# FINAL REPORT ON THE DEVELOPMENT OF AN EXPERT SYSTEM FOR FIRE MANAGEMENT IN KAKADU NATIONAL PARK, N.T.

J.R. Davis
G. Williams
P.M. Nanninga
J. Hoare

CSIRO
Division of Water and Land Resources

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In January 1985, the Division of Water and Land Resources (DWLR) accepted a contract to develop components of an expert system for fire management purposes in Kakadu National Park, N.T. It was envisaged that the system would be a development of the GEOKAK prototype system displayed at a workshop at the Division in October 1984, and able to run on a micro-computer in the Park Headquarters at Jabiru (anticipated to be a HP-150 micro-computer).

The contract drawn up between the DWLR and the Australian National Parks and Wildlife Service (ANPWS) specified six areas of work - the first five being part of the expert system development. The following section reports on the completion of this work.

1. Development of an expert system shell

Most of the research effort was directed to completing this part of the contract as it is anticipated that the shell program will subsequently form the core of a fire management system for Kakadu National Park. It is intended that the system will run on a micro-computer at the Park Headquarters and that requirement considerably restricted the sophistication possible in the system.

In many ways, use of the system (GEM) will integrate a number of research projects currently underway. Its construction will draw upon the specialized knowledge of CSIRO personnel (particularly Jamie Hoare); it will be able to use the spatial classification of the Park being developed by Ken Myers, Richard Thackway and Kim Malafant; it will draw upon information contained in a geographic data bank; and it will be able to utilize any process models that may eventually be proven reliable in this part of Australia.

The shell program is able to recognize and make independent decisions on each distinct spatial unit in the Park. Knowledge can be tagged so that the spatial extent of its application can be limited to selected areas in the Park, and information obtained about one area in the Park can be 'applied' to other areas if appropriate.

At present the system recognizes the land system/land unit spatial classification but that can be readily changed when another classification, better suited to predicting the effects of fire, becomes available.

The geographic data base (GDB) at present consists of 3 variables for each spatial unit - fuel type, fuel weight, and vegetation type - obtained from the land systems reports on the area and the knowledge of some CSIRO personnel. Because of technical limitations, this data base is presently restricted to a maximum of 15 variables per spatial unit although, with further work, this limitation could be removed. It is anticipated that the connection of the expert system with the GDB will prove to be one of its most powerful and useful features as, amongst other things, the system can then be used to interrogate the GDB in an 'intelligent' fashion.

Combining the expert system with process models requires an assembler interface that is specific to the machine on which the system is operating. Although we have designed the expert system to access such an interface on a DEC RAINBOW computer, we cannot provide an interface that is useful to the ANPWS since we are using a different micro-computer to that envisaged for the Park.

The shell has been written in a standard but powerful version of the PROLOG language on the DEC RAINBOW CPM/86 computer. This program should be readily transferable to any CPM/86 or MS-DOS computer. The program operates in 'real-time' and will accept a knowledge base of useable size. However there are limitations, inherent in this version of PROLOG, in increasing the knowledge base beyond about 200 rules (or equivalent other forms of knowledge).

The principal knowledge base (KB) uses a production rule formalism. At present this KB contains about 120 rules providing information on fire behaviour characteristics (most notably the height of scorch), and it is anticipated that approximately another 100 rules will be added in 1985/86 to describe fire effects on the flora of the Park. The production rule formalism is expected to be well-suited to the task with its modular, declarative style.

Extensive 'help' is available at any time during a consultation by typing '?' or 'help'. This will, for example, provide further information on the range of possible answers to a question, and other options available to the user.

The shell also possesses an editor to allow the KB to be updated. We anticipate that personnel in the Park may wish to alter the KB in light of their familiarity with fire behaviour in the Park. This editor is relatively simple, and personnel may wish to use the commercial editor supplied with their computer in order to have greater flexibility in modifying the KB.

The system allows a 'degree of certainty' to be attached to each rule in the KB, so that the system can estimate the reliability of decisions it makes.

The system can be queried about its reasoning both during a consultation (type 'WHY') and after a decision is reached (type

'REVIEW'). It is envisaged that this will allow the user to gain confidence in the decisions or, if he does not agree with them, to pinpoint the pieces of knowledge in the KB that he believes should be altered.

2. Construction of a knowledge base on fire behaviour

Jamie Hoare has generalized the KB demonstrated at the fire management workshop held in October 1984. Although the estimation of the scorch height is the princpal goal of the system, if the user desires any of the parameters in the KB can be chosen to be the goal. In particular, if the parameters stored in the GDB are nominated then the system will interrogate the GDB for the user, and if the user nominates a parameter calculated by a process model then the system will access such a model.

The KB consists of 120 production rules. Note that these are not intended to provide tactical assistance for fire control purposes. However, it would be possible to augment the present KB for fire control purposes with the assistance of Park personnel if that was though to be a valuable exercise.

The rules have been obtained from experimental data and general observations collected by Jamie Hoare at Munmarlary. Each rule can be directly traceable to either some experimental result or to recorded observations and, to this degree, the KB possesses authenticity. We have spent considerable time checking the consistency of the KB and we believe it is free of internal conflicts. If the KB is to be altered by Park personnel we would suggest that they provide a 'justification' with each additional rule for the benefit of other users.

The rules and parameters of the KB can be inspected at any time during a consultation by typing PR and PP respectively.

3. Gem Users manual

A draft users manual is included with this report. The manual will not be finalized for some months since it is likely Park personnel will detect omissions and errors in it. However, the present draft is sufficiently advanced to provide whatever assistance is needed to run GEM. In addition, the help facilities in the program act as a de facto users manual once the user has loaded GEM.

We would appreciate learning of any deficiencies in the manual so these can be corrected.

4. Omissions in the Knowledge Base

An appendix to this report provides details on areas where knowledge about fire behaviour is lacking.

The 'gaps' in the KB are not necessarily complete omissions - in some instances they are areas where the knowledge is of low 'certainty'.

Although we had hoped to systematically explore the extent of the KB using the expert system itself, we found this expectation to be too ambitious and the suggested areas needing further information have been obtained simply from direct inspection of the KB.

5. Installation

The GEM system will be installed on a ANPWS micro-computer at Jabiru when one becomes available. In the meantime, it will be installed on equipment at the ANPWS offices in Canberra.

6. Patch-burn algorithm

The FORTRAN program for modelling the effects of patch burns initiated from aerial incendaries has been completed. Although developed on a VAX 11/750 computer it should operate on any equipment running FORTRAN-77.

The program provides the user with information on the number of incendaries and the frequency with which they should be dropped in order to achieve a given degree of burn. It also provides details on the flight plan and it will draw a simple map showing the incendary drop pattern. Thus, if the user wishes to burn 50% of a management region, the program will deduce (from that day's fire behaviour characteristics and the speed of the aircraft), the incendary drop pattern within the region.

It is a simple geometric program and, although it would be possible to include the effects of vegetation type, landform, etc. we have not done so since we are unsure of the program's eventual use. It would be possible, for instance, to connect this program to the expert system so that the latter could supply information on the fire behaviour characteristics.

Finances

As set out in the interim report, there was an estimated carry-over of $3,500 because 2 budgeted person-trips to Kakadu National Park were not used, and DEC failed to supply ordered hardware. These funds will be spent in the 1985/86 financial year.

Conclusion

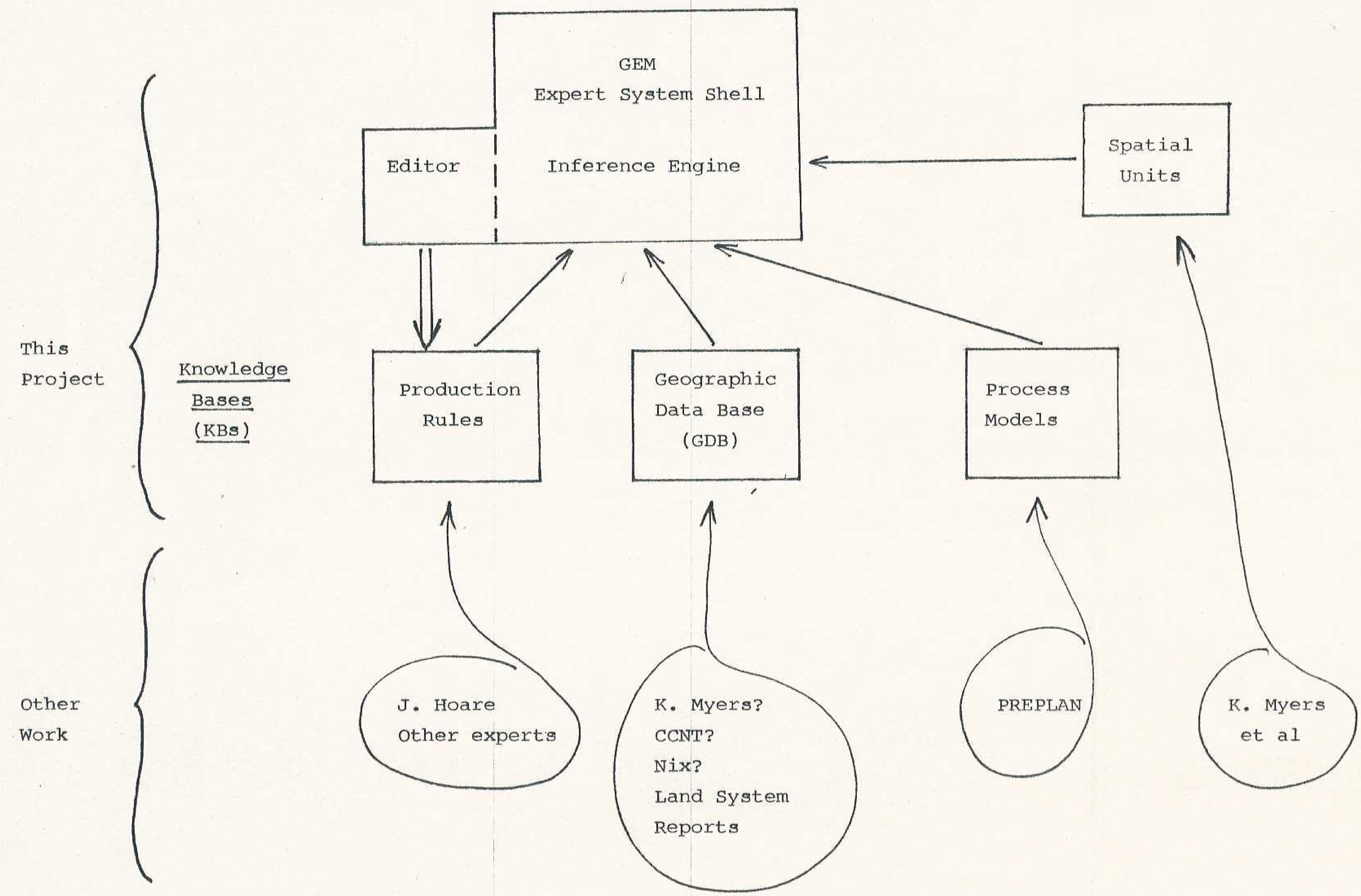
This has been a satisfying project for the CSIRO personnel from both a scientific and an application point of view. The GEM shell program incorporates some novel features (such as its ability to access GDBs and process models), and the discipline of constructing a realistic KB has forced us to systematize our knowledge during which we have identified areas requiring further research. We anticipate describing this work in recognized academic journals.

We believe that the expert system will prove of value to the Park managers, particularly when the KB is augmented to include expert knowledge about fire effects.

The project has been satisfying technically also. It is generally accepted that practical expert systems will only operate on machines at least as powerful as mini-computers. In the present instance, GEM operates successfully on a standard micro-computer, although we expect that it will prove difficult to significantly extend the capabilities of the program.

Our belief that expert systems offer considerable potential for assisting land managers, largely because of their ability to capture and apply expert knowledge that has not been formalized into equations, has been reinforced during this work. We know from the development of other expert systems, that their power is ultimately derived from an extensive and reliable knowledge base. Our proposed work in 1985/86, following the meeting of June 14th between CSIRO and ANPWS personnel, is in accordance with this understanding. The verification of the existing KB, the addition of rules describing the effects of fire, the improvement of the interface to a GDB so that factual knowledge can be better accessed, and the improvement of the interface to process models so that procedural knowledge can be drawn upon, are all aimed at checking and then extending the knowledge base.

Finally we would point out that we have attempted to design GEM as a general purpose expert system for problems of land management. Consequently, we believe that the ANPSW could employ it (with a different knowledge base, of course) for problems other than fire management in Kakadu National Park.


GEM
Expert System Shell
Editor
Inference Engine
Spatial
Units
This
Project
Knowledge
Bases
(KBs)
Production
Rules
Geographic
Data Base
(GDB)
Process
Models
Other
Work
J. Hoare
Other experts
K. Myers?
CCNT?
Nix?
Land System
Reports
PREPLAN
K. Myers
et al

Figure

APPENDIX

Areas requiring further research

Further research is required to, (a) verify, and (b) expand the fire behaviour - fire effects knowledge base in order to obtain greater certainty in the production rule knowledge base. This will allow the expert system to operate accurately and reliably as a day to day management tool -

1. Fuels

(a) A proper classification is required of fuel types and their distribution within the Park in relation to vegetation and land systems/units (or whatever system of vegetation and land classification is ultimately implemented). There is a need for a unifying system of land/vegetation classification for land management in general, and fire and species (flora and fauna) management in particular. This work should be carried out in close consultation with Myers et al.

(b) Rates of accumulation of each fuel type within the Park, i.e. changes in fuel weight in relation to time since a fire last occurred, are required. If sufficient systematic information was obtained, it could be incorporated into a process model for the relevant vegetation/fuel types. The GEM system is designed to access such process models, thereby enabling fuel weights to be estimated accurately.

(c) More information is required on the rate of curing and time of onset of full curing of grass fuels, i.e. availability of grass fuels for burning in relation to seasonal conditions such as frequency and amount of rainfall, temperature and humidity. This work would cover the period from the close of the monsoon and knock'em down seasons and the commencement of the cool burning period. It would accurately identify the time of year that burning in the Park is physically possible. This period will vary depending on the regions within the Park, and therefore both a spatial and temporal classification of fuel availability will be required.

(d) Once grass fuels are fully cured, fuel drying rates for both grass and litter fuels are needed to quantify the relationship between fuel flammability levels (i.e. percentage moisture content) and Burning Index. This would be done according to aboriginal season during the dry part of the year up to and including the early monsoon season (see Hoare in Technical Memorandum 2/85 CSIRO Division of Water and Land Resources).

2. Fire Behaviour

(a) Verify the relationships between fire behaviour (e.g. flame height), fire damage (e.g. scorch height) and Burning Index (see Hoare in Technical Memorandum as above) for each aboriginal burning period. It is suggested that observations be made of flame height, flame angle, flame depth, rate of spread of head fire and the size and shape of individual fires burning in each aboriginal burning period, and that these observations be correlated with fuel type, fuel quantity, percentage fuel moisture content, temperature, relative humidity, topography and wind direction and velocity at the time of the fire.

(b) From 2(a) identify the variability of the Burning Index, fire behaviour and fire damage within each aboriginal burning period and incorporate these findings within the rules of the expert system.

3. Fire damage

(a) The relationship between fire behaviour (e.g. flame height) and fire damage (e.g. scorch height) is an integral part of the 3-way relationship between fire behaviour, fire damage and Burning Index which is to be verified under 2(a) above. However special attention should be paid to the relationship between fire behaviour and fire damage according to the different aboriginal burning periods and different combinations of meteorological conditions. In particular it is possible that there are anomalies associated with wind velocity, when flame heights and corresponding scorch heights are reduced above a certain wind velocity, even though the Burning Index may be high or greater. In addition to this, it is suggested that fire behaviour and fire damage parameters be investigated in addition to those identified above (which are sensitive indicators of fire effects). Such additional parameters will depend on field observations of fire behaviour and related fire damage. Finally, these findings should be incorporated in the rules of the expert system.