers in their decisions as to the appropriateness of a specific site, and the weather and fuel moisture conditions under which a burn should be carried out. UPBX is currently being field tested by the OMNR (OMNR 1998).

Prevention

Prevention is an important but neglected aspect of fire management, and like most wildland fire management agencies, the OMNR has never been able to quantify the impact of its prevention efforts on fire occurrence. Although Ontario's prevention program managers have frequently expressed serious interest in supporting the development of prevention decision support systems (DSS's), there have been few efforts in this area. Martell attempted to use daily fire occurrence prediction models to relate a reduction in people-caused fire occurrence in a portion of the province to prevention program enhancements. One of Kourtz's fire occurrence prediction models indicated the predicted number of people-caused fires should be reduced by 50 percent when a forest closure is in effect. The OMNR currently uses a system of Woods Modifications Guidelines to advise companies operating in forested areas how operations should be modified on a daily basis in response to the current level of fire hazard (OMNR 1989).

Detection

The OMNR's extensive network of towers has been replaced by aircraft and it also depends upon the public to report fires near populated areas. The shift from very effective but expensive fixed towers to less expensive aircraft that provide intermittent coverage is consistent with Kourtz and O'Regan's (1968) analysis of the cost effectiveness of forest fire detection systems. Given the lack of towers and the use of charter aircraft for detection patrols, there have been no concerted efforts to develop strategic detection planning decision support systems in Ontario, but significant effort has been devoted to tactical detection patrol route planning. Basmadjian (1972) used a decision tree model to decide when to dispatch a single aircraft to look for fires in a single cell. Martell (1975) developed

an adaptive stochastic dynamic detection timing model to determine when to dispatch a detection patrol along a designated route through several cells.

Kourtz (1972) used dynamic programming to specify how to allocate detection patrol effort to sectors and incorporated his model in a simulation model to assess the cost effectiveness of high altitude airborne infrared detection systems in Ontario. He later (Kourtz 1973a) combined a fire occurrence prediction model with a refined version of his dynamic programming model to route patrol aircraft through a subset of a large number of cells to maximize the expected number of fires detected by a patrol of a specified duration dispatched at a designated time. Kourtz (1973b) then modified the infrared patrol system to deal with visual detection patrols. He field tested his model in Ontario during the 1972 fire season and found that it would have routed aircraft closer to undetected fires than the routes the detection planners had used that summer. In the 1980's Kourtz continued to work with a number of agencies to develop and test new detection patrol routing models that stipulated what cells should be visited by patrol aircraft based on the potential loss that might result from fires that might be burning undetected. One approach was to develop a patrol-routing algorithm based on a multiple-salesman traveling salesman algorithm (Kourtz 1991). A modified Lin-Kernighan algorithm and a simulated annealing algorithm were used to solve these large multiple-aircraft routing problems on a daily basis. Martell developed a detection demand index that can be used to specify the relative importance of visiting different cells.

Fire Response Systems

Fire suppression systems have a hierarchical structure, and when decisions support systems are developed for problems in one level of that hierarchy, they must be linked with the levels above and below. For example, when one decides how to home-base airtankers, one must consider the fleet composition level above, which determines how many airtankers are to be home-based, and the daily deployment level below which determines how the available airtankers will be deployed each day.

Fire Suppression Resource Acquisition

Although firefighter hiring can be varied from year to year with little long-term cost implications, the impacts of capital expenditures on aircraft and other infrastructure can last for years or even decades. Martell (1971) developed a simulation model of land-based airtanker operations at Dryden in northwestern Ontario. Cass (1977) developed a mathematical programming model for the management of power pumping units that are transferred from base to base to satisfy demand that varies over the course of a fire season. Doan (1974) developed a comprehensive hierarchical strategic initial attack planning model that embedded a model of the daily allocation of firefighters: transport aircraft and airtankers to initial attack fires in a strategic model designed to evaluate alternative strategies for hiring suppression resources for a season to minimize average annual cost plus loss. Martell and others (1984) developed a comprehensive model of the OMNR's initial attack system in response to a need to up-grade Ontario's aging aircraft fleet in the 1980's. That model, which predicts the consequences of using specified sets of airtankers, transport helicopters, and firefighters to fight historical fires, was used to evaluate initial attack system alternatives and support the OMNR's request to purchase CL-215 airtankers. Boychuk and Martell (1988) developed a strategic planning Markov model of seasonal firefighter needs in Ontario. Tithecott and Lemon (1993) formulated a mathematical programming model that they used to minimize the cost of seasonal helicopters assigned to initial attack bases in Ontario.

Home-Basing

Most forest fire management agencies are now highly centralized organizations that transfer their mobile fire suppression resources from low hazard areas to areas where destructive fires are expected to occur each day. It is essential that those resources be home-based at the start of the fire season to minimize the cost of implementing the daily transfers that take place as the fire season progresses. MacLellan and Martell (1996) developed a mathematical programming model that was used to help evaluate airtanker home-basing strategies in Ontario.

Daily Deployment

Moving down the planning hierarchy, daily suppression resource deployment poses significant challenges for fire managers who must cope with considerable uncertainty concerning fire occurrence and behavior processes that vary over both time and space as they attempt to minimize initial attack response times. Martell (1972) used a decision tree to model decisions concerning the number of initial attack crews required on standby at an initial attack base each day. Booth (1983) developed a stochastic dynamic programming model for determining optimal initial attack crew management strategies over a 3-day planning horizon. Vesprini and Brady (1974) developed a linear programming model that can be used to determine how to deploy fire suppression resources to minimize the cost of satisfying the expected daily demand for fire line in a region. Bookbinder and Martell (1979) modelled the use of helicopters to transport initial attack crews to fires as a queueing system and embedded their model in a dynamic programming model that could be used to evaluate daily helicopter deployment strategies. Two members of the OMNR staff developed a spreadsheet forecasting model that is used to help evaluate manpower planning strategies in anticipation of fire flaps.

Airtanker initial attack systems can be modelled as queueing systems with airtankers as servers and fires as customers. Martell and Tithecott (1991) developed and field tested an $M(t) / M / S$ queueing system model of airtanker operations in the OMNR's northwestern region. The managers that participated in the field test found the model to be interesting but indicated it would not be of any practical use to them unless it was enhanced to account for interaction between bases—that is, an aircraft from any base can be dispatched to any fire in the region within its strike range. Islam (1998) subsequently formulated the airtanker problem with multiple interacting bases and constraints on initial attack dispatch radius as a time dependent $M(t)/E_k / S$ extension of Larson's (Larson and Odoni 1981) hypercube queueing model, and we hope to field test his model during the 1999 fire season. Islam and Martell (1998) investigated how the optimal maximum initial attack strike range varies with daily projected fire load.

Initial Attack Dispatch

Initial attack dispatchers must consider many tangible and intangible factors when they balance the current demand for fire suppression resources with highly uncertain potential future demands. Kourtz (1994) developed an expert system to suggest how water bombers, firefighters, and helicopters should be dispatched to new fires. Expert rules that reflect the agency's policy are used to train a hierarchical set of neural networks that predict the ideal maximum response times and numbers of firefighters and airtankers required at a specific fire, irrespective of the current availability of those resources. A more complex version of that dispatch system uses a dynamic programming algorithm to identify how the available suppression resources can be used to modify the ideal dispatch strategy. Kourtz has also formulated the initial attack expert system problem as a sparse distributed memory problem. The performance of this pattern-based approach matched the best neural network formulation but

avoided the need for training sessions required for neural network development. It also enabled a reliable estimate of confidence in the proposed dispatch that the neural network solution lacked.

Fire Suppression

There have been no significant efforts to develop fire suppression decision support systems in Ontario other than Doan's (1974) work and Hirsch and others' (1998) development of a framework for encoding subjective assessments of initial attack firefighter productivity.

Project Fire Management

Fire managers assigned to large fires have a suite of laptop computer-based tools, such as the Fire Weather Index and Fire Behavior Prediction Systems, to assist their efforts. However, there has been very little work on the development of comprehensive DSS's for evaluating project fire management strategies and tactics in Ontario with the exception of Saporta (1995), who developed a prototype escaped fire situation analysis system. A geographic information system (GIS) is used to delineate a specific escaped fire and subjectively assess potential final fire perimeters, which are assigned subjective probabilities of occurring. The GIS descriptions of the final fire perimeters are linked to a forest level timber harvest scheduling model, which is used to assess the long term implications of each possible fire size on timber management in the forest. The OMNR has developed internally a set of "Comptrollership Tools," primarily spreadsheet templates and decision-trees that can be used on large fires, to assist with assessing the costs and impacts of decisions pertaining to base camp locations, fire service strategies, and demobilization schedules.

Level of Fire Protection Planning

The fire load reduction systems and the fire response systems must be designed to provide a level of protection that is compatible with strategic land management objectives. The OMNR, like many other forest fire management agencies, is now focused on strategic level of protection planning. It is well aware that it is neither economically or biologically desirable to exclude fire from forest landscapes and is developing and implementing planning procedures that relate levels of fire protection to strategic land use management objectives. Martell (1980) developed a stochastic optimal stand rotation model and used it to produce a very rough estimate of a hypothetical fire management agency similar to the OMNR, but stand level analyses are of questionable value for forest level policy analysis. Martell (1994) used Reed and Errico's (1986) forest level timber harvest scheduling model to assess the impact of fire on timber supply in Ontario. Boychuk and Martell (1996) used stochastic programming methods to determine how forest managers can explicitly account for probabilistic fire losses when they trade off harvest levels, economic returns, and harvest flow stability. Martell and Boychuk (1996) prepared a level of fire protection discussion paper that was used to help stimulate level of protection discussions in Ontario.

The initial attack simulation model (IAM) developed by Martell and others (1984) was later modified to meet the needs of another forest fire management agency and subsequently updated by Martell and others (1995) to produce Lanik, a modern desktop computer implementation of IAM to facilitate its use for strategic level of protection planning in Ontario. Lanik includes links to a database management system to facilitate the management of both input and output data. Lanik was later extended and embedded in a GIS to produce a model called Leopards (McAlpine and Hirsch [this volume]). Leopards has been used for a variety of purposes including an assessment of the potential implications of climate change, changes in initial attack fire crew staffing levels,

and the up-grading of the airtanker fleet with modern CL-415's. OMNR staff and others drew upon Reed and Errico's (1986) harvest scheduling model to develop the Strategic Forest Management Model (SFMM), which is now used extensively for forest management planning in Ontario. SFMM is emerging as an important link between the OMNR's fire organization and other forest management agencies and is expected to foster a significant improvement in the extent to which level of fire protection policies are assessed from broad land use management perspectives.

Fire Management Information Systems

Fire managers cannot fully exploit decision support systems technology unless they have a comprehensive fire management information system in which they can embed their DSS applications. Kourtz (1994) points out that decentralized organizations have little need for advanced information technology but centralized organizations cannot function effectively without it. He indicated that centralized control calls for monitoring the changing fire environment; predicting potential fire occurrence, behavior, and suppression work loads; deployment of suppression resources to minimize initial attack response times; allocating detection resources to ensure timely detection of new fires; and dispatching initial attack resources to minimize the expected number of fires that escape initial attack.

Fire Report and Fire Weather Record Processing

Like many forest fire management agencies, the Ontario Department of Lands and Forests began batch processing of its basic fire report information in the 1960's and continually refined it to the point where it is now embedded in the Daily Fire Operations Support System (DFOSS) fire management information system. The Department of Lands and Forests began archiving its fire weather data in a computer readable format in the 1970's. Doan and Martell (1973) describe the interactive mainframe computer system that was used to combine weather forecasts provided by meteorologists with fire weather observations collected at fire weather stations to produce daily observed and forecast values for the indices of the Canadian Forest Fire Weather Index System, the fire danger rating system that is used in Ontario. The system evolved from the use of telex machines as input and output devices linked to a central mainframe computer through the introduction of local calculations on first-generation microcomputers, to the use of regionally-based minicomputer-terminal systems, and to the current client-server architecture now in place across the province.

Fire Occurrence Prediction

Fire occurrence prediction systems provide essential information for managers who must decide how to allocate their detection resources and deploy and dispatch their fire suppression resources each day. Cunningham and Martell (1973) showed it is reasonable to assume the probability distribution of the number of people-caused fires that occur in an area each day is Poisson with a mean that varies with the Fine Fuel Moisture Code (FFMC), a component of the Canadian Forest Fire Weather Index System. Cunningham and Martell (1976) developed a methodology for eliciting subjective probability assessments concerning forest fire occurrence from experienced local fire managers. Martell and others (1987) used logistic regression methods to facilitate the inclusion of other fire danger rating indices in the model, which was further extended by Martell and others (1989) to model seasonal variation in daily fire occurrence. Those methods are now used to produce daily people-caused fire occurrence predictions in Ontario.

As early as 1973 Kourtz field-tested people and lightning-caused daily fire prediction models at Dryden in northwestern Ontario. He used a network of about 20 short-range lightning counters that produced daily observations, which were combined with estimates of the moisture content of medium-sized fuels (represented by the Duff Moisture Code of the Fire Weather Index System) to produce a daily forecast of lightning fire occurrence. His daily people-caused fire prediction model was based on correlations between historical occurrence and daily fire weather indices. Todd and Kourtz (1991) partitioned the protected area into 100 to 200 square km cells and used correlations of historical fire occurrence and fire weather data to predict average daily fire occurrence in each cell. Kourtz's (1989) people-caused fire occurrence predictor combines expert opinions concerning many factors that influence fire occurrence processes (e.g., land use patterns and fuel type data) provided by fire managers, with fuzzy logic, to produce daily people-cause fire occurrence predictions. Later he explored the use of neural networks to process such inputs for daily fire occurrence prediction purposes.

Kourtz and Todd (1992) developed a daily lightning fire occurrence prediction model that uses fuel moisture and lightning stroke data to predict fire ignitions. The hold-over smoldering process is modelled to predict how many "detectable" fires are burning undetected in an area each day. Kourtz's more recent work on lightning fire prediction involved the correlation of historical patterns of indicator variables with actual fire occurrence. Here, the pattern space was encoded as a sparse distributed memory and loaded with historical observations. Each new day, the current input pattern was matched in the memory and the most appropriate prediction of lightning fires made. It is an adaptive system in that each new day's input pattern and resulting fires are cumulated in the system's memory.

Kourtz's Prototype Fire Management Information System

Kourtz (1994) and his colleagues worked closely with a number of Canadian forest fire management agencies, including the OMNR, to develop and test a prototype fire management information system that is designed to use modern information technology to support cost effective centralized fire control. Although no particular agency is using the complete prototype system, many have adapted parts of it to fit within their own systems and have benefited from the considerable knowledge and experience gained during the development and testing of the components. The basic system described in Kourtz (1994) includes information acquisition, storage, and retrieval capabilities to process hourly and daily weather data, fire report data, detection reports of new fires, current and predicted fire weather and fire danger rating indices, fuel type maps, fire behavior maps for the current and predicted weather, lightning strike locations, fire occurrence prediction maps, digital or analog terrain maps, initial attack resource status, current aircraft location, physical features such as roads, lakes, rivers, boundaries, and detection planning system maps.

Kourtz's (1994) prototype system also includes many decision support subsystems designed to help managers resolve particular problems, including the daily people-caused fire occurrence prediction, daily lightning fire occurrence prediction, initial attack dispatching, and daily detection planning components.

Ontario's Current Fire Management Information System

In 1990, the OMNR began a comprehensive review of its fire management information needs, culminating in a feasibility study (OMNR 1991) that outlined the evolution of the information system from its aging minicomputer-terminal architecture. That study suggested a four-layer structure beginning with basic data collection and management, the preparation of primary information products, such as fire weather indices and fire behavior indices, and then advancing to more complex tactical and strategic decision support tools, such as

Table 1-Structure of Ontario's Fire Management Information System.

Strategic planning layer	Level of protection analysis system	Resource allocation models	Fire impacts analysis system	Performance measures assessment system	Natural resource supply models
Tactical planning layer	Resource deployment and scheduling systems	Initial attack coverage/ response time assessment systems	Initial attack dispatch support system	Detection planning and routing systems	Fire growth/ suppression effectiveness models
Daily information management layer	Fire weather index system	Fire behavior prediction system	Fire occurrence prediction systems	Resource tracking and utilization systems	Cost management systems
Data acquisition and management layer	Weather/lightning data management system	Incident and fire data management system	Values and fuels data management systems	Suppression resources data management system	Cost data tracking systems

fire occurrence prediction, resource deployment models, and level of protection planning (table 1).

The OMNR's DFOSS replaced an earlier decision support system in 1993 and was the first major product to arise from the FMIS feasibility study. DFOSS is a client-server system with more than 100 Macintosh⁶ workstations located in 30 fire management offices, linked to a central VAX/Alpha-Oracle server. DFOSS is used to capture and manage daily weather, fire and lightning data, and provides access to decision support systems for daily planning, weather analysis, fire behavior, and fire occurrence prediction and cost tracking. It has components that generate a wide variety of maps and reports. DFOSS contains various tools and sub-systems.

DFOSS was developed through an extensive user-consultation process designed to create an application that was easy to use, supported the daily operational needs of its users-sufficiently robust to deal with contingencies such as hardware failures and network outages-and could be operated from remote locations. The OMNR is currently migrating DFOSS to a new technology architecture and expanding its capabilities. In phase one, DFOSS data will be linked in real-time to its server network. Analysis and decision support tools will be migrated or new tools developed to access the data through the NT-servers; subsequently, the transaction processing/data capture applications will be migrated to the new environment. DFOSS addresses a number of the cells shown in the FMIS Structure Matrix (table 1). Other components are also now in place, such as the Fire Equipment Management Information System (FEMIS) for tracking and managing fire suppression equipment, and other developments are underway or planned to address the other components of the FMIS matrix.

Some Lessons Learned in Ontario

Collectively, we have been actively involved in the development, testing, and implementation of fire management decision support systems in Ontario for more than 25 years. We have had some successes, made many mistakes, and learned a great deal along the way. Many of our experiences are consistent with what operational researchers (OR) have reported in other areas, but we found some aspects of fire management to be a little different than the organizations others have described in the literature. The OR literature stresses the importance

⁶Mention of trade names or products is for information only and does not imply endorsement by the U.S. Department of Agriculture.

of gaining the support of senior management and having a senior manager champion OR projects. Some practitioners suggest operational researchers should begin there and rely on those senior managers to bring the organization along. Our experience differs. We found it was essential to convince middle managers that DSS will enable them and their colleagues to do a better job. We found that if and when they accept these DSS tools, they will convince senior managers and garner their support and the commitment of resources that is needed for them.

We believe researchers have to go to the field to find out what is going on "on the forest floor," to identify the needs of fire managers, and to stimulate their thinking. They must go beyond simple field trips and spend extended periods of time working alongside fire managers and studying what goes on. If they do so they will find interesting opportunities or problems fire managers might not otherwise bring to their attention.

Until very recently, almost all of the DSS research and development that took place in Ontario was carried out by researchers who conducted both basic and applied research in collaboration with OMNR staff. The OMNR staff played many roles, including facilitator, project manager, and in some cases, they were collaborating researchers. The OMNR was very cooperative and actively supported applied research they expected would benefit them in the near future, as well as more basic research that was of little apparent practical significance in the short run. That enlightened stance made Ontario a desirable place to carry out research on fire management decision support systems that benefited both the OMNR and the researchers involved.

One cannot measure success by documented implementations of specific decision support systems alone. Most projects carried out in Ontario, including many of those that "failed," provided valuable learning opportunities for both DSS specialists and fire managers, and all, to some extent, contributed to the development of knowledge, understanding, and expertise that has brought us to our current position. The most significant impact of the OMNR's DSS initiatives has been the development and widespread acceptance of a decision analysis culture within the OMNR's fire organization. Forest fire managers in Ontario recognize the need to augment their traditional reliance on training, experience, and intuition with formal decision analysis but the OMNR's fire management community now includes many informed OR consumers that use models developed by others and in some cases, develop and use their own models.

The OMNR has made a very significant and persistent commitment to modern information technology, and it has invested a great deal of time and money in research, development, field testing, and the implementation of computer-based decision support systems. It is clear that it has benefitted and, given past successes and future needs, we expect the OMNR will continue to play an active role in this area for many years to come.

Acknowledgments

Many researchers and fire management specialists have been involved with fire management decision support initiatives in Ontario; we acknowledge the contributions of Dennis Boychuk, Dick Brady, Glenn Doan, Jerry Drysdale, John Goodman, Ron Kincaid, Jim Maloney, Peter Parker, and Harold Redding.

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