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Moving to the Big Picture: Applying Knowledge from Landscape Ecology to Managing U.S. National Forests

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7.1. INTRODUCTION

United States National Forests encompass 77.7 million ha (192 million acres) of grasslands and forests, which comprise 7% of the nation's total land base and 20% of the nation's forested lands. Increasing demand for wood has raised concerns about producing forest products without impeding the land's ability to provide a variety of other renewable goods and ecosystem services (Aber et al. 2000). Land-use conflicts often arise that result in challenges to forest plans and, in many cases, costly and time-consuming litigation. A more comprehensive planning and management approach is needed that allows public lands to generate multiple values and benefits. Landscape ecologists are among those contributing concepts, perspectives, and information to help meet this need (e.g., Forman 1995; Lindenmayer and Franklin 2002; Liu and Taylor 2002; Wiens and Moss 2005).

The science of landscape ecology is applied to planning and managing the U.S. National Forests in at least six broad areas: National Forest planning, regional and national resource assessments, analyses of landscape and regional change, integrated landscape management, emulating natural disturbance in forest management, and managing roads. In this chapter, I explore the transfer of knowledge and technology from the science of landscape ecology to National Forest planners and managers in each of these topic areas. Because National Forests are part of broader landscapes with multiple ownerships, I do not focus solely on federal lands in this chapter. Indeed, a critical question concerns the role that public lands play and the unique opportunities they provide within the broader landscape context, which is characterized by multiple ownerships and varied management objectives.

To be consistent with other chapters in this book, I distinguish among technology transfer (tools, data, models), knowledge transfer (concepts and principles), and the process of transferring or communicating these tools and concepts. The transfer of knowledge and technology from science into practice ranges from informal and individual to formal events with broad participation and a national scope. In some cases, old but proven technologies have been utilized, such as revised timber management guides that include a landscape perspective (e.g., Gilmore et al. 2004); in other cases, new technologies are being employed, such as computer visualization (e.g., Wang et al. 2006), succession and disturbance simulations (e.g., Chew et al. 2004; Keane et al. 2002), or Web-based interactive models (e.g., HARVEST LITE; Gustafson and Rasmussen 2002). Throughout this chapter, examples of approaches are presented for transferring knowledge and technology into practice.

7.2. NATIONAL FOREST PLANNING

7.2.1. Background

The National Forest Management Act of 1976 commits the USDA Forest Service to managing National Forest lands according to land and resource management plans that provide for multiple uses and sustained yield of renewable resources. Currently, these plans—commonly called “forest plans”—are being revised. A “landscape perspective” is evident in these revisions. Specific topics in which concepts from landscape ecology are currently contributing to planning include:

- practicing stewardship across ownership boundaries
- using ecosystems as fundamental management and planning units
- allocating multiple uses in time and space
- managing landscape composition and structure to meet diverse management goals
- quantifying the cumulative impacts of local practices at larger spatial and temporal scales
- planning and managing at multiple spatial and temporal scales
- considering the social, economic, and ecological contexts in forest planning and implementation of the plans

7.2.2. Examples

Many issues common to forest planning—including management of old-growth forests, protection of threatened and endangered species, preservation of forest health, prevention of wildland fire, and wilderness management—necessitate broad-scale approaches to resource management. The Northwest Forest Plan, for example, addresses management on federal lands (including USDI Bureau of Land Management and National Parks land, and USDA Forest Service National Forests) across 9.7 million ha (24 million acres) in three states—Oregon, Washington, and northern California, defined primarily by the range of the northern spotted owl (*Strix occidentalis caurina*)—where federal lands are designated as either protected reserves or matrix lands that can be harvested (FEMAT 1993). The Plan is an early attempt at a comprehensive, ecosystem-based approach to public land management—that is, managing whole systems, including local, landscape, and regional ecosystems, and broad assemblages of plants and animals—meshed with the more common emphasis on individual forest stands and individual species, such as the northern spotted owl and the marbled murrelet (*Brachyramphus marmoratus*; Diaz 2004, FEMAT 1993). I consider the Northwest Forest Plan along with other regional and national resource assessments in more detail later in this chapter.

A landscape perspective is also apparent in the Chief of the USDA Forest Service’s list of perceived threats to the nation’s forests. Among these threats is the loss of open spaces, which includes fragmentation caused by land development and especially by the urbanization of private lands within and near public forests. Increasingly, National Forests are becoming islands of wild and semiwild land embedded within a matrix of developed lands. Agency managers recognize that landscape change outside the boundaries of National Forests has important implications for management within their boundaries.

Concepts and principles from landscape ecology are helping managers to address other perceived threats as well—forest health threats, wildland fire, invasive species, and use of off-road vehicles, among others. Each of these threats requires approaches that allow managers and planners to consider spatial relationships. For example, the Healthy Forests Restoration Act of 2003 (P.L. 148-108; http://www.healthyforests.gov/initiative/legislation.html) directs the USDA Forest Service and USDI Bureau of Land Management to plan and conduct projects to reduce hazardous accumulation of fuels so as to reduce the risk from wildfire and to improve forest and rangeland health. A critical question related to implementing this Act concerns a spatial element: where in the landscape should fuel reduction treatments be applied to maximize their benefits? Research conducted on predicting forest fire behavior and effects at the landscape level (e.g., Finney 1999; Gardner et al. 1999) has helped to address this question, but efforts to date have failed to provide managers with the tools necessary to more fully consider the various trade-offs when altering the composition, structure, and function of landscapes for a single purpose—to defuse the fire bomb.

Furthermore, there are questions related to assessing the effectiveness of fuel-reduction treatments. By necessity, treatments are local in their application, but there is increasing recognition that factors operating at the regional, subcontinental, and even continental scales are shaping local conditions (Hansen et al. 2001; Neilson 1995; Swetnam and Betancourt 1990). An important lesson learned from addressing the Chief's four threats, including forest health and fires, is the need to manage natural resources at multiple spatial and temporal scales. None of these threats can be resolved at a local scale alone nor can any of the threats be resolved independently of other important natural resource issues that are often regional or national in scope.

A spatial framework for management treatments, including fuel-reduction treatments, is a precursor for an ecosystem-based approach to land management (Crow 2002). Spatially explicit landscape models provide a means for adding this framework. Most spatial models, however, are designed as research tools and relatively few are available with "off the shelf" capabilities for management and planning. One such model is SIMPPLLE, the acronym for Simulating Patterns and Processes at Landscape Scales, which was designed primarily as a management and planning tool to formally incorporate spatial considerations into designing and evaluating land management alternatives over a range of spatial scales (Chew et al. 2004). The model is designed to:

- use existing inventory data, where possible, as the input in a polygon or grid format, with ArcView and ArcGIS extensions providing spatial outputs
- treat disturbances as probabilistic events
- distribute disturbance spatially within the landscape
- quantify the range of variability for vegetation conditions and disturbance processes
- simulate interactions among disturbances and vegetation patterns
- project future conditions under a variety of management options
- integrate knowledge from research with expert opinion

Terrestrial and aquatic ecosystems are recognized in the model, with terrestrial ecosystems including both forests and grasslands. Linkages between SIMPPLLE and scheduling and optimization models such as MAGIS and SPECTRUM can aid in evaluating alternative management scenarios (Zuuring et al. 1995). For example, SIMPPLLE can be used to assess health risks within the landscape based on the interactions among multiple stressors, then MAGIS can be used to schedule management activities to reduce the perceived risk to forests. The application of SIMPPLLE is required as part of management plan revision by the USDA Forest Service and the USDI Bureau of Land Management in Montana and Idaho (J.D. Chew, USDA Forest Service, Rocky Mountain Research Station, personal communication).

The timber harvest allocation model HARVEST is another example of a landscape model designed for practical application (Gustafson and Crow 1996). HARVEST provides a visual and quantitative means for predicting the spatial patterns produced by even-aged harvesting strategies. Timber harvests are allocated using a digital stand map in which the values for each cell in the grid represent stand age. The modeler specifies the size distribution of the harvests, the total area of forest to be harvested, the rotation length, and the width of buffers between adjacent harvested areas. HARVEST has been used to project landscape patterns under alternative forest plans for the Hoosier National Forest in Indiana (Gustafson and Crow 1996). The initial forest plan called primarily for clearcutting to be distributed across most of the National Forest; an amended plan featured group selection (harvesting in small groups) across a limited portion of the National Forest. HARVEST provided the means for projecting the landscape patterns produced under these two management scenarios over several timber rotations. As expected, these scenarios created two very different landscapes in terms of patch-size distribution and the amount of forest edge and forest interior that is present.

7.2.3. Challenges

Each application of a management or planning model offers an opportunity to transfer technology (e.g., Gustafson et al. 2006) and knowledge (e.g., Lytle et al. 2006) into practice. This transfer takes place in a variety of venues, from formal training sessions for managers conducted by modelers to joint projects involving researchers and managers in applying models such as SIMPPLLE and HARVEST to forest management planning. A Web-based model, HARVEST LITE (Gustafson and Rasmussen 2002), is now available that allows users to easily compare alternative harvesting strategies by changing harvest size, spatial distribution, and intensity (expressed as the area harvested per decade) within the limited range of simulated landscapes. By using these landscapes and limiting the amount of model parameterization, users can easily evaluate and compare a large number of management scenarios. This hands-on approach has been especially effective in workshops and training sessions for managers, where the model becomes the means for visualizing the outcomes of management decisions at a landscape level.

Successful implementation of the Healthy Forests Restoration Act of 2003 requires the USDA Forest Service to implement a major effort in technology and knowledge transfer. In support of these national-level transfer efforts, practical guidelines are being developed and presented as "desk guides" for managers. As with all national efforts, guidelines must be flexible enough to allow for differences in local conditions and sufficiently detailed to provide useful guidelines for application in the field. Meeting these standards is one of the main challenges in transferring knowledge into practice.

7.3. REGIONAL AND NATIONAL RESOURCE ASSESSMENTS

7.3.1. Background

The USDA Forest Service and other federal and state agencies have conducted numerous broad-scale biophysical and social assessments (Table 7.1) in response to a variety of issues and needs (Jensen and Bourgeron 2001; Johnson et al. 1999). In doing so, planners and managers are thinking beyond the boundaries of their National Forests, and taking into account the social, economic, and ecological contexts in which they manage public lands. The issues that provide the catalyst for regional assessments include fire danger, forest health, endangered species, and old-growth forests in assessments such as the Sierra Nevada Ecosystem Assessment in California and the Interior Columbia Basin Ecosystem Management Project (ICBEMP) in eastern Oregon and Washington, Idaho, and western Montana. The issues can also expand to include the need for considering more integrated management strategies at the stand and landscape levels, as is the case in the Ozark–Ouachita Highlands Assessment in Arkansas, Missouri, and Oklahoma, and the Great Lakes Ecological Assessment in Minnesota, Wisconsin, and Michigan (Table 7.1). Not all assessments had specific statutory mandates, but common to all assessments was a need to consider the broader landscape and regional conditions, trends, and resource issues in order to adequately plan within the boundaries of the National Forests (GAO 2000). Four of the assessments—the Northwest Forest Plan, ICBEMP, the Northern Forest Lands Study, and the Southern Forest Resources Assessment—are profiled below.

7.3.2. Examples

The Northwest Forest Plan remains one of the boldest efforts undertaken by a federal agency to implement adaptive management at the landscape and regional levels. After 10 years of this experiment in landscape and regional management on the western side of the Cascades, there has been little harvesting in either reserve or matrix lands, and as a result, Moeur et al. (2005) estimated a net increase of 251 000 ha (620 000 acres) of forest with trees greater than 51 cm (20 inches) in diameter at breast height (DBH). Despite this trend, the population of spotted owls declined on average by 3.7% per year from 1990 to 2003 (Lint 2005). Furthermore, while forests on federal lands are maturing, forests on private lands often are being intensively managed for timber, producing a contrast in forest structure between private and public lands.

The ICBEMP, initiated in 1994 and concluded in 2003, was a large, multiowner, interdisciplinary project encompassing 58.7 million ha (145 million acres) and 64 different jurisdictions, with an integrated terrestrial and aquatic assessment. The plan was implemented for public lands managed primarily by the USDA Forest Service and the USDI Bureau of Land Management (Quigley and Arbelbide 1997; Quigley et al. 1996). The issues driving the ICBEMP broadly relate to forest health and include the threats of wildfire and invasive species, as well as the protection and restoration of habitat for fish and wildlife species. Current landscapes within the interior basin are at greater risk of fire, insect infestation, and disease than under historical conditions (Hessburg et al. 1999), rangelands are highly susceptible to invasive species (Bunting et al. 2005), and aquatic systems are more fragmented and isolated than was historically the case, and are vulnerable to the introduction of nonnative fish species that threaten native species (Rieman et al. 2000). Unlike the Pacific Northwest Plan, however, the ICBEMP did not result in a formal regional plan for managing public lands; instead, the decision was made to incorporate the research findings into ongoing USDA Forest Service planning efforts. This piecemeal approach to applying the results from ICBEMP produced uneven applications at best and, in many respects, this decision negated many of the advantages offered by the landscape and regional perspective.

In 1988, Congress directed the USDA Forest Service to cooperate with several States in the Northern Forest Lands Study, which examined the timberland resources in northern New York, Vermont, New Hampshire, and Maine in order to assess the current condition of the forest resources and to develop alternative strategies that would protect the long-term integrity and traditional uses of the land (Harper et al. 1990). There were concerns about the future of the 10.5 million ha (26 million acres) of mostly private forest land in this four-state area of the United States. Changes in land ownership—specifically, the fragmentation of ownership in which large blocks of private forested lands were being subdivided into smaller parcels and, in many cases, developed to provide second homes and other residential uses—threatened the long-term integrity and traditional land uses in many parts of New England and northern New York. Within the Northern Forest Lands area, land adjacent to lakes and rivers and land with a scenic vista (such as ridge tops) are the most vulnerable to changes in land use. Proximity to highways and secondary roads also increases the likelihood of development. In their final report to the U.S. Congress and State Governors, the Task Force responsible for the study identified the important natural resources of the region, and established priorities and guidelines for conserving these resources at the landscape and regional levels (Harper et al. 1990). Twenty-eight conservation strategies were proposed for six broad areas: using land-use controls and planning for conservation, using easements and land purchases to meet conservation goals, maintaining large contiguous tracts of forest ownership by providing incentives to not fragment the land, combining community

Table 7.1. A summary of recent regional assessments conducted by the USDA Forest Service and their partners

Regional assessments	Area	Partners[a]	Mission
Forest Ecosystem Management Assessment (Northwest Forest Plan)	West of the Cascades divide in Washington, Oregon, and northern California	USFS, NOAA, National Marine Fisheries, BLM, F&W, NPS, and EPA	Define an ecosystem-management approach to sustain biological diversity, maintain long-term site productivity, and sustain natural resources, including timber.
Interior Columbia Basin Ecosystem Management Plan (ICBEMP)	58.7 million ha (145 million acres) of the Columbia Basin east of the Cascades crest	USFS, BLM, EPA, NOAA, and F&W	Provide the scientific basis for managing public lands in the Interior Columbia Basin to meet community needs in an ecologically sustainable way.
Southern Appalachian Assessment	15 million ha (37 million acres) from West Virginia and northeastern Virginia to northwestern South Carolina, northern Georgia, and northern Alabama	Southern Appalachian Man and Biosphere (SAMAB) Program	Summarize what is known about the regional ecosystems (their air, water, land, and people), and identify current and emerging resource-management problems.
Great Lakes Ecological Assessment	20.6 million ha (51 million acres) in Minnesota, Wisconsin, and Michigan	USFS, EPA, NRCS, NBS, States, and universities	Define scope and context for major resource management issues. Provide information about current status of regional forests to promote collaborative planning.
Sierra Nevada Ecosystems Project (SNEP)	The entire Sierra region of California and Nevada, including 11 National Forests (40% of the area)	Independent panel (i.e., non-USFS) of scientists	Assess the health and sustainability of the Sierra Nevada forest ecosystems. Provide strategies for protecting the health and sustainability of the forest while providing for human needs.

Northern Forest Lands Study	10.5 million ha (26 million acres) in Maine, northern Vermont and New Hampshire, and northeastern New York	States of Maine, Vermont, New Hampshire, and New York	Document recent changes in land ownership and land use that can be used for developing a common vision for the future of the regional forests.
Southern Forest Resource Assessment	Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Florida, Alabama, Mississippi, Louisiana, Arkansas, and eastern Texas	EPA, USGS, ACE, NPS, NBS, TVA, ORNL, F&W and States	Provide information about the current status and project likely future conditions of the regional forest in the South to enhance planning and management of the resource.
Ozark–Ouachita Highlands Assessment	107 counties, including 2.6 million ha (6.5 million acres) of state and federal lands in Arkansas, eastern Oklahoma, and southern Missouri	USFS: Eastern Region, Southern Region, North Central Research Station, and Southern Research Station	Characterize current status and trends within the study area for social and economic conditions; aquatic and terrestrial vegetation and wildlife; and air quality.

[a] ACE, Army Corps of Engineers; BLM, Department of the Interior, Bureau of Land Management; EPA, Environmental Protection Agency; F&W, Fish and Wildlife Service; NBS, National Biological Service; NRCS, U.S. Department of Agriculture, Natural Resources Conservation Service; NOAA, National Oceanic and Atmospheric Administration; NPS, National Parks Service; ORNL, U.S. Department of Energy, Oak Ridge National Lab; TVA, Tennessee Valley Authority; USFS, U.S. Department of Agriculture, Forest Service; USGS, U.S. Geological Service.

development with land conservation, keeping private land accessible to the public, and developing coordinated regional plans.

The recommendations of the Northern Forest Lands Plan were presented to nearly 1000 people who attended 21 public meetings (Harper et al. 1990). A consistent message throughout the study was the need for greater coordination and cooperation between public and private forest owners in planning and management at the landscape and regional levels. The goal of this effort was not to create new regulations, but rather to inform stakeholders and create the public awareness that is the prerequisite for political action.

The Southern Forest Resource Assessment was initiated in 1999 because of an expressed desire by natural resource managers, scientists, and the public to better understand current conditions as well as the forces shaping the future forest in the South (Wear and Greis 2002, 2003). Thus, the Southern Forest Assessment was not conducted in response to an immediate crisis or conflict, but rather to address long-term concerns about the effects of rapid urbanization of forested land, increasing demand for timber, declining forest health, and increasing air pollution on the future of the region's forests. As with most regional assessments, federal, state, and local partners participated (Table 7.1). Among the 81.3 million ha (201 million acres) of commercial forested land in the South, 89% is privately owned (Wear and Greis 2002). Ownership by timber companies has decreased during the past several decades, while ownership by investment companies has increased.

During the past 25 years, both timber harvesting and urbanization of timberlands have increased dramatically in the South, but neither can continue to increase indefinitely. Furthermore, invasive species, including diseases and insects, are having a significant impact on the health of southern forest ecosystems. Urbanization could also increase these impacts (Wear and Greis 2002). An important finding drawn from the assessment is the conclusion that "urbanization presents a substantial threat to the extent, condition, and health of forests." Among the forces of change in forested land, urbanization will have "the most direct, immediate, and permanent effect" at the landscape and regional levels (Wear and Greis 2003, p. 92).

A periodic national assessment of forests in the United States is required by the Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974. These periodic surveys provide information about the current status of the nation's forests as well as trends in their condition. The most recent national assessment, in 2002, was the fourth national assessment to be conducted, and covered a variety of topics. These included: conserving biological diversity, maintaining the productive capacity of forest and rangeland ecosystems, maintaining forest health and vitality, contributing to carbon sequestration, meeting the needs of society, and the legal, institutional, and economic frameworks for conserving and sustaining forests (USDA Forest Service 2001). RPA reports provide information about historical and projected supply and demand for timber at regional and national scales. For years, these reports have been effective in shaping perceptions about future commodity demands and supplies at these spatial scales. These perceptions, in turn, help guide forest policy in National Forests, and for that matter, in all forest ownerships in the United States.

Regional assessments provide an ideal perspective for identifying ecosystems at risk. In the Southern Forest Assessment, a total of 14 critically endangered forest ecosystems were listed as having been greatly reduced in their extent since European settlement. Among these are old forests of all types, high-elevation spruce–fir (*Picea–Abies*) forests, a variety of wetlands, bog complexes and pocosins (bogs that form in shallow, nondraining depressions) throughout the South, bottomland and flood-plain forests, open lands (including glades, barrens, and prairies), and long-leaf pine (*Pinus palustris* Mill.) forests and Atlantic white cedar (*Chamaecyparis thyoides* L.) swamps (Wear and Greis 2002). Given the ownership patterns in the South, most of these at-risk ecosystems (with the exception of old forests and high-elevation spruce–fir) occur on private land, so conservation strategies necessitate the involvement of multiple owners.

Landscape ecologists stress the importance of spatial context when evaluating local management opportunities. Although public ownership, including National Forests, represents only a small portion of the South's commercial forests, it provides unique ecological and social values within the region. When viewed at a regional level, public lands provide much of the interior (nonedge) forest habitat and a disproportional amount of the mature forests in the South. These represent both opportunities and responsibilities for public land managers.

7.3.3. Challenges

Regional assessments are an essential part of the National Forest planning process. They provide critical information for making local decisions and for setting the management direction for obtaining the desired future conditions within a National Forest's boundaries. There is, however, no clear legal mandate to conduct these assessments, funding to conduct regional assessments is often limited, and National Forest supervisors are not obligated to formally incorporate regional findings into their forest planning. In a recent study of USDA Forest Service planning and the Great Lakes Ecological Assessment (GAO 2000), the United States General Accounting Office (GAO) concluded that better integration of broad-scale assessments is needed for National Forest planning. The GAO report makes a number of useful recommendations to maximize the value of broad-scale biophysical and social assessments in forest planning (Table 7.2).

Conveying the information contained in these regional assessments to a variety of audiences, from professional land managers to the general public, is an ongoing challenge. In most cases, technical reports are published and then findings are presented in public forums and in newspaper articles in order to make the results available and hopefully meaningful to the general public. In many cases, the land management issues are sufficiently contentious that press coverage is substantial but not necessarily informative. The challenge, as always, is to present complex issues in a straightforward and understandable way.

For natural resource managers and planners, the story is more encouraging. Publications such as Jensen and Bourgeron's (2001) *A Guidebook for Integrated*

Table 7.2. United States General Accounting Office (GAO 2000) suggestions for increasing the value of regional assessments in National Forest planning

Guidelines for conducting regional assessments
• Assessments should occur early in the planning process.
• The process of conducting an assessment should be open to all interested parties.
• Clear objectives and identifiable products are needed prior to conducting the assessment.
• The geographic scope of the assessment should coincide with the nature of the issues to be addressed.
• To be effective, both federal and nonfederal lands need to be included in the assessment.
• Assessments include gathering information, analyses, and conclusions, but do not include making decisions.
• Realistic estimates of costs for conducting assessment are essential.
• Secure funding, specifically for the purposes of conducting assessments and reporting the results, is essential.
• Support for regional assessments is needed at the highest levels of the organization.

Ecological Assessments and Johnson and colleagues' (1999) *Bioregional Assessments* provide useful guidelines for conducting regional ecological assessments. In both cases, the guidelines are based on the practical experience of conducting regional assessments, and the authors use case studies (e.g., Great Lakes Ecological Assessment, Northern Forest Lands, Southern Appalachian Assessment, Upper Mississippi River Adaptive Environmental Assessment) to share their experiences with professional managers and planners. Publication in professional journals is another means for transferring knowledge about regional assessments. Wear and Greis (2002), for example, provide a useful summary of the Southern Forest Resource Assessment in a *Journal of Forestry* paper, and Haynes et al. (1998) used the same journal to explore the relationship between science and management based on their ICBEMP experience.

Active programs of technology and knowledge transfer are common to regional assessments. Most assessments have technology transfer or communication plans in place; however, a formal mechanism for evaluating the effectiveness of these transfer efforts is generally lacking.

7.4. ANALYSES OF LANDSCAPE AND REGIONAL CHANGE

7.4.1. Background

An expanding program of research within the USDA Forest Service, conducted in cooperation with university researchers, is aimed at better understanding the complex interactions among changes in landscape composition and structure, the factors driving change, and the ecological, social, and economic implications of the change. A number of interrelated landscape issues—including urban sprawl, forest fragmentation, forest health, loss of open spaces, invasive species, and forest productivity—are relevant to National Forest managers.

Many factors contribute to landscape change. Schulte et al. (2003) studied changes in the composition and age structure of regional forests in the Lake States that reflected both natural and human-related causes. In Michigan, for example, the aspen–birch (*Populus–Betula*) type has decreased by nearly 0.8 million ha (2 million acres) since 1935, while during the same period, the maple–beech–birch (*Acer–Fagus–Betula*) type increased by almost 1.0 million ha (2.5 million acres). These compositional changes have implications for forest productivity and carbon sequestration. As the fast-growing aspen becomes less abundant and the slow-growing maple becomes more prevalent in the regional forest, declines in regional forest productivity are likely to occur even with significant investments in silvicultural treatments. In the Lake States, conifers such as hemlock (*Tsuga canadensis* [L.] Carr.), white pine (*Pinus strobus* L.), red pine (*P. resinosa* Ait.), and jack pine (*P. banksiana* Lamb.) have declined in abundance since the original land survey (Schulte et al. 2003). In Figure 7.1, this information on changes in the dominance of conifers is plotted for ecological units, represented in this case by regional ecosystems or sections embedded within a Province of the Great Lakes region (Albert 1995), thus providing a means for displaying large amounts of geographic information in a concise way.

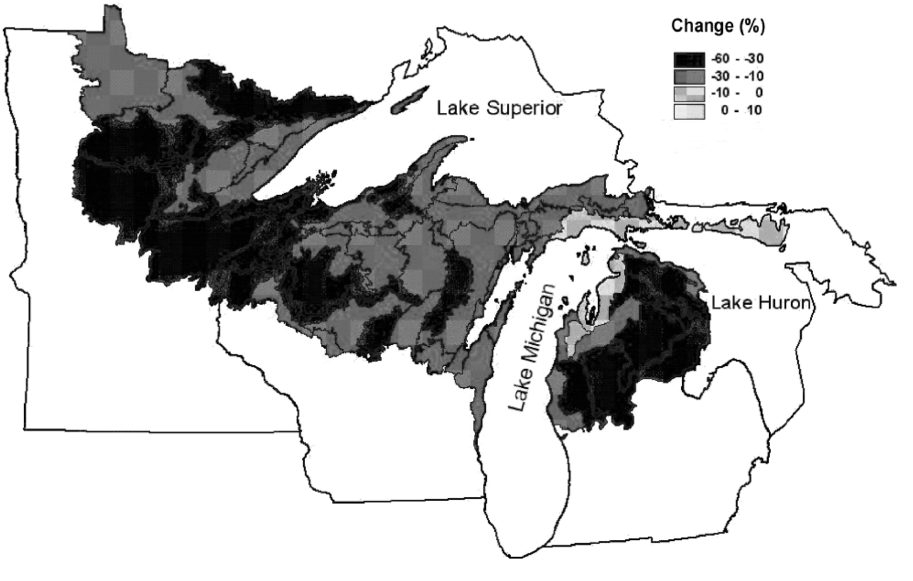

Figure 7.1. The change in the relative dominance (%) by conifers from presettlement times to the present for the regional ecosystems (sections) within Province 212 of the Great Lakes Region (Albert 1995). Presettlement values for relative dominance were based on Government Land Survey records (see Schulte et al. 2003; Schulte and Mladenoff 2001). Present values are based on Forest Inventory and Assessment (FIA) measurements.

7.4.2. Examples

The increased area of loblolly pine (*Pinus taeda* L.) plantations represents a significant change in regional forest composition. Before 1950, less than 1 million ha (2.5 million acres) of pines had been planted in the South; now there are more than 10 million ha (24.7 million acres) (Alig and Butler 2004). Higher timber prices are projected to result from the conversion of about 3 million ha (7.4 million acres) of forested land into agricultural land during the next 30 years unless there is an offsetting flow of land from agricultural production into forest cover (Alig and Butler 2004). The shifts in forest cover noted by Schulte et al. (2003) and Alig and Butler (2004) could significantly reduce regional carbon stores (Emanuel et al. 1984; Pennock and van Kessel 1997).

Changes in the connectivity of the forest landscape are also apparent. Fragmentation indices measure the extent to which patches of forest habitat have been subdivided and dispersed. Forest fragmentation is routinely influenced by human activities and is especially pervasive as a result of urbanization, agricultural activities, and timber harvesting (Riitters et al. 2000, 2002; Wade et al. 2003). Based on the analysis of land-cover maps with a 30-m resolution for the conterminous United States, Riitters et al. (2002) found that overall, 43% of the nation's forests were located within 90 m of a forest edge and 62% were located within 150 m of an edge. They concluded that this fragmentation is so pervasive that edges affect ecological processes in almost all forested land in the United States.

As mentioned in the previous section on regional and national resource assessments, a common source of forest fragmentation is an increase in the number of owners or the subdivision of larger landholdings into smaller blocks. Concerns about this process were a primary reason for conducting the Northern Lands Study and the Southern Forest Assessment (Table 7.1). The overriding concern is that this fragmentation will result in urbanization and conversion of forest and other open lands into other built-up land uses (Gobster and Rickenbach 2004). Another concern is that smaller parcels may not be economically viable for timber production (Mehmood and Zhang 2001). Although fragmentation has been occurring for a long time in the United States, the rate and extent have increased dramatically in recent years, due in large part to what Hammer et al. (2004) call the "spatial deconcentration" of human populations during the twentieth century and the associated expansion of human settlements (Figure 7.2). The net result is that small increases in human population can cause very large changes in the composition and structure of the landscape. Understanding where people choose to live provides valuable insights about the factors that drive landscape change (Dwyer and Childs 2004; Stewart et al. 2004).

7.4.3. Challenges

A great deal of information regarding landscape change has been effectively conveyed to broad audiences using Web sites. Figure 7.2, for example, is available on

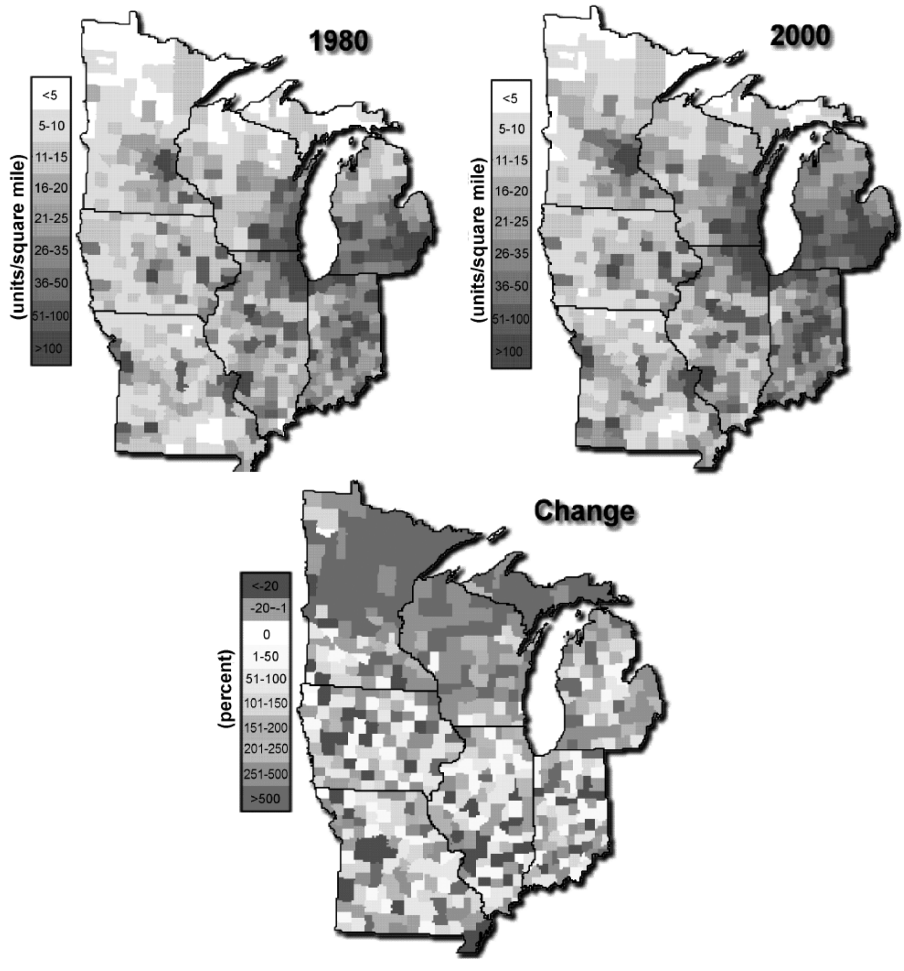

Figure 7.2. Changes in housing density between 1980 and 2000 in the north-central region of the United States. Major increases in housing density in the upper part of the region have occurred without major increases in human population because many new sites represent second homes for people already living in major metropolitan areas. Source: The Changing Midwest Assessment (http://ncrs.fs.fed.us/4153/deltawest/) (*See Colour Plates between pages 132–133.*).

the Web site for "The Changing Midwest Assessment," which is maintained by the Landscape Ecology Research Work Unit of the USDA Forest Service's North Central Research Station (http://ncrs.fs.fed.us/4153/deltawest/). Broad regional trends are readily apparent when change maps such as the example in Figure 7.2 are created. In addition to the trends, however, the implications of these trends must be articulated in terms that make sense to the public.

7.5. INTEGRATED LANDSCAPE MANAGEMENT

The term "landscape management" is now commonly used in the USDA Forest Service. The adoption of this terminology reflects the desire to improve stewardship across ownership boundaries, to better assess the cumulative impacts of many local decisions, to better understand the interactions between land and water, and to develop a more spatially defined approach to resource management. Often, the focus is on a specific geographic area such as the Greater Yellowstone Ecosystem, the Oregon Coast Range, the Chesapeake Bay Watershed, or the southern Appalachians.

The Coastal Landscape Analysis and Modeling Study (CLAMS), a large interdisciplinary effort being conducted by scientists at the USDA Forest Service's Pacific Northwest Research Station and university cooperators, supports a more holistic approach to resource management (Spies 1998). The CLAMS study area includes more than 2.0 million ha (5 million acres) of mixed ownership and is designed to help managers and planners evaluate the aggregate effects of different forest policies and practices on the ecological and socioeconomic conditions within the study area. Using both field and satellite information, researchers produce maps of current vegetation and use models to project changes in vegetation, wildlife habitat, and land use through time (Spies et al. 1994). This is a pioneering "big picture" approach to resource management across many ownerships over a large area in which federal lands such as the Siuslaw National Forest in the Oregon coastal range are only one part of the total picture. Similar studies are occurring elsewhere in the United States (e.g., the Lower Mississippi Alluvial Valley, the Chesapeake Bay Watershed) as managers give greater attention to stewardship across ownership boundaries.

Spatially explicit models of landscape dynamics are essential tools for integrated landscape management. Computer-generated animation that is developed as the output from such spatial models is especially useful for evaluating management scenarios at both stand and landscape scales (McGaughey 1998; Muhar 2001). Visualization tools have been linked to forest growth simulators, and a three-dimensional "flyover" of real landscapes is possible by "draping" GIS maps over digital elevation models (Wang et al. 2006). Although still in development, these technologies offer great potential for applying integrated landscape management and for transferring knowledge of landscape ecology. A variety of audiences, from professional land managers to the general public, can use realistic animations to simulate or understand the effects of management within a landscape. When the landscape being considered is their "home place," interest is especially high and opportunities for meaningful public participation in deciding the desired future conditions within the landscape are greatly enhanced.

The Minnesota Forest Resources Council is leading a successful effort in integrated resource management in which a wide range of interests—for example, commercial logging contractors, representatives from labor organizations, environmental interests, nonindustrial private forest landowners, tribal representatives, and State and federal agencies—are working together to delineate regional landscapes within the State, to identify principles and goals that help guide landscape-based planning and coordination, and to establish a general landscape-based planning process (see http://www.frc.state.mn.us/Landscp/Landscape.html for more information). Planning is accomplished by a volunteer, citizen-based "regional landscape committee" for each of eight regional landscapes within Minnesota. Fundamentally, the process is one of building trust and building relationships. Without these two prerequisites, there can be no landscape-based planning and coordination. Even when these conditions are present, the process can be messy. Partners can drag their feet on decisions, can passively resist, and can leave the table. This is inevitable given the imperfect nature of practicing stewardship across ownership boundaries.

7.6. EMULATING NATURAL DISTURBANCE

There is a growing interest in emulating natural disturbance and using knowledge of the landscape dynamics associated with natural disturbances as a guide for conducting management practices in National Forests in the United States (e.g., Swanson et al. 1997, Wallin et al. 1996, Wimberly et al. 2004; Zasada et al. 2004). The underlying assumption is that forest ecosystems have intrinsic properties that are related to the frequency, duration, and intensity of disturbance. If management impacts fall within the range of variability defined by historical natural disturbance, it is thought that the managed forest ecosystems are more likely to be sustainable (Landres et al. 1999). Thus, emulating natural disturbance has emerged as a means for achieving forest sustainability (Perera et al. 2004).

The general concepts that define this approach have taken several forms, including silvicultural applications (Bergeron and Harvey 1997; McRae et al. 2001), disturbance and forest dynamics (Armstrong 1999; He et al. 2004a), decision-support systems (Hessburg et al. 2004), and forest harvesting patterns (Franklin and Forman 1987; Gustafson and Crow 1996; Li et al. 1993). Landscape ecologists have made significant contributions to these topics.

The Augusta Creek Study, conducted in the Willamette National Forest in western Oregon, is a good example of applying the concept of emulating natural disturbance in the field. Here, a spatially and temporally explicit landscape plan was developed for a 7600-ha area (18 780 acres) with the primary objectives of maintaining native species, ecosystem processes, and landscape structures, and of maintaining long-term ecosystem productivity in a landscape where much of the area is allocated to timber management (Cissel et al. 1998). Although this intermediate step is a common operational step in the forest planning process, there are three aspects that make the Augusta Creek Study a useful guide for others.

First, historical fire regimes are used as the basis for vegetation management. Past fire frequencies, intensities, and spatial patterns were used as a template to guide rotation lengths, harvest rates, green-tree retention levels, and the spatial pattern of timber harvests. As in all such applications, the underlying assumption is that native species are adapted to the range of patterns created by historical disturbances. A second feature of the Augusta Creek Study is the integration of terrestrial and aquatic management objectives through the use of a landscape perspective. Specifically, the management of aquatic ecosystems was designed to be complemented by upslope management practices and patterns given both the larger landscape prescriptions and local conditions (Cissel et al. 1998). As this suggests, a third element was the linkage of management objectives across spatial scales. Local decisions were set in a regional and National Forest-scale context (Cissel et al. 1998). Such an approach is being applied in National Forest planning in the Great Lakes region and elsewhere in the United States.

Moving from concept to practice in emulating natural disturbance as a guide for forest management is hampered by inadequate knowledge (Cleland et al. 2004). Disturbances occur at widely different magnitudes, frequencies, and intensities and these differences produce varied responses and outcomes. For example, at many locations within the Augusta Creek landscape, there is the possibility of low, mixed, or high fire severity, producing differences in the structure and composition of the vegetation. Natural disturbances are caused by many factors—including diseases, insects, wind, ice, extreme temperatures, fire, prolonged drought, landslides, and floods—that operate at many temporal and spatial scales. Furthermore, natural disturbances often interact with human-caused disturbances such as timber harvesting and other land uses (He et al. 2004b; Loehle 2004; Shang et al. 2004). Better understanding of the nature of these interactions is a critical need in landscape and disturbance ecology.

7.7. MANAGING ROADS

Roads are a pervasive landscape feature and are essential to our modern mobile lifestyle. There are 6.3 million km (3.9 million miles) of roads in the United States (Forman et al. 2003), the vast majority of which are public roads or private roads open to the public. Riitters and Wickham (2003) measured the proportion of land area within the conterminous United States that was located near roads of any type. Nationwide, 20% of the land area was within 127 m of a road and only 3% was more than 5176 m away. Such studies corroborate what is obvious through observation—a dense network of roads exists in most landscapes.

A host of natural resource issues such as access, remoteness, forest fragmentation, edge effects, and water quality relate to building and maintaining roads (Forman and Alexander 1998; Spellerberg 1998; Trombulak and Frissell 2000). Roads are channels for water and sediment, and are barriers to movement for some species and conduits for the dispersal of others. As road traffic and density increase, wildlife mortality increases due to vehicle–animal collisions. Roads increase the amount of edge in the landscape and decrease the amount of interior habitat. Road density is positively correlated with the level of environmental impact (Lee et al. 1997; Rieman et al. 2000). Although factors other than roads cause forest fragmentation (Heilman et al. 2002; Hessburg and Agee 2003), the relative contribution of roads to forest fragmentation is much higher in predominantly forested landscapes such as those of the Pacific Northwest or the Southern Appalachian Mountains where road densities are high (Riitters and Wickham 2003).

The USDA Forest Service manages a significant portion of the public road system in the United States—nearly 10% of its total length (Forman et al. 2003). Most forest roads are initially built for harvesting timber and are used secondarily to provide access for fire suppression, for recreational activities such as hunting and fishing, and for harvesting other forest products (e.g., mushrooms, conifer boughs for floral and wreath arrangements).

Road management by the USDA Forest Service is changing, due in part to inadequate funding to maintain the extensive current road network (as a result of declining timber harvesting in National Forests) and in part due to research on the effects of roads on terrestrial and aquatic ecosystems (e.g., Forman et al. 2003; Hann et al. 1997; Lee et al. 1997; Quigley et al. 1996; Rieman et al. 2000). In a speech to the annual conference of the Society of Environmental Journalists in September 2003, USDA Forest Service Chief Dale Bosworth stated that "for every mile of road we build, we decommission 14 miles of road. In the last 5 years, we've decommissioned 10,000 miles of road." Decommissioning roads on public lands is not easy. Once built, the public expects to use them and to continue to have access to the landscapes in which the roads exist.

Although there is a growing body of literature related to the ecological impacts of roads on both terrestrial and aquatic ecosystems and the organisms that depend on these systems, guidelines for building roads in National Forests largely reflect engineering and economic factors rather than ecological factors. Given the importance of roads to human communities and their impacts on the environment, a much more robust program of knowledge transfer is needed to balance the engineering and economic considerations with environmental concerns.

7.8. CONCLUSIONS

The value of a landscape perspective is recognized by managers and planners in the USDA Forest Service and most other resource management agencies. Scientists no longer need to convince them of its value. When viewed at the local level, no individual forest can provide all the benefits that are desired from a forest. When the local forest is viewed as part of a broader mix of forests and other land uses within the landscape, including old and young forests with varied compositions and structures, the choices are more likely to change from "either–or" to "and." Moving toward this model for resource management requires placing management decisions and actions into a more formal spatial and temporal framework (Crow and Gustafson 1997). Providing the support necessary for applying this spatial temporal framework to resource management should be a high priority among landscape ecologists. However, the metaphorical bridge that connects science with its users and represents all the mechanisms and tools for transferring information to and from users is currently far too narrow. Landscape ecologists need to deliver their knowledge in usable forms to managers, and to develop and distribute practical tools that can support the application of their emerging science.

The specific concepts and principles from landscape ecology that contribute to resource management in National Forests can be identified—managing at multiple spatial scales, relating spatial and temporal variability to the benefits derived from landscapes, and considering the ecological, economic, and social context when making local decisions (see Crow 2005 for others)—but the major contribution from landscape ecology is one of perspective. By this, I mean that this perspective supplements the view from within the forest (the common view) with a view taken from above the forest (the landscape view). When these two perspectives are combined, managers and planners have new and powerful insights available for resolving difficult problems.

The picture, however, should not be painted with too broad a brush. Scientific knowledge is but one source of information used in the decisionmaking process when managing resources. Differences also exist within and among regions in applying concepts and principles from landscape ecology to resource management. The fact remains, however, that resource managers are receptive to a landscape perspective because they perceive it to be useful for addressing pressing issues in resource management. Now it is up to scientists to deliver their science in a usable form to those wishing to apply it.

Acknowledgments

I am grateful to Ajith Perera and Lisa Buse (Ontario Ministry of Natural Resources), Janet Silbernagel (University of Wisconsin), Louise Levy (University of Minnesota), and an anonymous reviewer for their constructive comments on early drafts.

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