Ecosystem Management, Forest Health, and Silviculture

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Abstract.—Forest health issues include the effects of fire suppression and grazing on forest stands, reduction in amount of old-growth forests, stand structural changes associated with even-aged management, changes in structure of the landscape mosaic, loss of habitat for threatened species, and the introduction of exotic species. The consequences of these impacts can be evaluated using an ecological approach based on conservation biology and several subdivisions of ecology. These disciplines provide a basis for assessing how the forested landscape has been altered from earlier conditions and for determining the potential consequences of these changes on forest health. Forest health issues are multiscaled, and landscape approaches may be especially helpful in identifying silviculture needs and approaches for improving the forest condition. The study of reference conditions and conducting a coarse-filter analysis are especially useful for identifying how existing conditions succeed or fail to maintain a healthy forest landscape.

INTRODUCTION

Forests in most areas have been altered from their natural state as a result of human activity. These effects resulted from forest management and timber harvest, grazing, introduction of weedy and exotic species and suppression of wildfires, as well as encroachment by rural and urban development. Even though certain features of forests were adversely impacted by these activities, past treatment of forests in many cases does not result in obvious loss of tree health at the individual level, making certain ecosystem or forest health problems hard to detect. Forests that were harvested in past decades, even by clearcutting large areas, often have regenerated and are growing vigorously. In many grazed stands, trees appear to be productive. Where fire suppression has seriously altered stand structure in forest types that normally experienced fire, stands usually contain large numbers of trees that appear healthy.

Even when forests appear to be healthy, their condition may be far from ideal for sustaining their productivity and for sustaining features in the landscape important for conserving biodiversity. For example, fire suppression in ponderosa pine, caused initially by heavy grazing and later by a policy of putting out small fires, has resulted in much higher stand densities than might have occurred historically (Covington and Moore 1994). In turn, this may have contributed to outbreaks of mountain pine beetle that have been severe in some heavily-stocked stands. When fires have occurred in dense stands, they often have burned much more intensely than they would have historically, killing many trees and either resetting the stand back to the regeneration stage or even putting the site on an entirely new successional trajectory. Similar conditions are found in mixed conifer and other forest types.

At larger scales, the condition of many landscapes also has been altered in ways that have left the landscape considerably different from the historical condition. The landscape mosaic may consist of healthy forest stands, but if a significant component has been removed or reduced in occurrence, or if the landscape has been fragmented or

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unnaturally connected, the condition of the forest landscape may be far from ideal. As an example, old-growth forests have been depleted in many regions, resulting in a loss of habitat and forest function not readily substituted by other seral stages (Kaufmann et al. 1992).

The consequences of altering landscape mosaics are not completely known, but it is becoming increasingly clear that landscape pattern influences processes that operate at landscape scales. Impacts of fragmentation, including alteration in the mix, spatial extent, and spatial arrangement of seral stages, may have strongly negative effects on conserving historical biodiversity through habitat loss, isolation effects on reproduction, dispersal, and other migration processes, and population and community processes associated with edge and matrix effects (Fahrig and Merriam 1994; Saunders et al. 1991). In addition, alterations of the landscape scale pattern of distributions of stand structures may rescale keystone processes such as fire (Holling 1992; Turner and Romme 1994; Turner et al. 1993).

Some of these problems with forest or landscape conditions are apparent, but many have not been easy to recognize because many changes have been slow, and we tend to view existing conditions as normal and acceptable. The effects on forest structure and composition resulting from fire suppression went undetected for decades by most foresters and ecologists until early photographs or inventories were examined to determine how earlier stands were structured. Reductions of the old growth seral stage occurred incrementally, and it was not until old-growth forests in the Pacific Northwest became limited in extent that the amount of old growth in the landscape became an important issue. Similarly, landscape fragmentation has become a concern as a result of extensive modification of past forests and encroachment associated with road-building and population increases, particularly in mountain valleys and adjacent to urban centers (Kaufmann and Boyce 1995). In addition, forest insects and pathogens once treated as pests and stresses are now are recognized increasingly as forest regulating and control organisms (Haack and Byler 1993).

Forest management is undergoing a transition from a traditional silvicultural focus on timber production and multiple use ('utilitarian' silviculture, Kolb, this volume) to couching silviculture in an ecological approach to land stewardship (Swanson and Franklin 1992). Consequently, good silvicultural practice involves the use of silvicultural tools to address forest management in ways that place increased emphasis on sustaining or restoring conditions in the forest landscape. The challenge of forest management is to find ways to meet commodity needs while conserving ecosystem functions and long-term sustainability. Thus a critical need is for a systematic, defendable process for identifying how new management practices can help resolve ecological (e.g. forest health) problems found in present forest ecosystems and at the same time allow for commodity production without adding to or exacerbating existing problems.

EVALUATION PROCESSES

Forest management on National Forest lands focuses on ecosystems and long-term sustainability more clearly than it has in the past. Consequently, the context within which silviculture now occurs includes a perspective from additional disciplines that were not commonly addressed in earlier management. These include conservation biology and subdivisions of ecology dealing with landscapes, disturbances, and restoration. Conservation biology provides information regarding the conservation of biodiversity and factors that influence biodiversity and is often single species oriented. Landscape ecology addresses not only spatial and temporal hierarchies of scale, but also multiple levels of organization (species, communities, ecosystems). It addresses the roles of pattern, such as of seral stage and habitat type distribution, in ecosystem composition and function. Landscape ecology also focuses on processes that occur at larger scales than have been traditionally studied at tree or stand scales, such as migration of animals and plants, certain disturbances, hydrological processes, and land use. Disturbance ecology provides an understanding of the often nondeterministic way in which ecosystems change over time through disturbance phenomena such as fire, wind, drought, or insect and disease outbreak. Restoration ecology helps address the possibilities and limitations of recapturing ecosystem features lost or made rare by past human impacts on ecosystems. Thus silviculture, in the context of an ecological approach to land stewardship, requires a systematic use of information from these additional disciplines to assure that forest management meets the goals of long-term sustainability and conservation.

Ecosystem assessments are now accepted as the basis for determining the ecological status of forest and rangeland systems (Bourgeron and Jensen 1993; FEMAT 1993). A number of questions, which should be applied at multiple scales, may be addressed by the assessment process. For example, what is a reasonable model of the structure of the reference or historical landscape (stand, etc.)? What is the structure of existing landscapes and stands, and what are the consequences of differences from historical conditions? What events or practices (e.g. fires, fire suppression, logging, grazing, urbanization) contributed to the development of the existing landscape or stand structure? What are the temporal changes in landscape and stand structure, both with and without significant human impacts? How do changes in landscape structure affect species, communities, or ecosystems? What are the impacts of introduced species, or of native species that have become weedy as a result of human alteration of ecosystems? What future scenarios are probable under different types of management strategies, and what are the consequences of these alternatives on biodiversity and sustainability?

Kaufmann et al. (1994) outlined a process for an ecosystem needs assessment to identify specific ecosystem needs for conserving or restoring ecosystem structure, composition, and function. The assessment process (fig. 1) involves selecting an analysis area, evaluating the current status of the area relative to its historical condition using a coarse-filter analysis process, and then addressing rare or threatened components in the analysis area with a fine-filter analysis. While an ecosystem analysis may focus initially on a relatively small area, a complete ecosystem needs assessment ultimately must involve a wide range of spatial and temporal scales.

Reference conditions help characterize the variability associated with biotic communities and native species diversity in systems not severely impacted by human activity. They are examined to learn about the historical condition of vegetation and associated biodiversity and the ecological processes that affected them (fig. 2). Reference conditions provide critical information about the range of variability of natural conditions, or at least of conditions much less influenced by human impacts than present or recent conditions provide. A study of earlier conditions provides insight regarding soil capabilities and potential vegetation, landscape structure, natural disturbance patterns

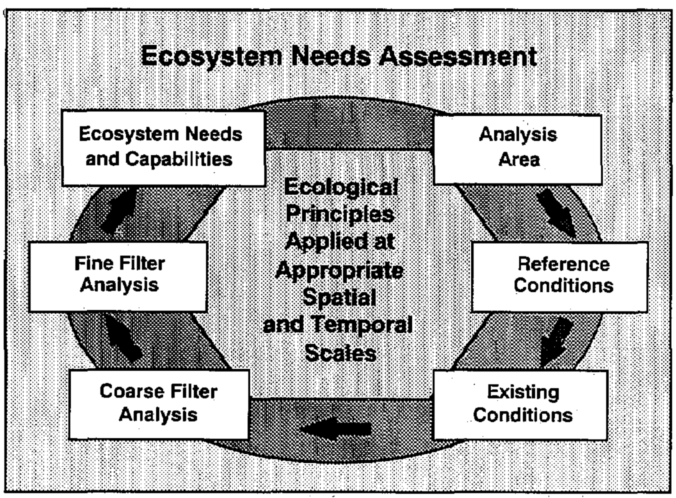

Figure 1.—Ecosystem needs assessment process for identifying ecosystem needs and capabilities in the context of ecological principles applied across spatial and hierarchical scales (from Kaufmann et al., 1994).

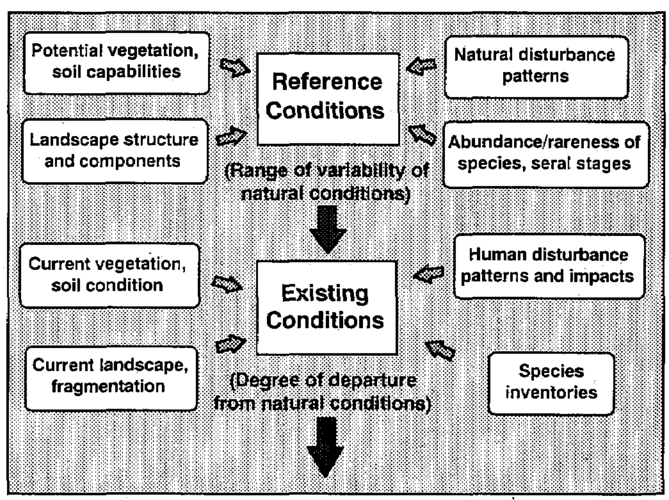

Figure 2.—Factors addressed in analyzing reference and existing conditions in the ecosystem needs assessment process.

that contribute to landscape structure, and the abundance or rareness of components of the system.

Reference information is often widely available (Kaufmann et al., 1994, Table 2). In a study of reference conditions on the Lincoln National Forest, we have assembled a large amount of information for characterizing the historical condition of the Sacramento Mountain ecosystem. Information sources include General Land Office surveys, historical timber inventories, early logging records, dendrochronological records of fire and insects, historical maps of fire occurrence and extent, etc. These information sources allow us to estimate historical forest extent, composition, and structure, and the extent and intensity of natural disturbance phenomena such as fire and insect outbreaks. While pre-European human influences may have been large in some areas, archeological evidence also may indicate relatively limited early human impacts in other areas, and in these areas knowledge of conditions at the time of European settlement may be especially instructive.

Information on existing conditions is available from more obvious sources such as existing inventory records, aerial photographs, etc. Increasingly these data are available in GIS formats that lend themselves to multiscale, spatially explicit analyses. The assessment process involves the development and use of three types of maps. Base maps characterize the biophysical environment, including both physiographic and environmental information. Maps of historical and existing ecosystem patterns provide an understanding of species and community distributions and disturbance events such as land use changes and fire, and their changes over time. Maps of historical and existing conditions must be developed in appropriate ways to avoid differences in criteria that confound map comparisons. Derived maps are often developed as research tools for examining and modeling species and community responses to disturbance, simulations of probable future ecological scenarios, etc.

The weakness of using only existing conditions in the assessment process is that existing conditions provide no or very limited insight into the impacts of management practices or other human impacts on ecosystem sustainability and conservation of biodiversity. It is incorrect to assume that existing conditions indicate a sustainable, healthy basis for identifying desired conditions; they may, in fact, indicate the opposite. Thus the comparison of existing conditions with reference conditions is critical for determining the degree of departure of existing conditions in the landscape from historical conditions. Whether or not we use reference conditions as a template for future landscapes, reference information provides important knowledge needed to avoid pitfalls in management practices that often have led to poor landscape or ecosystem conditions such as unsustainability, reduced productivity, and reduced biodiversity.

Coarse-filter analyses are used to evaluate how well the existing landscape mosaic provides the mixture and spatial distribution of habitat types and seral stages expected under more natural conditions (fig. 3; Bourgeron and Jensen 1993). It is argued that the proper mixture and arrangement of vegetation in the landscape protects 85–90 percent of biodiversity (Hunter 1990, 1991). Thus the coarse-filter approach provides a basis for determining, for example, how much old growth should exist in an area, how it should be distributed spatially, and whether or not adequate amounts and appropriate spatial distributions of old growth presently exist. Using the old growth example, it is probably incorrect to assume that historical forested landscapes were entirely in an old growth condition, especially in regions influenced by large scale disturbances such as fire and wind. It is also

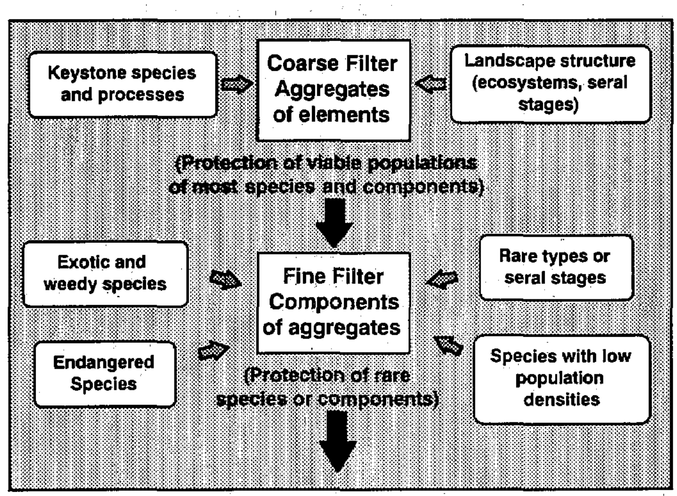

Figure 3.—Factors addressed in the coarse-filter and fine-filter steps of the ecosystem needs assessment process.

probably incorrect to assume that only 5 or 10 percent of historical landscapes was dominated by old forests, as often prescribed in Forest Plans. The coarse-filter analysis of reference conditions helps determine the extent of forested landscapes that were old-growth without intensive logging and unnaturally large scale catastrophic fires, and comparison with existing conditions helps determine if an ecosystem need exists to bring the old-growth component into closer alignment with the historic ecosystem condition.

The fine-filter analysis is concerned with specific components of ecosystems that are uncommon or rare. The usual concern addressed by the fine-filter analysis is rarity of specific species, seral stages, or habitat types. However, the process may be equally useful for assessing the introduction of exotic species or for evaluating how endemic species become weedy through changes in habitat conditions. In either case, the fine-filter approach focuses on ecosystem or landscape components not observed or measured by the coarse-filter analysis.

Underlying the analyses of reference and existing conditions with the coarse- and fine-filter approach are principles of conservation biology (Kaufmann et al. 1994; Grumbine 1992, 1994) and information and approaches from the other aspects of ecology previously discussed. These principles help assure that species, habitats, and processes are protected by focusing on sustaining ecosystem structure, composition, and function. The principles and analyses do not focus simply on one spatial scale such as a stand. Rather, the principles and analyses are applied hierarchically over space and time using approaches and ideas from landscape ecology, with precautions regarding the blending of information derived from and pertinent to the various scales. This increases our understanding of the impacts not only of past changes in forested ecosystems and landscapes, but also the likely future changes, particularly those brought about by management practices and population increases.

The outcome of the ecosystem needs assessment process is the identification of ecosystem needs. These needs focus specifically on the ecological features of ecosystems and landscapes that are found to need attention for conserving or restoring the condition of these systems. They are not meant to address the economic and social elements that enter into decision deliberations. The advantage of the ecosystem needs assessment process is that it provides an evaluation of ecosystem and landscape well-being independent of economic and social concerns, and it allows for a specific focus on ecosystem sustainability and protection of biodiversity. Thus the ecosystem analysis process helps determine, for example, what should be done to ecosystems to provide or protect adequate mixtures of seral stages in the landscape, protect or restore riparian areas, restore critical habitat for threatened species, protect against negative impacts of introduced species, or guard against negative effects of urban encroachment.

Ecological, social, and economic needs are blended in the decision-making process (Kaufmann et al. 1994). It is in this process that the consequences of various courses of action are considered. The use of ecological guidelines in making decisions helps focus on meeting economic and social needs in ways that lead to biological integrity of ecosystems and ecological, economic, and social sustainability (fig. 4). This approach also helps identify the trade-offs and ecological costs of operating outside the ecological capabilities of ecosystems (Allen and Hoekstra 1994). These include the loss of species, degradation of environments, social dissatisfaction, and economic instability.

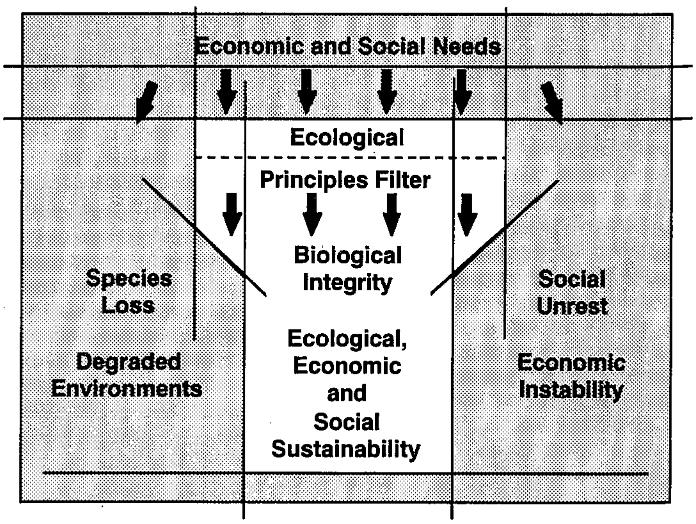

Figure 4.—Consequences of meeting economic and social needs in ways consistent with or inconsistent with ecological principles (from Kaufmann et al., 1994).

SILVICULTURE BASED ON AN ECOLOGICAL APPROACH FOR LAND STEWARDSHIP

The ecosystem needs assessment process often may identify specific changes recommended in the landscape to maintain or improve the forest or landscape condition. The adjustments may involve treatments of structure or composition of forest stands that would contribute to the restoration of healthy conditions or that would assure production of goods and services while sustaining the structure and function of healthy ecosystems.

Clearly the context for silviculture has changed. It is no longer acceptable for forest management practices to focus on wood production without considering the long-term consequences related to ecosystem sustainability. On the other hand, standard silvicultural practices such as tree removal and the use of prescribed fire may be entirely appropriate tools to accomplish ecosystem goals, provided they are used innovatively to meet prescriptions for forest stands based upon specific ecological goals and maintaining sustainability. These innovations may include, for example, live tree retention, aggregation of harvest areas to allow higher proportions of interior species, manipulations conserving the forest/stream relationship, and evaluations based upon residual diversity rather than residual stand density (Franklin 1989; Swanson and Franklin 1992). Thus ecosystem-based silviculture may result in significant on-the-ground treatment of forest stands where the primary reasons may involve non-traditional factors such as conservation of habitat types or seral stages, restoration of landscape components and processes, or emphasis on natural disturbance processes at both large and small scales.

The challenge to everyone concerned with the management of forested ecosystems is to determine how silviculture can and must play a role in regulating the conditions of forest systems such that their ecological integrity is conserved or restored, and where possible to provide for the safe production of useable goods from those systems. While to some degree and in some locations this shifts the traditional commodity-oriented goals of silviculture to a more secondary role than in the past, the silviculture profession provides many of the tools for accomplishing the changes identified in assessment processes as necessary for sustaining ecosystems for the future.

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