Role of Managed Forestlands and Models for Sustainable Forest Management: Perspectives from North America

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Introduction

For decades the best way to sustain forest ecosystems, while also providing a broad range of ecosystem goods and services, has been the subject of debate. Conservationists favored the establishment of comprehensive protected area networks, arguing that this carried the least risk to species survival (Noss and Scott 1997). Other constituencies preferred active silvicultural management. Under this approach, sustained production of harvestable resources was the primary objective, with ecological objectives derived as a by-product of scientifically informed planning (Oliver 1992). More recently, ecosystem management models (see Yaffee 2002) bridged this ideological divide, viewing protected areas and actively managed forestlands as complementary approaches if coordinated at landscape or regional scales (Keeton and Aplet 1997; Poiani et al. 2000). Not every ecosystem good or service (ecological or commercial) can be provided on every hectare; this requires a mosaic of differently managed forest stands or patches. But the relative mix of protected areas versus managed forestlands necessary to achieve broad sustainability objectives remains contentious in many regions of the world. Arriving at a desirable mix will always involve trade-offs between different economic and ecological objectives, values, and interests.

How much of the landscape can be realistically and justifiably allocated to protected areas? And perhaps even more importantly, on the remaining actively managed landscape, what forest management practices should be employed and how can these be encouraged? Answers to these questions must be adaptive to evolving models of sustainable ecosystem management as well as geopolitical context and local community involvement. In this paper I discuss several evolving models intended to guide sustainable forestry on managed forestlands, with the assumption that these would be used in conjunction with protected areas. Examples and case studies from the United States and Canada are presented. These showcase several innovative ideas in sustainable forest management, with the explicit recognition that there is no universal "one size fits all" solution. However, recent developments in North America may provide a perspective relevant to efforts elsewhere in the world.

The role of sustainably managed forestlands in an uncertain future

If 19th- and 20th-century conservation models were concerned primarily with the establishment of protected areas, such as national parks, wilderness areas, and biological reserves, what will conservation look like over the 21st century? Reserves will always be a critical element of sustainable ecosystem management (Noss and Scott 1997; Lindenmayer and Franklin 2002). But ecologically based stewardship of managed forestlands will assume a much greater role than it has in the past. The world's human population, currently 6.7 billion, is predicted to reach 9.2 billion by 2050 (UNPD 2007). Global demand for forest products, currently about 1.6 billion cubic meters per year, has been relatively constant over the last two decades, due to non-wood substitutes, recycling, and more efficient processing of raw wood. Demand is projected to increase moderately (e.g., 5–10%) over the next decade, due in large part to explosive economic growth and increased wood importation in China (White et al. 2006).

With these trends and increasing rates of per capita consumption, forested landscapes will face increasing pressures over the coming century. Sprawl and exurban development are now viewed as one of the greatest threats facing forest ecosystem integrity in the U.S. (Theobald 2005). In the 1990s, more than 80% of housing development was in rural areas (Heimlich and Anderson 2001); each year the U.S. loses almost 500,000 ha of forestland to the "direct footprint" of development and other land conversions, and there is a much larger "indirect footprint" that includes fragmentation effects (USFS 2004). These changes will be superimposed on the effects of other anthropogenic stressors, such as atmospheric pollution, spread of exotic species, and global climate change. Some effects likely will be experienced unevenly throughout the world, such as changes in forest productivity (Aber et al. 2001) and natural disturbance regimes (Keeton, Franklin, and Mote 2007) associated with global climate change. In this context—with human-caused stress in forest ecosystems felt ever more broadly and intensively—relying on protected areas alone to safeguard forest ecosystems will no longer be realistic or scientifically defensible, especially if these become islands in otherwise compromised landscapes. Careful, adaptive, scientifically based management of the unprotected landscape (i.e., those areas outside of core ecological reserves) will be essential to sustain forest ecosystems.

There are several reasons why this is likely. Perhaps foremost among these is the fact that managed forestlands will continue to comprise the majority of the forested landscape. About 11.5 to 12.5% of the world's major forest types are currently protected in formally established protected areas following international guidelines, such as IUCN's six-category classification system. And this number is not likely to surpass 15% for the foreseeable future. Moreover, only about 8% of forests worldwide are included in strictly protected areas (IUCN category I), and this number varies considerably region to region. For instance, only 1.7% of the forested area across 26 European countries is strictly protected (Parviainen et al. 2000). Consequently, the vast majority of terrestrial biodiversity will continue to depend, either in part or in full, on habitat provided by lands outside of core protected areas (Lindenmayer and Franklin 2002). We cannot count on core reserves alone to do the job. For example, the majority of species diversity in the U.S. is not sufficiently represented within existing federal protected areas to ensure long-term population viability (Grumbine 1990; Scott et al. 2001).

Current conservation goals advocated by international organizations (e.g., IUCN–The World Conservation Union, WWF–The World Wide Fund for Nature) may be inadequate to protect biodiversity. By one estimate, 50 % of tropical taxa are predicted to go extinct within several decades even with significant increases in tropical forest protection (Soulé and Sanjayan 1998). Half of the world's terrestrial species will remain at high risk of extinction even with 10–12% of every major ecosystem type protected (Soulé and Sanjayan 1998). Moreover, biodiversity is protected unevenly, with certain taxa and ecosystem types (e.g., low-elevation, biologically productive) left more susceptible to risk than others. For example, there is a consistent bias towards high elevations and the least productive soils found in protected area systems (Scott et al. 2001). Protection varies dramatically by forest type around the world. For example, whereas about 27% of broadleaf evergreen forests have some degree of protection (IUCN categories I–V), far less deciduous broadleaf (4%) or evergreen needleleaf (7%) forest is similarly protected (World Conservation Monitoring Centre 2007). IUCN category VI (managed resource protected areas) designations cover about 1–2% of the world's forests, but degree and type of protections varies considerably within this category.

Alternatives have been proposed to help address these problems. For instance, expanding protected area systems to include more comprehensive representation of ecosystem diversity is a frequently advocated approach (Noss and Scott 1997). This is the basic premise behind the U.S. Gap Analysis Program and similar efforts elsewhere; these have identified high-priority areas for inclusion within protected area systems. However, by one estimate core reserves would need to cover 30–75% of most geographic regions to encompass adequate representation of all ecosystem types (Solomon et al. 2004). Expanding protected area networks to this level is unlikely in many regions of the world. Thus, survival for many if not most species will continue to depend on unprotected landscapes.

Another alternative is to focus new protected areas establishment on so-called "hotspots of biological diversity," which are areas of exceptionally high species richness and endemism. Protecting hotspots is efficient in terms of biodiversity return per unit area protected because one-third of terrestrial plant and animal species are confined to less than 2% of the Earth's surface. Some 25 hotspots have been identified globally, representing 1.4% of the Earth's land surface (Myers et al. 2000). These areas alone contain 35% of vertebrate species within four major groups and 44% of the world's vascular plant species. Yet most hotspots currently have no formal protection.

Despite opportunities for improving protected areas' coverage, managed forestlands will continue to comprise the largest proportion of terrestrial biodiversity. Consider that forestlands today account for only 30% (or 3.9 billion ha) of the world's land area, yet they harbor close to 90% of known terrestrial species. Moreover, it is these lands that will sequester the majority of forest carbon (46% of carbon in the terrestrial biosphere is sequestered in forests), produce clean water, and provide the lion's share of the forest ecosystem services upon which life and humanity depend in many regions of the world. The challenge lies in developing sustainable forest management approaches that balance economic and ecological objectives on the unprotected (or less fully protected) forest lands. In their 1997 book *Creating a Forestry for the 21st Century*, Kohm and Franklin described this problem as follows: "If 20th century forestry was about managing individual forest stands, simplifying stand structure, and providing timber, 21st century forestry will be defined by understanding and managing complexity, providing a wide range of ecological goods and services, and managing across broad landscapes."

In North America, past management approaches have not been adequate to sustain a full array of biodiversity and ecosystem functions (Committee of Scientists 1999). New approaches are needed, although it is important to recognize that management history, such as harvesting intensity, extent of scientifically based planning, and adequacy of biodiversity conservation, has been highly variable. It has varied dramatically depending on ownership, region, silvicultural systems employed, degree of conflict over ecological versus economic outputs, and other factors. For instance, past approaches on the federally owned national forest system in the United States were generally output driven, focusing on achieving a desired harvest level, intensity of recreational use, etc. (Yaffee 1994). Ecologically sustainable approaches, by contrast, would begin with an assessment of the capacity of the ecosystem to sustain a variety of uses over time within biological and ecological constraints. Only once sufficient attention is given to providing habitat for native organisms would it be possible to determine an acceptable level of timber harvest. In the late 1990s a committee of leading forest scientists and economists, charged with developing recommendations for sustainable forestry on federal lands, determined that a fundamental reversal in forest management was necessary, described as follows:

> Sustainability … has three aspects: ecological, economic, and social.… [T]he sustainability of ecological systems is a necessary prerequisite for strong productive economies, enduring human communities, and the values people seek from wildlands. We compromise human welfare if we fail to sustain vital, functioning ecological systems. It is also true that strong economies and communities are often a prerequisite to societies possessing the will and patience needed to sustain ecological systems (Committee of Scientists 1999).

The committee's recommendation, while still not fully adopted on federal forestlands, represented a revolutionary way of thinking. No longer would the federal government mandate an output level for each national forest (e.g., harvestable timber volume) based on a maximum sustained yield model. Instead, forest management would start with an understanding of the capacity of an ecosystem to produce a full range goods and services—including biodiversity. Only then, and within these constraints, could output targets be established. At the same time, however, it was recognized that commitment to ecosystem protection was a choice not likely to be made by peoples and communities, particularly in impoverished regions of the world, struggling to meet the basic necessities of life. Thus, sustainable economic development must occur concurrently with development of the social and economic capital necessary for investments in ecosystem protection.

Matrix management

As the dominant element of the landscape, managed forestlands will have a controlling influence on ecological processes, such as biological connectivity and watershed functioning. They will also be the primary source for production of ecosystem goods and services upon which society depends. Because this "patch" or dominant landscape element surrounds and occupies the critical intervening areas between protected areas and intensively developed areas, such as cities, rural residential, and agricultural land, forest scientists now describe this middle ground as the "matrix." It can include both private and publicly owned lands, of any parcel size, so long as these are allocated primarily to natural resource management, conservation, or open space of some kind. Lindenmayer and Franklin (2002) identified five critical roles for the matrix:

- Supporting populations of species;
- Regulating the movement of organisms;
- Buffering sensitive areas;
- Maintaining the integrity of aquatic ecosystems; and
- Providing for the production of commodities and services.

In the U.S., Canada, and other countries (e.g., Australia), recognition of the importance of the matrix has given rise to a new approach called "matrix management" (Figure 1). In my view, this approach goes beyond the "buffer zone" management model employed, for example, by biosphere reserves and integrated conservation and development projects. Unlike more limited buffer zones, the matrix approach recognizes that sustainable forestry practices are necessary across much larger landscapes, drainage basins, complexes of land ownerships, and geopolitical boundaries. Matrix management incorporates many concepts from the field of conservation biology. For instance, Lindenmayer and Franklin (2002) identify "maintenance of suitable habitat at multiple spatial scales" as an "overarching" goal of matrix management, stressing the importance of providing well-distributed habitats, including both large core habitats and smaller habitat islands within more intensively managed areas. Habitat is seen as an "emergent" property of ecosystems, with certain attributes (e.g., large trees, downed logs) provided at fine scales (e.g., within stands) and other attributes (e.g., large, unfragmented patches) provided at coarser scales (e.g., multiple stands, landscapes, watersheds, bioregions). According to Lindenmayer and Franklin's framework, five principles must be followed in order to achieve the overall goal:

- Maintenance of stand structural complexity;
- Maintenance of connectivity;
- Maintenance of landscape heterogeneity;
- Maintenance of aquatic ecosystem integrity; and
- "Risk-spreading," or the application of multiple conservation strategies.

The first principle recognizes that intensive and industrial forestry practices usually simplify stand structure, resulting in lesser vertical complexity in the forest canopy, less horizontal variation in stand density, and lower densities of key habitat elements like large dead trees and downed logs (Swanson and Franklin 1992; Franklin et al. 1997). Thus, an alternative is to promote greater structural complexity (e.g., vertically differentiated canopies, higher

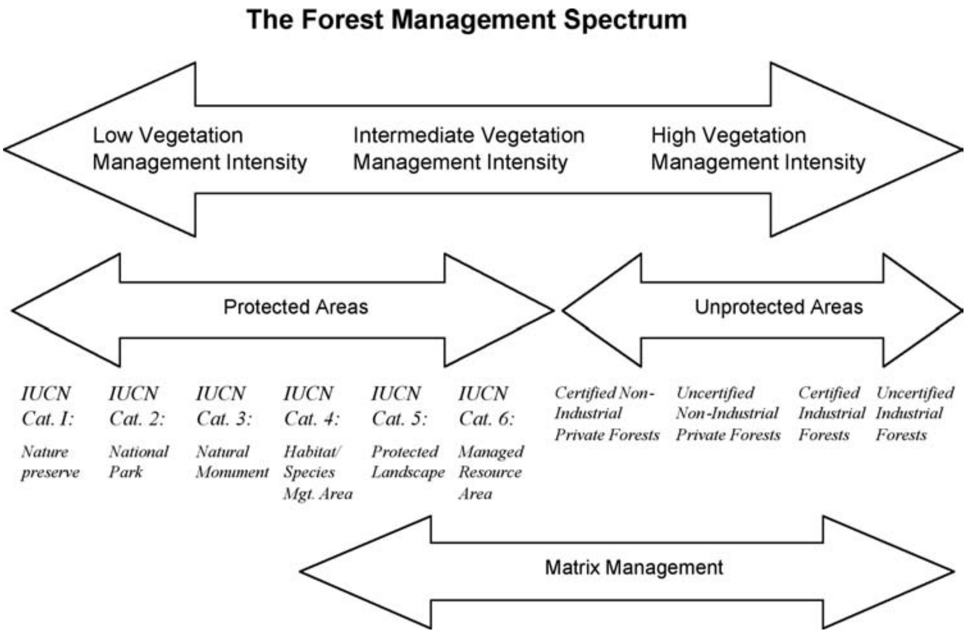

Figure 1. Forest management approaches arrayed along a spectrum defined by vegetation manipulation intensity. Matrix management principles are relevant to a wide range of forest management contexts, including both actively managed protected areas as well as forests managed primarily for timber. Matrix management's position space along the forest management spectrum is indicated at the bottom of the figure. Actual intensity of management on private, unprotected lands will vary considerably and not always be as shown (for illustrative purposes) here.

volumes of coarse woody debris) in actively managed stands (Hunter 1999; Keeton 2006), reflecting a broader diversity of stand development stages (as consistent with stand dynamics specific to individual forest types). This may benefit those organisms not well represented in simplified stands, as long as sufficient habitat is provided across multiple stands to support viable populations (McKenny et al. 2006).

Maintaining biological connectivity in managed forest systems is essential for the persistence of viable populations of organisms (FEMAT 1993). Thus, the second principle of matrix management involves strategies that allow organisms to disperse, migrate, access resources, and interact demographically, such as terrestrial and riparian corridors, retention of well-distributed habitat blocks and structures that provide "stepping stones" across harvested areas, and restoration of linkage habitats. Maintaining a diverse landscape (principle three) supports an array of ecological functions while also increasing ecosystem resilience to disturbance and stress (Perry and Amaranthus 1997).

Principle four relates to minimizing deleterious forest management effects on surface waters and watersheds. Scientists have documented important ecological interactions between riparian forests and aquatic ecosystems (Ward et al. 2002; Naiman et al. 2005; Keeton, Kraft, and Warren 2007). Thus, delineation of riparian buffers, riparian forest restoration, ecologically informed forest road management, and other best-management practices for watershed protection are essential elements of matrix management (Gregory et al. 1997; Stuart and Edwards 2006).

Finally, "risk-spreading" (principle five) deals directly with the scientific uncertainty associated with over-reliance on any one forest management approach. For instance, if we are uncertain how sensitive species will respond to silvicultural treatments, it would be prudent to employ reserves in conjunction with active management. If it is uncertain whether we can control the spread of exotic species or restore fire regimes using reserve-based approaches alone, then active manipulations may also be necessary. Actively managed reserves offer an intermediate option (Figure 1). In short, uncertainty and risk are reduced if we employ multiple management and conservation strategies, addressing different spatial scales and applied to different portions of the landscape (Lindenmayer and Franklin 2002).

Disturbance-based forestry

Matrix management principles are well grounded in the science, but will be challenging to implement when balancing competing objectives. Managers will face difficult questions, such as: How much is enough? How much of a particular type of habitat or ecosystem function should be provided by matrix management? Should this be static or a dynamic, ever-changing mix of habitats?

Some answers are provided by recent silvicultural developments in the U.S. and Canada, often referred to as "disturbance-based forestry" (Mitchell et al. 2002; Seymour et al. 2002). Disturbance-based forestry and matrix management are complementary; the former offers guidance on implementing the latter. The idea is that an understanding of natural disturbance dynamics can help us develop low-risk, ecologically friendly forestry practices. Keeton (2006) summarizes this as follows:

> Sustainable forestry practices across managed forest landscapes contribute to the maintenance of biological diversity and ecosystem functioning. The challenge lies in determining the mix of management approaches—including type, timing, intensity, and spatial configuration of silvicultural treatments—necessary to achieve sustainability objectives. One possibility is to focus on the architecture of individual forest stands and their spatial arrangement, with consideration given to the aggregate representation of multiple structural (or habitat) conditions at landscape scales. Patch and successional dynamics associated with natural disturbance regimes provide a useful guide for designing this type of structure or disturbance-based approach. A recommendation is to manage for currently under-represented structures and age classes on some portion of the landscape.

An implicit assumption in these approaches is that forest management will be ecologically sustainable—i.e., it has a greater likelihood of providing viable habitats for a full range of native species—if it maintains or approximates ecosystem patterns and processes associated with natural disturbance regimes and successional processes (Aplet and Keeton 1999). This bounded range within which attributes of ecosystem structure and function vary over time and space has been termed the "historic range of variability" (HRV). According to this line of thinking, if HRV represents the conditions under which organisms evolved and have adapted, then species will have the greatest likelihood of survival if similar conditions are provided through management. There are examples of forest management plans based on reconstructions of HRV (e.g. Cissel et al. 1999; Moore et al. 1999). Yet HRV-based approaches are difficult to implement. To begin with, the feasibility of quantifying HRV for a given landscape varies greatly depending on data availability and modeling requirements (Parsons et al. 1999). There is the added difficulty of finding appropriate historical reference periods (Millar and Woolfenden 1999). Thirdly, forest managers must determine whether HRV offers a realistic target for management, considering the extent to which conditions within the HRV are compatible with contemporary management objectives, altered ecosystem conditions and dynamics attributable to land-use history, and changing climatic conditions. Despite these limitations, HRV provides an informative benchmark or reference for understanding landscape change (Aplet and Keeton 1999).

Disturbance-based forestry has largely developed along two lines of investigation in moist temperate and boreal regions of North America (Figure 2). The first is developing silvicultural practices that more closely approximate natural disturbance patterns, scales, and frequencies (Mladenoff and Pastor 1993; Seymour et al. 2002) and related regional stand age-class distributions (Lorimer and White 2003). Natural disturbance return intervals inform harvesting frequency (rotation or entry cycle) and disturbance sizes (or extent) guide the scale of individual harvest units. In the northeastern U.S., for instance, small-group selection methods (a form of uneven-aged silviculture), practiced on entry cycles of several decades or more, best approximate the fine-scale, high-frequency disturbance regime of the region's temperate deciduous and mixed hardwood–conifer forests. Seymour et al. (2002) developed a "comparability index" that depicts the correspondence between a range of silvicultural systems and natural disturbance scales and frequencies. Some of these disturbance-based methods are currently being experimentally tested (e.g., Seymour 2005; Keeton 2006).

The second focus of work in disturbance-based forestry is investigating ecosystem recovery following disturbances and long-term processes of stand development (Franklin et al. 2002). This has included a growing appreciation for the role of biological legacies in ecosystem recovery following disturbances (Keeton and Franklin 2005). Biological legacies are "the organisms, organic materials, and organically-generated patterns that persist through a disturbance and are incorporated into the recovering ecosystem" (Franklin et al. 2000:11). Disturbance-based silvicultural systems developed in the western U.S. and Canada are designed to provide ecological functions similar to those associated with biological legacies. Examples include the "variable retention harvest system" (Franklin et al. 1997) and other retention systems (Marshall and Curtis 2005; Beese et al. 2005); these retain biologically significant elements of stand structure (e.g., large live and dead trees) following regeneration harvest. Structures are retained in varying densities and volumes and in different spatial patterns (e.g., aggregated versus dispersed; Aubry et al. 1999). Retention schemes can mimic the landscape-level patterns created

Figure 2. Examples of disturbance-based silvicultural practices. A group selection cut with retention (both live and dead trees) within small (0.05-ha) harvested patches on the Mount Mansfield State Forest in Vermont (northeastern U.S.) is shown to the left. This system approximates the fine-scale canopy disturbances and spatially heterogeneous tree mortality patterns typical of the region's natural disturbance regime (see Keeton 2006). To the right are examples of both dispersed and aggregated retention in the U.S. Pacific Northwest. These practices provide functions similar to those associated with biological legacies left by natural disturbances (see Franklin et al. 2002). They differ from conventional even-aged systems (e.g., shelterwood) in that residual trees are retained either permanently or over multiple rotations. Photos courtesy of Jeremy Stovall (left) and Jerry F. Franklin (upper and lower right).

by natural disturbances, such as greater tree survivorship within riparian areas in areas burned by wildfire (Keeton and Franklin 2004).

An extension of this research has investigated effects of natural disturbances in mediating late-successional stand development (Abrams and Scott 1989; Lorimer and Frelich 1994). The objective is to develop silvicultural systems that provide a broader range of stand development stages, including old-growth forest habitats and associated functions (Franklin et al. 2002; Keeton 2006). These systems accelerate rates of stand development in young, mature, and riparian forests through under-planting, variable density thinning, crown release, and other methods (Berg 1995; Singer and Lorimer 1997; Harrington et al. 2005). Both these and retention forestry are prescribed as elements of the Northwest Forest Plan, a bioregional plan for federally owned forests in the U.S. Pacific Northwest (FEMAT 1993). As another example, an approach called "structural complexity enhancement" has been experimentally tested in northern hardwood–conifer forests in the northeastern United States. This system accelerates late-successional forest development through a variety of unconventional silvicultural techniques, some of which approximate fine-scale natural disturbance effects (Keeton 2006).

Strategies for promoting sustainable forest management

Strategies for promoting ecologically based forest management, including matrix management and disturbance-based forestry, will vary by geographic region, land tenure context, and other factors. In the U.S., a variety of strategies are currently employed. These range from regulatory approaches on publicly owned lands to incentive-based approaches on landscapes dominated by private lands, such as in the eastern states. Innovative approaches to the latter are particularly important because 63% of U.S. forests are privately owned and increasingly subject to development pressure.

Forest management in the U.S. is conducted under a set of federal and state laws regulating many aspects of forest and environmental management on public (and sometimes on private) lands. These laws incorporate some elements of sustainable forest management, such as consideration of multiple resource values (i.e., "multiple use"), planning procedures, safeguards for threatened and endangered species, and watershed protections. However, the degree to which these laws have resulted in ecologically sustainable management has been the subject of considerable debate (see Grumbine 1990; Yaffee 1994; Davis et al. 2001). Laws such as the National Forest Management Act of 1976 are focused primarily on activities at the individual administrative unit level (e.g., a national forest). For this reason, more holistic, transboundary, landscape-level projects—those applying matrix management principles, for instance—have not occurred nationally in a consistent manner. Rather they have responded to regionally specific issues, such as the need for a comprehensive plan to conserve old-growth forest ecosystems in the U.S. Pacific Northwest. Thus, these projects are often implemented through regulatory development and administrative procedures under statutory authority.

Regulatory approaches in the U.S. Northwest have included creation of a bioregional reserve system and delineations of of 1.6 million ha of "matrix" lands where disturbance-based forestry methods, such as retention forestry, are required. In this case, such top-down approaches are possible because over two-thirds of the forest land is publicly owned. Large, federally controlled landscapes can be managed holistically under a unified plan. Application of matrix management principles has also occurred in a number of other regions with significant amounts of public land. These include the Sierra Nevada Range in California, the Greater Yellowstone Ecosystem in the northern Rocky Mountains, and the southern Appalachian Mountain region of the southeastern U.S.

In regions of the country dominated by privately owned lands and smaller forest parcel sizes, such as the northeastern U.S., other approaches are necessary, often on an individual owner-by-owner basis, to collectively achieve the same landscape-level objectives. Matrix management objectives are thus achieved (indirectly, not explicitly) through a combination of limited conservation land acquisition, land-use review and regulation (varying greatly by state and locale), and incentive-based programs. The latter include property tax relief for open space conservation and sustainable forest management. As an example, the Current

Use Value Appraisal Program in the state of Vermont assesses property tax rates based not on the residential or commercial development potential of a parcel of land—as is the case generally—but rather based on its "current use" as actively managed timberland. There are similar programs in other northeastern U.S. states. The federal Forest Legacy Program offers limited funding for private landowners who agree to keep forestlands in sustainable forest management or open space.

Conservation easements represent another tool frequently used to prevent forest lands from being split into smaller parcels and sold for real estate development. Easements transfer development rights to a willing third-party buyer, typically a public agency or a non-governmental organization (e.g., a land trust), while the original landowners retain other property rights (e.g., timber, minerals, access, etc.). In a few cases, lands sold under conservation agreements have included deed restrictions requiring sustainable forest management practices. Where lands are developed for housing, clustered developments that include habitat and open space protections can achieve limited conservation value and opportunities for forest stewardship if planned carefully (Pejchar et al. 2007). Growth (i.e., development) management planning around rapidly expanding suburban and exurban areas has become another indispensable tool to conserve forestland and manage forest fire threats.

Market-based mechanisms, such as "green labeling," are also used to promote sustainable forest management. In North America there is widespread interest in forest certification systems, including frameworks developed both by the Forest Stewardship Council (FSC, a non-governmental organization) and the Sustainable Forestry Initiative (an industry-sponsored program). According to Foster et al. (in press), "over 67 million hectares of forest land (approximately 16–22% of total commercial forest land) in North America have been certified to FSC standards, and the FSC certified area worldwide has tripled over the last six years." Initially it was hoped that certified wood products would earn a premium in the marketplace, but this has been slow in coming. However, certification has given producers special access to buyers (e.g., institutions, environmentally motivated corporations, etc.) looking for certified products, making certified forests, mills, and distributors more competitive in these cases.

Developing markets for environmental services and amenities, such as water and recreational use, have great potential in terms of providing financial incentives for sustainable forest management. These can create market value for ecosystem services that currently have none. Foremost among these at present are rapidly developing "cap and trade" carbon markets. While the U.S. is not currently a signatory to the Kyoto agreement on climate change, voluntary carbon credit trading, such as the Chicago Climate Exchange, is growing and includes several timber companies as participants.

A final promising trend in North America is the increasing interest in community-based forestry. These efforts take different forms, but generally share the objective of enhancing community participation in and benefits from local forests. Examples include establishment of town forests, forestry cooperatives involving multiple small ownerships, community sort yards, efforts to stimulate locally based value-added manufacturing, and others. Community-based initiatives accomplish three primary things. First, they increase awareness of values provided by local forests, thereby stimulating public support for forest conservation and sustainable (often small-scale) forest management. Second, they help return more of the economic benefits derived from forests directly to the community. And third, they provide strength in numbers. Multiple landowners, in effect, pool their resources and, to some degree, coordinate management across a larger area. This gives participants access to market opportunities not readily available to individuals. If conducted under a set of agreed-upon standards, it also generally results in lower-impact forestry practices and better provision of ecological values. Hence there is an opportunity for matrix management and disturbance-based forestry through community forestry.

Globalization is reshaping the forest products industry, and with it the nature of sustainable forest management. In recent years there has been large-scale divestiture of industrial timberlands in North America and reallocation of investments and capital to the southern hemisphere, primarily for establishment of high-yield plantations, often utilizing exotic species (Franklin 2003). As industrial timberland is placed on the real estate market, or acquired by shareholder groups interested primarily in short-term profit-making (e.g., real estate investment trusts and timberland investment management organizations), the ability of unprotected forestlands to contribute to sustainable forest management objectives becomes increasingly uncertain. In this context, application of incentive-, market-, and community-based strategies will be even more vital for keeping forestland in open space, habitat, and sustainable productive use. Without expanded use of these conservation mechanisms, the option for sustainable management of the matrix will rapidly decline.

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