4-1992

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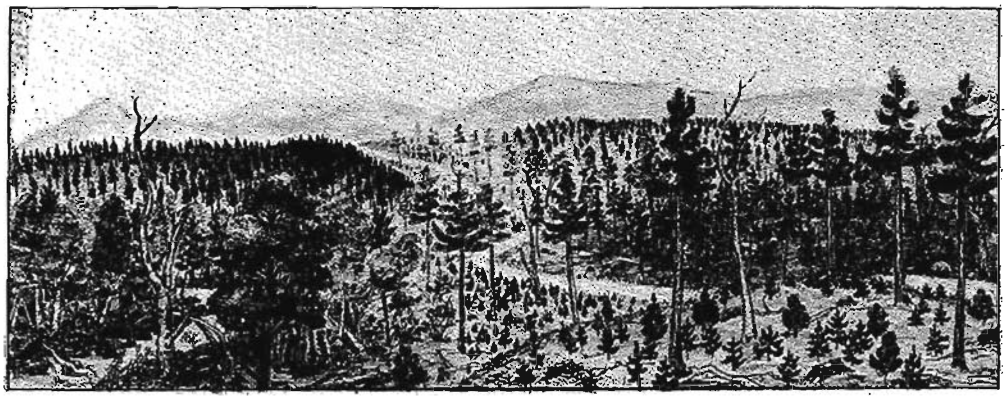
ISSN 1070-1508



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Miscellaneous Publication 716

April 1992

MAINE AGRICULTURAL AND FOREST EXPERIMENT STATION
University of Maine

# New Forestry in Eastern Spruce-Fir Forests: Principles and Applications to Maine

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Maine Agricultural and Forest Experiment Station
Miscellaneous Report 716
revised and reprinted March 1994

# PREFACE

In 1991 the organizers of the National Convention of the Society of American Foresters decided to sponsor a session in which forest ecologists representing the major forest regions of North America would discuss the application of "New Forestry" to their respective regions, and we were invited to represent the eastern spruce-fir forests. The resulting papers were presented at the technical session of the Forest Ecology Working Group at the August, 1991, meeting in San Francisco. Dr. David Perry, organizer of this national effort, is currently arranging for all papers to be submitted for publication, with the goal of presenting a comprehensive national treatment of this topic in the refereed literature. This bulletin is a version of our original paper, revised and expanded in response to comments from ten reviewers, including industrial foresters, wildlife biologists, and environmentalists from Maine, New Brunswick, and Ontario. Given the likelihood that the national publication will not be available for one or two years and that space constraints will force us to greatly condense our contribution, we are releasing this version to expedite dissemination and discussion of our ideas.

### What is New Forestry?

Many eastern foresters, particularly in the private sector, have had little exposure to New Forestry. The concept emerged on public forests of the Pacific Northwest, largely as a result of the efforts of Dr. Jerry Franklin, a prominent forest ecologist who is currently at the University of Washington and was formerly an influential researcher for the USDA Forest Service. Franklin's (1989) seminal work, published in *American Forests*, reveals how his research on regeneration of old-growth Douglas-fir led him to a new appreciation for the unique ecological values associated with old-growth forests. New Forestry represents an attempt to retain some of these values in a landscape of managed forests--values that Franklin and other critics (most notably Chris Maser in his influential book *The Redesigned Forest*) believe are being unduly compromised by traditional plantation forestry. In essence, New Forestry advocates a new emphasis in forest management, away from single-purpose timber production and toward a more holistic ecosystem orientation (Gillis 1990).

Advocates of New Forestry believe that by modifying silvicultural practices, substantial levels of wood production can be maintained without threatening biological diversity. (For a comprehensive review of the principles, see Hunter [1990].) In practice, these modifications often focus on two aspects of forest structure: (1) creating and maintaining vertical diversity in the forest canopy, and (2) ensuring that the biological "legacy" of the old-growth forest (i.e., the full spectrum of biota present there) is transferred to the regenerating stands. These goals are achieved largely by leaving some large living trees, standing dead snags, and large downed woody debris during the regeneration phase of stand development. It also requires careful attention to design of harvest blocks and the resulting stand configurations on the forest landscape. Exactly how these things are accomplished in a particular situation is an emerging science, and is the subject of this and other papers. As will be explained in this report, some of the practices advocated by New Forestry practitioners in the Pacific Northwest require considerable modification for application to eastern spruce-fir forests.

New Forestry has begun to affect public forest management throughout the United States via the "New Perspectives" initiative of the USDA Forest Service. Hal Salwasser summarized the basis for this influential and controversial program in the November, 1990, *Journal of Forestry*. Not surprisingly, New Forestry also has its critics. One common reaction is that "there really isn't anything new here," in part because many of the practices promoted by advocates of New Forestry have long been a part of the silvicultural repertoire. In this light, New Forestry can be viewed as yet another step in the continuing evolution of silvicultural practice for new public mandates (O'Hara and Oliver 1991). Others have argued that New Forestry has evolved through a flawed scientific process and that it ignores much of the scientific basis for traditional plantation forestry that has developed from research over the past several decades (Atkinson 1991). Particularly in our region, New Forestry is a concept based largely on experience and intuition and modest amounts of relevant research. Thus we offer our ideas not as a definitive statement about the best way to manage our spruce-fir forests, but rather as a focal point for critical debate and discussion about the future of this important resource.

## Acknowledgments

We would like to thank Dave Perry for organizing this nationwide effort to address New Forestry, and Si Balch, Mike Cline, Tom Charles, Mike Coffman, Mike Greenwood, Carl Haag, Dan Keppie, Mitch Lansky, Pete Ludwig, and Dan Welsh for unusually thorough reviews of our manuscript. Andrea Sulzer's illustration of the Triad (Fig. 1) is worth at least a thousand of our words in attempting to describe this important concept. Our work on forestry issues has been supported by McIntire-Stennis funds of the Maine Agricultural and Forest Experiment Station, the Holt Woodlands Research Foundation, and the Cooperative Forestry Research Unit.

## Suggested Reading:

Franklin, J.F. 1989. Toward a new forestry. *Amer. Forests* (Nov.-Dec.): 37–44.

Gillis, A.M. 1990. The new forestry. An ecosystem approach to land management. *BioScience* 40(8): 558–562.

Hunter, M.L., Jr. 1990. *Wildlife, forests, and forestry: Principles of managing forests for biological diversity*. Englewood Cliffs, NJ: Prentice-Hall. 370p.

Maser, C. 1988. *The redesigned forest*. San Pedro, CA: R. & E. Miles. 234p.

O'Loughlin, J., editor. 1992. *Western Wildlands* 17(4). Montana Forest and Conservation Experiment Station, Missoula, MT. Special issue on New Forestry, with 7 articles including:

O'Hara, K.L., and C.D. Oliver. 1992. Silviculture: Achieving new objectives through stand and landscape management. pp. 28–33.

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Salwasser, H. 1990. Gaining perspective: forestry for the future. *J. Forestry* 88(11): 32–38.

## ABSTRACT

Eastern North America's spruce-fir forests have a unique ecological and human history which is reflected in their current vegetation, ownership patterns, and forest management practices. Furthermore, there are important differences within the region between the true boreal forest and the sub-boreal Acadian forest; this paper emphasizes the Acadian forest. Applying New Forestry to this region will require a modified approach which we outline by describing three basic principles. First, to provide the landscape context for New Forestry, we propose a triad of forest land allocation in which reserves and plantations would co-exist, surrounded by and embedded within a landscape managed by alternative silvicultural systems based on New Forestry principles. The second principle is that silvicultural systems should be patterned after local natural disturbance regimes. The third principle is that ecosystems that have been altered by past practices should be restored. Implementing these principles is discussed in a review of specific silvicultural practices: conservation and restoration of seed sources; retention of residual trees; long rotations; limited whole-tree harvesting; and two-aged stands maintained by irregular shelterwood cutting. At the landscape level we discuss how the triad might be implemented and the importance of size and distribution of harvest areas and riparian zones.

# INTRODUCTION

"New Forestry" in eastern spruce-fir forests is indeed new. In 1991, two years after Jerry Franklin introduced the idea in the pages of *American Forests,* discussion of the topic among professionals is only now beginning in our region, despite its recent national prominence in forestry circles. This lack of awareness of New Forestry could well be due to a paucity of publicly owned and managed land in this region. The eastern spruce-fir forest arguably has more of its area under industrial timber management, and correspondingly the least in public ownership, of any forest type in North America. Despite the scarcity of public lands we believe that the principles of New Forestry are relevant to the eastern spruce-fir forest now and will become increasingly important as society's demands for various forest resources grow.

The paper has four parts beginning with a brief review (Part I) of some key features of the eastern spruce-fir forest—forest types and disturbance regimes, land ownership patterns, and current management practices—from which we have distilled a list of deficiencies of the existing forest and its management. In Part II we have taken the basic idea of New Forestry, ecological sensitivity, and distilled three principles that could guide New Forestry in eastern spruce-fir forests. Finally, we have described a series of specific tactics, at both the stand (Part III) and landscape (Part IV) level, that could be used to implement New Forestry in the eastern spruce-fir forest.

# PART I: CONTEXT FOR IMPLEMENTING NEW FORESTRY

## Forest Types and Natural Disturbance Patterns

There are many classifications of eastern North American forest vegetation dominated by *Picea* and *Abies*, but for simplicity we distinguish two contrasting zones based mainly on prevailing natural disturbance regimes and species diversity: the true boreal forest and the sub-boreal Acadian forest. Our collective experience in research and forest management has been entirely within the less-extensive, but more studied, Acadian forests, so we will risk being provincialists and focus this paper on this southerly zone. Because this zone is more complex, and the silvicultural options more encompassing, foresters experienced in boreal silviculture should be able to extrapolate many ideas to their circumstances.

### The true boreal forest

The more northerly true boreal forest is considered to lie entirely within Canada (Larsen 1980). Stands are relatively simple in species composition and age structure, originating largely after stand-replacing fires that range from 1,000 to 10,000 ha (Foster 1983; Heinselman 1981; Cogbill 1985; Payette et al. 1989). Smaller fires also are common, but cover little total area; very large fires (over 100,000 ha) occur occasionally. Fires typically recur at 50–150-year intervals that lengthen as one goes northward. In the southern boreal forest where most commercial harvesting takes place, balsam fir (*Abies balsamea*), jack pine (*Pinus banksiana*), paper birch (*Betula papyrifera*) and *Populus* spp. dominate stand composition. White (*Picea glauca*) and black spruces (*P. mariana*) become more prevalent in the northern boreal that eventually grades into open tundra. Large stand-replacing windstorms are very rare (Cogbill 1985).

### Sub-boreal Acadian forest

Between the eastern boreal forest and the temperate deciduous forest, there is an ecological transition zone, often called the Acadian forest. One reasonable delineation of this zone is the overlap of the ranges of the boreal balsam fir and the Appalachian red spruce (*P. rubens*). In the east, many important species approach their northern limits here, including the tolerant northern hardwoods, eastern white pine (*P. strobus*), northern white-cedar (*Thuja occidentalis*), and eastern hemlock (*Tsuga canadensis*).

True boreal species such as black and white spruce occur, but rarely dominate stands except under specific local conditions (e.g., black spruce bogs, old-field white spruce, and fire-origin aspen). Tree species diversity is greater than in the true boreal region. Limited historical evidence suggests that fires of natural origin are much rarer here (700–2000-year return intervals; Lorimer 1977). The predominant natural disturbances prior to European settlement were insect outbreaks (spruce budworm [*Choristoneura fumiferana*] and bark beetles [*Dendroctonus rufipennis*]) and windstorms recurring at intervals of several decades (Lorimer 1977; Seymour 1992). Unlike fires, these disturbances are usually not completely stand replacing, and thus lead to the development of a wider range of age structures. The greater potential diversity in both species composition and age structure clearly offers a broader array of silvicultural options with which to achieve New Forestry goals than is possible in the true boreal forest.

### Forest Land Ownership

The long history of private ownership of the eastern spruce-fir resource in northern New England began when investors purchased large tracts from the public domain in the early 1800s. During the next century, the entire region was almost entirely harvested, first for pine then for spruce and hardwood sawlogs. Unlike other forest regions where the early history of sawlog harvesting and forest fires left the forest in such a depleted condition that public acquisition was the obvious salvation, the eastern spruce-fir forest remained well stocked with pulpwood-sized trees. The first pulp and paper mills were constructed in the 1890s to utilize this resource. At the same time, large-scale industrial acquisitions of timberland began the history of forestry and private stewardship that continues to this day. In Canada, lands remained under crown (public) ownership, but long-term leases to industrial interests have resulted in a management history that is quite similar to that in northern New England.

On both sides of the border, very few areas have been set aside as forest preserves or wilderness areas, or as publicly managed forest where wildlife and recreation are coequal with timber management. Some data from Maine (Powell and Dickson 1984) illustrate this point. Nearly half of Maine's 6.8 million ha of forest is owned by forest industry, by far the largest area of any state. Less than 280,000 ha (4%) of managed forest are in public ownership. Formal reserves encompass under 130,000 ha (<2%), mostly in four large ownerships (Baxter State Park, Acadia National Park, the Appalachian Trail corridor, and the Allagash Wilderness Waterway). Harvesting is also strictly regulated on an unknown, but substantial, area of privately owned riparian zones, deer-wintering areas, and high-elevation stands. Of the 105,756 ha harvested in 1988, only 7,164 ha (<7% of the harvested area) were managed intensively either by planting or precommercial thinning (Seymour 1992). In short, Maine's forests are dominated by low-intensity, industrial timber management.

## Current Forest Management Practices

### Intensive high-yield silviculture

Intensive practices are similar to other regions, except that artificial regeneration is less common. A typical regime would begin with a complete overstory removal ("one-cut shelterwood") to release small advance regeneration that is usually abundant (Smith 1986; Seymour et al. 1986). Planting is used mainly to convert repeatedly high-graded, but potentially productive, sites from poor quality hardwoods to spruce, red pine (*P. resinosa*), or exotic larch (*Larix* spp.) plantations, and occasionally to remedy natural regeneration failures. About 2–5 years later, herbicide is applied aerially to control intolerant brush, then at ages 10–15 a precommercial thinning (spacing) operation is sometimes undertaken to create 2000–2500 uniformly spaced crop trees per hectare (Seymour and McCormack 1989). Some, but not all, foresters anticipate undertaking commercial thinnings when these stands reach merchantable size.

Expected rotations of 30–50 years will be determined mainly by timber supply shortfalls resulting from age-class imbalances, rather than by optimum financial or biological maturity of individual stands. Mean annual yields are expected to be 6–10 $m^3$/ha/year, modest in comparison with the Pacific Northwest and South but still about 2–5 times the average of current unmanaged stands (Greenwood et al. 1988; Seymour and Lemin 1991). Intensive management practices expanded greatly during the 1980s and are now standard operating procedure on crown lands in the Canadian Maritimes. In New England increases have been more modest. Herbicide release is by far the dominant practice due to its low cost, with the more expensive practice of precommercial thinning far behind.

Extensive management

Where intensive management is not applied, stands are often cut heavily at intervals ranging from 20–60 years. Here, harvesting, not silvicultural treatment, has the most profound effect on future stand development. Some stands are completely clearcut, but receive no follow-up treatment. More commonly, partial cuttings create stands that are best described as "two-aged" in structure. Partial cuttings range from the conservative (light cuttings marked by a forester) to the highly exploitative (uncontrolled diameter-limit cuts or commercial clearcuts driven entirely by short-term economics). Thus, it is difficult to generalize about these harvests except to say that they are usually neither classic even-aged silviculture nor true selection (all-aged) management. Many of these stands already have a somewhat irregular structure with a substantial lower stratum of shade-tolerant trees. Thus, these partial cuttings often leave residual stands that resemble what might be proposed as "green retention" modifications to more complete clearcuts. This resemblance is superficial, however, because often there is no attention paid to designating the trees being left.

## What's "Wrong" with the Present Forest?

Because management has not intensified to the extent that it has in other industrial conifer-producing regions, activities that resemble New Forestry practices, such as "commercial" (incomplete) clearcutting, are still common in the eastern spruce-fir forest. Furthermore, the great variability in topography, soils, and associated vegetation arguably creates more inherent diversity (regardless of treatment) than in some regions. Finally, large private forest holdings have long provided recreational opportunities, watershed protection, and other non-timber benefits at little cost to the region's taxpayers. Thus, one might ask, "Why does the eastern spruce-fir region need New Forestry?"

While acknowledging these characteristics, we believe that they may not endure. Moreover, we argue that there is much about the present forest that could be improved:

1. **There are few old-growth stands in the subboreal forest and accessible parts of the true boreal forest.** The common perception of old-growth requires some revision in regions, such as the true boreal forest, where natural disturbances replace stands at frequent intervals (Hunter 1989). Nevertheless, it is

clear that, using a locally appropriate definition, old-growth stands have become rare throughout much of the eastern spruce-fir region because of widespread harvesting. Currently there are few plans for deliberately retaining old stands by removing them from harvest plans.

2. **A few commercially valuable species (e.g., white pine, red spruce, and yellow birch) have been greatly reduced in certain stand types through preferential high-grading and disease.** Although these species are generally abundant (Powell and Dickson 1984), forest-level data tend to mask losses in ecosystems where they originally constituted a minor, but structurally important, component.

3. **Some desirable aspects of current harvesting practices (incomplete clearcuts, etc.) happen largely by default, not by design, thus creating an inherently unstable forest management situation.** If economics changed and practices truly intensified on a large scale, these "leftovers" could cease to exist. For example, the recent advent of biomass markets and whole-tree harvesting makes site preparation for planting feasible, thereby enhancing opportunities for high-yield silviculture. However, such complete removal of formerly unmerchantable residues eliminates their potential role as a structural component (both living and dead) of future landscapes.

4. **Extensive clearcutting and the associated road systems have created a fragmented landscape in some regions.** Clearcut harvesting only became widespread during the late 1960s in eastern spruce-fir, mostly in response to the widespread spruce budworm outbreak. Formerly inaccessible areas were roaded at a greatly accelerated pace, and harvests were concentrated on stands where balsam fir, the favored budworm host, predominated. This "first pass" probably enhanced landscape diversity, accounting for a population explosion of moose (*Alces alces*) and other species requiring large areas of early successional vegetation. Usually

enough old second-growth stands dominated by spruce were left so that species requiring old forests such as pine martens (*Martes americana*) were not jeopardized. As the budworm outbreak subsided, however, harvesting did not abate: Rather, a "second pass" of clearcutting the remaining mature stands adjacent to the original clearcuts has produced a fundamentally altered landscape in many areas. Within a span of less than 20 years, entire townships formerly dominated by mature stands were virtually entirely regenerated.

Because the problems of forest fragmentation have been documented largely for small patches of forest surrounded by agriculture, it is not known how relevant these issues are in forested landscapes that have been fragmented by clearcuts and roads (Hunter 1990). Nevertheless because clearcuts and associated roads do break up tracts of continuous forest, fragmentation should concern foresters in the eastern spruce-fir region, unless future research demonstrates that it is not a problem.

5. **The region has only a few formal reserves, and they do not adequately represent the region's ecological diversity.** Although the total area presently withdrawn (largely for economic reasons) from timber harvesting is more extensive than the limited public ownership would suggest, current reserves are not a good representation of the region's ecosystems because: (a) they were not selected to be representative; (b) they are dominated by the types of sites where timber management is difficult (e.g,. steep slopes); and (c) their total area is small.

6. **There is limited land formally dedicated to multiple-use management, in which non-timber values are weighed equally with forest products.** Historically, much of the industrially owned land has provided a wide array of non-timber benefits while also supplying fiber needs of dependent mills. We share a concern that future increases in demand for wood, or growing financial pressures for increasing earnings

from private holdings, could quickly reverse this situation on industrial lands where timber production remains the dominant use.

7. **Not enough land is producing high timber yields.** On the surface, this point may seem to conflict with the general aversion of New Forestry to high-yield silvicultural practices. However, continued widespread application of low-cost, low-yield extensive management, coupled with increasing industrial demands, has created the prospect of future wood supply shortfalls. If the response to such shortfalls is simply accelerated harvesting of the present forest, then attempts to address problems such as the dearth of reserves will likely result in divisive, politically imposed decisions and ultimately economic hardship. As we explain more fully later in the text, expanded high-yield management on a strategically designed resource could significantly reduce pressure for extensive harvesting at the landscape level, thereby freeing lands to meet other needs.

# PART II: PROPOSED PRINCIPLES FOR NEW FORESTRY IN EASTERN SPRUCE-FIR

The unique interplay of ecological and economic history outlined in Part I means that the eastern spruce-fir forest presents a very different set of issues than the Pacific Northwest, and thus requires some different strategies to accomplish two goals that we strongly endorse: (1) to make timber management more ecosystem oriented, and (2) to ensure the maintenance of ecological values that timber management of any kind can preclude if one is not careful. Before presenting specific practices that address these goals, it is important to discuss three important ideas that provide the conceptual framework for our recommendations.

### Managing for Landscape Diversity -- A Triad Approach to Forest Land Allocation

One major thrust of New Forestry has been to maintain a middle-ground for multiple-use forestry by bridging the seeming chasm between reserves and plantations. This emphasis makes sense in regions like the Pacific Northwest where large tracts of high-volume, undisturbed forest are being opened to timber management, and timber management, once initiated, tends to be intensive. We contend, however, that areas allocated for reserves and plantations should both be increased in the eastern spruce-fir region. Indeed, wider application of truly intensive, very high-yield silviculture could actually enhance society's opportunity to establish ecological reserves. This seeming paradox results from the fact that intensively managed high-yield conifer stands are expected to increase yields over current unmanaged spruce-fir stands by 2–5 times or more (Greenwood et al. 1988). In the long run, supplying timber demands on fewer, more intensively managed hectares would allow substantial areas to be set aside as reserves without threatening future wood supplies (Seymour and McCormack 1989). A different situation prevails in the Pacific Northwest, where future timber yields usually decline in comparison to those obtained during liquidation of high-volume old-growth stands (the so-called "fall-down effect"), even though the regenerated stands are managed intensively. The transition from the original old-growth forests to second-growth stands has long since taken place in the Acadian forest, and any fall-down effect was limited to the sawmill industry in the early 1900s.

We envision a three-part or triad approach to forest land allocation (Figure 1). First, selected high-productivity sites with no special ecological characteristics would be allocated to high-yield silviculture, while other lands of unique ecological value would be acquired by the public, if necessary, and set aside as reserves. Then, on the remaining lands that do not qualify for the "high-yield" or "reserve" status, application of New Forestry practices would be substituted gradually for the present largely extensive or exploitative management.

The usual point of departure for such discussions is that the present level of timber production would be maintained both during and after the transition to the restructured forest. We retain this assumption, but also acknowledge other scenarios. For example, many advocates of economic growth would argue that timber production should be increased wherever feasible, while many advocates of ecological integrity would argue that timber production could be reduced through recycling and more efficient usage of materials. Other assumptions are: (1) that implementing New Forestry practices would reduce the profitability of growing timber on the affected acreage; and (2) that New Forestry would not provide certain benefits that flow only from completely unharvested forest lands. If both assumptions were false, then New Forestry would be recommended everywhere. Some environmentalists would argue that the first assumption is false and that only New Forestry management and reserves are needed. Some industrialists would argue that the second assumption is false and only high-yield and New Forestry management are needed.

We further assume that professionals know how to carry out the requisite allocations and that they are able to manage and conserve forests within each category once the allocations are codified. Many of the details of high-yield silviculture have been basically worked out, as they have in other coniferous regions. Thus, lack of funds, not ignorance, apparently is the main obstacle to expanding these practices. Similarly, concepts and specific action plans have been developed for creating systems of ecological reserves out of an essentially industrial forest landscape although they remain untested (McMahon in press; Hunter et al. 1988; Hunter 1986). Here too, the major obstacle is a source of funds to acquire or otherwise preserve the selected lands. The greatest challenge could well be revamping silvicultural practices on the third category of forest land, where low-intensity timber management is currently the rule, but where highly intensive New Forestry practices would be substituted. This is an especially daunting task, The TRIAD Concept of Forest Land Allocation

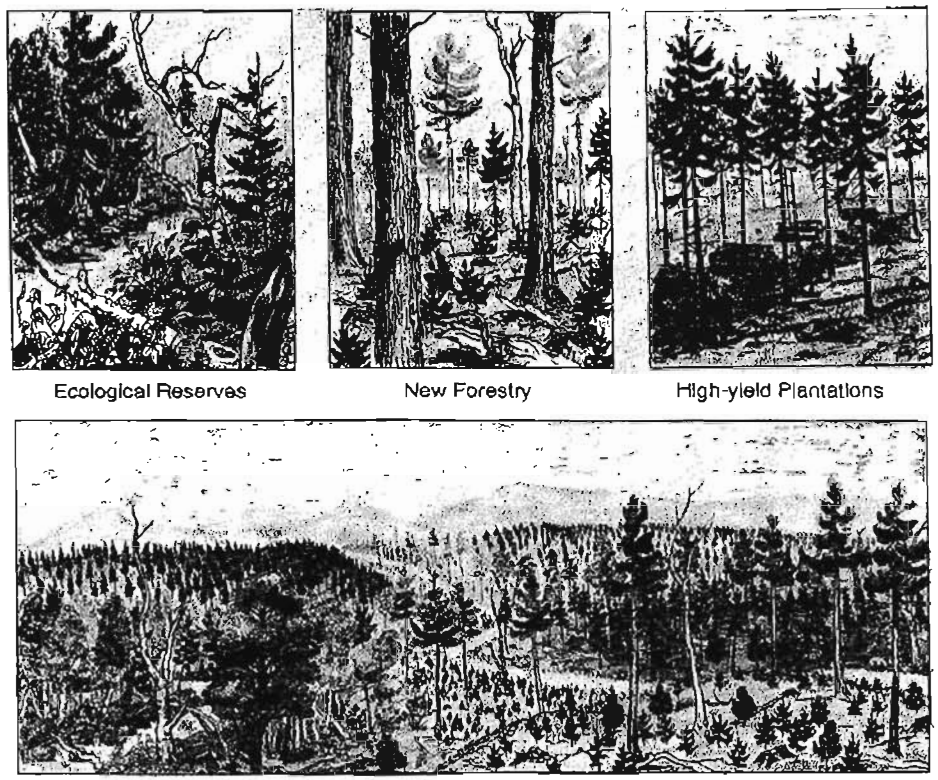


*Figure 1. The Triad Approach to Forest Land Allocation*

because this category is expected to be the largest one in area, with potentially large increases in management costs. Unlike the Pacific Northwest, these would have to be undertaken largely by private landowners, and thus incentive programs may be required.

The triad addresses a fundamentally political problem of land allocation that cannot be solved merely by widespread alteration of silvicultural practices via New Forestry. Whether any such allocation occurs depends mainly on the U.S. Congress, Canadian Parliament, and state and provincial governments, as well as the interplay between market forces and regulatory constraints that affect private land. However, there are technical aspects of this issue that should be mentioned. First, the problem of future wood supplies must be analyzed to estimate the necessary areas in the two commodity-producing categories. Preliminary estimates are encouraging (Seymour and McCormack 1989); they suggest that we truly can "have our forest and harvest it too." However, the critical transition strategy must be devised. For example, how can we place significant areas in reserves now if it takes 40 years to obtain production from areas converted to high-yield production? Also, who will pay for land taken out of production and for the accelerated application of intensive and New Forestry silviculture on the remaining lands? Formulating transition strategies is a complex issue that lies outside the scope of this paper; the issue of "Who pays?" has been addressed by Hunter (1990: Chap. 15). We also recognize that concerns such as nutrient depletion and increased susceptibility to pests have led many authors (e.g., Maser 1988, Lansky in press) to question the long-term viability of plantations over multiple rotations. Future research may reveal significant short-comings in high-yield forestry as it is currently practiced, but the triad concept will be valid as long as timber production is dominant over other goals in some parts of the landscape, and yields of those stands are significantly higher than in other parts of the landscape where multiple-use goals prevail.

### Natural Disturbance Patterns as Models for Silvicultural Systems under New Forestry

The ethical foundation of New Forestry is often summarized in three words, "kinder and gentler." To the silviculturist, "kinder and gentler" suggests an emphasis on the structure and function of forests as natural ecosystems rather than as commodity farms (Gillis 1990). A knowledge of ecosystem dynamics, particularly how forests renew themselves after natural disturbances, is thus a prerequisite to designing appropriate silvicultural systems. Obviously, this is not a new concept. This premise was firmly established in early silvicultural practice, because prior to widespread use of planting, the only way to ensure adequate regeneration was to mimic the way "Nature" did it. Indeed, the outmoded convention of naming entire systems of silviculture after the regeneration method, without regard to equally important thinning schedules or other intermediate treatments, was an attempt of early silviculturists to emphasize the fundamental importance of imitating natural disturbances.

In the sub-boreal Acadian spruce-fir forest, each partial disturbance tends to regenerate a new cohort of trees while also releasing survivors of older cohorts to respond and grow. If the disturbance recurs at intervals shorter than the life span of the trees, then truly multi-cohort structures can develop. Silvicultural analogues to this pattern lie outside traditional even-aged management, although not as far as one might suspect. Options range from an essentially even-aged irregular or extended shelterwood harvest, to a truly uneven-aged, balanced selection system, depending upon the number of cohorts desired in the stand. An example of this is presented later in the text where we address stand-level implementation of these ideas.

The true boreal forests tend to follow the simpler, classic single-cohort model, in which large-scale stand-replacing disturbances completely eliminate previous cohorts over the affected areas. Few or no survivors remain, and stands have a clear single-cohort age structure dominated by species with relatively short longevity (Cogbill 1985). The obvious silvicultural analogue here is true clearcutting, with a single cohort becoming established entirely after the disturbance. However, if natural disturbance patterns are rigidly imitated, results may conflict with attempts to minimize aspects of timber management that the public finds most intrusive. For example, mimicking a 10,000 ha crown fire with an equivalent clearcut is no different in principle from matching natural tree-fall gaps with single-tree selection cuttings (Hunter 1990; Runkle 1991). While the public usually regards the latter practice as exemplary, the former would not be well accepted because from a human perspective, it is hard not to think of a clearcut covering thousands of hectares as a calamity.

## Ecosystem Restoration

The extreme scarcity of old, virgin forests in the Acadian region makes it easy to argue that the few remaining old-growth stands should all be preserved. This scarcity also highlights a related issue: the extent to which human intervention has altered the original spruce-fir forest and the "need" to restore some forests to their original state. Discussion centers on two issues: stand and forest age structures; and species composition. In a comprehensive review of early descriptions of virgin red spruce forests, Seymour (1992) concluded that stand age structures have been greatly altered by more than a century of harvesting, and possibly by more frequent and persistent spruce budworm outbreaks. Because many tree species are quite long-lived (250–400+ years) relative to a typical timber rotation of 40–80 years and also tend to survive and respond to partial disturbances, original stands were probably older and more diverse in age structure than the present younger, more even-aged stands originating after heavy cutting.

Furthermore, it is likely that certain commercially valuable species were more common in virgin forests. The well-documented waves of exploitation, first for white pine, then for red spruce, then for the valuable hardwoods especially yellow birch (*B. alleghaniensis*), are legendary. Examples of important changes in forest composition would include the former "spruce-yellow birch type," now often dominated by red maple and balsam fir; and the former mountainside "spruce slope" type, large areas of which have been converted to "off-site" paper birch stands by extensive clearcutting during the first half of the 20th century. This evidence, although limited and somewhat anecdotal, clearly suggests that the long history of exploitation for forest products has substantially altered the spruce-fir forest from its presettlement condition.

Evidence from a recent comprehensive study in the Pacific Northwest suggests that ecosystems are indeed simplified if "legacies" (living and dead snags, large woody debris, etc., that survive natural catastrophes) from old-growth forests are destroyed in logging (Hansen et al. 1991). In the Acadian forest, we do not know definitively whether the structural changes noted above have had substantial ramifications for other aspects of the ecosystem, in part because so few examples of the original forest remain to serve as benchmarks. Furthermore, factors such as climate change and possible impacts of pre-European inhabitants make the idea of restoring the "original" forest analogous to hitting a moving target. However, we believe that changing the trajectory of stand development in some forests, so that they better resemble what they might have been without European colonization, should be an essential component of New Forestry in eastern spruce-fir.

# PART III: SPECIFIC APPLICATIONS AT THE STAND LEVEL

This section discusses some key issues involving the modification of stand-level silvicultural practices to achieve New Forestry goals. First, a few specific practices are described, then a general silvicultural system for incorporating these practices is outlined.

## Conservation and Restoration of Seed Sources

To restore the original tree species composition of forest ecosystems altered by past practices, two tactics are available: (1) conserving and enhancing the seed-bearing status of those rare individuals that remain; and (2) augmenting natural regeneration through artificial means. Because trees take so long to grow, neither practice will bring about noticeable changes in the short run; perhaps the best one can hope for is to forestall continued losses.

The biology of the species in question has been well known for many decades, so this is not a case where more basic research is needed. However, published silvicultural guidelines for regenerating these species have been developed largely through observations and experiments in pure stands where the species is dominant. In contrast, empirical evidence of regeneration procedures that could increase the abundance of an initially rare species is lacking and must be created from knowledge of silvical properties. The desultory tactic of leaving a residual stand of the rare species as seed trees, as a token modification of a clearcut, is a risky practice at best. Seed tree cuttings work well only for species that are windfirm as individual trees and thrive in exposed post-disturbance microenvironments. Furthermore, trees must have reached an age where seed production from a few individuals is sufficient to ensure an adequate representation in the next stand, and success often depends on carefully timing the harvest to coincide with a good seed year. The only species of the eastern spruce-fir forest that comes close to matching these requirements is eastern white pine.

In the Acadian forest, variants of the shelterwood method offer the best potential for addressing New Forestry concerns while meeting the species' silvical requirements. With this method foresters have wide latitude in controlling the overwood density to favor the species in question. Also, the method is robust in that if adequate regeneration is not obtained in the establishment cutting, one often has future opportunities to establish new seedlings unless the understory becomes overwhelmed by competing species. Generally it is best to err on the side of lighter, not heavier, cuttings, especially if follow-up weed control is not possible. True clearcutting is the extreme example which offers no second chance. Even shade-intolerant species will germinate and survive for at least a few years under moderate overstory cover and can then be released promptly to ensure seedling establishment.

This example illustrates that it is often easier to control species composition (in favor of either tolerants or intolerants) by varying the timing of subsequent removal cuttings, rather than the severity of the initial establishment cutting. For example, to favor an intermediate species like white pine over a tolerant like balsam fir, one could remove perhaps 30–40% of the original stand in a good pine seed year, then make a second cutting (either complete or partial removal) as soon as pine seedlings are established. Delaying the second cutting could allow the fir to outcompete the pine. Making a heavier establishment cutting might work, but provides no fall-back position if pine seedlings do not become established and the understory then becomes occupied by brush. If the objective were to favor a very tolerant species like red spruce over less tolerant competitors such as red maple, then extreme patience may be required. A light establishment cutting followed by a long holding period while the spruces reach sapling size and competitors die from lack of light might be necessary.

If the species in question has been extirpated from the stand, then the little-used practice of enrichment planting should be considered. Here the goal is not to create a monoculture, as with a conventional plantation, but rather to restore a semblance of the original diverse mixture. Some foresters view Planting (with a capital P) not as a distinct practice, but as an entire system of silviculture including site preparation and herbicide release to create even-spaced, artificial monocultures at a very high cost. If we eliminate this mind-set, then it is easy to envision planting (small p) under almost any circumstances where the objective is simply to ensure perpetuation of a given species. For example, planting about 100–200 white pines per hectare immediately after overstory removal, to enrich what would otherwise be a pure spruce-fir stand, gives foresters additional future options. If the previous stand had been logged using controlled skidding patterns, then planters need only walk up and down widely spaced skid trails, opportunistically planting trees at wide spacings on favorable microsites, rather than walking over the entire harvest area. While this practice is more expensive per tree planted than a standard plantation with ten times the density, the total cost per hectare is much less. A rough estimate might be that one could plant 10% as many trees as a "standard" plantation at about 20–30% of the total cost—only 100-150 dollars per hectare instead of 500. Such low planting costs could allow a given regeneration budget to be spread over far more area than spending it in the conventional way.

Another species conservation issue involves the small, but growing, practice of precommercial thinning in dense fir-spruce regeneration. When this practice began in the late 1970s, attempts were made to favor red spruce over fir due to its greater resistance to spruce budworm damage. Because firs are usually taller and more abundant at this stage of development, especially on productive sites (Meng and Seymour in press), favoring spruce potentially can reduce stand growth on short rotations. More recently, several landowners have modified crop-tree selection procedures to merely select the tallest tree on the chosen spacing, but this discriminates against red spruce and other species and leaves residual stands that are unnaturally pure monocultures of fir. A more conservative approach would be to leave the best few hundred spruces per hectare regardless of their competitive position, along with populations of less common species such as pine and cedar. Little, if any, growth would be lost and future management options would be greatly enhanced. Without the long-lived spruce component, these stands may well be destined for short rotations (under 70 years) limited by the pathological rotation of balsam fir.

### Retention of Residual Trees

The general purpose of retaining residual trees is to provide structural diversity that can be created only by large old trees, living and dead, both immediately after harvest and throughout the next rotation. Although practices such as dead-snag retention may temporarily enhance these values, these trees typically have been treated as a one-time residue from the previously unmanaged forest. If future silvicultural systems make no provision to grow such trees, not merely preserve and retain them, then this important component of the forest is reduced to the status of a nonrenewable resource.

The practice of retaining trees has been widely advocated (e.g., Thomas 1978; Hunter 1990) and can be easily summarized. First, the trees should be inherently long-lived species in order to provide continuing structural diversity beyond the first decade or two after harvesting. Second, they should be left in a configuration that is robust against windstorms. Some deep-rooted species may resist wind as individual trees, while other shallow-rooted species may need to be left in small clumps. Third, the retention trees should provide as little direct competition to the developing stand as possible. Tall trees with narrow, medium-length crowns that maintain strong epinastic control and continue to grow in height would be preferred over shorter, wide-crowned individuals that expand outward, not upward, and thus tend to develop into the proverbial "wolf-trees." Finally and ideally, such trees would continue to grow in economic value as well as volume, and thus provide a financial incentive to retain some of them for later harvest.

In general, the last two criteria tend to favor conifers over hardwoods due to their geotropic form and generally higher value, at least in the spruce-fir region. Eastern white pine is the only species that can meet all of these requirements. It is long-lived, windfirm, and highly valuable if not damaged by the white pine weevil or blister rust. Other long-lived conifers include red spruce, northern white-cedar, and eastern hemlock. Spruce is the most valuable of these three, but also the least windfirm; it is suitable as a retention tree only if left in clumps of sufficient size to resist wind damage, or if trees are much shorter than average. Hemlock and cedar are more windfirm, but tend to be slow growing with wide crowns that offer more competition to the developing stand than pine or spruce.

Several hardwood species (red maple [*Acer rubrum*], sugar maple [*A. saccharum*], American beech [*Fagus grandifolia*], and yellow birch) also are long-lived, windfirm, and valuable, thus making them potential choices as retention trees. Moreover, hardwood trees provide a substantially different habitat for many animals. Unfortunately, these northern hardwoods are restricted mainly to better drained soils, limiting their use to mixedwood stands, and they tend to suffer severe loss in quality (epicormic branching, crown dieback, etc.) when left as exposed individuals. Furthermore, their wide-spreading crowns clearly offer more shade and competition for the developing stand, unless trees are severely weakened. Balsam fir, paper birch, and aspen are important components of the spruce-fir forest, but their limited longevity (usually under 100 years) essentially prevents their consideration as long-lived retention trees. However, this should not preclude their retention as more temporary "snags," especially in cases where the preferred longer-lived species are rare or absent.

The long-term fate of retention trees need not be predestined at the time they are selected as residuals. We envision a system where some, but not all, such trees could be removed in subsequent harvests of the younger developing stand. If an adequate population of potentially high-value trees was retained at each major stand entry, future harvests could select among these, retaining some indefinitely while harvesting others. Trees that responded to the previous release and maintained high quality for lumber or veneer would be harvested. Trees that were damaged by natural disturbances (e.g., lightning strikes, broken tops) since the previous entry, thus reducing their economic value but not their ecological value, would be retained. Over time, examples of at least three cohorts would be maintained in all stands: the main age class comprised of the young, developing stand; the middle-aged retention trees carefully selected from the next-oldest cohort when it was largely harvested, and finally the very old or permanently retained individuals that are at least as old as three rotations of the main cohort.

### Longer Rotations

The "ancient forest" concerns that dominate the agenda in the Pacific Northwest are, unfortunately, largely moot in the eastern spruce-fir region. If we seek to have our equivalent of ancient forests well represented throughout the landscape, we must grow them back by lengthening rotations. The main arguments for longer rotations involve (1) conservation of the site's nutrient capital according to the concept of the "ecological rotation" (Kimmins 1987; Smith et al. 1986); and (2) maintenance of some of the stand features, such as large snags and logs and vertical diversity, required by wildlife species characteristic of older forests (Hunter 1990). Longer rotations are also necessary because certain high-value products can be made only from large trees, and because to many people old trees have undeniable aesthetic and spiritual value. Although large diameter trees can be grown in a much shorter time with aggressive, low-density thinning schedules, there is no silvicultural tactic, short of simply lengthening the rotation, to make trees grow taller. For many applications, rotations designed around the peak mean annual increment (MAI) of sawtimber-sized trees should suffice. Trends in MAI over stand age are often quite flat over a wide range in ages, especially if commercial thinnings are undertaken (Davis and Johnson 1987). This suggests that managers can lengthen rotations with little loss in average annual growth. The costs of such a strategy could be significant, however. They include: the opportunity cost of tying up more capital in trees rather than other investments; the greater risk of unsalvageable catastrophic losses; and a likely reduction in annual harvests during the transition period as longer rotations are phased in, akin to a negative allowable-cut effect.

### Limited Whole-tree Harvesting

Whole-tree harvesting, in which the entire above-ground portion of the tree is removed from the site, has expanded greatly during the past decade. In response to higher labor and insurance costs, logging contractors have substituted mechanized felling and delimbing at roadside for motor-manual (chainsaw) delimbing at the stump. Furthermore, several electricity-generating biomass plants have provided a greatly expanded market for whole-tree chips. Unfortunately, whole-tree harvesting can deplete the nutrient and organic matter capital of certain types of sites, potentially reducing future timber yields, and decreasing the habitat of species that require large woody material.

We advocate limiting whole-tree harvesting to one-time site-conversion operations on those portions of the landscape allocated to the high-yield component of the triad. Many of the stands most appropriate for conversion are dominated by low-quality hardwoods with a long history of high-grading. Typically such stands have deep soils and large nutrient reserves, so the risks appear to be small relative to the large future gains in timber productivity. Whole-tree harvesting is potentially much more harmful on poorly drained, shallow soils in which much of the nutrient capital is tied up in the organic horizons. Because these stands are inherently lower in productivity, under our proposed triad arrangement most of them would not be managed under high-yield systems, but rather would be assigned to New Forestry or reserve lands. Obviously, kinder-gentler forestry would attempt to conserve forest residues by on-site delimbing. This can be done with existing technology either conventionally (motormanually), or by using recently introduced single-grip harvesters developed in Scandinavia. Unfortunately, workers' compensation costs are very high for motormanual operations, and costs of single-grip harvester operations are not yet well established for a variety of conditions.

### Expanded Application of Non-standard Silvicultural Systems--Two-aged Stands Maintained by Irregular Shelterwood Cutting

Clearly, it would be difficult to incorporate many of the practices recommended above into the even-aged silvicultural systems now in use without sacrificing certain operational efficiencies. Widespread implementation of New Forestry in the eastern spruce-fir forest requires a different silvicultural paradigm. Critics of even-aged silvicultural systems tend to view uneven-aged silviculture, implemented through single-tree selection cuttings, as the only satisfactory alternative. While selection harvesting is certainly appropriate from a New Forestry perspective in some Acadian forest types, in this section we will describe a lesser-known silvicultural system with potentially broader application.

These intermediate silvicultural systems tend to maintain two age classes or cohorts in the stand at all times and are best described as "two-aged" in structure. Harvest cuttings used to regenerate and maintain the structure of such stands would most likely fall under the irregular shelterwood method (Smith 1986; Seymour 1992). This method is similar to conventional even-aged shelterwood management, except that some trees from the older cohort are not harvested in the final removal cutting, but are left as retention trees through part or all of the subsequent rotation of the younger cohort (Figure 2). These large trees add vertical structure and economic value during a period of stand development when these attributes are absent from conventional even-aged systems.

Silvicultural treatment of the younger, dominant cohort is similar to conventional single-cohort systems, but with several additional considerations (Seymour 1992). First, competition between cohorts must be considered. Some old-cohort retention trees might need to be removed about midway through the rotation of the younger cohort, perhaps coinciding with an early commercial thinning. Second, fostering the development of stems that will ultimately be left as retention trees must be considered. Here, canopy stratification by species *within* a single cohort (Smith 1986; Oliver and Larson 1990), especially the potential of shade-tolerant species to respond to release at advanced ages, must be recognized and used to advantage. For example, removing small spruces or cedars from lower canopy strata in an early thinning of a fir-dominated stand would preclude their later use as retention trees. Finally, when the first rotation of the dominant cohort ends, there must be explicit provision for regenerating the requisite mixture of species.

Two-aged silvicultural systems mimic the small, patchy natural disturbance patterns of the Acadian forest reasonably well. They provide vertical structure approaching that of true selection forests, yet retain much of the managerial simplicity of even-aged systems. Furthermore, they are less susceptible to the major shortcoming of nominal selection silviculture--the difficulty of preventing cuttings from degenerating into high-grading operations that pay inadequate attention to structure or future development of residual stands (Seymour et al. 1986).

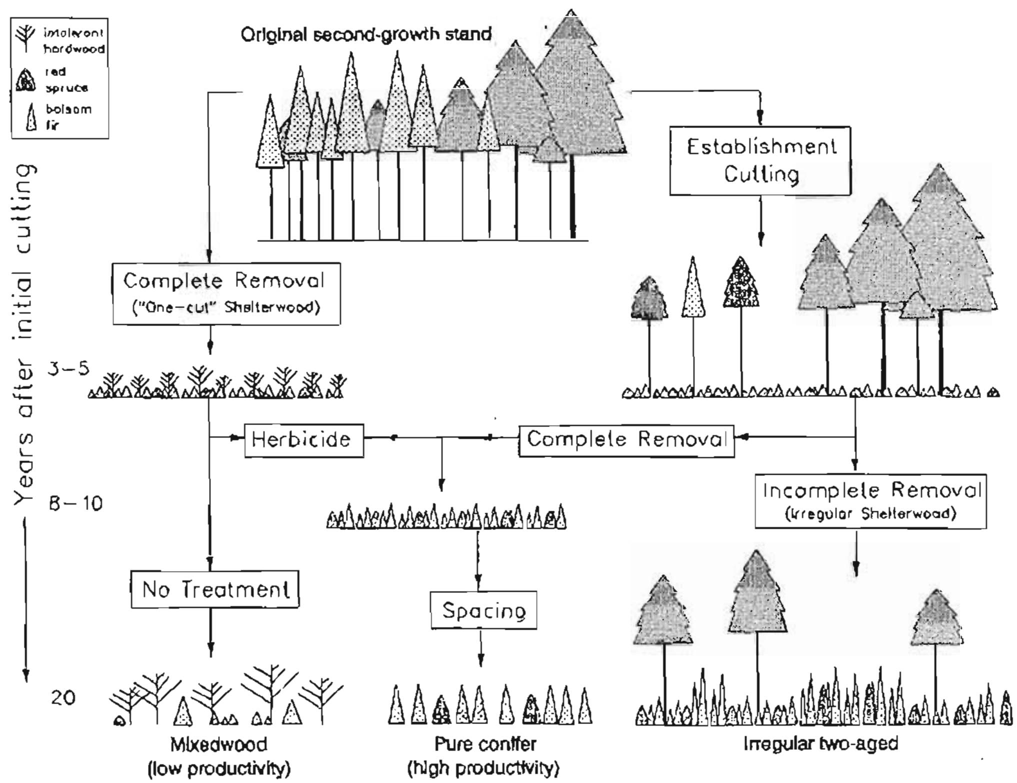


*Figure 2. Comparison of the two-cohort, irregular shelterwood system, (lower right) with typical silvicultural pathways leading to single-cohort stand structures (Source: Seymour 1992)*

There is considerable debate over whether forest productivity is reduced or enhanced by maintaining multi-cohort stand structures. Advocates of single-cohort monocultures can cite a substantial body of evidence supporting their claim that such stands produce high timber yields in comparison to unmanaged natural stands. Unfortunately, very little evidence exists either in support of or opposition to the largely theoretical contention that productivity is enhanced by maintaining vertically diverse canopy structures. The few long-term comparative yield studies reviewed by Assmann (1970) suggest that neither age structure is inherently superior. As long as stands remain fully stocked and species are well adapted to the site, the prevailing view is that the appropriate stand age structure should be based on criteria other than timber yields (Smith 1986). In the face of this equivocal evidence, one can presume that the widespread popularity of plantation-like silviculture for industrial timber production is strongly influenced by financial and managerial considerations. Our qualified support for these practices in the high-yield component of the triad is contingent therefore on the presumption that plantations will continue to be the most economic means of achieving high timber yields.

Critics of two-aged silvicultural systems have characterized retention trees only as a negative, competing influence on the young stand. Rarely has the possibility been considered that growth of residual stems might actually enhance total-stand productivity. Growing a few residual white pines to large size above a younger cohort of spruce and fir provides a particularly compelling example. A single pine tree of 60 cm dbh easily can be worth \$200, given the high value of clear, wide boards. Only seven such trees would equal an entire hectare of spruce-fir pulpwood of 240 $m^3$ at \$6/$m^3$! It is possible to grow such a tree in only 40–60 years starting from a point where pole-size pines (age 40, 20–25 cm dbh) are left as holdover trees when the bulk of the stand of spruce-fir pulpwood is harvested. Innovative foresters should be able to develop similar silvicultural systems to incorporate New Forestry principles with little sacrifice and perhaps even economic gain. The main added cost, relative to simpler, even-aged systems, is the added time of professional personnel; actual expenditures for silvicultural treatments could even be less than under intensive high-yield systems.

# PART IV: SPECIFICS–APPLICATIONS AT THE LANDSCAPE LEVEL

## Implementation of the Triad Approach to Land Allocation

Deciding which parts of the landscape are most suitable for intensive timber production, ecological reserves, and New Forestry management is conceptually straightforward. Simplest to identify are the locations for plantations: ideally, these would be productive sites that are close to mills and access roads. Important sites for ecological reserves are places that harbor uncommon features such as old-growth ecosystems or habitat for rare species. However, it is also important that reserves represent the entire range of ecosystems, not just the rare or unique ones. This means that some fertile, moderately well drained, low elevation sites good for timber production need to be included in a reserve system too. Design issues for reserves--size, shape, proximity to other reserves, etc.--are critical; see Shafer (1990) for a recent review.

Land allocated to New Forestry management could be what is left over after plantations and reserves are identified, but this does not mean that this component of the Triad should necessarily be the smallest piece of the pie. In some parts of the eastern spruce-fir region, small private landholdings dominate the landscape and New Forestry style management is likely to be the best choice for meeting the goals of most private landowners. Many practices used by participants in the Tree Farm system agree fully with New Forestry, and this system may provide the best mechanism for expanding awareness and application of new methods. In many cases New Forestry management will be appropriate where management of resources such as aesthetics, recreation, water, and wildlife (particularly game species) is primary, but readily integrated with timber management. In other cases, these interests will best be served by reserves.

The three types of land management might be distributed across a hypothetical landscape as large blocks, perhaps with the New Forestry areas as buffers between the reserves and plantations (Figure 1). Real landscapes will necessitate many compromises. For example, sensitive areas such as riparian strips and steep slopes need to be reserved from intensive timber harvesting, but are often too spread out across the landscape to delineate as reserves. This situation will require the zoning of these areas for some degree of protection, as done by the Maine Land Use Regulation Commission, even when they bisect land that is generally well suited for intensive production.

Moving from the status quo to a landscape with a sound balance between the three elements of the triad cannot happen overnight, especially in regions where private interests own the forests or have long-term leases. Nevertheless, forest land is constantly being shifted from one type of management to another, and with vision and foresight these shifts can be directed to facilitate wise natural resource management.

### Size and Distribution of Harvest Areas

How large harvest units should be, especially clearcuts, and how they should be distributed across the landscape are critical questions. Unfortunately the answers to these questions are closely linked to two controversial issues, clearcutting and forest fragmentation. In the spruce-fir forest region, these issues are poorly understood both because of a lack of relevant research and because polarized opinions obfuscate objective discussions.

Conceptually it should be easy to match the size and distribution of harvests to the size and distribution of natural disturbances that initiate a whole new stand, primarily crown fires, or a new cohort, primarily spruce budworm and windstorms. In practice, there are some difficulties, especially with designing clearcuts to imitate the crown fires of the true boreal forest (Hunter in review). First, most people are unwilling to accept huge clearcuts (hundreds and thousands of hectares) that mimic fires of this size. Second, harvesting efficiency and other economy-of-scale arguments that favor clearcutting diminish in importance at very large scales. Third, important differences between clearcuts and crown fires such as the frequency of disturbance and the fate of residual trees, seedlings, seeds, snags, logs, and slash, undermine the argument that clearcuts are similar to fires.

The issue of forest fragmentation further complicates this picture. Many conservationists believe that fragmentation is one of the most important forms of forest habitat degradation (Harris 1984). However, research on this issue comes largely from landscapes in which forests are small patches in a matrix of agriculture, whereas in the eastern spruce-fir region, forests still dominate the landscape and mature stands are isolated from one another primarily by roads, younger stands, and water bodies (Hunter 1990). If fragmentation is a problem in the eastern spruce-fir forest then this is an argument for increasing the size of harvests because a few large harvests fragment the landscape less than many smaller ones of the same total area (Franklin and Forman 1987). If fragmentation is not an issue, then it may be better to let social values such as aesthetics determine their maximum size.

In the absence of definitive information, we advocate that harvesting take place on a variety of scales ranging from selection cutting to moderately large harvests, perhaps 100 hectares. Allocating roughly equal amounts of harvest area to different points along the size continuum is likely to maintain biological diversity (Hunter 1990). It is especially critical not to let controversy over the scale of harvesting lead to a compromise in which there is a low maximum size of harvest openings, e.g., 20 ha, and most harvests end up being just below this limit.

The location of harvest areas on the landscape is also critical. Some ideas are obvious, such as using small-scale management in sensitive areas such as riparian zones and recreational areas. A less obvious idea is that large-scale management should be concentrated in one part of the landscape, for example clustering clearcuts with buffer strips between them. In the true boreal forest, clusters of clearcuts less than 100 ha each could collectively imitate much larger crown fires. If buffers between clearcuts were left along shorelines, they imitate stringers of unburnt lowland forest that often break up a large fire.

In 1990, the Maine legislature passed a new forest practices act that regulates clearcutting (defined as any harvest of five acres or more that results in a residual basal area under 30 square feet per acre). Clearcutting is constrained under a three-tiered system that requires increasingly rigorous temporal and spatial (linear and areal) separation as the size of the cut increases up to the legal maximum of 250 acres (100 ha). The provisions of this act and how they relate to the issue of fragmentation are discussed in the Appendix.

### Riparian Zones

The eastern spruce-fir forest lies in a recently glaciated terrain with a large number of lakes, rivers, streams, and wetlands. Riparian zones associated with these water bodies are key elements of the landscape and merit special consideration (Brinson et al. 1981; Hunter 1990). Riparian zones serve as buffers to protect water quality from disturbances originating in terrestrial ecosystems; they provide visual screens for aquatic recreationists; they serve as corridors to allow forest species to move across the landscape; and, in many cases, they comprise distinctive ecosystems with their own unique biota.

Because of these values we believe that intensive timber production should rarely take place within 50-100 m of a water body. New Forestry management of riparian areas is feasible if issues such as avoiding erosion, maintaining canopy cover, and providing logs and snags are carefully considered. However, often it will be easiest to deal with these issues if there is a narrow zone (perhaps 10-25 m) without any timber harvest at all. These narrow zones will develop some of the attributes of old-growth forests and allow some species, woodpeckers for example, to use much of the landscape traversed by streams. Many riparian trees will die because of spruce budworm and other disturbances, but this should not precipitate a timber salvage operation. Dead trees are an integral part of forests and streams, where they provide important structural diversity after falling.

## CONCLUSION

We conclude by proposing an Agenda for Action. Specifically, we recommend:

1. **Widespread professional acceptance and political support of the Triad concept of land allocation and management.** We believe this model offers a true "win-win" scenario for resolving conflicts between environmentalists and industrialists which have been so divisive.

2. **Development and implementation of New Forestry-based silvicultural systems on lands not specifically dedicated to high-yield timber management or preservation.** Despite its laudable intent of making multiple-use forestry a truly operational concept, New Forestry is not a panacea for resolving all forest resource management conflicts. Nevertheless, we believe that it merits wide application to help ensure that benefits in addition to timber continue to flow from managed forests.

3. **Greatly accelerated research on both stand-level and landscape-level effects.** Despite their appeal to those seeking an alternative to current forestry practices, the premises of New Forestry are still working hypotheses, not proven management systems. As such, they must be examined critically in light of current knowledge and experience with their application. Much can be done with retrospective studies using stand reconstruction and other methods. For example, the post-harvest growth of retention trees and their effects on the younger developing stand can be quantified by studying the many fortuitous examples created by past harvests and natural disturbances. Other issues will require controlled, prospective studies, probably using large-scale operational trials on permanent plots that will be expensive and difficult to maintain.

4. **A revamped view by land management professionals of what constitutes "good" forestry.** Professional curricula have inculcated certain values in foresters that can, at times, be counterproductive when responding to society's demands. Examples include:

equating high timber yields and "clean" clearcuts with "good" forestry; opposition to forest preservation in principle because it ostensibly conflicts with the hallowed doctrine of multiple use; and emphasis on economic expediency over ecological integrity. Although such narrow views may represent certain private interests, they seem increasingly inappropriate, even arrogant, in an era when society is demanding more than cheap commodities from its forests. Without such a change in perspective by foresters, New Forestry may be viewed negatively as simply another threat to timber management, and the welcome opportunity it offers for achieving a renewed mandate from the public could be lost.

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# APPENDIX: AN ATTEMPT TO REGULATE LANDSCAPE DIVERSITY—THE MAINE FOREST PRACTICES ACT.

Salvaging timber killed by the spruce budworm led to extensive clearcutting in Maine during the 1970s and early 1980s that continued after the budworm epidemic abated. Clearcutting and ancillary issues such as use of herbicides led many Mainers to criticize what was happening in the Maine woods. This criticism catalyzed a group of people representing the timber industry, environmental groups, and state government to develop a forest practices act that was passed by the state legislature in 1989. The story behind this process is complex and interesting (Hunter and Seymour 1989), but here we will limit ourselves to describing the outcome.

### Summary of the Rules Related to Clearcutting

Any harvest that leaves an opening of over five acres with less than 30 square feet of basal area per acre (6.9 $m^2$/ha) is defined as a clearcut. An exception, known as the "shelterwood exemption," excludes from these area limits any cuttings that leave a "well-distributed" stand of trees that meets the regeneration requirements. Clearcuts from 5–35 acres (2–14 ha; Class 1) must be buffered from adjacent clearcuts by a 250 foot (76 m) wide separation zone. The clearcut is no longer a clearcut, and the separation zone can be clearcut, after ten years have passed *and* regeneration has grown 10 feet (3 m) tall for hardwoods or 5 feet (1.5 m) tall for softwoods. Partial harvesting can take place in the separation zone as long as it does not break the 30 sq. ft of basal area rule.

For clearcuts of 35–125 acres (14–51 ha; Class 2) the 250 foot wide separation zones must have a total area equal to 1.5 times the size of the clearcut. This means that the separation zone must be much wider than 250 feet in some areas and cannot be cut in its entirety after the original clearcut regenerates. Partial cutting in the Class 2 separation zones cannot remove more than 40% of the volume of trees 6" (15 cm) and larger and must leave 50 square feet of basal area per acre (11.5 sq m/ha).

Exceptions up to 250 acres (101 ha) will be routinely allowed if the separation zone is 500 feet (152 m) wide and has a total area twice that of the clearcut. Under special circumstances, e.g., timber salvage, cuts of any size can be given a variance; one variance was granted during the first 12 months, but was then relinquished by the applicant.

It is instructive to contrast the act with an alternative advocated by members of the Maine Dept. of Inland Fisheries and Wildlife. Their proposal called for no upper limit on clearcut size, but a separation zone equal to three times the size of the cut. This approach would have created a progressively greater disincentive to large cuts, but no absolute limits, and would have meant that regularly harvested landscapes would eventually have four age classes, each differing by at least 10 years. State forestry officials felt there had to be an upper limit on clearcut size to satisfy the general public; timber industry representatives felt that the requirements for age class diversity were too restrictive.

### Evaluation

It is too early to determine how forest managers will comply with the act, but most of the major companies apparently intend to follow both the letter and the spirit of the law. Some people predicted that many loggers would comply with the law by leaving 31 square feet of basal area of poor quality trees, or laying out a checkerboard of 34 acre clearcuts interspersed with 34 acre residual stands that could be cut ten years later. These practices may yet prove to be widespread, especially on the 50% of the industrial forest base owned by smaller companies and private individuals.

From a New Forestry perspective leaving 31 square feet of basal area per acre could be thought of as green retention, although the retained trees will almost certainly be chosen because of their lack of commercial value, rather than their positive contributions to forest diversity. If much of the forest becomes a checkerboard of 34 acre squares this would be a highly fragmented situation for reasons described by Franklin and Forman (1987).

We believe the major positive features of the act are: (1) it makes it much more difficult to clearcut most of a region in a short period; (2) it forces foresters to look beyond the individual stand and consider how their cutting plans affect distribution of stands in both time and space; and (3) it avoids a simplistic solution, such as no clearcuts over 50 acres, that would produce many 49 acre clearcuts and a fragmented landscape.

We feel the act's major shortcoming is its failure to adequately provide for age class diversity, as the Inland Fisheries and Wildlife alternative would have done. Essentially the act assumes that adequate wildlife habitat can be provided by ten-year-old, five-foot-tall conifer forests. Possible other shortcomings include the potential loopholes described above (cuts leaving 31 square feet of basal area or covering 34 acres; large-scale overstory removal operations that leave only tall regeneration), but it is too soon to know if these will be widely exploited. No component of the act deals with the issue of old-growth forests, although previous laws limiting cutting in deer wintering areas, riparian zones, steep slopes, and high altitudes tend to lead to some of these areas being ignored as long as more accessible and unregulated stands are available for harvesting.