Chapter 1

Compatible Forest Management: Background and Context

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1. Introduction

Let us begin by defining our area of interest: the moist maritime forests of the Pacific Northwest (PNW). Geographically (as shown in Figure 1), this includes western Oregon and Washington (the west side of the Cascade Range, the Coast Range, and the Olympic Mountains), coastal British Columbia (Coast Mountains), and island-dominated southeastern Alaska (as far north as the Kenai Peninsula). Collectively, this is the world's northernmost temperate rainforest (Walter 1985). Although this coastal rainforest zone stretches southward to San Francisco, California, we focus our research northward from the California-Oregon border. The east-west extent of this coastal forest varies as a function of climate and elevation; the zone ranges from a few kilometers at the northern and southern extremes to several hundred kilometers in the middle of its range. Much of the northern half of this range (British Columbia north of Vancouver Island to southeastern Alaska) is in a relatively undisturbed, natural state. The forest from Vancouver Island, British Columbia to northern California contains some of the world's most valuable and productive commercial timberlands. An important subset of the PNW is the Douglas-fir region (western Washington and Oregon), which is dominated by the fast-growing coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco).

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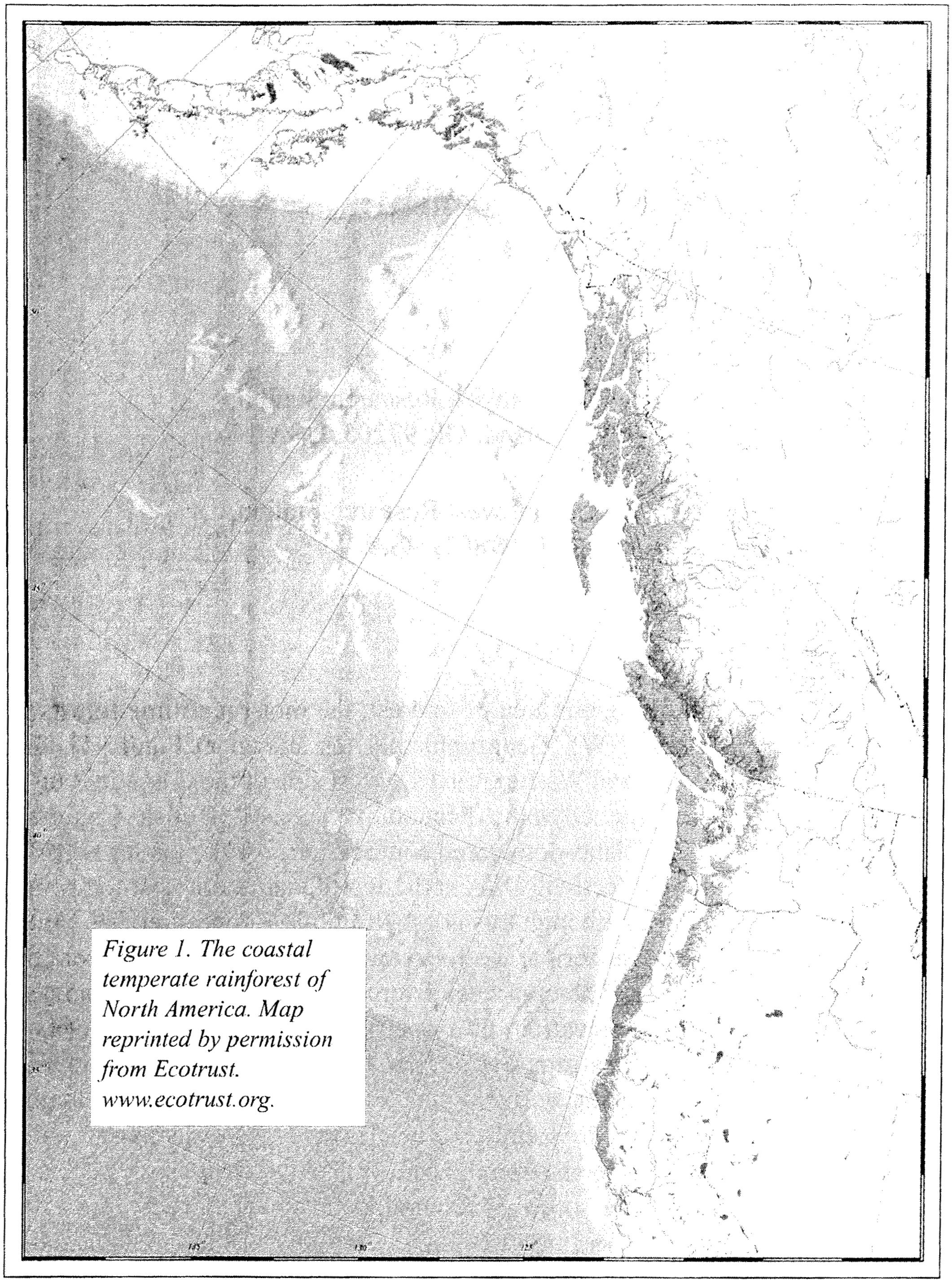

Figure 1. The coastal temperate rainforest of North America. Map reprinted by permission from Ecotrust. www.ecotrust.org.

The Pacific Northwest has a relatively long tradition of science-based forest management (Meidinger and Pojar 1991, Kimmins 1992, Peterson et al. 1997, Duncan 2000). Since the mid-1980s there has been an evolving interest in forest management that is compatible with commodity production and ecological, social, and cultural values (Peterson and Monserud 2002).

Compatible management focuses on outcomes that can be managed for simultaneously. In the simplest sense, compatible forest management simultaneously produces multiple products of value without decreasing other values, all in a socially acceptable manner. Hereafter, we refer to this as *compatible forest management*.

Interest in compatible forest management regimes has been stimulated by the public debate over forest management, which often portrays management choices as tradeoffs between biophysical and socioeconomic components of ecosystems (Peterson and Monserud 2002). This portrayal often leads to a focus on dichotomous tradeoffs rather than on the opportunities for compatible changes in outputs (either goods or services) that may exist among alternative management strategies. Here we focus on management strategies and emphasize broad goals such as wood production, biodiversity, and habitat conservation while maintaining other values from forestlands desired by the public. We show how different management approaches can offer alternatives to the divisive arena of "either-or" choices.

In general, our purpose is to explore the proposition: "*Commodity production (timber and nontimber forest products) and the other forest values (biodiversity, fish and wildlife habitat) can be simultaneously produced from the same area in a socially acceptable manner.*" This proposition will be expanded to consider natural and managed systems across a range of scales, uniform and non-uniform landscapes, and dynamic and static systems. We will examine the proposition from the point of view of several disciplines (e.g., wildlife, sociology, and economics). Inferences will be drawn about the nature and extent of joint production at different geographic and temporal scales. Inferences will also be drawn about how variation in joint production capability is related to the inherent productivity of the land (stand, watershed, province), the legacies of past land management, and differences due to ownership itself.

Much of the work discussed in this book is a product of recent research in the Pacific Northwest that addresses two aspects of the compatibility issue. First, how are various forest management practices related to an array of associated goods and services? Second, how do different approaches to forest management affect relatively large and complex ecosystems? Much of this work was organized as a research initiative (the Wood Compatibility Initiative) at the Pacific Northwest Research Station (Haynes and Monserud 2002, Johnson et al. 2002, Peterson and Monserud 2002). Its purpose was to expand information on the options that may increase the compatibility between wood production and other societal values derived from forestlands. We generally take a broad view of values related to forests (e.g., Donoghue 2003). These include life support, economic, recreation, aesthetic, wildlife, biotic diversity, scientific, natural history, cultural, spiritual, and intrinsic values (Rolston and Coufal 1991).

To set the context for the rest of the book, we summarize the management history in the Pacific Northwest (with a description of the forests), the forest sector, and the conceptual model underlying discussions of compatibility. We also provide a brief discussion of the policy issues motivating our interest in compatible forest management, and a brief introduction to the following chapters.

2. Management History

European settlement of the Pacific Northwest began in the mid-1800s (Alaska was settled earlier by the Russians). At that time, forests were seen as unlimited or as impediments to settlement. By the early 1900s, however, efforts were underway in the United States to establish federal forest reserves to protect forest resources, water quality and wildlife habitat. Most timber production during this period came from private timberlands and early forest management problems dealt with fire protection, regeneration, growth and yield studies, and harvest practices. Until World War II, most management on federal timberlands was focused on conserving forest resources. Following World War II there was a deliberate decision to increase the level of forest management on public timberlands to help meet the growing demand for forest products (e.g., homes) from a booming population and economy.

From the 1940s until the late 1960s in the United States, there was general agreement among both federal and private land managers that timber production was the primary objective in management of most forest land (Curtis et al. 1998, Peterson and Monserud 2002). Basic assumptions were that wood production in old-growth stands was essentially static (no net growth), and that insects and disease were diminishing the amount of usable wood in these stands. It seemed desirable, therefore, to replace old-growth forests with young, rapidly growing stands (USDA FS 1963, Curtis et al. 1998). Furthermore, in the Douglas-fir region, clearcut logging and broadcast burning were justified as mimicking the catastrophic, stand-replacing fires typical of the region before fire suppression (Halpern 1995). Management practices during this period attempted to meet increasing wood demands by relying on the economic efficiencies of clearcutting and plantation management. At the same time, public concerns about fire protection and, later, restocking of cutover timberland led the states of Oregon, Washington, California, and Alaska to adopt forest practice acts in 1971, 1974, 1974, and 1978, respectively. These rely on a combination of best management practices, logger and landowner education, and enforcement activities by state agencies.

Over the years, conflicts among demands for different forest values have intensified (Cissel et al. 1999, Peterson and Monserud 2002). The public has become increasingly aware that forests can produce more than wood (Behan 1990, Beese and Phillips 1997). Current public debate over forest management of public lands centers on interactions between wood production and the needs of wildlife, aquatic resources, biodiversity, and social acceptance (Peterson and Monserud 2002). These include most of the major factors setting the public agenda on the future of forest management in the Pacific Northwest. Given that the public has strongly held values and opinions regarding the appropriate use of forest land (especially public forestland), the process of deciding how best to manage it has become increasingly polarized. Simply put, public opinion has often been at odds with forest management goals, especially on public land.

As a consequence, the focus of management in the Pacific Northwest during the 1990s shifted from producing timber to maintaining sustainable forest ecosystems (Behan 1990). This shift culminated in the Northwest Forest Plan (USDA and USDI 1994a,b) for western Oregon and Washington, the new Forest Practices Code of British Columbia (1994), and the Tongass Land Management Plan (USDA 1997a,b,c) for the Tongass National Forest in southeastern Alaska. Instead of the traditional goal of economically efficient wood production, which relied on even-aged plantations, the focus in these recent efforts is toward "old-growth" and multi-resource ecosystem management, which attempt to protect the habitat of endangered species and fish habitat, and promote biodiversity (FEMAT 1993, Clayoquot Scientific Panel 1995). There is interest and need for science-based silvicultural practices and management regimes that will reduce conflicts among user groups while producing the many values associated with forest lands on a biologically and economically sustainable basis (Curtis et al. 1998, Committee of Scientists 1999). In this changing context, silviculture still plays a key management role in the sense that various treatments may be applied to forest stands to maintain and enhance their utility for a given purpose (Smith's (1986, p.1) definition of silviculture).

Although forest management is science-based, much of that science is not based on scientific experimentation (Franklin et al. 1999). It is rare that resource management approaches are formulated from a systematic scientific approach that is tested before widespread application (Franklin et al. 1999, Monserud 2003). For example, dispersed patch clearcutting was widely adopted on national forest land after World War II without experimental testing, largely with the support of Isaac (1943) and other experts. Alternative silvicultural approaches were rejected (Isaac 1956) based on a few ill-chosen case studies rather than a scientific test of alternative methods (Curtis 1998). The consequent lack of research into alternatives to clearcutting has severely handicapped current efforts to meet changing objectives and public concerns (Curtis 1998). Other harvest experiments were implemented at a very small scale and generally lacked statistical rigor and replication (Tappeiner et al. 1997, Franklin et al. 1999). Since then, methods for regenerating vigorous young stands of primary timber species following clearcut logging have been extensively researched and tested throughout the Pacific Northwest (Loucks et al. 1996, Smith et al. 1997). Foresters have accumulated an enormous amount of information and experience on even-age silviculture and plantation management in the past 50 years (Curtis et al. 1998), but this scientific basis did not exist when widespread implementation of modern plantation management began decades earlier in the Douglas-fir region. After a half century of implementation, it was a short step to the belief that this intensive plantation management was the only silvicultural regime that worked in the Pacific Northwest (Peterson and Monserud 2002).

The management history of the coastal forests of British Columbia and southeastern Alaska is similar to that in the Douglas-fir region—a strong reliance on clearcut logging (especially in old growth) followed by even-age plantation management (Beese and Bryant 1999, McClellan et al. 2000). Except for experiments with shelterwood cutting in mature and old-growth stands (e.g., Williamson 1973), well-documented comparative trials of other possible silvicultural systems in the Pacific Northwest were conspicuously lacking before the mid-1990s (Curtis 1996).

Recently, several new large-scale, multidisciplinary silvicultural experiments from the Pacific Northwest have been initiated (e.g., Curtis 1996, Carey et al. 1999, Halpern and Raphael 1999, McClellan et al. 2000). All are implementing silvicultural alternatives (e.g., variable retention, and variable density thinning) to the widely used plantation management of the previous 50 years (Monserud 2002, 2003). Some are attempting to hasten the approach to old-growth structure and composition. All examine the joint production of wood and some other forest value (e.g., biodiversity).

2.1. Forests of the Pacific Northwest

We focus our research on the temperate rainforests on the northwest coast of North America. This zone includes the Douglas-fir region of western Oregon and Washington north to the vast coastal Sitka spruce (*Picea sitchensis* (Bong.) Carr.)/western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) forests of British Columbia and southeastern Alaska. These coniferous forests contain the highest quality wood-producing lands on the continent, and exhibit some of the greatest biomass accumulations and highest productivity levels of any in the world, temperate or tropical (Franklin and Dyrness 1973, Fujimori et al. 1976, Franklin and Waring 1981, Walter 1985, Franklin 1988). These forests are valued for their scenery, recreational opportunities, watershed protection, and fish and wildlife habitat (Peterson and Monserud 2002). The northern extent of this rainforest (coastal British Columbia and southeastern Alaska) is relatively unaltered (Everest et al. 1997).

Moist maritime conditions characterize the region, producing expanses of forests dominated by massive evergreen conifers, including Douglas-fir, western hemlock, western redcedar, (*Thuja plicata* Donn ex D. Don), Sitka spruce, Pacific silver fir (*Abies amabilis* Dougl. ex Forbes), and noble fir (*A. procera* Rehd.). A mediterranean climate of mild winters and relatively dry summers prevails (Walter 1985), although summer dryness decreases markedly to the north. This climate favors needle-leaved conifers by permitting extensive photosynthesis outside the growing season and reducing transpiration losses during the summer months (Waring and Franklin 1979). The summer climate is controlled by a large, semi-permanent, high-pressure center in the Pacific Ocean, which greatly reduces the frequency and intensity of Pacific storms (Meidinger and Pojar 1991). Infrequent catastrophic events, such as wildfires and hurricanes at intervals of several hundred years, allow for the genetic expression of enormous biomass and extremely tall and long-lived forest trees (Franklin 1988). Such favorable conditions for forest growth result in dominance by coniferous species that are the tallest, largest, and oldest of their genera (Franklin 1988). Unlike the other temperate rainforests of the world (see Walter 1985), this is the only one dominated by conifers rather than hardwoods (Franklin 1988).

The vegetation zone classification of Franklin (1988) is used, which is based on the system of Franklin and Dyrness (1973) but has larger geographic coverage. Most of the studies covered in this book lie within three forest vegetation zones: the broad Douglas-fir-western hemlock zone, the coastal Sitka spruce-western hemlock zone, and the montane Pacific silver fir-western hemlock zone (Franklin and Dyrness 1973, Franklin 1988). However, as Appendix 1 illustrates, there are many ways to describe forest developmental stages and their associated characteristics (Appendix 1, developed by B. Kerns; see list of contributors).

2.2. Timber Markets

Current forest conditions in the southern part of the Pacific Northwest are a function of the markets for various forest products. This area is one of the major timber producing regions in the world and is recognized for its productive timberlands, forest management institutions, well-organized markets, and large-scale timber processing industries. Indeed, many of the concerns about compatible forest management arise from the opportunities to derive valuable products from the forest. Here we briefly discuss the importance of various aspects of timber markets in Oregon and Washington, both in terms of incentives for forest management and for maintaining a vigorous processing sector that offers opportunities to profitably use an array of timber species and sizes.

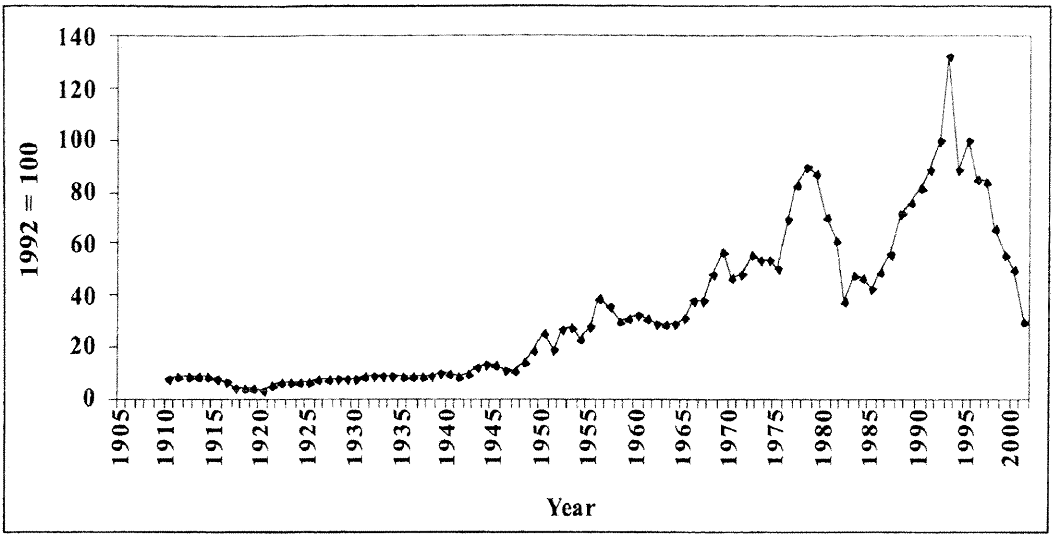

Figure 2. Oregon and Washington stumpage price index, 1909-2001.

Figure 2 illustrates the growth and the volatility of stumpage prices in Oregon and Washington. It provides evidence of the returns landowners have seen from investments in forest management. It also illustrates how different events have influenced timber prices and shaped the perceptions of land managers. For example, before World War II there were efforts to limit harvests from public timberlands. The goal was to provide incentives for private land managers to improve forest stewardship. The elimination of World War II price controls, rapid economic adjustment, and expansion in demand led to increases in prices. By the late 1950s, the increases in public harvests and slowdowns in economic growth were limiting the growth in stumpage prices. In the next three decades there were increased harvests, decrease in available timber, structural shifts in the economy, rapid inflation in commodity prices, and a severe recession in the early 1980s. All of these factors contributed to the price volatility illustrated in Figure 2. In the 1990s, the reductions in federal harvest, loss of both lumber and manufacturing productive capacity, and the reductions in exports following the economic slowdown in Asian counties all acted to reduce stumpage prices.

Stumpage prices (Figure 2) have increased in real terms, offering an incentive to apply forest management regimes that improve stand conditions. More recently, the growing importance and value of non-timber forest products (NTFP) is being recognized and addressed in management regimes (Alexander et al. 2001).

Tables 1 and 2 reveal that the timber industry in Oregon and Washington (the data for both states are further split between the Douglas-fir region and the ponderosa pine region—the area east of the Cascade Mountains) has declined for much of the past decade. In terms of importance in the United States, it peaked in the 1960-70s when it supplied roughly 33% of the U.S. softwood

Table 1. Lumber and plywood production for Oregon and Washington and United States, 1952-97, with projections to 2050.

	Historical							Projections				
Product and region	1952	1962	1970	1976	1986	1990	1996	2010	2020	2030	2040	2050
						Million cubic meters						
Softwood lumber:												
Douglas-fir region	24.3	20.3	17.9	20.1	21.9	21.2	17.5	19.6	22.7	23.4	26.7	30.2
Ponderosa pine region	5.4	5.7	5.7	6.4	6.6	6.8	3.5	3.3	4.2	5.4	6.6	8.0
Oregon and Washington	29.7	26.0	23.6	26.4	28.6	28.1	21.0	22.9	26.9	28.8	33.3	38.2
Total U.S.	71.3	63.2	64.9	70.1	83.3	84.5	78.6	76.7	85.2	88.3	93.2	102.2
Plywood:												
Douglas-fir region	2.4	7.0	7.5	8.1	7.7	4.3	2.2	1.5	0.8	0.7	0.7	0.7
Ponderosa pine region	0.0	.2	.7	.9	.9	.9	1.0	1.0	1.0	1.0	1.0	1.0
Oregon and Washington	2.4	7.2	8.2	8.9	8.6	5.2	3.2	2.5	1.8	1.7	1.7	1.7
Total U.S.	2.7	8.4	12.7	18.9	21.6	18.3	16.5	12.7	11.7	11.3	11.3	11.3

Table 2. Softwood timber removals, harvest, growth, and inventory in Oregon and Washington and United States, 1952-97, with projections to 2050.

Item	Historical							Projections				
	1952	1962	1970	1976	1986	1991	1997	2010	2020	2030	2040	2050
	Million cubic meters											
Douglas-fir region:												
Softwoods--												
Removals	56	55	68	70	67	50	34	43	45	44	47	51
Harvest	59	58	65	68	72	59	33	44	46	46	48	52
Net annual growth	28	34	40	44	61	54	70	77	79	81	84	82
Inventory	3110	2955	2806	2651	2363	2233	2791	3209	3569	3944	4353	4690
Ponderosa pine region:												
Softwoods--												
Removals	11	14	17	18	21	18	13	9	10	12	13	14
Harvest	10	13	16	17	19	17	15	9	11	12	14	15
Net annual growth	14	17	18	17	18	18	19	23	22	22	22	22
Inventory	1123	1149	1165	1099	921	971	1056	1252	1381	1493	1590	1670
United States:												
Softwoods--												
Removals	220	215	260	283	322	307	286	273	305	333	355	378
Harvest	213	207	246	269	319	311	286	279	312	340	363	387
Net annual growth	219	272	321	354	354	339	384	446	460	469	474	464
Inventory	12 220	12 728	13 018	13 215	12 817	12 732	13 693	15 536	17 216	18 705	20 019	21 001

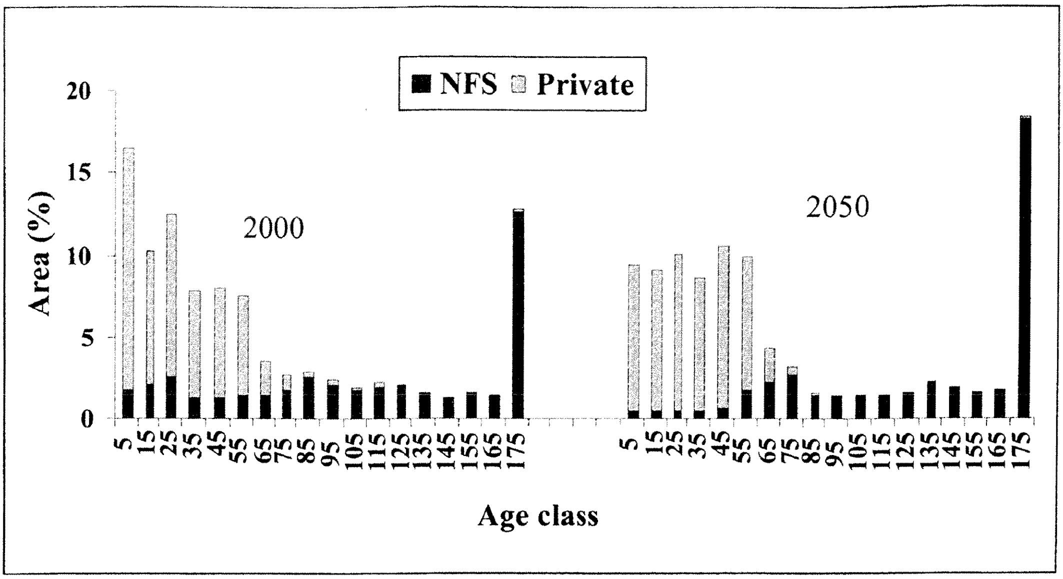

Figure 3. Age-class distribution by ownership for softwood forest types on timberland in the Douglas-fir region for 2000 and projected for 2050.
Note: NFS = National Forest System.

harvest. In 1997, these two states accounted for 27% of the softwood lumber, 19% of the softwood plywood, 17% of the softwood harvest, and 28% of the softwood timber inventories of the United States (Haynes 2003). The steep declines that began in the early 1990s followed reductions in federal harvest (Table 3) associated with the adoption of various habitat conservation strategies, such as the Northwest Forest Plan (USDA and USDI 1994a,b). Projections (shown in Table 1) reveal a more stable role for Oregon and Washington. Lumber is expected to increase after 2020 as private timber inventories improve.

The projected 60% increase in inventory volume for the Douglas-fir region (Table 2) reflects an improving timber resource situation. Most of this increase in timber inventories is on public timberlands as a result of habitat conservation strategies, and a sharp reduction in harvesting. The most dramatic changes in the timber inventories are shown in Figure 3 (also see Haynes et al. 2003). The age-class structure of the inventories is expected to shift from the unimodal distribution shown on the left to the more bimodal distribution shown on the right. The later type of age-class distribution suggests that there will be fewer mid-seral forests by 2050. In Oregon and Washington, most of the younger stands will be on private timberlands, whereas the older forest will be on public lands. This changing mix of demographics may alter our perceptions of forest health so that we perceive the situation as a public land management problem in dealing with a gradually aging inventory that may (for some types) exacerbate an already severe overstocking problem.

Table 3. Softwood harvest in Oregon and Washington and United States, by ownership, 1952-97, with projections to 2050.

	Historical							Projections				
Item	**1952**	**1962**	**1970**	**1976**	**1986**	**1991**	**1997**	**2010**	**2020**	**2030**	**2040**	**2050**
	Million cubic meters											
Douglas-fir region:												
National forest	10	17	14	14	19	8	2	1	2	2	2	3
Other public	4	8	10	12	12	7	5	5	5	5	5	5
Forest industry	35	28	35	36	35	31	18	28	29	27	27	29
Nonindustrial private forest	9	6	7	6	7	12	8	9	11	12	14	15
Total	59	58	65	68	72	59	33	44	46	46	48	52
Ponderosa pine region:												
National forest	3	7	8	8	11	10	2	2	2	3	3	4
Other public	1	2	3	3	2	2	2	2	2	2	2	2
Forest industry	3	3	3	4	5	3	5	3	3	3	3	4
Nonindustrial private forest	3	2	1	2	2	2	6	3	4	5	5	6
Total	10	13	16	17	19	17	15	9	11	12	14	15
United States:												
National forest	27	46	54	53	61	51	20	15	19	21	22	23
Other public	11	16	20	23	23	22	16	16	16	16	16	16
Forest industry	79	65	82	97	119	117	103	113	136	152	148	148
Nonindustrial private forest	95	80	90	96	116	121	147	134	140	151	176	200
Total	213	207	246	269	319	311	286	279	312	340	363	387

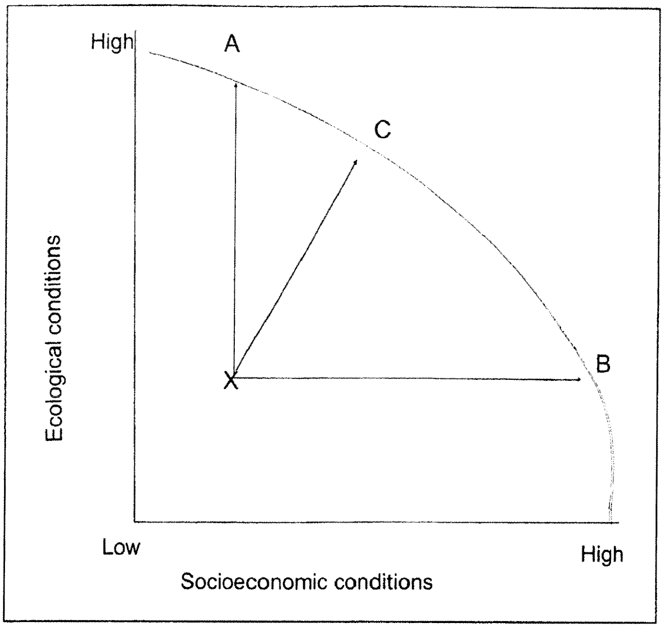

Figure 4. Hypothetical joint production function between ecological and socioeconomic conditions showing opportunities for compatible changes of both.

Timber markets have influenced the goals for land management and the evolution and application of various management regimes. How then can markets be harnessed to assist in the development of strategies that emphasize compatible forest management? First, what are the management regimes that produce a reliable supply of sawtimber? How can landowners be assured a fair return for implementing these management practices? Second, what are the realistic opportunities for smaller scale enterprises using less popular species and smaller sizes of timber? These opportunities have to be attractive in capital markets and offer a fair wage to workers. Third, what is the public's willingness to accept and pay for forestry restoration? Is it possible to combine some traditional activities (like thinning and under-burning) with efforts to restore selected ecological conditions?

3. The Conceptual Model

Notions of compatible forest management rest on two conceptual models. The first (Figure 4) represents an abstract representation of the challenge facing land managers, and provides a framework for considering the nature of the various relations involved in the compatibility arguments. The second (Figure 5) represents the more traditional view of the challenge facing land managers. It also provides a framework for looking at the links among the components of the land management problem.

Figure 4 illustrates the challenge facing land managers who are trying to manage for ecological and socioeconomic well-being (the general forest management problem has been described by Gregory 1972). The curve represents the production possibility frontier. This is the set of all combinations of ecological and socioeconomic conditions with no waste or inputs left over from which more of one output could be achieved without giving up some of the other (see Montgomery 2003). If, for example, our current position is point X, society will theoretically be better off if we move closer to the production possibility frontier in any positive direction. However, people who place high value on socioeconomic conditions are concerned that improvements in ecological conditions will likely mean a move to the left of point A, at which point socioeconomic conditions will be reduced. Similarly, people who place high value on ecological conditions are concerned that improvements in socioeconomic conditions will likely mean a move below point B, at which point ecological conditions will suffer. Resistance to change means we forgo opportunities to move toward C, the point where both ecological and socioeconomic conditions improve and everybody is better off. This move toward C—in which nobody is worse off and at least someone is better off—is a move closer to Pareto optimality, a useful concept that does not require the marketplace to determine value. In this simple two-dimensional example, all points bounded by A-X-B are desirable; either condition is at least as good as at point X, the status quo. The challenge is to identify point C—and the path to reach it—in a dynamic world with multiple inputs and multiple desired outputs.

Figure 5 illustrates the basic interactions among multiple values, ideas, actions, and outcomes that provide the context for research. Social values influence institutional policy that in turn affects managerial decisions and actions, resulting in a change in forest resource components and the associated mix of outcomes. Those decisions and proposed actions are evaluated—and often challenged—by society before they are implemented. Note that social concerns are not just at the top of this cycle in constructing policy and goals. Social actions are woven through dimensions such as water quality, biodiversity, and economics. Thus, we need to distinguish social activity and public use from the outcome of social acceptability. Once a management action is executed, it is evaluated in relation to the desired mix of measurable outcomes (often stated in the management prescription). The evaluation is complicated because many of the values are realized in different areas and over varying lengths of time after the management action. This also suggests that much of the research information, given its uncertain nature, should be amenable to socioeconomic evaluation of risks and consequences.

Figure 4 largely serves as a guide in discussions of broadscale policy and science issues. Some land managers and scientists see it as too simple. They argue, for example, that ecological integrity should have two or three axes,

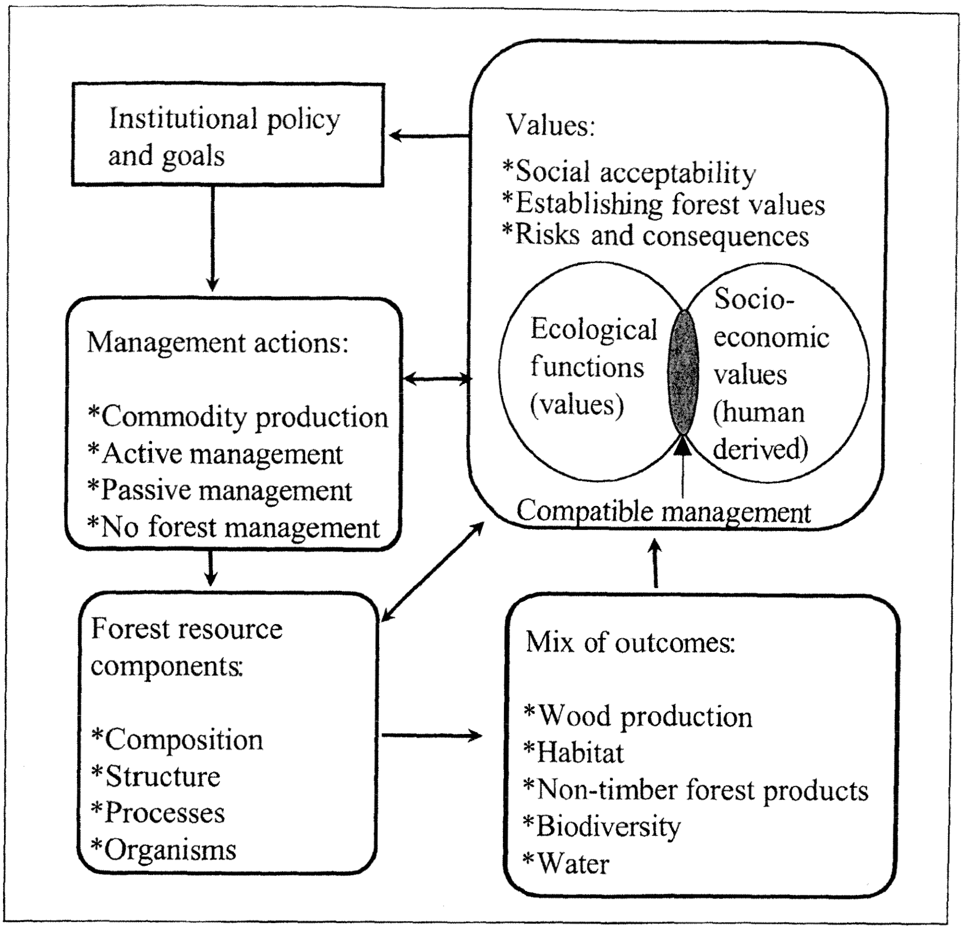

Figure 5. A general conceptual model for the Wood Compatibility Initiative.

given the complexity and sometimes competing or contradictory dimensions to the problem. Though this would add more dimensions, the essential topology of policy and science issues would be much the same.

The second conceptual model (Figure 5) provides a practical framework for the various components and links that can be used at multiple spatial scales. It illustrates the key role that social values play in shaping institutional context, management actions, and various forest resource components. It also illustrates the role that a mix of outputs has in shaping social values. This conceptual model specifies the management regimes and considers the multiple ownerships making up different broad-scale landscapes. Thus, questions regarding the management of public lands are examined within the context of broader, spatially complex landscapes.

These models are applied at three different spatial scales in the development of compatible forest management. The first scale is the traditional stand scale of forest management. Compatibility, at this scale, usually depends on management actions that meet relatively specific land management objectives.

The emphasis may be on a selected stand, but there is also interest in the cumulative effects of actions across neighboring stands and the entire watershed.

The second scale is composed of broader landscapes that include multiple watersheds, sub-basins, or counties. The importance of this larger scale is that it sets the context for finer scales where management (and much research) is actually implemented. In this case, most tradeoffs still involve choices among management actions. Notions of public tradeoffs in terms of social acceptability regarding specific land management actions are important at this scale.

The third scale is the ecoregion. This corresponds, for example, to the Douglas-fir region. At this scale, tradeoffs involve choices among different mosaics of fine and mid-scale management objectives. Broad-scale measures are often developed from relatively coarse data to describe conditions on relatively large areas such as a subregion (see Haynes 2003). Planning tools such as ATLAS (Mills and Kincaid 1992) provide analytical models that can be used to examine tradeoffs for western Oregon and Washington, for example, in the context of changes in the U.S. forest sector. Such planning tools can also be used to explore the links among different land management-owner strategies, broad-scale resource conditions, and various outputs at the regional scale (see Haynes et al. 2003, Spies and Johnson 2003).

4. Policy Context

The context for research on compatible management is set by three converging policy interests: shifting public recognition of the array of goods and services produced by forests; the growing debate about sustainable forest management; and recognition within the scientific community of the connectiveness among processes and outputs. These interests all shape the emerging recognition that we need approaches to forest management that emphasize the compatibility among various goods and services so we can avoid counterproductive arguments about tradeoffs.

The Douglas-fir region has a long history of very deliberate forest management debates (e.g., Behan 1990, Curtis et al. 1998, Peterson and Monserud 2002). These debates have contributed to considerable scientific information on the compatibilities and tradeoffs between commodity production and the other values (e.g., nontimber forest products, fish, and wildlife habitat) that the public desires from these forests (Johnson et al. 2002).

By using this information, we can integrate key scientific findings to enhance good stewardship of our forestlands, both public and private. Key in this is the role that scientific information can be used to increase opportunities for producing compatible bundles of goods and services. These goods and services include wood, wildlife habitat, scenery, recreation, water quality (including water as a commodity), and riparian habitat provided in a manner that is socially acceptable and economically viable. This is consistent with the emerging emphasis we see on sustainable forest management and concerns about ways to meet rising demands for goods and services from the forest in an environmentally acceptable manner.

4.1. The Relation between Sustainable and Compatible Forest Management

Sustainable forest management is an enduring issue that in the past decade has taken on increased importance out of concerns for resource overexploitation (Powers 2001), sustainable development (World Commission on Environment and Development 1987), and possible climate change effects (Watson et al. 1995, Schwalm and Ek 2001). During its 200-year history, the concept of sustainable forest ecosystem management has been the focus of scientific and political discussion, with varying degrees of intensity—it is promoted with vehement fervor during periods of social or economic crisis and less intensely during periods of stability (von Gadow et al. 2000).

Sustainable forestry is difficult to define and quantify (Amaranthus 1997, Schlaepfer and Elliott 2000). In its broadest sense, sustainability is a deliberate management goal that implies an ability to maintain the productivity and ecological integrity of the forest in perpetuity (Monserud, in press). This statement includes the interactions among both temporal and spatial scales by expressing the need to consider the timeframe and the spatial extent of management goals. Clearly, measures of sustainability become increasingly complex as the scale increases from stand to landscape to region, and on to national and global scales. Almost all of the work with criteria and indicators of sustainability is at the national scale. Forest management, however, is implemented at the stand scale, which introduces a profound scale effect (Hall 2000).

Before the 1990s, most countries managed their forests under the principle of *sustained yield*, with a nearly exclusive focus on timber yield of forest stands or contiguous groups of stands (Tittler et al. 2001). The selection of sustainable forestry practices depends on what one is trying to sustain, a choice often driven by utilitarian principles (Amaranthus 1997). In response to rising social pressure for a larger variety of goods and services from the forest, the concept of sustainable forestry has expanded to include much larger areas and forest uses. Wilson and Wang (1999) define *sustainable forestry* as comprising a host of management regimes to maintain and enhance the long-term health and integrity of forest ecosystems and forest-dependent communities, while providing ecological, economic, social, and cultural opportunities for the benefit of present and future generations. This is a multi-dimensional definition including biological, sociological, political, and economic factors (Perry and Amaranthus 1997, Wilson and Wang, 1999). Although an all-encompassing definition might seem appealing, it does not lend itself easily to quantifiable science, especially at small scales.

The shift in attitude from sustained yield to sustainable forestry was triggered internationally by the Brundtland Report on sustainable development in 1987 (World Commission on Environment and Development 1987) and later solidified at the Earth Summit in Rio de Janeiro in 1992, with the adoption of the Forest Principles (Tittler et al. 2001). In response, several initiatives and international agreements have attempted to quantify broad-scale sustainability (Mendoza and Prabhu 2000, Tittler et al. 2001), such as the Montreal Accord (Mihajlovich 2001). The emphasis is on criteria and indicators for judging if sustainable forestry is occurring over broad areas, usually at the national scale (Mendoza and Prabhu 2000).

The development of forest certification programs by nongovernment groups such as the Forest Stewardship Council or the American Forest and Paper Association is another indicator of the shift in public attitudes and the need for landowners to demonstrate their commitment to responsible forest management. These programs develop principles and objectives or criteria for sustainable forest management that can be applied to a participant's forests. Both emphasize the use of forest planning, best management practices, and logger and landowner education to achieve sustainable forest management (see AF&PA 1999).

In this book we examine forest management as a set of compatible production opportunities at the stand and landscape levels, and from the landowners' and managers' perspectives. These opportunities simultaneously seek to produce multiple forest goods and services, maintain the ecological integrity of the forest resource, and reduce social conflict regarding management. Clearly, this goal is complementary to (and likely a subset of) sustainable forest management. The emphasis in this book is on management approaches that can increase joint production in a socially acceptable manner. We refer to this as compatible forest management. In our work, we look across scales (stand to regional) to understand how compatibility can be increased. We seek solutions that reduce conflict and eschew dichotomous tradeoffs.

5. Research Summary

This book is structured around 17 chapters that provide information on options that may increase compatibility between wood production and other societal values derived from forestlands. Our goal is to emphasize a more balanced view of forest management rather than the often diametrically opposed views that pit environmental issues against economic interests with little regard to the equity of those positions.

The following chapters summarize research findings and the results of formal syntheses. Potential management opportunities are presented and illustrated for a range of case studies (e.g., chapters 2, 3, 8, 14). These case studies are drawn from an area that has a rich history of forest management based both on market incentives as well as public regulations. They serve as models for practicing forest managers elsewhere.

Chapters 2 and 3 give examples of research associated with compatible management. Chapter 2 reviews the production possibility approach to compatibility research. Forest policymakers may find this approach helpful when they evaluate competing forest uses and identify situations where opportunity to improve current management exists. Chapter 3 is a case study from southeastern Alaska where the current objective is to manage upland forests for wood products, wildlife, and fish. In this ecosystem, the presence of red alder (*Alnus rubra* Bong.) may help alleviate some of the problems associated with fish and wildlife habitat that develop in the dense conifer-dominated young-growth forests that typically regenerate following clearcutting. This is also an ecosystem where compatibility and tradeoffs among resources are clearly evident.

Chapters 4 through 7 deal with silviculture, experimental approaches to joint forest production, stand modeling, and landscape management issues. The discussion on silviculture in Chapter 4 begins with a review of silvicultural methods in the Pacific Northwest. New silvicultural systems are discussed in relation to traditional methods and new management goals, such as biodiversity. Chapter 5 examines several large-scale management experiments initiated in the Pacific Northwest in the 1990s, partially in response to contentious resource management debates. All of these experiments focus on joint production. They examine alternative silvicultural treatments aimed at enhancing wildlife habitat, biodiversity, or the conservation of aquatic resources in a manner that is socially acceptable. We examine several of these experiments for their utility in providing an experimental basis for compatible forest management. Chapters 6 and 7 highlight the importance of simulating stand growth and landscape dynamics under heterogeneous structures and mixed-species compositions to evaluate the compatibility of management alternatives. The adaptability and utility of forest growth simulation models is assessed for alternative silvicultural systems under experimentation in the Pacific Northwest.

Chapters 8 through 10 address scale. For instance, Chapter 8 questions whether alternative policies, examined at broader scales, provide greater overall compatibility among wood production and ecological integrity than current policies. This initial work reveals that management changes that seem drastic at stand or landscape levels may have small or slow effects on ecological conditions at larger spatial scales. Chapter 9 expands this discussion to include problems encountered when scaling from the stand to landscape in the Cascade Range of western Oregon. Here, both broad time and space contexts are considered, and multiple goods and services from these natural resource systems are examined. Chapter 10 focuses on contemporary management regimes in the Douglas-fir region where the diversity of timberland ownerships has led to a patchwork mosaic. Management regimes have evolved to take advantage of the inherent biophysical productivity, while being robust in a highly volatile economic and (more recently) regulatory climate.

Chapters 11 through 14 deal with different aspects of compatible management. First, the implications for timber quality associated with these management regimes are assessed, including prospective issues in marketing larger trees and the types of timber that might be available from various habitat conservation strategies used in the Douglas-fir region. Chapter 12 describes the opportunities for managing for nontimber forest products. It links understory development and relations with overstory variables and provides insights to help guide compatible forest management. For example, the authors assess silvicultural treatments that may affect commercial understory species supply, product attributes, species, and site-specific responses. Chapter 13 describes access to nontimber forest products. Emphasis is placed on user groups, current regulations, and opportunities for compatible management. Chapter 14 investigates different approaches for managing for wildlife where opportunities exist for a simultaneous increase in both wildlife habitat and wood production. Examples include management options developed for different landowners in western Washington.

Chapter 15 suggests that the relation between social values and forests must be understood to determine if compatible management exists. Furthermore, this knowledge of forest values needs to be integrated into forest management strategies. Emphasis is placed on the role of values in shaping change, assessing social values, and participatory approaches to management. The need to devise management strategies that are supported by the public is outlined in Chapter 16. Specifically, it is critical to understand how the public forms opinions and judges the acceptability of forest management practices and the decisionmaking processes. This chapter summarizes key findings from several studies that examine the acceptability of a range of management practices.

The concluding chapter summarizes our progress toward developing compatible management regimes. These regimes can help us meet the increasing demands for wood and other timberland goods and services in the Pacific Northwest. They require both ecologists and economists to seek compatible approaches to forest management. These approaches will need to improve environmental conditions while accommodating growth in use. The recent emphasis on sustainable forest management expands this management quest to include concerns about social equity. In this evolving context, there are emergent lessons from the Pacific Northwest that can apply to forest managers elsewhere.

6. References

American Forest & Paper Association [AF&PA]. 1999. Sustainable forestry initiatives standard: principles and objectives. Washington, DC: American Forest & Paper Association. 5 p.

Alexander, S.J., McLain, R.J., and Blatner, K.A. 2001. Socio-economic research on non-timber forest products in the Pacific Northwest. *Journal of Sustainable Forestry*, 13(3/4): 95-103.

Amaranthus, M.R. 1997. Forest sustainability: an approach to definition and assessment. General Technical Report PNW-GTR-416. Portland OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 14 p.

Beese, W.J., and Bryant, A.A. 1999. Effect of alternative silvicultural systems on vegetation and bird communities in coastal montane forests of British Columbia, Canada. *Forest Ecology and Management*, 115: 231-242.

Beese, W.J., and Phillips, E.J. 1997. Harvesting costs and impacts of alternative silviculture prescriptions in old growth. In: Forest management into the next century: What will make it work? (pp. 102-110). Publication 7276. Madison, WI: Forest Products Society.

Behan, R. 1990. Multiresource forest management: a paradigmatic challenge to professional forestry. *Journal of Forestry*, 88(4): 12-18.

Bormann, F.H., and Likens, G.E. 1979. Pattern and process in a forested ecosystem. New York: Springer-Verlag. 253 p.

Carey, A.B., and Curtis, R.O. 1996. Conservation of biodiversity: a useful paradigm for forest ecosystem management. *Wildlife Society Bulletin*, 24: 610-620.

Carey, A.B., Thysell, D.R., and Brodie, A.W. 1999. The forest ecosystem study: background, rationale, implementation, baseline conditions, and silvicultural assessment. General Technical Report PNW-GTR-457. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 129 p.

Cissel, J.H., Swanson, F.J., and Weisberg, P.J. 1999. Landscape management using historical fire regimes: Blue River, Oregon. *Ecological Applications*, 9(4): 1217-1231.

Clayoquot Scientific Panel. 1995. Scientific panel for sustainable forest practices in Clayoquot Sound, Report 5, sustainable ecosystem management in Clayoquot Sound: planning and practices, Victoria, BC. 296 p.

Committee of Scientists. 1999. Sustaining the people's lands: recommendations for stewardship of the national forests and grasslands into the next century. Washington, DC: U.S. Department of Agriculture. 235 p. Retrieved April 1999 from http://www.fs.fed.us/news/science/.

Curtis, R.O. 1996. Silvicultural options for harvesting young-growth production forests. Prospectus for DNR/PNW Cooperative Project. 5 p. Unpublished document. On file with: Forestry Sciences Laboratory, 3625 93rd Avenue SW, Olympia, WA 98512-9193.

Curtis, R.O. 1998. "Selective cutting" in Douglas-fir: history revisited. *Journal of Forestry*, 96(7): 40-46.

Curtis, R.O., DeBell, D.S., Harrington, C.A., Lavender, D.P., St. Clair, J.B., Tappeiner, J.C., and Walstad, J.D. 1998. Silviculture for multiple objectives in the Douglas-fir region. General Technical Report PNW-GTR-435. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 123 p.

Donoghue, E. 2003. Social values and compatible forest management. Chapter 15. In: R.A. Monserud, R.W. Haynes, and A.C. Johnson (Eds.), Compatible forest management. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Duncan, S. 2000. Closer to the truth: 75 years of discovery in forest & range research. Miscellaneous publication. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 76 p.

Everest, F.H., Swanston, D.N., Shaw, C.G., III, Smith, W.P., Julin, K.R., and Allen, S.D. 1997. Evaluation of the use of scientific information in developing the 1997 forest plan for the Tongass National Forest. General Technical Report PNW-GTR-415. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 69 p.

Forest Ecosystem Management Assessment Team (FEMAT). 1993. Forest ecosystem management: an ecological, economic, and social assessment. Washington, DC: U.S. Department of the Interior [and others]. [Irregular pagination].

Forest Practices Code of British Columbia Act. 1994. Statutes of B.C., Bill 40. Victoria, BC: Queen's Printer. Retrieved April 4, 2003 from http://www.legis.gov.bc.ca/1994/3rd_read/gov40-3.htm.

Franklin, J.F. 1988. Pacific Northwest forests. In: M.G. Barbour, and W.D. Billings (Eds.), North American terrestrial vegetation. New York: Cambridge University Press. 434 p.

Franklin, J.F., and Dyrness, C.T. 1973. Natural vegetation of Oregon and Washington. General Technical Report PNW-GTR-8. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 417 p.

Franklin, J.F., Norris, L.A., Berg, D.R., and Smith, G.R. 1999. The history of DEMO: an experiment in regeneration harvest of northwestern forest ecosystems. *Northwest Science*, 73(special issue): 3-11.

Franklin, J.F., Spies, T.A., Van Pelt, R., Carey, A., Thornburgh, D.A., Berg, R., Lindenmayer, D.B., Harmon, M.E., Keeton, W.S., Shaw, D.C., Bible, K., and Chen, J. 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir as an example. *Forest Ecology and Management*, 155: 399-423.

Franklin, J.F., and Waring, R.H. 1981. Distinctive features of the northwestern coniferous forest: development, structure, and function. In: R.H. Waring (Ed.), Forests: fresh perspectives from ecosystem research (pp. 59-86). Corvallis, OR: Oregon State University Press.

Fujimori, T., Kawanabe, S., Saito, H., Grier, C.C., and Shidei, T. 1976. Biomass and primary production in forests of three major vegetation zones of the northwestern United States. *Journal of Japanese Forestry Society*, 58: 360-373.

Gregory, R.G. 1972. Forest resource economics. Chapter 13. New York: Forest Resource Economics. 254 p.

Hall, P. 2000. The issue of scale in the aggregation of data on indicators of sustainable forest management from subnational to national levels. *Forestry Chronicle*, 76(3): 419-422.

Halpern, C.B. 1995. Response of forest communities to green-tree retention harvest: a study plan for the vegetation component of the Demonstration of Ecosystem Management Options (DEMO) study. Seattle, WA: College Forestry Resources, University of Washington. 36 p. plus appendix.

Halpern, C.B., and Raphael, M.G. (Eds.). 1999. Retention harvests in Northwestern forest ecosystems: the demonstration of ecosystem management options (DEMO) study. *Northwest Science*, 73(special issue): 125 p.

Haynes, R.W. (Tech. coord.). 2003. An analysis of the timber situation in the United States: 1952 to 2050. A technical document supporting the 2000 USDA Forest Service RPA assessment. General Technical Report PNW-GTR-560. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 254 p.

Haynes, R.W., Adams, D.M., and Mills, J.R. 2003. Contemporary management regimes in the Pacific Northwest: balancing biophysical and economic concerns. Chapter 10. In: R.A. Monserud, R.W. Haynes, and A.C. Johnson (Eds.), Compatible forest management. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Haynes, R.W., and Monserud, R.A. 2002. A basis for understanding compatibility among wood production and other forest values. General Technical Report PNW-GTR-529. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 46 p.

Isaac, L.A. 1943. Reproductive habits of Douglas-fir. Washington, DC: Charles Lathrop Pack Forestry Foundation.

Isaac, L.A. 1956. Place of partial cutting in old-growth stands of the Douglas-fir region. Research Paper PNW-RP-16. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 48 p.

Johnson, A.C., Haynes, R.W., and Monserud, R.A. (Eds.). 2002. Congruent management of multiple resources: proceedings from the wood compatibility workshop. General Technical Report PNW-GTR-563. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 252 p.

Kimmins, H. 1992. Balancing act: environmental issues in forestry. Vancouver, BC: University of British Columbia Press. 245 p.

Loucks, D.M., Knowe, S.A., Shainsky, L.J., and Pancheco, A.A. 1996. Regenerating coastal forests in Oregon: an annotated bibliography of selected ecological literature. Research Contribution 14. Corvallis, OR: Oregon State University, Forest Research Laboratory. 122 p.

McClellan, M.H., Swanston, D.N., Hennon, P.E., Deal, R.L., De Santo, T.L., and Wipfli, M.S. 2000. Alternatives to clearcutting in the old growth forests of southeast Alaska: study plan and establishment report. General Technical Report PNW-GTR-494. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 40 p.

Meidinger, D., and Pojar, J. (Eds.). 1991. Ecosystems of British Columbia. Special Report Series 6. Victoria, BC: British Columbia Ministry of Forests. 330 p.

Mendoza, G.A., and Prabhu, R. 2000. Qualitative multi-criteria approaches to assessing indicators of sustainable forest resource management. *Forest Ecology and Management*, 131: 107-126.

Mihajlovich, M. 2001. Does forest certification assure sustainability? *Forestry Chronicle*, 77(6): 994-997.

Mills, J.R., and Kincaid, J.C. 1992. The aggregate timberland assessment system-ATLAS: a comprehensive timber projection model. General Technical Report PNW-GTR-281. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 66 p.

Monserud, R.A. 2002. Large-scale management experiments in the moist maritime forests of the Pacific Northwest. *Landscape and Urban Planning*, 59: 159-180.

Monserud, R.A. 2003. Experimental approaches to joint forest production. Chapter 5. In: R.A. Monserud, R.W. Haynes, and A.C. Johnson (Eds.), Compatible forest management. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Monserud, R.A. [In press]. Evaluating forest models in a sustainable forest management context. *Forest Biometry, Modelling and Information Sciences (FBMIS)*. To be available on: http://www.fbmis.info/.

Montgomery, C.A. 2003. The production possibilities approach to understanding and modeling compatibility. Chapter 2. In: R.A. Monserud, R.W. Haynes, and A.C. Johnson (Eds.), Compatible forest management. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Oliver, C.D., and Larson, B.C. 1990. Forest stand dynamics. New York: McGraw-Hill. 467 p.

O'Neil, T.A., Bettinger, K.A., Heyden, M.V., Marcot, B.G., Barrett, C.B., Mellen, I Vanderhaegen, W.M., Johnson, D.H., Doran, P.J., Wunder, L., and Boula, K.M. 20(Structural conditions and habitat elements of Oregon and Washington. In: D.H. Johnson, a T.A. O'Neil (Eds.), Wildlife-habitat relationships in Oregon and Washington (pp. 115-13 Corvallis, OR: Oregon State University Press.

Perry, D.A., and Amaranthus, M.P. 1997. Disturbance, recovery, and stability. In: K. Kohm, and J.F. Franklin (Eds.), Creating a forestry for the 21st century (pp. 31-5 Washington, DC: Island Press.

Peterson, C.E., and Monserud, R.A. 2002. Compatibility between wood production and otl values and uses on forested lands. A problem analysis. General Technical Report PN GTR-564. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northw Research Station. 50 p.

Peterson, E.B., Peterson, N.M., Weetman, G.F., and Martin, P.J. 1997. Ecology and m agement of Sitka spruce, emphasizing its natural range. Vancouver, BC: University British Columbia Press. 336 p.

Powers, R.F. 2001. Assessing potential sustainable wood yield. In: J. Evans (Ed.), The fores handbook. Applying forest science for sustainable management (Vol 2. pp. 105-12 Oxford, UK: Blackwell Science, Ltd.

Rolston, H., and Coufal, J. 1991. A forest ethic and multivalue forest management. *Journa Forestry*, 89(4): 35-40.

Schlaepfer, R., and Elliott, C. 2000. Ecological and landscape considerations in forest m agement—The end of forestry? In: K. von Gadow, T. Pukkala, and M. Tomé (Ed Sustainable forest management (pp. 1-68). Dordrecht, The Netherlands: Kluwer Acade Publishers.

Schwalm, C., and Ek, A.R. 2001. Climate change and site: relevant mechanisms and mo(ing techniques. *Forest Ecology and Management*, 150: 241-257.

Smith, D.M. 1986. The practice of silviculture (8th ed.). New York: John Wiley & Sons.

Smith, J.P, Gresswell, R.E., and Hayes, J.P. 1997. A research problem analysis in suppor the Cooperative Forest Ecosystem Research (CFER) Program. Corvallis, OR: l Geological Society. 92 p.

Spies, T.A., and Franklin, J.F. 1991. The structure of natural young, mature, and old-gro Douglas-fir forests in Oregon and Washington. In: L.F. Ruggiero, K.B. Aubry, A.B. Ca and M.H. Huff (Eds.), Wildlife and vegetation of unmanaged Douglas-fir forests (pp. 109). General Technical Report PNW-GTR-285. Portland, OR: U.S. Department Agriculture, Forest Service, Pacific Northwest Research Station.

Spies, T.A., and Franklin, J.F. 1996. The diversity of maintenance of old-growth forests R.C. Szaro, and D.W. Johnson (Eds.), Biodiversity in managed landscapes: theory and p tice (pp. 296-314). New York: Oxford.

Spies, T.A., and Johnson, K.N. 2003. The importance of scale in assessing the compatib of forest commodities and biodiversity. Chapter 8. In: R.A. Monserud, R.W. Haynes, A.C. Johnson (Eds.), Compatible forest management. Dordrecht, The Netherlands: Klı Academic Publishers.

Tappeiner, J.C., Lavender, D., Walstad, J., Curtis, R.O., and DeBell, D.S. 1997. Silvicult systems and regeneration methods: current practices and new alternatives. In: K.A. Kc and J.F. Franklin (Eds.), Creating a forestry for the 21st century. (pp. 151-164). Washing DC: Island Press.

Tittler, R., Messier, C., and Burton, P.I. 2001. Hierarchical forest management planning sustainable forest management in the boreal forest. *Forestry Chronicle*, 77(6): 998-100

U.S. Department of Agriculture, Forest Service. 1963. Timber trends in western Oregon and western Washington. Research Paper PNW-5. Portland, OR: Pacific Northwest Forest and Range Experiment Station, Division of Forest Economics Research. 154 p.

U.S. Department of Agriculture, Forest Service. 1997a. Land and resource management plan: Tongass National Forest. R10-MB-338dd [Juneau, AK]: Alaska Region.

U.S. Department of Agriculture, Forest Service. 1997b. Tongass land management plan revision: final environmental impact statement [FEIS]. Part 1: Summary, chapters 1 through 3 (physical and biological environment). R10-MB-338b. [Juneau, AK]: Alaska Region.

U.S. Department of Agriculture, Forest Service 1997c. Tongass land management plan revision: record of decision [ROD]. R10-MB-338a. [Juneau, AK]: Alaska Region.

U.S. Department of Agriculture, Forest Service and U.S. Department of the Interior, Bureau of Land Management. 1994a. Final supplemental environmental impact statement on management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. Vol. 1 and 2. Washington, DC: U.S. Department of Agriculture, Forest Service and U.S. Department of the Interior, Bureau of Land Management.

U.S. Department of Agriculture, Forest Service and U.S. Department of the Interior, Bureau of Land Management. 1994b. Record of decision for the President's forest plan. Washington, DC: U.S. Department of Agriculture, Forest Service and U.S. Department of the Interior, Bureau of Land Management. 74 p. plus appendices.

von Gadow, K., Pukkala, T., and Tomé, M. (Eds.). 2000. Sustainable forest management. Dordrecht, The Netherlands: Kluwer Academic Publishers. 356 p.

Walter, H. 1985. Vegetation of the Earth and ecological systems of the geobiosphere (3^{rd} ed.). New York: Springer-Verlag. 318 p.

Waring, R.F., and Franklin, J.F. 1979. Evergreen coniferous forests of the Pacific Northwest. *Science*, 204: 1380-1386.

Watson, R.T., Zinyowera, M.C., and Moss, R.H. (Eds.). 1995. Climate change 1995: impacts, adaptations and mitigation of climate change: scientific-technical analyses. Contribution of working group 2 to the second assessment of the intergovernmental panel on climate change. Cambridge, UK: Cambridge University Press. 878 p.

Williamson, R.L. 1973. Results of shelterwood harvesting of Douglas-fir in the Cascades of western Oregon. Research Paper PNW-RP-1161. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 13 p.

Wilson, B., and Wang, S. 1999. Sustainable forestry—the policy prescription in British Columbia. In: A. Yoshimoto, and K. Yukutake (Eds.), Global concerns for forest resource utilization—sustainable use and management (pp. 35-45). London: Kluwer Academic Publishers.

World Commission on Environment and Development. 1987. Our common future: report of the World Commission on Environment and Development. New York: Oxford University Press.

Appendix 1. Major classification schemes used to describe forest developmental stages and associated characteristics. Characteristics are illustrated from various ecosystem perspectives by using a Douglas-fir (*Pseudotsuga menziesii*) dominated sere growing in the western hemlock (*Tsuga heterophylla*) zone (Franklin and Dyrness 1988). Characteristics will vary widely based on site location, disturbance history, management, and forest types. This table was developed by B. Kerns (see list of contributors).

Major classification systems and characteristics for forest developmental stages

Ecosystem perspective → Forest development stage ↓	Ecological structure and process	Wildlife habitat	Timber production
First	Reorganization (Bormann and Likens 1979) Stand initiation (Oliver and Larson 1990) Establishment (Spies and Franklin 1991) Ecosystem initiation (Carey and Curtis 1996) Disturbance/legacy creation and cohort establishment (Franklin et al. 2002)	Grass/Forb-Open, Grass/Forb-Closed, Shrub/Seedling-Open, Shrub/Seedling-Closed, Sapling/Pole-Open (O'Neil et al. 2001)	Seedling (Haynes 2003) Early seral (FEMAT 1993)
Characteristics	• Pioneer tree cohort established with a range of regeneration densities • Biological legacies present depending on initial disturbance type, intensity and management • Rapid biomass accumulation • Biological legacies retained provide habitat • Above- and below-ground resource availability high • Nutrient transfer from soil to biomass • Possible introduction and spread of exotic/invasive species	• Biodiversity high • Herb and shrub understory may be abundant or persistent • Open canopy conditions important for birds and mammals	Stand age typically 0-15 years Single species tree cohort densely seeded or planted, typically with genetically altered stock Competing vegetation controlled or removed Precommercial Includes first tree age class of seedlings (average age of 5 years)

Appendix 1. Major classification schemes used to describe forest developmental stages and associated characteristics. Characteristics are illustrated from various ecosystem perspectives by using a Douglas-fir (*Pseudotsuga menziesii*) dominated sere growing in the western hemlock (*Tsuga heterophylla*) zone (Franklin and Dyrness 1988). Characteristics will vary widely based on site location, disturbance history, management, and forest types. This table was developed by B. Kerns (see list of contributors). (continued)

Major classification systems and characteristics for forest developmental stages

Ecosystem perspective → Forest development stage ↓	Ecological structure and process	Wildlife habitat	Timber production
Second	Aggradation (Bormann and Likens 1979) Stem (Oliver and Larson 1990) Thinning (Spies and Franklin 1991) Competitive exclusion (Carey and Curtis 1996) Canopy closure (Franklin et al. 2002)	Sapling/Pole-Moderate, Sapling/Pole-Closed (O'Neil et al. 2001)	Poles and saplings (Haynes 2003) Mid-seral (FEMAT 1993)
Characteristics	• Taller vegetation becomes dominant • Leaf area and biomass accumulate • Canopies close on some sites—rate depends on regeneration density and site productivity • Few snags and coarse woody debris (CWD) in managed stands • Rapid understory environment changes • Resource availability decline	• Biodiversity declines • Depending on canopy structure, herb and shrub understory abundance declines • Amphibians associated with closed canopies • Minimize stage through precommercial and variable-density thinning	• Stand age typically 15 to 35 years • Conventional precommercial thinning to maintain evenly spaced trees and promote tree growth • Pole and sapling sized trees usually not merchantable • Commercial thinning can occur depending on market conditions
Third	Aggradation (Bormann and Likens 1979) Stem exclusion (Oliver and Larson 1990) Thinning (Spies and Franklin 1991) Competitive exclusion (Carey and Curtis 1996) Biomass accumulation/competitive exclusion (Franklin et al. 2002)	Small Tree-Single Story-Moderate, Small Tree-Single Story-Closed, Medium Tree-Single Story-Moderate, Medium Tree-Single Story-Closed, Large Tree-Single Story-Moderate, Large Tree-Single Story-Closed (O'Neil et al. 2001)	Young (Haynes 2003) Late seral (FEMAT 1993)

Appendix 1. Major classification schemes used to describe forest developmental stages and associated characteristics. Characteristics are illustrated from various ecosystem perspectives by using a Douglas-fir (*Pseudotsuga menziesii*) dominated sere growing in the western hemlock (*Tsuga heterophylla*) zone (Franklin and Dyrness 1988). Characteristics will vary widely based on site location, disturbance history, management, and forest types. This table was developed by B. Kerns (see list of contributors). (continued)

Major classification systems and characteristics for forest developmental stages

Ecosystem perspective → / Forest development stage ↓	Ecological structure and process	Wildlife habitat	Timber production
Characteristics	• Woody biomass development • Tree crown differentiation and lower branch pruning • Low resource availability early, increases later • Density dependent tree mortality with high stand density • Few snags and CWD • Competitive exclusion of many organisms	• Low biodiversity • Depending on canopy structure, herb and shrub abundance may be low • Amphibians associated with closed canopies • Minimize stage through precommercial and variable density thinning	• Stand age typically 45 to 75 years • Pioneer tree cohort dominates site • Sawtimber and nonsawtimber size trees • Conventionally thought of as the culmination of mean annual increment • For many private industrial land-owners, may reflect typical rotation lengths and stand developments ends
Fourth	Transition (Bormann and Likens 1979) Understory reinitiation (Oliver and Larson 1990) Mature (Spies and Franklin 1991) Understory reinitiation, developed understory (Carey and Curtis 1996) Maturation (Franklin et al. 2002)	Small Tree-Single Story-Open, Medium Tree-Single Story-Open, Large Tree-Single Story-Open (O'Neil et al. 2001)	Mature seral (FEMAT 1993) Mature (Haynes 2003)

Appendix 1. Major classification schemes used to describe forest developmental stages and associated characteristics. Characteristics are illustrated from various ecosystem perspectives by using a Douglas-fir (*Pseudotsuga menziesii*) dominated sere growing in the western hemlock (*Tsuga heterophylla*) zone (Franklin and Dyrness 1988). Characteristics will vary widely based on site location, disturbance history, management, and forest types. This table was developed by B. Kerns (see list of contributors). (continued)

Major classification systems and characteristics for forest developmental stages			
Ecosystem perspective → Forest development stage ↓	Ecological structure and process	Wildlife habitat	Timber production
Characteristics	• Maximum height and crown spread of pioneer tree cohort • Minimal coarse woody debris • Heterogeneous resource availability • Shift to density independent mortality • Sub-lethal tree damage produces greater individual tree conditions and niche diversification	• Extended rotations (> 80 years) to provide habitat • Re-establishment of understory species, including shade-tolerant conifers • Increase in diversity of fauna, especially with multi-stored canopies • Increase habitat through commercial thinning and CWD management	• Stand age typically 85 to 135 years • Less common stage on private industrial lands • Composed mostly of sawtimber size trees • Conventionally thought of as over-culmination of mean annual increment
Fifth	Steady-state (Bormann and Likens 1979) Old-growth (Oliver and Larson 1990) Transitionand shifting-gap (Spies and Franklin 1996) Botanically diverse, niche diversification fully functional (managed) and old-growth (Carey and Curtis 1996) Vertical diversification, horizontal diversification and pioneer cohort loss (Franklin et al. 2002)	Small Tree-Multistory-Open, Small Tree-Multistory-Moderate, Small Tree-Multistory-Closed, Medium Tree-Multistory-Open, Medium Tree-Multistory-Moderate, Medium Tree-Multistory-Closed, Large Tree-Multistory-Open, Large Tree-Multistory-Moderate, Large Tree-Multistory-Closed, Giant Tree-Multistory (O'Neil et al. 2001)	Mature (FEMAT 1993) Old mature stage (Haynes 2003)

Appendix 1. Major classification schemes used to describe forest developmental stages and associated characteristics. Characteristics are illustrated from various ecosystem perspectives by using a Douglas-fir (*Pseudotsuga menziesii*) dominated sere growing in the western hemlock (*Tsuga heterophylla*) zone (Franklin and Dyrness 1988). Characteristics will vary widely based on site location, disturbance history, management, and forest types. This table was developed by B. Kerns (see list of contributors). (continued)

Major classification systems and characteristics for forest developmental stages			
Ecosystem perspective → Forest development stage ↓	Ecological structure and process	Wildlife habitat	Timber production
Characteristics	• Slow decline in aboveground biomass • Many substages for long-lived species • Development of late successional and old-growth attributes (Spies and Franklin 1996) • Density-independent mortality increases, large, persistent gaps may form • Accelerated generation of cwd • Highly heterogeneous resource availability • Sub-lethal tree damage continues • Loss of dominants (800 to 1300 yrs.)	• Extended rotations to provide habitat • Large trees, multiple stories, snags, CWD, and closed canopies create habitats for numerous species • Faunal diversity, especially birds and mammals is high	• Stand age typically more than 145 years • Uncommon stage on private industrial lands • Conventionally thought of as past the point where net annual growth has peaked