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Influence of forest planning alternatives on landscape pattern and ecosystem processes in northern Wisconsin, USA

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Abstract

Incorporating an ecosystem management perspective into forest planning requires consideration of the impacts of timber management on a suite of landscape characteristics at broad spatial and long temporal scales. We used the LANDIS forest landscape simulation model to predict forest composition and landscape pattern under seven alternative forest management plans drafted for the Chequamegon-Nicolet National Forest in Wisconsin. We analyzed 20 response variables representing changes in landscape characteristics that relate to eight timber and wildlife management objectives. A MANOVA showed significant variation in the response variables among the alternative management plans. For most (16 out of 20) response variables, plans ranked either directly or inversely to the extent of even-aged management. The amount of hemlock on the landscape had a surprising positive relationship with even-aged management because hemlock is never cut, even in a clear cut. Our results also show that multiple management objectives can create conflicts related to the amount and arrangement of management activities. For example, American marten and ruffed grouse habitat are maintained by mutually exclusive activities. Our approach demonstrates a way to evaluate alternative management plans and assess if they are likely to meet their stated, multiple objectives.
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1. Introduction

Management of forests for a stable supply of products and amenities while insuring the maintenance of healthy ecosystems requires consideration of long time periods and broad spatial areas (Shifley et al., 2000; Boutin and Herbert, 2002). In the past 50 years there has been a shift in the goals of forest management to produce more non-timber benefits such as wildlife habitat (Bettinger and Chung, 2004). Ecosystem-based approaches to managing dynamic forest landscapes emphasize the maintenance of ecological processes as the key to sustaining economic and non-economic benefits. Sustaining ecological processes necessitates planning at multiple spatial and temporal scales (Crow, 2002), and accounting for complex interactions among natural and management processes (Mladenoff and Pastor, 1993; Kurz et al., 2000).

Applications of ecosystem science to forest management are often limited by significant informational gaps regarding the cumulative impacts and interactions of management actions on ecosystem processes (Mladenoff and Pastor, 1993; Mladenoff, 2004). Forest managers possess a wide variety of tools for assessing the results of timber management, but the majority of these are aspatial (Turner et al., 2002; Bettinger and Chung, 2004). The growing importance of resource goals that rely upon the appropriate juxtaposition of management activities (e.g. wildlife habitat, stream buffers) emphasizes the need to explicitly consider the spatial implications of forest management actions at appropriate temporal and spatial resolutions.

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Spatially explicit simulations of forest succession and disturbance (including timber harvesting) provide a crucial tool for understanding the interactions between ecosystem processes and management activities (Crow, 2002; Boutin and Herbert, 2002). The long lifespan of trees and slow transition of some forest communities necessitates simulations that span many decades to centuries. Landscape simulators have been used to assess patterns of disturbance by wildfire (Gustafson et al., 2004; Sturtevant et al., 2004a), susceptibility of a landscape to outbreaks of forest pests (Sturtevant et al., 2004b), volume of coarse woody debris on the forest floor (Shifley et al., 2000), distribution of old growth patches across landscape (Klenner et al., 2000; Perera et al., 2003), and the distribution of woody biomass across landscapes (Scheller and Mladenoff, 2004). The spatially explicit output of these simulations allows for quantification of the landscape characteristics that respond to forest management over time and that are indicators of key ecosystem processes. These landscape characteristics include forest composition, age class distributions, patch size distributions, forest fragmentation and wildlife habitat (Marzluff et al., 2002; Akcakaya et al., 2003; Radeloff et al., 2006). Thus, forest landscape simulation models such as those reviewed by Scheller and Mladenoff (2007) offer great utility for forest planning and management.

Important differences in landscape characteristics and ecosystem function have been found with the Lake States region of North America by comparing remnant old growth landscapes with managed forests. Modern landscapes contain structurally simpler forests with fewer tree species and smaller patches (Mladenoff et al., 1993). This change resulted from extensive clear cutting and burning 75–150 years ago followed by a dramatic shift toward subsistence agriculture and timber harvesting. The resulting changes in structural diversity, age class distributions, and disturbance intervals have altered ecological processes within this region to a state that rarely existed naturally (Mladenoff and Pastor, 1993). These changes have a profound impact on wildlife habitat configuration, connectivity, and ecological processes such as disturbance (Crow et al., 1999). Modern landscapes are also depauperate of older age classes of several tree species that were once historically important in this region and are now rare as dominant species in large patches (Schulte et al., 2002), including hemlock (*Tsuga canadensis*), red pine (*Pinus resinosa*), and white pine (*Pinus strobus*).

The Chequamegon-Nicolet National Forest (CNNF) in northern Wisconsin used knowledge of the links between landscape pattern and ecosystem function to design management "alternatives" (Table 1) as part of its forest plan revision process (CNNF, 2004a). The range of alternatives considered represents the efforts of the CNNF to manage landscape pattern rather than to allow pattern to emerge from a series of independent aspatial decisions. The alternatives share some objectives such as; increasing the size of patches to maintain forest interior conditions, increasing the occurrence of mid to late successional forest types, and decreasing the interspersion of early successional habitat within blocks of late successional habitat (Crow et al., 2006). However, a diverse array of ecosystem conditions are also explicit management objectives, including habitat for specific wildlife species.

Table 1
Description of the alternative forest plans simulated using LANDIS. The alternatives were developed for the Chequamegon-Nicolet National Forest Plan revision process, except the 'no-harvest' baseline alternative (A), which was developed for comparative purposes for this study. For each alternative the last column lists the percent of the study area where even aged harvesting practices were implemented during each decade of the simulation

Alternative	Management objective	% Even aged
A	No harvest (baseline alternative)	0.00
B	Decrease aspen and increase hardwoods	4.34
C	Emphasize ecosystem restoration	4.70
D	Increase hardwoods and restore ecosystems	4.86
E	Decrease aspen increase pine and hardwoods	5.05
F	Emphasize saw timber (pine and hardwoods)	5.46
G	Maintain aspen increase pine and hardwoods	5.93
H	Emphasize early-successional habitat (aspen)	6.60

We used a landscape level forest succession and disturbance model (LANDIS) to simulate forest dynamics under the alternative forest plans developed by the CNNF (Table 1). We examined whether these plans differed in their impacts on ecologically important landscape characteristics (Table 2). Because even-aged management produces the greatest disruption in the continuity of forests (Lord and Norton, 1990), we hypothesized that the relative impacts of the alternatives on landscape pattern (Table 2) will be directly related to the amount of even-aged management prescribed within each alternative. We consider how the alternatives affect (1) the extent to which the resulting landscapes are dominated by a single forest type, (2) the frequency of occurrence of early and late successional forest types across the study area, (3) the total area and patch characteristics (patch size and complexity of shape) of three tree species (eastern hemlock, red pine, and white pine), and (4) the potential of the resulting landscapes to provide habitat for American marten (*Martes americana*), ruffed grouse (*Bonasa umbellus*) and Kirtland's warbler (*Dendrocia kirtlandii*).

In this study, we assess the efficacy of these alternative plans at meeting the CNNF's ecosystem function objectives by monitoring the amount and spatial pattern of habitat for three wildlife species with very different habitat requirements. The American marten is a small carnivorous mammal that is a state threatened species and is strongly associated with large blocks of mature northern hardwoods habitat in Wisconsin (Gilbert et al., 1997; Wright, 1999). The ruffed grouse is a popular game bird (Fearer and Stauffer, 2003) that is strongly associated with areas where there is an even mixture of age classes of early successional aspen (Rickers et al., 1995). The Kirtland's warbler is a federally threatened migratory song bird that occurs rarely in Wisconsin (Probst et al., 2003) and is strongly associated with early successional jack pine (*Pinus banksiana*) on xeric land types (Probst, 1986). The land allocated to habitat for any of these species can eliminate habitat for the others, illustrating the difficulty of managing forest landscapes for multiple objectives.