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New Approaches to Forest Management

Background, science issues, and research agenda

The first part of this article, published in January, examined the scientific, management, and social factors that have contributed to the need for rethinking some basic precepts of forest management. This second part outlines a framework for research and suggests some directions and approaches that must be more fully developed by scientists from many disciplines.—Ed.

Part Two of Two Parts

Given the wide range of issues encompassed by concerns over forest management, a conceptual framework must be developed to identify the scope of necessary research, to lay out key research objectives and approaches, and to assign priorities to research tasks. An overarching framework is needed to provide a common language, frame and test hypotheses, and communicate the results. This framework must accommodate currently prominent issues and must lead us forward—that is, make productive sense of the results of science.

A systems approach, which has a broad and deep tradition in ecology and economics, helps clarify complex issues and couches them in terms accessible to a broad scientific community (Watt 1966, Smith 1970, Shugart and O'Neill 1979, Boyce 1985). The systems approach is especially appropriate to integrate the contributions of many disciplines and focus on common or compatible hypotheses.

Definition of Terms

We begin with the premise that a forest ecosystem can be described in terms of its states, stocks, and flows. A *state* describes the condition with respect to certain observable attributes measured at a given moment. Key attributes are age, structure, and composition of vegetation; type, abundance, and distribution of wildlife; and type, magnitude, and distribution of human benefits. Old-growth, for example, is a forest condition defined by an age-class of vegetation, structure of forest canopy, volume of dead and downed woody debris, and other attributes; old-growth is trees, other vegetation (including decaying material), birds, mammals, and other organisms and the manner in which they associate and interact in communities. No single measure, such as age, is sufficient to describe it (Franklin et al. 1981). Similarly, other states can be identified by condition and consequent processes.

Old-growth is a state with tremendous popular appeal; however, other states are equally important to forest ecosystem processes and to forest-dependent organisms. The limited nomenclature of states reflects the fact that little attention has been paid to describing or defining them. State descriptions depend on spatial scale; particular states may not be meaningful at all spatial scales, but all states are scale-dependent. An old-growth stand, for example, will have a different collection of attributes than will an old-growth landscape. Although some state definitions are distinctive and somewhat intuitive in their meaning (such as old-growth), others are less clear and for convenience may be defined as discrete conditions along a continuum. By definition, each state is a distinct and unique collection of attributes; however, one or more attributes may have equivalent values in one or more states.

Ecosystems change states over time in response to both successional and disturbance forces; disturbances include human management as well as natural events such as fire, disease, and insects. Factors that develop slowly, such as atmospheric pollution and climate change, are less obviously "disturbances" in the same sense, but are likely to affect both successional and disturbance processes.

One obvious model for this discussion is the successional stages of plant communities; in fact, a terminology and topology of states developed within our current understanding of forest succession would provide the basis for examining interactions among conditions, processes, spatial and temporal scales, and disciplines. The essential difference from traditional modeling (e.g., Shugart and West 1980) is that humans are included as an integral part of the system.

A given state supports various stocks and flows. *Stocks* are quantities of resources per unit area (e.g., number or volume of standing trees, density of spotted owls or pine martens, miles of trail). Stocks are likely to be among the attributes useful in defining a system's state. *Flows* are the periodic yields from the stock of the system (water or sediment discharge, annual production of fiber, annual smolt escapement, forest-dependent jobs). Stocks can be viewed as the "capital" of the system (Costanza et al. 1991, El Serafy 1991), flows the income produced by this capital.

Organization and Focus

Forest science has historically developed tools and methods for manipulating stocks and flows without much attention to states. This emphasis reflects society's

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Research is needed on how and why specific ecosystems and landscapes change over time.

general perception that forests are primarily sources of commodities for human consumption—tangible flows separable from the system and often characterized in economic terms. Some of the most visible (and volatile) political issues in forestry relate to reductions in stocks or disruptions in flows; for example, the loss of individual species or economic dislocations resulting from reduced timber harvests. But a more appropriate focus for many major forest issues—forest fragmentation, biological diversity, forest health, long-term sustainability—is the state of the ecosystem. A shift in perspective, from concern with stocks and flows to concern with states and associated stocks and flows, may be a "scientific revolution" (Kuhn 1970).

Looking at effects on states, stocks, and flows provides a common reference point for analyzing past, present, and future practices. As an example, many of our current silvicultural practices increase the certainty of future wood fiber production (flow) by reducing risk of regeneration failure or mortality from interspecific competition. In doing so, we may have reduced biological, structural, or functional diversity—risks related to forest state. On the other hand, proposed new forestry techniques—such as green-tree retention—may accept increased risks to certain flows such as wood fiber production, or produce states with higher susceptibility to catastrophic loss, while reducing the risk of reduction in long-term productivity or system complexity (state characteristics), or loss of spotted owls (stock).

States, stocks, and flows define the nature of the trade-offs associated with various actions; scenario analysis organizes this information and examines possible future conditions. A *scenario* describes hypothetical changes in states over time, and thus illustrates transitions between two states or transitions between a state and several successive states. The rules and assumptions used to generate changes in either conditions or processes must be stated. To fully depict a scenario, analysts must specify the basis for changes in climate, land use, or management practices and how the system responds to those changes. A consistent analytical framework—ideally, a formal model—provides the basis for interpreting the effects of assumed changes in these factors. For example, alternate scenarios could describe progressive changes in forest landscape structure over several decades under either dispersed harvesting or aggregated harvesting.

A Research Agenda

After states, stocks, and flows are defined, then scenarios can be developed to describe the essential features of possible future conditions. This scientific approach has six broad objectives:

(1) define, characterize, and measure different forest ecosystem states;

(2) develop methods to analyze stocks and flows associated with different ecosystem states;

(3) evaluate social benefits, values, costs, and preferences associated with different states, stocks, and flows;

(4) determine factors that influence transitions between states;

(5) develop scenarios and analyze associated changes in states, stocks, and flows; and

(6) propose methods of public participation in defining objectives and in designing and implementing forest demonstration and research areas.

Characterize states. Producing scientifically credible and workable definitions of possible states is the first and fundamental step. Developing ways to define, characterize, and measure different forest ecosystem states is one of the principal challenges facing the research community. Research must provide both quantitative and qualitative descriptions of alternative forest states—either designed or unintentional—at all relevant spatial scales. Characteristics should encompass a broad range of biological, physical, and social (including economic) features.

Designed forest states are those developed for one or more specific management objectives, such as diversity, productivity, resiliency, complexity, or old-growth. One such state might be the "desired future conditions" identified in national forest plans. Unintentional states may result from natural disturbances, such as wind and fire, interacting with either a natural or designed landscape. Given a description of possible future states, social and political processes can determine which of them society prefers.

Research must identify the full range of states possible for specific ecosystems and landscapes. For example, can all sites support old-growth? Do disturbances produce distinct states or a continuum of possible states? What characteristics distinguish plantation forests from natural forests?

Stocks and flows. Continued societal interest in the flow of products from forest ecosystems requires knowledge about the quantities and qualities of stocks and flows associated with different ecosystem states. With this knowledge, the effects of alternative forest states on key flows (timber, water, sediment, target or indicator wildlife species, CO_2, user-days) can be assessed. Both quantity and quality characteristics must be addressed.

Scientists need accurate methods to evaluate and measure flows of ecologically significant products, keeping in mind likely distinctions between ecological significance and market-based value. Possible approaches include retrospective studies, process studies, field experiments, computer modeling, and large-scale landscape experiments.

Social science. What social benefits, values, and costs are associated with different states, stocks, and flows? Studies must identify the range of societal benefits represented by different states. One obvious component is the direct economic benefits associated with specific states or scenarios (for example, forests managed primarily for timber, biodiversity, or spotted owls). However, economics research must go beyond simple measures, such as the number of jobs and the value of wages, to produce a comprehensive view of the role of forest resources in economies and communities. We also must improve our ability to assess the economic and social benefits of forest attributes other than timber.

In a more general sense, we also need to identify the values assigned by the public to different forest states and scenarios. For example, what are the values attached to old-growth? To plantation forests? To a forest managed primarily for diversity? To a fragmented forest? Important results may be more effective communication among different groups of forest users regarding their visions of the future forest and a clearer expression of preferences.

Transitions between states. Greater understanding is needed concerning the factors that influence transitions between states—i.e., how natural and anthropogenic processes (vegetation age, structure, composition, pattern) change the forest attributes that define states. Changes may be due to succession, competition, and other autogenic processes or in response to environmental conditions such as fire, wind, and climate change. Such research will evaluate probabilities and paths for transitions between states and for scenarios, and elucidate mechanisms of ecosystem change. This work can be viewed as defining the "topology" of states: the domain of possible states for particular ecosystems.

Scenarios. An integrated and interdisciplinary analysis of forest stand and landscape change is a fifth area for research. Scientists must describe ecosystem change through time and analyze changes in states, stocks, and flows, and benefits associated with each of them. After scenarios are defined, alternative future states can compare, for example, even-aged and uneven-aged management at the stand scale, or aggregated and dispersed cutting patterns at the landscape scale. A major emphasis will be to portray the effects of alternative mechanisms, patterns, or rates of vegetative change over time and at a variety of spatial scales. This effort could expand communication among researchers, strengthen research planning, and formulate alternative hypotheses of future forest conditions.

After scenarios are defined, individual disciplines must analyze effects of the alternative scenarios on stocks and flows of interest (e.g., marketable commodities, stream flow, or specific wildlife species). This process is iterative in the sense that the results from the first round would logically lead to development of additional scenarios.

Public participation. Finally, researchers should develop new methods to involve the public in defining objectives for forest management, and in designing and implementing efforts to demonstrate and examine the consequences of these objectives. The public plays a critical role in evaluating and choosing among alternative future states; new approaches to expand public involvement should include experiments in both forest management (effects on forest ecosystems) and the effectiveness of public participation. This approach, which represents a new opportunity, may play a key role in producing a publicly acceptable—and technically feasible—vision of future forests.

Demonstration areas can be part of traditional, controlled experiments, and part of a broadened experimental design (in which strict controls are not possible) to evaluate new forestry practices. Adjustments in future management strategies—adaptive management (Walters 1986)—can be based on these experiences with ecosystems and human expectations. Demonstration areas offer a vital meeting ground for researchers, managers, and the public, and a medium for transfer of research results into practice.

Conclusions

This research agenda will require many years, and process, retrospective, modeling, and field experiment studies must occur simultaneously. Because large-scale experiments and data collection take many years to complete, these activities require early attention and in-

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vestment. Meanwhile, scientists must demonstrate an ability to contribute to near-term management and policy decisions. Such participation is risky, as scientists will increasingly be drawn into conflicts over resource use that are based on conflicts in values. Under these conditions, evaluating information and making decisions become increasingly difficult for policy-makers and the public; to contribute effectively, scientists must maintain scientific credibility.

Early efforts should concentrate on retrospective studies—analyzing forest pattern changes through time, identifying ecological responses to alternative silvicultural treatments, comparing historical stream flow data with patterns of harvest, and compiling and analyzing economic and social benefits at various spatial scales.

New scientific issues in forest management include the wide range of scales at which questions are being raised; a more systematic view of forests; broader objectives and concerns for forested ecosystems; and improved public participation in setting a research agenda. The difference from previous forest management science is the attention to issues at larger spatial scales and explicit recognition of the need for interdisciplinary approaches. Only by considering groups of stands (landscapes, multilandscapes, and regions) can biological diversity, habitat and hydrological impact, and interaction with human communities be addressed.

Although this research agenda incorporates some new approaches to forest management and forest research, it is deeply rooted in the past 50 years of forest science. Shifting social values, an expanded understanding of ecosystem dynamics, emerging technologies, and a ripe political and social climate allow us to reevaluate basic assumptions about the role of forests in society. These new approaches reflect a growing recognition of the need to view forests as integrated ecosystems operating within a range of tolerance, rather than as limitless producers of commodities for human consumption. Research cannot define social objectives for forests, but it can help evaluate the ecological, social, and economic tradeoffs between alternative visions. ■

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