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Predicting Prescribed Fire Effects on Ecosystems: Present Capabilities and Future Research Needs[1]

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Introduction

Increasing concern for ecosystem maintenance in parks and protected areas has prompted land and resource managers to use various vegetation management techniques to achieve ecosystem objectives. Prescribed burning has often been selected as the method of choice because of the natural role of fire in the plant communities being managed. In fact, fire is often the primary successional force in many western forest and grassland ecosystems (Wein and MacLean 1983, Wright and Bailey 1982, Pyne 1984). General fire weather zones in Figure 1 indicate the distribution of relative burning conditions in western boreal forest and grassland zones (Rowe 1972). Although Figure 1 does not indicate fire occurrence, it does illustrate the potential for extreme burning conditions which can lead to large, intense fires.

During the last 60-70 years, development of a fire exclusion policy (Murphy 1985) and increased fire suppression capabilities has often been interpreted as a reduction in the effect of natural fire on ecosystems. Fire history and vegetation studies (Tande 1979, Masters 1990, Tymstra 1991) tend to support this. In order to preserve ecosystems in many natural areas, managers have selected an objective of increased fire frequency for many plant communities in order to compensate for successful fire suppression activities.

This increase in the use of prescribed fire for ecological reasons has led to a demand for predictors of fire effects (in order to meet ecological goals) and of fire behavior (for control purposes). Fire behavior prediction (including rate of spread, fire intensity, and degree of crowning) can be readily accomplished using components of the Canadian Forest Fire Danger Rating System (CFFDRS) (Van Wagner 1987, Stocks *et al* 1989, Forestry Canada Fire Danger Group 1992). However, fire effects prediction is considerably more difficult. This paper proposes a procedure to predict fire effects using decision-aids and techniques applicable to operational burning programs in Canada.

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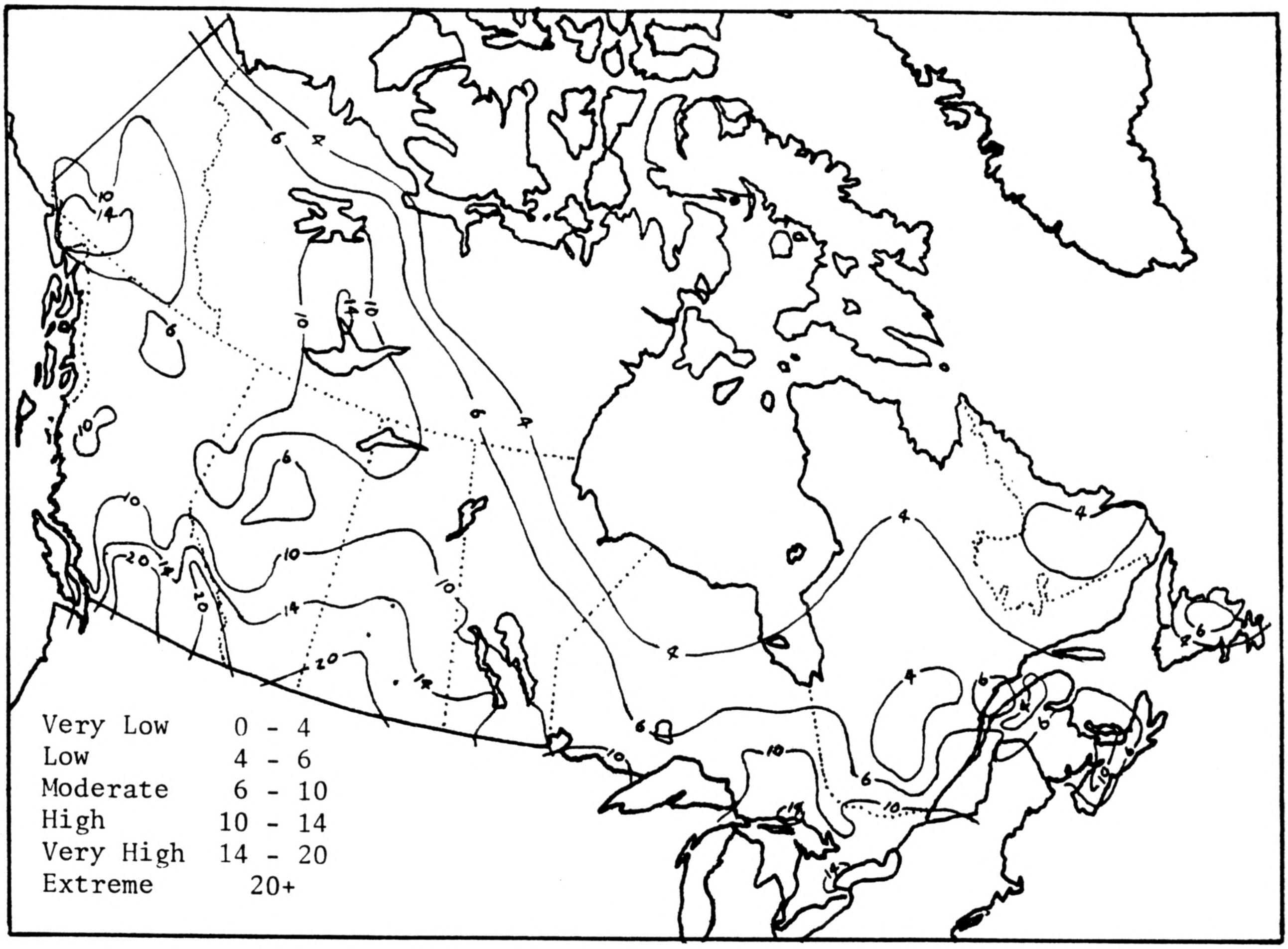

Figure 1. Fire weather zones in Canada (adapted from Simard 1973).

Present Capabilities

Studies on the ecological effects of fire have predominantly been done using an analysis of preburn vegetation and postburn response. Unfortunately, documentation of fire characteristics, weather conditions, and preburn fuel status is often qualitative or anecdotal. Burning conditions are almost never recorded using CFFDRS parameters. This makes development of operational predictive tools difficult because burning programs in all provinces and territories are based on the CFFDRS. At present, the only means of predicting ecological effects is by using the combined information from ecological models, predictors of physical fire characteristics, and biological knowledge of the plant community being manipulated.

Although a number of fire ecology models have been developed (e.g., Potter *et al* 1979), a notable succession model was developed by Noble and Slatyer (1980). The model is based on three life history attributes (or 'vital attributes') which describe the method of persistence following disturbance, ability to grow, and the time necessary to reach critical life stages. It has been shown to have wide application, with examples in Australia and the Rocky Mountains in Montana (Cattelino *et al* 1979).

The Noble and Slatyer model is described as being most applicable to modelling recurrent disturbances in terrestrial communities dominated by higher plants. Because it is a qualitative model, it only deals with disturbance variation in a subjective way. For example, fire intensity would be classified as mild, normal or severe. This may be the reason that the model is restricted in its application. Disturbance variation (including season of disturbance in relation to physiological plant condition) likely results in a wide variation of plant survival at all levels of the plant community.

Physical fire and fuel characteristics that could play an important role in determining plant survival are fire intensity (crown scorch height); rate of spread (duration of lethal heat pulse); surface fuel load, size and moisture content (involving fuel consumption as it affects fire intensity and duration); organic soil depth and moisture content profile (depth of lethal heat penetration); and vertical and horizontal fuel continuity for both above surface and below surface fuels (causing further disturbance variation).

For prescribed burn purposes, the most important weather parameters which can affect plant survival during fire are wind speed (which can vary instantaneously) and relative humidity (varying in a period of minutes). Both these parameters have immediate and direct influence on rate of spread, and therefore, fire intensity.

Plant succession is dependant on the interaction of plant vital attributes and the fire characteristics (as determined by fuel and weather factors). It is at this point that a predictive model of fire effects must become quantitative. For instance, a fire with an intensity of 5,000 kW/m may kill the overstory of a 10m white spruce stand (and possibly the seed crop), but not a 20m lodgepole pine stand. Similarly, a 1,000 kW/m fire may completely destroy all underground propagules on a deep, dry organic soil site, but a 10,000 kW/m fire may have no effect on underground propagules in a moist soil location. The potential for variation is great, and the results can only be determined through a quantitative approach.

A suggested procedure for predicting fire effects on an operational scale (Fig. 2) begins with the CFFDRS. Fuel and vegetation sampling (Daubenmire 1954, McRae *et al* 1979, Brown *et al* 1982) is combined with previous weather conditions through the CFFDRS to determine fuel condition. Forecasted weather conditions are then used in the CFFDRS to predict physical fire

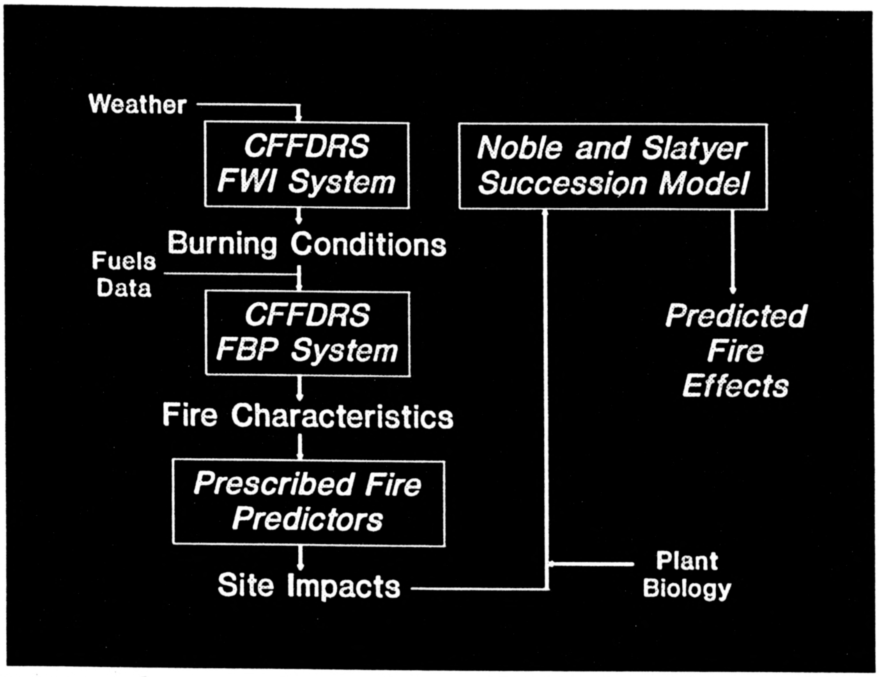

Figure 2. Proposed procedure for predicting fire effects using Noble and Slatyer (1980) model.

characteristics[3] (fuel consumption, rate of spread and intensity). These fire parameters are then applied to various prescribed fire predictors such as Alexander (1986) to predict crown scorch height; Chrosciewicz (1978a, 1978b) for estimation of depth of burn; and Ryan (1982) to estimate stem mortality in relation to bark thickness. It should be noted that there is a dearth of available predictors.

The next step is to link the impacts determined by these predictors to plant survival and succession. For this, the Noble and Slatyer model is used with the predicted site impacts and plant biology. Tying site impact (e.g., crown scorch height, depth of burn) to plant biology to determine plant response can be a difficult task because of limited available research. In most cases, professional judgement is required. This whole procedure for predicting the effects of fire on plant communities (at an operational management scale) is still at a very preliminary stage.

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[3] CFFDRS fire behavior predictions are only valid for wildfires and line ignitions on prescribed fires. They do not apply to centre-firing and other non-linear ignition techniques.

Future Research Needs

Obviously, present predictive capabilities are limited. There are two primary needs in the prediction of fire effects on ecosystems: further site specific predictors tying fire characteristics to physical site impact (e.g., depth of lethal heat penetration), and plant reponse models based on species biology and site impact. Also, to make such a predictive system truly useful in ecosystem management, it must be incorporated in a GIS-based decision support system. Only this way can ecosystem modelling be done on a full management scale using gradient modelling techniques (Kessell 1979). At present, we are only capable of dealing with fire effects prediction at a very local operational scale.

Concluding Remarks

Considerable progress in fire behavior prediction and ecosystem modelling during the last 15 years has set the stage for development of new fire effects models. The major challenge is to link these two disciplines together with plant biology in a single predictive model. This will require continued basic research in fire ecology, applied research in the site impacts of fire, and technology transfer efforts to ensure all sources of information are put together in a compatible fashion.

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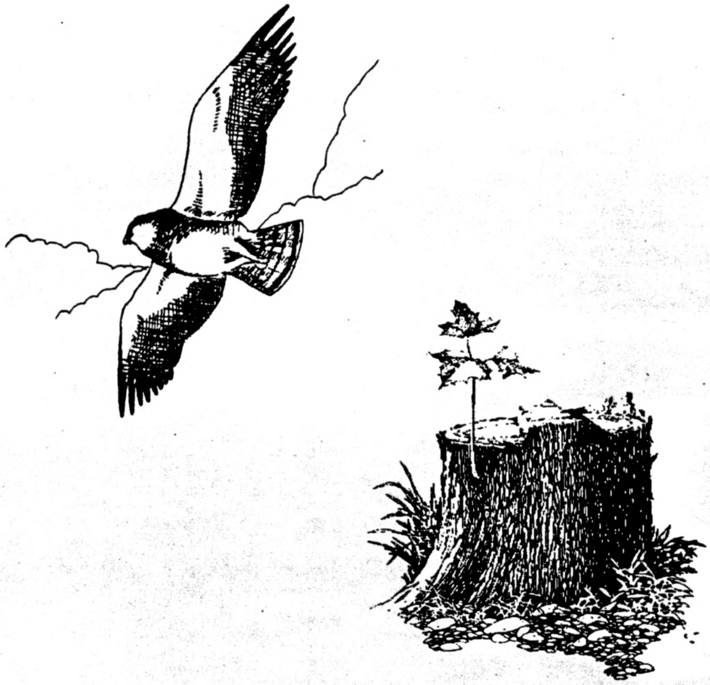

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