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Foreword

Landscape analysis: Projecting the effects of management and natural disturbances on forest and watershed resources of the Blue Mountains, Oregon, USA

1. Introduction

Governments around the world have enacted a variety of forest and watershed management policies intended to address a range of natural resource issues. Examples include policies that address reforestation following timber harvest in Europe (e.g., Bauer et al., 2004) and water quantity and quality protection in South Africa (e.g., South African National Water Act, 1998). Although often effective, such policies sometimes can produce unanticipated or undesirable consequences either by exacerbating existing problems or creating new ones. The history of fire suppression on federal lands in the Western United States is a good example. Major forest fires in 1910, soon after the establishment of the Federal Forest Reserves, led to nation-wide policies of fire suppression (Pyne, 2001). These policies evolved over time into a highly institutionalized effort to limit the number and size of wildfires on forest and rangelands (Pyne, 2001; Stephens and Ruth, 2005). Fire fighting initially was motivated by the desire to protect human life, timber, and water resources, with little understanding of the potential broad-scale and long-term consequences to forest conditions. Today, however, there is near consensus that the past century of fire suppression has produced excessive accumulations of woody fuels and corresponding increases in the likelihood of wildfire throughout western North America (e.g., Agee, 1993; Yazvenko and Rapport, 1997; Dellasala et al., 2004).

Fire suppression policy and its outcome in the United States might have followed a different path had policymakers and managers been better able to anticipate long-term consequences. New federal laws and policies now target perceived threats to the long-term health of western forests, including insect pests, such as bark beetles, introduced pathogens, and both fuel accumulations and wildfire risk. This is evidenced by the Healthy Forests Initiative (Office of the President, 2002) and passage by the US Congress of Healthy Forest Restoration Act (2003) and the pending Forest Emergency Recovery and Research Act (2006). While natural resource polices, such as these set general direction for managing Federal forest lands, specific details of implementation are determined locally. Local land managers face numerous choices when deciding on the type, location, and frequency of management actions to be implemented, yet often must make such choices with limited or imperfect knowledge about their potential long-term consequences. Management activities are conducted in systems with high natural variability that have been altered by past land management. Public lands managers may have little information regarding management objectives and activities on neighboring private lands, complicating any assessment of potential consequences of public lands management across whole landscapes. Consequently, the potential ecological and socioeconomic responses of management choices often involve significant uncertainty (Rieman et al., 2001).

Ideally, decision makers would be able to anticipate the likely outcomes of policy and management alternatives under consideration to avoid unintended and undesirable consequences. Federal land managers have long been involved in broad-scale planning efforts for national forests and other public lands as required by the National Forest Management Act (1976) and the Federal Land Policy and Management Act (1976). More recently, Federal agencies have developed plans that provide general direction and assess potential outcomes of land management over large regions (million hectare) and long periods (100 years). Examples include the Northwest Forest Plan (USDA and USDI, 1994) and the Sierra Nevada Forest Plan Amendment (USFS, 2004). At the other extreme, Federal land managers also plan for specific projects covering 100s to 1000s of hectares and must assess their likely effects over shorter time frames. However, intermediate scales may be more convenient for management planning as they more closely match administrative boundaries and the scale is more human-relevant so that planning areas are more likely to be familiar to managers (Wu and Qi, 2000). Further, because scaling relationships can be complex (Wiens, 1989; Wu, 2004) changing scales can dramatically affect the results of landscape analyses (McGarigal et al., 2001). Thus, intermediate-scale landscape assessments are an important step in translating broad-scale planning directives into specific management projects.

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2. The INLAS project

The Interior Northwest Landscape Analysis System (INLAS) was conceived in 2000 to develop tools for evaluating projected outcomes of alternative land management scenarios at intermediate spatial scales (Hayes et al., 2004). Models developed in the INLAS project were intended to account for interactions between management activities, forest succession, and natural disturbances and thereby enable evaluations of the likely responses of multiple resources to different management scenarios. The large fires of 2000 and 2002, which respectively burned 3.4 and 2.8 million ha, in the United States (NIFC, 2006) prompted the INLAS project to expand its focus on wildfire risk and related issues.

The origins of the INLAS project – its purpose as originally conceived by project leaders – and key results and conclusions are discussed by Barbour et al. (2007a). Project scientists selected a core study area in the upper Grande Ronde River watershed in northeastern Oregon, USA, a mostly forested area with public and private land ownership. The INLAS project was organized around discipline-specific modules (Fig. 1) that allowed for independent development of each module, but with the intent of linking modules through common variables when appropriate and feasible. The vegetation module (Hemstrom et al., 2007) based on state and transition models developed for the Blue Mountains of northeastern Oregon provided the empirical foundation for landscape analyses of the INLAS project. Several modules were directly linked to this vegetation module (Fig. 1). Direct linkages were not possible with other modules owing to a variety of factors, including differences in geographic scope and use of alternative modeling approaches. The “un-linked” modules did, however, provide context that informed the overall INLAS effort.

Hemstrom et al. (2007) projected the forest structure and other vegetation effects resulting from three management scenarios: (1) background natural disturbance, (2) fire suppression, and (3) active fuel management. Results showed that current forest structure across the landscape is very different from that expected under a natural disturbance regime. Forest composition and structure changed slowly in response to changes in management activities because of the time required to grow large trees and the feedback among disturbances and forest succession that limits the ability of active management to generate some types of forest structure. Vavra et al. (2007) extended Hemstrom et al. analyses to examine the effects of native and non-native ungulate herbivores on forest structure. They found that grazing can substantially influence forest development. High levels of grazing changed competitive interactions thereby favoring regeneration of conifers that tended to increase the area in dense forest. Feedbacks to other disturbances were complex, however, and long-term outcomes were quite different among the three scenarios examined.

Barbour et al. (2007b) analyzed the potential to use wood products produced from the active fuel management scenario as a financial incentive (or internal subsidy) to pay for silvicultural treatments. Barbour et al. results show that over the next 100 years, only 3% of the study area can be treated with positive net revenues. Even if current environmental and administrative restrictions are dropped, only 10–15% of the area can be treated without a net loss. Many hectares are projected to be near the financial break-even point, so that a relatively small subsidy (US$ 243 ha^{-1}) would approximately double the area that could be treated under each scenario. Criteria for determining the location and frequency of treatments, however, must also include other objectives, strategically locating treatments to reduce wildfire risks, for example. Thus actual costs of treatment are likely to differ from those projected.

Wales et al. (2007) used the vegetation models of Hemstrom et al. (2007) to evaluate the effects of different management scenarios on the area of forests dominated by medium- and large-diameter trees that provide habitat for many wildlife species. They specifically evaluated projected trends in denning and foraging habitat for Canada lynx (*Lynx canadensis*), a threatened species under the United States Endangered Species Act (1973). Wales et al. found that the area of forest in large-diameter trees is currently well below the estimated natural range of variability, and that it might take over 100 years to return to more natural levels regardless of the management scenario implemented. Projected amounts of Canada lynx habitat differed among the scenarios, however, denning habitat decreased from current levels under all scenarios, while foraging habitat generally increased.

A number of the INLAS modules were not closely (or empirically) linked with the landscape analysis. For example, the aquatic and riparian modules (Wondzell et al., 2007; Fonnesbeck, 2007) used a network (linear) rather than a landscape (planar) approach, making direct linkages with the vegetation models of Hemstrom et al. (2007) difficult. Other modules provided supporting information and context, including estimates of snag abundance (Bate et al., 2007) and regional projections of human development in forest and rangelands (Kline et al., 2007). Still other modules used different modeling approaches that contributed to process-based understanding of the likely feedbacks between management activities and natural disturbances (Ager et al., 2007a,b; Graetz et al., 2007).

Riparian and stream ecosystems pose substantial management concerns within upper Grande Ronde River watershed because they provide critical habitat for Snake River spring chinook salmon (*Oncorhynchus tshawytscha*), which are listed as threatened under the United States Endangered Species Act (1973). However, robust analytical models were not available to incorporate riparian and aquatic components into the INLAS landscape analyses. Thus, Wondzell et al. (2007) developed a suite of aquatic-riparian state and transition models linked to an expert systems model for assessing salmon habitat quality. Fonnesbeck (2007) demonstrated how the reach-scale models developed by Wondzell et al. could be linked together into a dynamic network model using discrete event simulation. Although not currently joined with the whole watershed vegetation state and transition models of Hemstrom et al. (2007), these riparian and stream models provide the foundation for such developments.

Maintaining densities of snags (standing dead trees) sufficient to provide wildlife habitat is a key consideration for forest man-

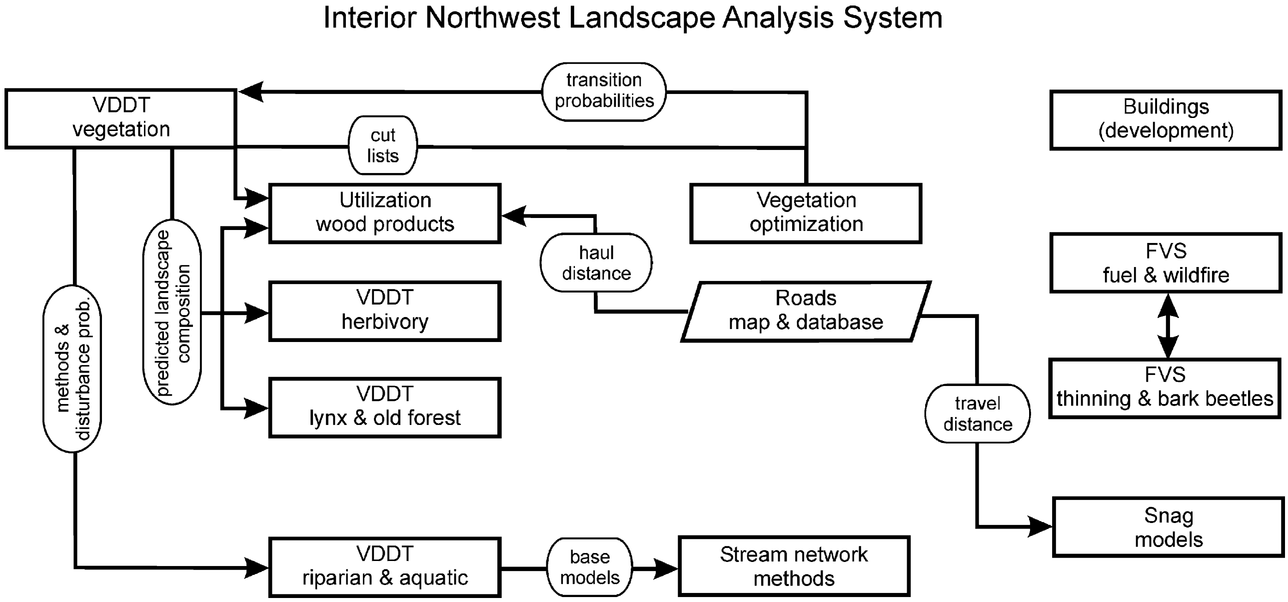

Fig. 1. Relation between INLAS modules (boxes) showing types of information (ovals) transferred between modules. Although the description of the roads module (parallelogram) is published elsewhere (Aitken and Hayes, in press), information on the road network was used to estimate haul distances for wood products removed from the forest and for estimating travel distances to access areas for fuel wood cutting.

agers. Bate et al. (2007) attempted to explain variation in snag densities relative to human-access and land-management variables. Bate et al. analyzed two datasets. They showed that snag densities were related to a variety of management factors, including past land management and ease of human access. They also showed that existing networks of systematically located monitoring plots (Current Vegetation Survey or CVS plots; Johnson, 2002) may be of little utility for modeling snag density and discussed the importance of sampling design on their results.

State and transition models are excellent tools to explore the long-term effects of multiple factors that can alter landscapes, but offer limited ability to explore specific mechanisms and interactions driving predicted changes. Ager et al. (2007a) used an alternative modeling approach that employed the Forest Vegetation Simulator (FVS) (Dixon, 2002) and related software packages. They examined the effect of thinning and fuel reduction scenarios on forest structure, composition, and potential wildfire behavior in a wildland–urban interface along the boundary of the INLAS study area. Their analyses showed that treatments were effective in reducing stand characteristics that contribute to stand replacing fire. However, to be effective over the long term, treatments needed to cover much of the area and be repeated in each subsequent decade. Ager et al. (2007b) also used the FVS-based approach to examine the interactions between forest thinning, bark beetle impacts, and wildfire potential. Thinning increased the relative proportion and size of host tree species within stands so that tree mortality caused by the bark beetle was greater during a simulated beetle outbreak in thinned stands than in unthinned stands. This mortality did increase surface fuel loadings and the potential for stands to sustain crown fire, but these effects were small relative to the effects of thinning.

Forest managers charged with reducing crown fire potential have been challenged by the complexity of possible management options, especially difficulties in determining the optimum combination of entries, the timing of entries, and the type of treatments applied to a stand to best meet management goals. Graetz et al. (2007) demonstrate the capability of a dynamic programming based algorithm to find near-optimal solutions to reduce crown-fire hazard by managing for two stand attributes, canopy base height and canopy bulk density. The model derived long-term prescriptions that achieved a relatively low crown-fire potential over the projected 100-years timeframe for a wide variety of stands in the INLAS project area. Results of the study illustrated the potential use of optimization methods in designing forest-management strategies and scheduling management activities to reduce crown fire hazard.

The risks that wildfires pose for homes and other structures are a major concern of public lands policy and management. Kline et al. (2007) projected future building densities likely to occur from development on privately owned forest and rangelands. They examined three regions in eastern Oregon to better account for regional socioeconomic factors that influence forest and rangeland development. Model projections suggest that future building development could be relatively limited within the upper Grande Ronde River watershed owing to poor physical access to the area from major population centers, as well as historically slow rates of population growth. However, the results also raise conceptual and methodological questions about how best to anticipate future development in rural locations when past growth rates provide few clues with which to evaluate potential future trends.

3. Beyond INLAS

The INLAS project demonstrated some of the complexities involved in integrated landscape planning. Projecting outcomes of alternative management scenarios will always be difficult because of complex interactions among management activities, forest succession, and natural disturbance. However, these particular factors were successfully addressed by the mid-scale planning tools developed and applied in the INLAS project. These tools enabled incorporation of multiple factors in a landscape-level analysis of how policy and management may influence forests and related ecological and socioeconomic systems. The pilot application in the upper Grande Ronde River watershed established that the INLAS planning tools can contribute to multi-resource, multi-owner, landscape-level analyses.

Some of the INLAS tools have already been expanded or adapted for use in other assessments. For example, the analysis framework refined by Ager et al. (2007a,b) is being coupled with landscape-scale wildfire simulation models to provide a framework for analyzing landscape wildfire risk and developing efficient mitigation strategies (Ager et al., in press). This modeling approach is being applied in several ongoing environmental assessments. The Ager et al. case studies also led to the integration of Forest Service vegetation and wildfire models within an ArcGIS interface, a package that is now being incorporated into nationwide training programs for the Fireshed Assessment process (McDaniel, 2006). The STM models linking natural disturbance, plant succession, and vegetation management (Hemstrom et al., 2007; Vavra et al., 2007) are being used in the Interagency Mapping and Assessment Project—a cooperative effort between the USDA Forest Service, USDI Bureau of Land Management, the Oregon Department of Forestry, and the Nature Conservancy. This project is developing and demonstrating methods for the upcoming State-wide Oregon Forest Assessment, land management plans, and ecoregional analyses. Some INLAS supporting research, such as Kline et al. (2007), also are informing that effort.

Analysis of management effects on some resources proved difficult. In general, the more resource responses were directly tied to forest structure and composition, the more successful were attempts to project the effect of management activities on these resources (e.g., Wales et al., 2007). In contrast, where the links between upland forests and resources of interest were weak or poorly understood, attempts to project the effects of management activities on those resources were also difficult (e.g., Wondzell et al., 2007). Further, integrating linear-network features, such as roads (Aitken and Hayes, in press) or streams and their riparian zones into analyses of planar landscapes contributed additional difficulties. As a result, many components of the INLAS project were not well integrated into the landscape analysis. Given the persistent desire for information with which to anticipate the effects of policy and management practices at landscape-levels, conducting broad-scale and multi-disciplinary research evaluating those effects will remain a critical challenge in landscape planning on public lands in the western United States.

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