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Introduction

Emulating natural landscape disturbance in forest management – an introduction

Thomas R. Crow[1,*] and Ajith H. Perera[2]
[1]*USDA Forest Service, North Central Research Station, 1831 Hwy 169 E., Grand Rapids, Minnesota 55744 USA;* [2]*Ontario Forest Research Institute, 1235 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5 Canada;* [*]*Author for correspondence*

Because forest ecosystems have evolved with natural disturbances such as fire, windthrow, and pest epidemics, they are generally thought to be resilient following recurring natural perturbations. Therefore, researchers, managers, and policy makers are increasingly interested in forest management practices based on stand- and landscape-scale natural disturbances (Palik et al. 2002, Seymour et al. 2002, Perera et al., *in press*). In North America, these approaches are referred to as managing within the historic range of natural variation or emulating natural forest disturbance (ENFD). In Europe, the term "close-to-nature silviculture" is often used.

Although many existing silvicultural systems have been designed to mimic stand-scale natural disturbances, McRae et al. (2001) and Palik et al. (2002) remind us that natural disturbances are inherently different from those of silviculture. One difference, of course, relates to the amount of carbon removed from the site when harvesting a forest. Removals tend to be much greater with harvesting than for fire, for example. Fire tends to create a complex mosaic of forest types and ages on the landscape. Forest harvesting, as commonly practiced, tends to simplify forest composition and structure on the landscape (Crow et al. 2002). Further, less attention has been given to emulating natural disturbances patterns and processes at the landscape level than at the forest stand level. It is important to consider both levels together if an integrated approach is to be realized (Harvey et al. 2002).

Emulating natural forest disturbances in landscapes has the broad goal of maintaining the composition and structure of the forest within the spatial and temporal characteristics generated by prevailing natural disturbance regimes. Doing so presumably promotes ecosystem resilience. In some situations, abandoning or altering human suppression of disturbances such as fire is vital to restoring forest ecosystems (Baker 1994). Emulating natural disturbances is also considered a "coarse-filter approach" to conserving ecological diversity (Haila 1994).

A symposium sponsored by the Ontario Ministry of Natural Resources, the Canadian Society of Landscape Ecology, and the IUFRO Working Party for Landscape Ecology, with the goal of exploring ENFD and synthesizing the state-of-knowledge for this topic in North American, was held May 2002, in Sault Ste. Marie, Ontario, Canada. This special issue of *Landscape Ecology* resulted from papers presented in the subsequent IUFRO workshop that focused specifically on the Great Lakes region of North America. We feel, however, the results of these papers are relevant to scientists and managers elsewhere. Papers in this issue represent a mix of empirical studies and computer simulations. Both approaches are needed to better incorporate ENFD into policy and practice.

A fundamental feature of a natural disturbance regime is its variation in extent, timing, intensity, and spatial location. Understanding this variation is a daunting challenging for both managers and scientists. A popular approach in North America has been to quantify historical disturbances, mostly of pre-European settlement era, through various sources of information. In their study "Characterizing Historical and Modern Fire Regimes in the Lake States, USA: A Landscape Ecosystem Approach," Cleland et al. determined fire locations and extents during the pre-suppression era (the 1800's) to characterize historical fire regimes and compare these data to current fire regimes. When averaged over all landscape ecosystems, fire rotation increased from ~ 250 years in the past to ~ 3000 years at present. To really understand these changes, however, it is necessary to consider each landscape ecosystem and the context in which that ecosystem exists. For example, those landscape ecosystems that were fire-prone historically remain so today due to the interactions between their physical environment and the vegetation these environments support.

In another empirical study, Bresee et al. provide a broad-scale characterization of landscape change between 1972 and 2001 on public lands in northern Wisconsin, USA. Disturbances, including timber harvesting, windthrow, and jack pine budworm outbreaks, created most of the landscape change. Significant increases in forest fragmentation, as reflected in a 46% decrease in mean patch size and a 19% increase in total edge length, were measured during the 30-year period. Bresee's study provides the linkage between contemporary disturbance regimes and changes in landscape composition and structure. Measurements such as those reported in this study are needed to implement adaptive management.

Simulating disturbance regimes through modeling, an alternative approach to empirical studies, is gaining popularity. Using spatial models, we can better understand the relationship between landscape change and the factors such as disturbance that create change. The application of land cover transition models (LCTM), one class of spatial models, is widespread. However, many LCTM do not account for spatial dependency, that is, they simulate the fate of each pixel as if it was independent of all other pixels. Not accounting for spatial dependency in a model may affect spatial outputs. Weaver and Perera explore this problem in their paper "Modelling Land Cover Transitions: A Solution to the Problem of Spatial Dependence in Data." Their results should be of interest to researchers using spatial models.

In North America and elsewhere, suppressing fire in landscapes in which fire was historically important has increased the risk of catastrophic fires. Spatial models are helpful in evaluating strategies to reduce this risk. Gustafson et al. use the model LANDIS to evaluate seven alternative vegetation management scenarios on forest succession and fire risk on a 66-km^2 landscape in northern Wisconsin, USA. Their study area, a mixture of fire-prone and fire-resistant land types, represents the real world, and so their results have relevance to contemporary issues.

In another application of LANDIS, Sturtevant et al. consider the combined effects of fire suppression and timber harvesting on the abundance and connectivity of high-risk fuels in an actual landscape. Both factors, fire suppression and timber harvesting, significantly influenced the landscape pattern of high-risk fuels and there was also a significant interaction between the two factors. Their results strongly suggest that "one size" as it relates to the reduction of fire risk does not fit all situations. Different conditions require different strategies. Current policies that are being advocated for reducing fire risk may be far too general and simplistic to solve such a complex problem.

The metrics that are used to characterize landscape change are critical to developing approaches that emulate natural disturbance in resource management. These metrics are known to be sensitive to the extent, resolution, and detail of classifications based on remote sensing, but rarely has this sensitivity been tested in a systematic way that will improve their application. Among 19 landscape indices studied, Baldwin et al. found 17 to be sensitive to spatial extent, 13 with changes in spatial resolution, and 18 sensitive to changes in classification detail (thematic resolution). The results from this study provide important information for developing and implementing disturbance emulation monitoring programs.

Knowledge about natural disturbance is obviously a prerequisite if ENFD is to be a useful tool. The interactions between natural and human-caused disturbances also need to be understood (Mladenoff et al. 1993, Crow et al. 1999). Landscape ecology provides a spatial and temporal framework for considering these complex relationships. Principles from landscape ecology are helping make ENFD a viable management option. This special issue of *Landscape Ecology,* along with the book resulting from the symposium, *Emulating Natural Forest Disturbances: Concepts and Applications (Columbia University Press, 2004)*, are intended to move both the science of landscape ecology and the practice of emulating natural forest disturbance forward.

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