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# BOREAL FIRE ECOLOGY: IMPLICATIONS FOR ECOSYSTEM MANAGEMENT

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The increasing focus on ecosystem management in forestry has caused renewed interest in the role of fire in natural forest ecosystems. Similar interest in the subject of fire ecology occurred 20-30 years ago when fire protection agencies moved from an emphasis strictly on fire control to one of fire management, implying the use of prescribed fire to meet other resource objectives. During the last 10-15 years, wilderness area managers have become more pro-active with respect to the natural role of fire in ecosystem processes. Fire ecology research has historically followed this rise and fall of interest, and its importance will no doubt increase again as holistic ecosystem management becomes the basis for planning on all forested lands.

In reality, our ability to manage ecosystems consists primarily of manipulating (or managing) vegetation with consideration for known effects on other ecosystem components. Therefore, it could be stated that ecosystem management is the process of managing the vegetation complex while using natural ecosystem condition as a model. Because fire is the most pervasive natural force in the boreal forest, the role of fire ecology in ecosystem management is to assist in providing a baseline measure of the natural ecosystem condition. This obviously is a complex task because of the dynamic nature of the forest. However, we can begin to define the 'natural' vegetation complex (including composition, structure and distribution) by describing the fire regime which initiates change in the natural forest, the effect this regime has on various plant species, and modeling how these effects alter plant communities and influence succession. The purpose of this paper is to outline a process that could be used to determine the natural vegetation dynamics of a fire-dominated ecosystem, and to discuss some of the implications of substituting fire disturbance with commercial timber harvesting.

## Fire Regime

The first stage in elucidating the role of fire is to compile a description of the long term fire activity within the area of concern, or the local fire regime. In brief, this can be defined as the net effect of fuels, weather, topography and ignition sources (whether the cultural use and/or suppression of fire is considered part of the fire regime is dependent on management policy). Fire regime is often described by characteristics such as type of fire (crown vs. ground), fire intensity, fire cycle, season of burn , size of burn and depth of burn. Fire regime provides a general description of the fire environment that a plant lives in and is considered dynamic in that it changes with the factors affecting it (e.g., climate change, suppression policy, fuels management). Although fire regime may be defined for a particular area over the long term, it should be noted that the actual fire activity that occurs can be highly variable. A review of historical weather, lightning occurrence and study of the local fire history (fire scars, fire records, lake sediments, age-class structure, dendroclimatology) are often used to determine fire regime.

When comparing fire regimes, it should be noted that fire activity can be described in several ways. Fire cycle (Merrill and Alexander 1987), or fire rotation (Stokes and Dieterich 1980), is defined as the amount of time required to burn an area of size equal to the area of concern. Therefore, the sum of either a few large fires or numerous small fires may result in the same fire cycle (e.g., 80 years). On the other hand, fire frequency (Stokes and Dieterich 1980), or fire incidence (Merrill and Alexander 1987), is the average number of fires that occur over a given period of time for the area of concern and is not a reflection of area burned. For instance, a fire frequency of 50 fires per 100 years may represent 50 large fires or 50 small fires. The mean fire return interval is the average number of years between fires for the area of concern (2 years in the previous example) and also provides no indication of area burned. In practical terms, fire effects at the landscape level are dominated by the influence of large (>100 ha) fires, whereas very small fires (<0.1 ha) are relatively inconsequential (except at a very local level). Therefore, fire frequency and mean fire return interval do not have much ecological meaning in the boreal forest because it is dominated by large fires (Heinselman 1981).

Even though a given fire regime is difficult to quantify, it is possible to display certain aspects of fire activity. Because fire is strongly influenced by weather, Simard's (1973) map of "Forest Fire Weather Zones of Canada" provides a good indication of the variability in potential fire activity across the boreal forest This map is based on weather data for a ten-year period starting in the mid-1950's and can be interpreted as a spatial distribution of the measure of potential fire intensity. A similar map for the 1980's would almost certainly be different, in reflection of climate variability. Another indicator of fire regime is the occurrence of large fires (Stocks *et al* 1995) which also includes the effect of fire management policy.

**Fire Effects**

The next step to understanding the local fire ecology is to describe the effect of fire regime characteristics (or fire behavior) on vegetation. For instance, crown fires may consume seed stored in tree canopies while surface fires have little impact. Individual tree mortality is closely linked to fire intensity (Ryan 1990). Short fire cycles tend to promote species that quickly regenerate or invade. Depth of burn is important to all sprouting plant species, and season of burn often influences the vigor of new growth. A short fire interval may cause local extinction of late maturing species, while fire size affects the rate of ingress of new plant individuals that must seed-in from outside the burn. Combining fire behavior and plant biology information provides the next level of knowledge: fire effects (de Groot 1992). In order to incorporate fire ecology into ecosystem management planning , we need to quantify fire effects.

Despite our current limited knowledge base in fire effects, there are two factors that will allow forest management agencies in Canada to quickly take a global lead in operational ecosystem management. Firstly, a fundamentally sound method exists for assessing fire potential in the form of the Canadian Forest Fire Danger Rating System (CFFDRS) (Stocks *et al* 1989). The CFFDRS enables the transformation of historical weather data to estimates of historical fire activity by broad fuel or vegetation type and topographic features. Thus, fire behavior climatologies can be generated to provide a quantified description of the local fire environment. More importantly, once fire effects thresholds are defined for plant species (i.e., the fire intensity required to kill mature white spruce), an estimate of the historical cycle of these events can be provided through a fire effects climatology. Secondly, there is a high level of proficiency in the spatial application of CFFDRS-related products in Canada, particularly those designed for the operational field and management levels (Lee and Anderson 1989, Lee 1995). Having already climbed the learning curve will allow an easy transition from research to implementation through GIS-based decision support systems. These two factors are direct spin-offs from fire suppression research, and it appears that the distinction between fire suppression, fire ecology and ecosystem management will continue to gradually fade.

**Successional Models**

Once the estimated historical burning conditions and fire effects thresholds have been defined, the effects on whole plant communities and succession can be modeled. A number of multiple pathway succession models based on general burning conditions have been developed (e.g., Davis *et al* 1980, Fischer and Clayton 1983, Bradley *et al* 1992). These kinds of succession models can be developed in a quantitative fashion using fire effects thresholds and plant vital attributes (Cattelino *et al* 1979, Noble and Slayter 1980, Keane *et al* 1989). Although model resolution may never likely reach the level of sophistication to predict, for example, seedling density after fire, they should be able to estimate species composition and relative abundance. At this point in time, a first approximation for succession models of major tree species could be produced using data from current fire effects studies and silvical characteristics. These results would then require field validation. Development of similar models for understory vegetation will require considerable additional research due to the complexity of below ground heat transfer.

**Management Implications**

Once successional models based on fire disturbance are developed, ecosystem managers will be able to interpret the local role of fire by constructing various scenarios through the application of these models to the historical fire regime, coupled with vegetation and topography databases. As fires occur over the landscape, the natural range in vegetation composition and distribution will become apparent, and this should serve as a guideline for vegetation management goals. Modeling landscape changes will be a continual process as additional research data is collected over time.

Undoubtedly, there will be continued debate in the future regarding the ability to maintain a natural vegetation complex by replacing fire with commercial timber harvesting. There is a tendency among forest managers to imply that harvesting practices can be designed to simulate fire disturbance. This is a very misleading perception. Although both are disturbances and certain parallels can be drawn, the fact remains that you cannot truly duplicate all the multifaceted aspects of fire (Alexander and Ruler 1981) through logging practices. There are obvious differences in the amount of residual standing stems, dead and downed surface debris, type of lower vegetation, and soil condition (pH, nutrients, moisture, temperature, structure, organic matter content) (Feller 1982, Macadam 1989, Feller 1991, Keenan and Kimmins 1993). Even though sites affected by different disturbances tend to become more similar over time (e.g., fire-killed snags gradually fall down, soil pH and nutrient status generally return to original condition, woody debris decays), the greatest differences are present during the earliest stages of new forest growth. As well, the majority of forested land is found in the early age-classes of natural fire-dominated boreal ecosystems (Van Wagner 1978). Therefore, it could be argued that the greatest difference occurs on the greatest proportion of the landscape.

There are also some problems with planning harvest operations to simulate fire patterns (Hunter 1993). The assumption that a 10,000 ha fire represents 10,000 ha of burned land is not true. In fact, there is a significant amount of unburned islands within the outer burn boundary, and this amount increases (perhaps up to 18% or more) with total fire size (Eberhart and Woodard 1987). There is also a great diversity in the level of fire severity (intensity, depth of lethal heat penetration) within the burn. Some stands may experience a low intensity surface fire and trees will survive; other areas will have some trees removed by intermittent torching, while some stands will be completely killed by crown fire. This pyrodiversity is a significant contributor to biodiversity in terms of variability within a burn, as well as by variability between burns (Martin and Sapsis 1991). Therefore, a large burned area cannot simply be replaced by a large clearcut.

However, replacing fire is not the true issue. More important than the physical differences between cutting and burning is the ecological significance of those differences. For instance, moose may prefer cutovers to burns because of better browse production (Alexander and Euler 1981, Weber 1991), but there may be no difference to animals that require 'edge' habitat. Similarly, certain plants are fire-dependent, while others are true fire-avoiders (Rowe 1983). Although disturbance by cutting and burning is different in a number of ways, it cannot be said that the effects of one is ecologically better than the other because it depends on the measuring stick being used. 'Naturalness' is often used to measure the level of ecological goodness. Wilderness areas are generally perceived to be ecologically better than licensed areas because they are 'natural', although many wilderness areas have an unnatural age class distribution due to attempted fire exclusion during the last half century. Pro-active burning programs to return the natural balance of fire in these areas are considered ecologically correct, but hardly natural. But the application of fire by natural or prescribed means is "irrelevant" because "the forest certainly cannot tell the difference" (Van Wagner and Methven 1980). Management of wilderness areas is no different from ecosystem management in that the main concern "is not the natural fire regime per se, but rather the vegetation complex that the natural fire regime would have created" (Van Wagner and Methven 1980).

Whether vegetation management is achieved by cutting or burning is also irrelevant, as long as there is no overall, significant ecological difference. Undoubtedly, the natural boreal vegetation complex requires a certain amount of fire to maintain fire-dependent flora (and probably fauna). Some level of burning is required in all age-classes, although this could be represented by either wildfires or prescribed burns. Prescribed fire is a valid site treatment option to successfully meet both silvicultural and ecological objectives (Weber and Taylor 1992). Maintaining the spatial diversity of the natural vegetation complex will require considerable variation in the size, shape and pattern of cutblocks and uncut patches. If the negative exponential age-class distribution of natural forests (Van Wagner 1978) is considered a goal of ecosystem management, then the annual allowable disturbance (cut or burn) must be equally distributed among all age-classes. In other words, ecosystem management based on natural forest conditions will require harvest of older stands for profit, and disturbance of younger stands for ecological reasons.

Ecosystem management will definitely challenge some traditional forestry views and public perceptions. A concerted effort by management and research is required to address a lot of the outstanding issues. Even though there is a considerable amount of work required to accomplish this, ecosystem management should be viewed as a process rather than a product.

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# BOREAL ECOSYSTEM MANAGEMENT FOREST

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