An Overview of I[illegible] the Intelligent Fire Management I[illegible]

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ABSTRACT

The Intelligent Fire Management Information System (IFMIS) is a microcomputer based decision support system developed primarily for forest fire preparedness planning and for dispatching initial attack resources to wildfires. IFMIS integrates large data bases with spatial analysis techniques, linear programming, and expert systems to provide improved decision making for forest fire management. This paper is an overview of IFMIS and its application by forest fire management agencies in Canada and Alaska.

INTRODUCTION

Canadian forest fire management agencies in recent years have become more dependent on decision support systems for planning and real-time decision making. In western Canada, a number of forest fire management agencies have adopted forest fire preparedness planning approaches to determine daily initial attack resource requirements (Gray and Janz 1985; Lanoville and Mawdsley 1990). Forest fire preparedness planning is the process of ensuring that adequate suppression resources are available to cope with daily anticipated fire events. Until recently, preparedness planning was strictly weather based and did not incorporate fuels or topography. The Intelligent Fire Management Information System (IFMIS) offers a new approach by integrating weather, fuels, and topography into a spatially based procedure for forest fire preparedness planning. The spatial approaches used by IFMIS also improve real-time decision support for dispatching initial attack resources to wildfires by providing better estimates of fire weather and fire behavior potential.

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INTELLIGENT FIRE MANAGEMENT INFORMATION SYSTEM

IFMIS is a decision support system developed at Forestry Canada's Northwest Region (Lee 1990; Lee and Anderson 1990; Lee and Smith 1990). It was initially conceived as an expert system advisory tool for initial attack dispatching of fire control resources to wildfires. Since initiation of its development, however, it has slowly evolved to a full featured decision support system for forest fire management. Its success is no doubt in part due to the close cooperation and involvement of client agencies from the inception of the system to its operational implementation.

History

IFMIS has been under development since 1987 and was first demonstrated to the Alberta Forest Service at Whitecourt Forest, Alberta, Canada, in September of 1988 (Table 1). Since then, a total of six Canadian and one US agency have either adopted IFMIS or are evaluating its application within their organizations. The first operational trials of IFMIS were conducted in 1989. In that year four installations were tested in the Canadian provinces of Alberta and Saskatchewan. In 1990, six installations were added including four forests in Alberta, the State of Alaska, and Kootenay National Park. At least five more installations are being planned for the 1991 fire season. Figure 1 shows the areas of western Canada and Alaska where IFMIS is either currently being used or being considered for use.

Description

The system integrates a number of advanced technologies including: relational data bases, mathematical modeling, geographic information display, and expert systems. Lee (1990) described the conceptual basis and structure of IFMIS software as of the 1988 fire season. Since then, the PROLOG programming environment has been abandoned in favour of the more efficient C programming language. Also, the artificial intelligence work currently uses a hybrid expert system shell to deliver the expert system applications. To the user, however, the system is functionally the same as in the 1988 version. Since then, the spatial analysis procedure for forest fire preparedness has been added to enhance the planning capability of IFMIS.

Table 1: Table of IFMIS installations listing the year of installation, size of the protection area, the number of records in the cell data base, mean cell size, number of weather stations, the number of initial attack bases, and the number of air tanker bases. (Totals reflect only those installations identified by shading to prevent duplication of values.)

IFMIS Installation	Year	Area (km^2)	Cells	Cell Size (ha)	Weather Stations	Initial Attack Bases	Air Tanker Bases
Whitecourt Forest, Alberta Canada	1988	19,948	31168	64	14	19	1
Grande Prairie Forest, Alberta Canada	1989	49,028	76606	64	21	21	1
Province of Alberta Canada	1989	378,363	591192	64	208	214	15
Province of Saskatchewan Canada	1989	121,000	121000	100	43	41	5
Athabasca Forest, Alberta Canada	1990	42,454	66335	64	20	23	1
Bow-Crow Forest, Alberta Canada	1990	16,036	25056	64	14	14	2
Lac La Biche Forest, Alberta Canada	1990	32,850	51328	64	17	19	1
Slave Lake Forest, Alberta Canada	1990	55,132	86144	64	30	26	2
Kootenay National Park, Canada	1990	1,404	5616	25	3	5	0
State of Alaska, USA	1990	-	-	-	84	21	7
Province of Manitoba, Canada	1991	-	-	-	42	61	5
Eastern Region, Manitoba Canada	1991	-	-	-	6	7	0
Northwest Territories, Canada	1991	1,065,165	5525	19279	48	38	6
Hudson Bay Region, Sask. Canada	1991	-	-	100	5	6	1
Prince Albert Region, Sask. Canada	1991	-	-	100	9	8	1
Province of Ontario, Canada	1991	-	-	-	-	-	-
Totals		1,565,932	723,333		428	380	38

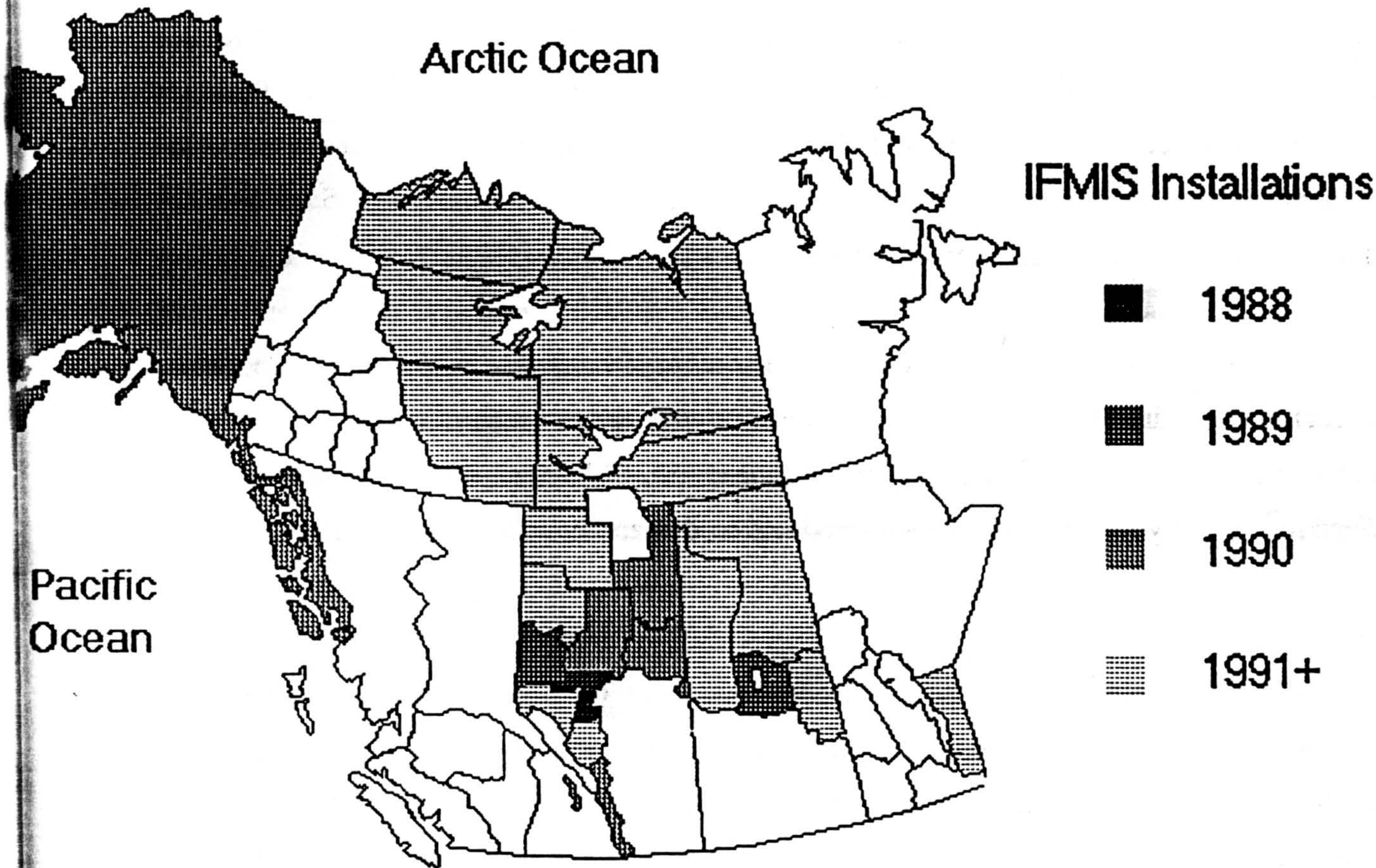

Figure 1: Map of IFMIS installations in western Canada and Alaska by year of establishment.

SPATIAL ANALYSIS

Fire management operations and planning is a spatial problem. In this respect, IFMIS has the ability to integrate and analyze spatial data such as weather, forest fuels, and topography (Lee and Anderson 1990). Central to this approach is the forest environment data base. This data base consists of geographically referenced cells containing forest fuel type, slope, aspect, and elevation information. The cell size depends on available data, with most IFMIS installations using cell sizes varying from 25 to 100 hectares (Table 1).

Using the forest environment data base, IFMIS applies models to predict the fire danger for each cell within a region. This approach can provide the forest fire manager with daily or hourly maps and reports depicting fire weather, fire behavior, and resource utilization effectiveness. IFMIS can produce these products on demand in a matter of minutes.

Fire Weather

IFMIS uses the Canadian Forest Fire Weather Index (FWI) System (Van Wagner 1987) as a basis for modeling and interpreting fire weather. The FWI System estimates forest fuel moisture conditions using empirical models driven by daily 1200 LST[3] weather readings. These weather readings include temperature, relative humidity, 10 metre wind speed, and precipitation. Outputs from the system include three fuel moisture codes and three fire behavior indices. Typically, the input data are collected from a network of fire weather stations using either manual or automated weather stations.

IFMIS can produce fire weather maps using a variety of interpolation schemes. The preferred approach uses a weighted moving average shown in the following equation,

$$x' = \frac{\Sigma x_i / d_i^2}{\Sigma 1 / d_i^2}$$

[3] Local standard time.

where x' is the interpolated weather value at a location x_i, and d_i is the distance from the location to the weather station (Figure 2a).

Fire Behavior

The Canadian Forest Fire Behavior Prediction (FBP) System has been in use in Canada since 1984 (Lawson *et al* 1985). The FBP system estimates the forward rate of spread (ROS) of a fire for a number of defined fuel classes using input FWI values. Additional FBP outputs include the head fire intensity (HFI), the crown fraction burned (CFB), and the total fuel consumed (TFC).

Using the FBP system with the forest environment data base and interpolated FWI values, IFMIS can produce maps of potential fire behavior such as ROS (Figure 2b), HFI, CFB, and TFC. This integration of interpolated weather with fuels and topography to produce quantitative estimates of potential fire behavior has greatly improved the ability of fire management agencies to respond to daily fire management planning issues.

Preparedness Planning

Lee and Anderson (1990) described a spatial approach to forest fire preparedness planning that incorporated weather, fuels, and topography to sub-optimally determine the daily allocation of suppression resources. Fire management planning in western Canada is based upon the philosophy of early detection of forest fires and rapid initial attack. In order to meet this goal, all fires must receive initial attack before they reach a critical size. This criteria is called the initial attack size objective. Using such a policy, IFMIS can assess the efficiency of pre-positioned resources within a forest region on a daily or hourly basis.

For each cell, IFMIS computes the time it would take a potential fire to reach the initial attack size objective. This elapsed time criteria, referred to as the attack time, can be displayed in map form (Figure 2c). With this type of information, the forest fire manager can use IFMIS to determine how many resources can reach the cell within this time from predetermined bases. This elapsed time includes both the get-a-way time and travel time to a cell. By selectively activating and deactivating initial attack bases, a coverage assessment map (Figure 2d) can be

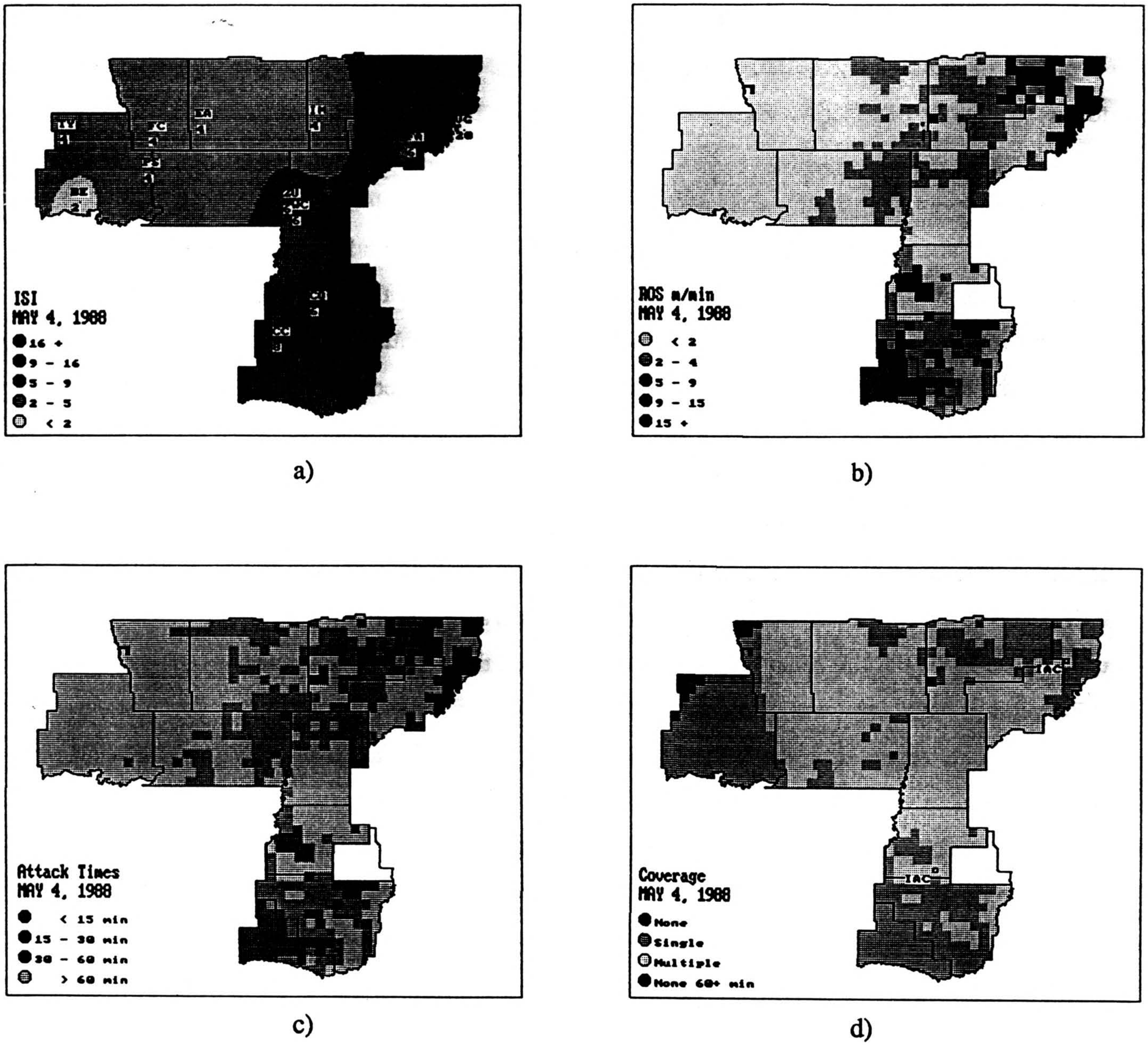

Figure 2: Examples of IFMIS map products showing (a) the initial spread index (ISI), (b) the head fire rate-of-spread (ROS), (c) attack times, and (d) initial attack crew coverage for May 4, 1988, Whitecourt Forest, Alberta Canada.

produced. Coverage for a cell is often classified as none, single, or multiple meaning that zero, one, or more than one initial attack resource can reach the cell within the attack time required. Those cells classified as no coverage are considered to have a higher probability for an escaped wildfire to occur given an potential ignition source.

DECISION SUPPORT

In order to extend the capabilities of IFMIS, research and development is currently being focused in two areas; mathematical modeling to determine optimal preparedness planning levels and expert systems for policy integration and initial attack dispatching.

Optimization

Building on the spatial analysis approach described by Lee and Anderson (1990) to determine the number of initial attack resources to be activated on any one given day, a linear programming approach has been developed to determine this information optimally. The methodology uses integer programming to determine the minimum number of initial attack crews or air tanker groups to activated on any one given day. In addition, the algorithm determines the optimal geographical positioning of these resources.

This initial attack resource allocation problem belongs to a class of integer programming problems called covering (Schrage 1986). The problem can be formulated as collection of demand points throughout the forest. These demand points are represented by the cell (fire environment) data base used by IFMIS. Initial attack bases and/or airports make up the supply points for the daily pre-positioning of air attack resources.

The decision variables are:

x = the initial attack bases

c = the daily cost of operating the initial attack base

a = a binary coefficient (0 or 1)

For j = 1,2,.....,n, define a zero-one variable x_j to designate whether or not initial attack base j is selected.

The optimization problem is to minimize the number of initial attack bases activated on any given day while ensuring the maximum cell coverage possible. The objective function for the formulation can be written as follows:

$$minimize \sum c_j x_j$$

subject to

$$\sum a_{ij} x_j \geq 1$$

where the coefficient a_{ij} equals 1 if cell i is covered by initial attack base j, otherwise it equals 0. Coverage is determined by comparing the get-a-way time plus the travel time from each initial attack base with the attack time. If the get-a-way time plus the travel time is equal to or less than the attack time, the coefficient a_{ij} is given the value of 1, else it is assigned the value 0. Cells in which no travel times meet the initial attack objective time are excluded from the analysis and are assumed to be not covered. The formulation incorporates the cost (c) of activating each initial attack base. If c is not available it can be considered to be the same for each initial attack base.

The current formulation of this problem looks only at the aspect of ensuring that initial attack resources will arrive at the cell prior to a fire reaching a certain size. The formulation does not consider the risk of a fire occurring within a particular cell within a given day. Also, the approach does not yet incorporate any containment modeling or resistance to control criteria. In spite of these limitations, the approach provides a good starting point to determine the initial attack requirements of a forest on any given day. An example of the output from the optimization algorithm is presented in Figure 3.

Expert Systems

Expert systems are computer programs that undertake the solution of complex tasks or problems using knowledge rather than data and by mimicking the solution methods of human experts. The knowledge embodied in an expert system may be that of one or more experts within a narrow field of endeavour. As such, expert systems are well suited to problems which

INITIAL ATTACK OPTIMIZATION

Initial Attack Crews:

Base	Aircraft	Status	Location
W20	206B	15 Minutes	Cold Creek R.S.
W43	206B	15 Minutes	Timeu

Figure 3: Initial attack optimization report for May 4, 1988, Whitecourt Forest, Alberta, Canada showing the requirement for two helicopter transported initial attack crews.

Appropriate suppression response expert system summary

Initial attack strategy: Direct and indirect attack

Fire intensity rank: 3

Low to vigorous fire behavior.
Hand prepared fire line likely to be challenged.
Heavy equipment may be required.

Special considerations:

Gas plant located at SE-13-19-58 W of 5

Recommended appropriate suppression response:

Helitack crew 1 from W14 Grizzly

Air tanker group 1 from Grande Prairie

Figure 4: Appropriate suppression response expert system summary for a hypothetical fire occurring on May 4, 1988, in the SW quarter of Section 1, Township 58, Range 18, west of the 5th meridian in the Whitecourt Forest of central Alberta.

are too imprecise to be defined in terms of mathematical models, although mathematical models may be used to derive facts for use in the knowledge base.

Current research and development work with expert systems is centred around encoding agency policies and human expertise into knowledge processing activities such as preparedness planning and recommending an appropriate suppression responses for new fire starts. A presuppression planning advisory system has been developed for Kootenay National Park which makes recommendations on how to deploy fire crews, when to charter or release rotary wing aircraft, and appropriate detection and prevention activities. In addition, an appropriate suppression response expert system has been demonstrated that recommends resources to be dispatched to new fire starts and the appropriate tactics to be used (Figure 4).

CONCLUSIONS

IFMIS was originally developed to be a cost effective decision support system for initial attack dispatching. Since its inception in 1987, it has gradually matured to a full featured fire management information system that has been adopted by seven fire management agencies in Canada and the United States.

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REFERENCES

Gray, H.W. and Janz, B. 1985. Initial attack initiatives in Alberta: a response to the 1980s. In Proc. of the Intermountain Fire Council 1983 Fire Management Workshop, Banff, Alberta

Lanoville, R.A and Mawdsley, W.M. 1990. Systematic assessment of daily fire preparedness requirements. Pages 253-261 in Alexander, M.E. and Bisgrove, G.F. 1990. The art and science of fire management. Proc. of the first Interior West Fire Council Annual Meeting and workshop, Kananaskis Village, Alberta, Oct. 24-27, 1988. Forestry Canada Info. Rep. NOR-X-309.

Lawson, B.D.; Stocks, B.J; Alexander, M.E.; Van Wagner, C.E. 1985. A system for predicting fire behavior in Canadian Forests. Pages 6-16 in L.R. Donoghue and R.E. Martin, eds. Proceedings of the eighth conference on fire and forest meteorology. Soc. Am. For., Bethesda, Maryland. SAF Publ. 85-04.

Lee, B.S. 1990. Use of advanced concepts in dispatching fire control resources. Pages 137-147 in Alexander, M.E. and Bisgrove, G.F. 1990. The art and science of fire management. Proc. of the first Interior West Fire Council Annual Meeting and workshop, Kananaskis Village, Alberta, Oct. 24-27, 1988. Forestry Canada Info. Rep. NOR-X-309.

Lee, B.S. and Anderson, K.R. 1990. A spatial analysis approach for forest fire preparedness planning. Pages 339-345 in Proc. 10th Conf. on Fire and For. Meteor., Apr. 17-21, 1989.

Lee, B.S. and Smith, R.M. 1990. Applying new technologies to forest fire management. Page 99 in Alexander, M.E. and Bisgrove, G.F. 1990. The art and science of fire management. Proc. of the first Interior West Fire Council Annual Meeting and workshop, Kananaskis Village, Alberta, Oct. 24-27, 1988. Forestry Canada Info. Rep. NOR-X-309.

Plane, D.R. and T.E. Hendrick. 1977. Mathematical programming and the location of fire companies for the Denver Fire Department. Operations Research 25(4:563-578).

Schrage, L. 1986. Linear, integer and quadratic programming with LINDO. The Scientific Press, Redwood City, CA.

Van Wagner, C.E. 1987. Development and structure of the Canadian Forest Fire Weather Index System. Can. For. Serv., Ottawa, Ontario. For. Tech. Rep. 35.

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