

# WOOD SUPPLY AND OTHER VALUES AND ECOSYSTEM MANAGEMENT IN WESTERN INTERIOR FORESTS

Chadwick D. Oliver and Bruce R. Lippke

## ABSTRACT

Ecosystem management has been proposed, as an alternative to traditional commodity-based management for the Inland West's forests, as a means of improving biodiversity. Other objectives such as employment, cost to the public, and timber flows with their impacts on the global environment are also important and result in significant trade-offs between ecosystem approaches and commodity management approaches; but ecosystem management can mean different things, depending on which ecological paradigm is followed. By the now-outdated "steady state ecological theory," it means the creation of large, untouched reserves; or it can allow controlled burning to prevent excessively hot fires; or it can even allow salvage for timber production—each of these three being a preservation-centered alternative with a different set of tradeoffs between objectives. By contrast, the more accepted dynamic ecological theory leads to a landscape approach to ecosystem management, which employs active treatments of the land to create diversity of structure to meet biodiversity objectives and provides a very different set of trade offs.

This paper analyzes the effectiveness of a range of alternative management approaches in meeting the cited goals for the Inland West's public lands. The consequences of the several alternatives provide the context for the decisions which policy makers will ultimately make. While the impacts of the alternative ecosystem management approaches differ substantially from commodity management, the tradeoffs between goals other than biodiversity can also be substantial. If attention is shifted to the tradeoffs between several goals, the issue is no longer biodiversity versus commodity timber production, since both are possible. Determining the relative importance of policy objectives, and ways to implement policy change, remain the policy makers' dilemmas, but the magnitude of the trade offs should be of important consequence.

## INTRODUCTION

Several approaches to managing the Inland West's forests have been proposed. Ecosystem management has been proposed as an alternative to traditional, commodity-based management. However, ecosystem management has been interpreted either as creating large reserves where most human activities—especially

the extraction of timber—are generally excluded (FEMAT 1993), or as maintaining patterns and processes across the landscape through active management, with timber removal as a by-product of the process (Oliver 1992; Boyce and McNab 1994). To determine whether one of these is more desirable, the impacts of each approach on the objectives of management must be examined.

This paper first describes the general condition of the Inland West forests, recent timber management practices, and the rationale for these practices. It describes the general objectives people have for forests in the United States and several recently popular management approaches for achieving these objectives. It then analyzes the effectiveness of each management approach. Policy makers will ultimately decide which management approach is preferred; however, this paper discusses the consequences of various decisions as a setting for policy decisions. Finally, it discusses effective ways to implement the decision.

This paper primarily discusses national forests, since most forests of the Inland West are on federal lands; however, the trends are also applicable to other public and privately-held forest lands.

## ECOLOGY AND MANAGEMENT HISTORY

Forests of the Inland Western United States—from the Cascade and Sierra Crest to the Great Plains—consist of 140 million acres, 54% of which can grow a least 20 cubic feet per acre per year of timber, and so is designated commercial forest land. Sixteen percent of that productive land is set aside as national parks, wilderness areas, etc. Of the productive area remaining, 36.4 million acres (58%) constitute national forest lands (Powell et al. 1993). The commercial forest lands of the Inland West generally do not grow timber as rapidly as those of the Pacific Northwestern and Southeastern United States.

The condition of forests of the Inland West is the result of past natural and human disturbances and regrowth. Most management has been a combination of commodity management and preservation.

Before European-Americans dominated the area, the forests grew as in Figure 1 (Johnson et al. 1993). At low elevations, frequent ground fires kept the forests in park-like stands. This type of fire and the park-like forest structure (primarily ponderosa pine forests) were common in the southern Rocky Mountains and at low elevations in the central and northern Cascade Mountains (Covington and Moore 1994; Agee 1993). Forests at mid- and upper elevations in the eastern Cascades and central and

northern Rocky Mountains burned in hot, stand-replacing fires at intervals of about one or two centuries.

A combination of natural stand-replacing fires, commodity management for sheep, cattle, horses, and timber, and human-caused burning of the late 1800s and early 1900s created conditions of relatively low fire susceptibility in the first few decades of this century. By the 1950's, a preservation approach excluding all fires, natural and otherwise, was effective enough to allow a regrowth of dense forests at both upper and lower elevations. At upper elevations, the regrowth was part of a natural cycle. At lower elevations and in the southern Rocky Mountains, the regrowth to dense forests (stem exclusion and later stages of the lower part of Figure 1) created quite abnormal conditions.

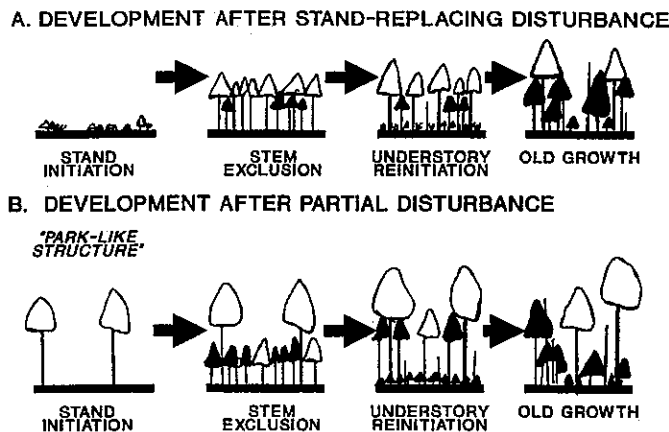


Figure 1.—Stands in the Inland West generally developed after infrequent, stand replacing disturbances (usually fires) at upper elevations (A) and after frequent partial disturbances (ground fires) at low elevations (B). Present fire and forest health dangers in the Inland West are high because forest growth following fire exclusion at low elevations and regrowth following old fires at upper elevations have created predominantly closed forests (forests not in the stand initiation condition; Johnson et al. 1993).

Forest management in the Inland West has generally been funded by timber removal to avoid below-cost timber sales (which appear as timber subsidies) on public lands, and to avoid bankruptcy on private lands. Much of the timber removal in the past century has been through uneven-aged harvesting (often "highgrading"), in contrast to the clearcutting practiced in the faster-growing regions of Western Oregon and Washington (Adams 1980; Daniel 1980). Uneven-aged harvesting removed larger trees and allowed growth of smaller trees which were often of different species than the larger ones. This predominance of uneven-aged harvesting has been contrary to the public's perceptions of clearcutting and to highly publicized cases such as the Bitterroot Controversy, Montana (Burk 1970).

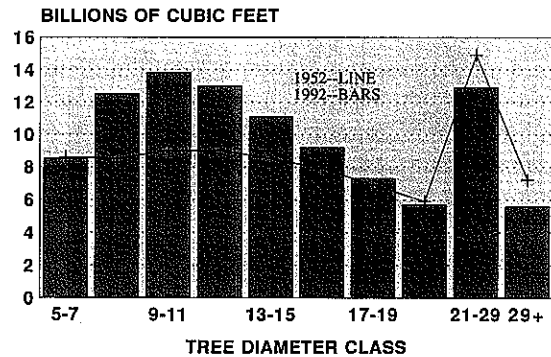
### PRESENT CONDITION

Because of uneven-aged harvesting practices and fire prevention, the Inland West presently contains many forests of overly-crowded, small-diameter trees and many uneven-aged forests

(Figure 2). Standing volume is about 100 times as much as annual growth, indicating the forests have been increasing in volume for many decades. The forest's overcrowded condition is reflected in the high mortality rate (Figure 3).

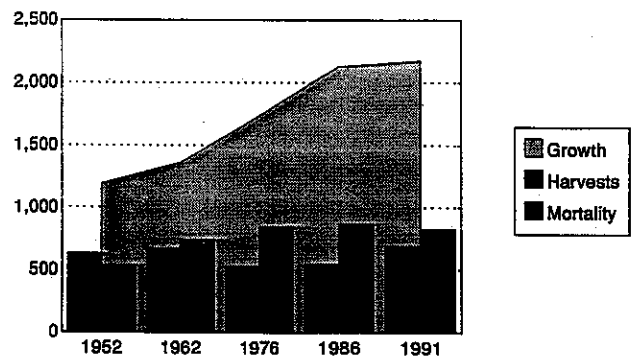
### DIAMETER DISTRIBUTION CHANGE

1952-1992



For Intermountain West, USDA Forest Service 1992

Figure 2.—Change in diameter distribution of trees in the Intermountain West between 1952 (line) and 1992 (bars). Forests are increasingly composed of small diameter, crowded stands whose harvesting costs exceed their commercial timber value. Much of the timber not harvested is of small diameters; the employment created and timber value, combined, could make harvesting economically feasible (data from Powell et al. 1993; North and South Dakota, eastern Oregon and Washington not included).



(Excludes eastern Washington & Oregon; USDA Forest Service 1982 & 1993)

Figure 3.—Net annual growth, mortality, and harvested forest tree volume (in millions of cubic feet) in the Inland West in selected years between 1952 and 1991. Stand volumes for the same area were 50 to 100 times as much as annual growth. Much of the volume is not harvested because the costs of harvesting exceed the timber value; however, if more volume is not harvested soon, the excess volume will be reduced by catastrophic wildfires at a very high public cost (data from Powell et al. 1993). (For conversion, one cubic foot equals approximately 5 board feet.)

These overcrowded forests with many dead trees presently provide habitat for such old-growth-dependent species as the spotted owl (in eastern Washington and the Oregon Cascades); however, they are also extremely susceptible to insects, diseases, and fires (Sampson et al. 1994), disturbances which change stand structures very quickly. At the same time, there is a relatively small amount of open forest area. Species which depend on this habitat, such as Canadian lynx, grizzly bear, bighorn sheep, and the grey wolf, are jeopardized.

The Inland West's forests are growing much faster than they are being harvested (Figure 3). Dry summers have prevented dying trees from rotting, leading to a buildup of fuel. Within the next few decades, millions of forested acres of the Inland West can be expected to burn, returning them to the stand initiation stage (Sampson et al. 1994). These changes in stand structure will occur either through destructive, stand-replacement wildfires or through active management to reduce the excess fuels in forests in the older stages. After these disturbances occur, there will be larger amounts of open habitat for species dependent on it.

Presently, trees of smaller size than ever before are being removed and processed for timber in both thinning and harvesting operations in the Inland West. If continued and expanded, these operations could greatly reduce the risk of very large disturbances while helping achieve a greater diversity of structures across the region over time (Oliver et al. 1994). Recent federal policies which emphasize untouched set-asides seem more likely to increase fuel loads and stand replacement fires. The harvesting of smaller trees may be a temporary response of logging companies to the reduced timber supply from regions impacted by set-asides. Companies are paying high prices for timber and logs, and incurring higher costs in the processing of small-diameter trees, in order to depreciate their equipment investments rather than lose their capital investment prematurely. Ultimately, many businesses will close when substitute products—wood from elsewhere in the world, steel, aluminum, concrete, or plastic—gain in share. This business closure and substitution process is already underway; however, policy alternatives may still have a significant impact on the outcome.

## OBJECTIVES FOR MANAGEMENT

The overall objectives for management of forests have been expressed directly and indirectly in many ways—through the Endangered Species Act, the National Forest Management Act, the U.S. Congressional budgetary process, and the U.S. free market system—which require landowners and businesses to make a profit.

For this paper, the objectives are categorized as follows: biodiversity; timber flow and the global environment; employment; and cost to the public. Other objectives could be considered as well; however, these are sufficient to demonstrate important tradeoffs that exist. Each of these criteria is described in detail below.

## Biodiversity

Biodiversity refers to variation in life forms, genetic makeup, biological processes, and ecological niches. Maintaining stable populations by managing for individual species is an impossible task. There are too many species, including some not yet known. Requirements for the survival of many are unknown. Alternatively, biodiversity can be promoted by maintaining a diversity of habitats. In forested areas, these habitats are the various stand structures. They can be identified and measured in terms of amount and transition from one structure to another.

## Timber Flow and the Global Environment

The use of wood from the Inland West and protection of the global environment are probably complementary objectives. If wood products are not produced from areas where other ecosystem values are maintained, they will be produced from elsewhere in the world where ecosystem values are less regarded, with greater harm to the global environment. Products such as steel, aluminum, concrete, brick, and plastic may be used as substitutes for wood products causing more pollution. For example, each 2 billion board feet of timber harvested reduces the U.S.'s contribution to global carbon (as carbon dioxide) emissions to the atmosphere by 0.3%. This is 3.8% of President Clinton's gas emission reduction target by the year 2000 if the wood replaces such fossil-fuel-intensive substitutes as steel, aluminum, brick, and concrete (Koch 1991; Clinton et al. 1993). Some of the harvest would not, in fact, replace energy-intensive products, but may prevent increased harvests in the tropics, Siberia, and other places with fewer ecological safeguards. These environmental benefits, though less quantifiable, may be as significant. About two billion board feet—about 20% of the forest growth—are harvested annually from national forests in the Inland West (Powell et al. 1993).

Timber production and the impacts on trade flows can be measured and simulated to gain insights into such impacts on the global environment (Perez Garcia 1993), however, this is beyond the scope of this paper. Instead, the global impacts of changes in timber harvest from the 1991 level under different management scenarios is expressed in terms of contributions to the U.S.'s gas emissions reduction target.

## Employment

Unemployment is a public cost which reduces the ability to spend taxes on other environmental or social values. Rural unemployment remains a structural problem of significant policy importance. In addition, forest ecosystems are generally more diverse where human economic well-being is above the subsistence level and local people have an active interest in maintaining the forest in an ecologically sound condition.

Forest management produces employment through silvicultural treatments, fire fighting, timber harvesting, and timber manufacturing (Table 1). Each million board feet of timber harvested generates approximately 3 woods jobs, 5 primary and secondary manufacturing jobs, an equal number of indirect jobs in the local community, and more in adjacent population centers.

Table 1.—Silvicultural and management operations, costs (or each entry) labor, and returns assumed for different silvicultural regimes.

Silvicultural regime/operation	HI	MED	LOW	Employment Silv. Ops.
<b>Uneven-aged (selection)</b>				
Plant (4x) (\$/Acre)	400	0	0	1
Precomm th.(4x)	240	240	0	1
Timber hvst (MBF)	60	40	20	
Timber hvst (\$/MBF)	230	220	210	
Empl. in hvst (per-days)	120	80	140	
Fire fighting	75	75	75	4 <sup>4</sup>
Road maintenance	200	200	200	2
<b>Even-aged, no thinning</b>				
Broadcast burn	200	200	200	0.8
Regenerate	400	400	400	2
Precomm. thin	240	240	240	1
Timber hvst (MBF)	54	36	18	
Timber hvst (\$/MBF)	190	170	160	
Empl. in hvst (per-days)	108	72	36	
Fire fighting	75	75	75	4 <sup>4</sup>
Road maintenance	200	200	200	2
<b>Even-aged with thinning</b>				
Broadcast burn(\$/Acre)	200	200	200	0.8
Regenerate (\$/Acre)	400	400	400	2
Precomm. thin (\$/Acre)	240	240	240	1
Underburn (2x) (\$/Acre)	400	400	400	0.8
Harvest				
Thin (2x) (MBF)	30	20	10	
Thin (\$/MBF)	120	60	50	
Final hvst (MBF)	30	20	10	
Final hvst (\$/MBF)	240	190	180	
Empl'd in hvst (p-dys)	120	80	40	
Fire fighting	0	0	0	0
Road maintenance	200	200	200	2
<b>Prescribed burning, no harvest</b>				
Prescribed burn(4X) (\$/acre)	800	800	800	8
Fire fighting (\$/Acre)	0	0	0	
Road maintenance <sup>3</sup>	400	400	400	
<b>Salvage of burned timber</b>				
Timber harvest	VALUES ARE 60% OF EVEN-AGED, NO THINNING			
Fire fighting (\$/Acre)	110 <sup>4</sup>	110 <sup>4</sup>	110 <sup>4</sup>	8 <sup>4</sup>
Road maintenance (\$/Acre)	200	200	200	
<b>No active mgt. except fire fighting</b>				
Timber harvest (MBF)	0	0	0	0
Fire fighting (\$/Acre) <sup>150<sup>4</sup></sup>	150 <sup>4</sup>	150 <sup>4</sup>	8 <sup>4</sup>	
Road maintenance(\$/Acre)	200	200	200	2

<sup>1</sup> Plant needed only on high sites. Precommercial thin on high and medium sites.

<sup>2</sup> Labor included in other operations.

<sup>3</sup> Road maintenance without timber harvest would be twice as expensive, since logging companies pay for half of road maintenance.

<sup>4</sup> Fire fighting is less where salvage logging reduces reburning, or harvesting reduces fuels and provides access.

Estimates based on Lippke and Oliver 1993.

For this paper, employment will be calculated at 8-person years per million board feet. Jobs created in processing other values from the forests are relatively few compared to timber harvesting and manufacturing, and are not included in this analysis. These jobs may or may not be compatible with timber harvest.

### Cost to the Public

The public's ability to pay for various ecological values through taxes (or foregoing taxes through reducing commerce) competes with many other social objectives. Where more tax money is spent to obtain ecological values in one area, less money is available to provide protection of ecological values in other areas. If costs become so high that a decline in living standard is perceived, the public tends to reject both the management approach and the ecological values as not being of high priority to its welfare. The costs of alternative approaches can be measured and demonstrated as potential tradeoffs for policy alternatives. Where the values are not well known, policy makers must often make choices on the basis of perceived benefits to relative costs.

This paper divides costs into three categories: costs to the federal government, costs to local (non-federal) governments, and costs to consumers. For this paper, costs to the federal government are the changes in U.S. Forest Service expenses for managing national forests in different ways. In 1989 the Forest Service spent about \$2.5 billion and generated revenue (primarily from timber) of about \$1.1 billion. In 1993, it spent about \$2.9 billion and generated revenue of about \$700 million.

Non-federal government costs are affected in two ways:

- i. Local governments receive funds from national forests in lieu of taxes, which are referred to as "surrogate taxes" in this paper. These funds are 25% of timber receipts from national forests within the local area, minus the cost of certain silvicultural operations necessary for harvest. For purposes of this paper, 1991 receipts are estimated based on the board feet harvested and cost and revenue shown in Tables 2 and 3. Receipts above and below that amount are considered gains and losses to the local government.
- ii. Local governments also bear the costs of unemployment and benefit from increased employment. The cost of maintaining someone on welfare is estimated to be \$40 per day. Present employment is estimated from the amount of timber harvest in Table 1. Employment above and below this amount are considered benefits and costs.
- iii. Consumers pay for wood or its substitutes. A change in wood supply creates an opposite change in costs of wood or its substitutes. For this paper, changes in costs to consumers are described in relative terms, with increases in available timber volume causing decreases in costs to consumers.

## SILVICULTURAL REGIMES FOR MANAGING FORESTS

Silvicultural regimes are a sequence of silvicultural operations done to a stand over time to achieve specific objectives. For this paper, six silvicultural regimes are analyzed:

1. uneven-aged (selection) management;
2. even-aged management without thinning;
3. even-aged management with thinning;
4. no management except prescribed burning;
5. no management except salvage of burned timber following natural fires; and
6. no active management except fire fighting.

Silvicultural operations, costs, and labor assumptions are shown in Table 1. Other basic values for the analysis are the same as Lippke and Oliver (1993a). Fighting wildfires in unmanaged forests is assumed to cost \$150/acre. Road maintenance is assumed to cost \$4/acre/year, with half of this cost paid by harvest operations where they occur.

It is assumed that similar amounts of timber would be obtained from even-aged management with thinning and from uneven-aged management (Larson 1982). Even-aged management without thinning would provide slightly less volume (Table 1), since more trees will die from suppression and not be harvested. Differences in timber quality and species between regimes are considered in terms of stumpage returns. It is also possible that the uneven-age management regime is not completely sustainable, since it may lead to more shade-tolerant true firs (*Abies*) and other species than can be supported without insect and disease outbreaks, followed by fires.

More detailed analysis of the costs and revenues from silvicultural regimes could increase the precision in the example; however, it is improbable that the results shown here would be different in trends or provide a significant difference for policy analysis.

## ALTERNATIVE APPROACHES TO MANAGEMENT

Historically, forest management has been targeted for specific commodities: timber, grazing, or water, among others. With the recent interest in improving biodiversity, an alternative—ecosystem management—has been proposed which attempts to maintain the many patterns, processes, and species rather than emphasizing a few commodities or a few species. Ecosystem management has been used in two contrasting approaches based on changing theories of how ecosystems function. They are referred to as the "preservation" and "landscape management" approaches in this paper.

Four basic management approaches are compared for this paper: 1) present management, 2) expanded commodity management, 3) ecosystem management using a landscape approach, and 4) ecosystem management using a preservation approach.

Table 2. —Values per acre for different management regimes.

Values Per Acre	Present Management	Expanded Commodity	Landscape Management	Preservation	Preservation & Controlled Burn	Preservation & Salvage
<b>National Forest</b>						
Returns (\$)	\$6,648	\$3,324	\$2,634	\$ 0	\$ 0	\$1,447
Mgmt. Costs(\$)	481	481	894	0	-800	504
Net \$	6,167	2,843	1,740	0	-800	943
"Tax Surrogate"(\$)	1,542	711	435	0	0	236
Road & Fire Cost	275	275	0	150	400	310
Federal Net	4,350	1,857	1,305	-150	1,200	397
<b>Local Government</b>						
Employment(\$)	2,736	2,736	2,417	320	320	1,920
"Tax Surrogate"(\$)	1,542	711	435	0	0	236
Net	4,278	3,447	2,851	320	320	2,156
<b>Other</b>						
Volume Flow(MBF/AC)	31	31	31	0	0	17
Timber Availability	Medium	High	High	Low	Low	Medium
Road Access	Some	Yes	Yes	No	Yes	Yes
Employed(Person Days)	68	68	60	8	8	48

Table 3. —Values if all non-reserved, productive national forest lands in Inland West were managed under different regimes (except "present" management, in which only about 20% of the area is managed). Values would be proportionately less if less area is managed.

Values For All Acres	Present Management	Expanded Commodity	Landscape Management	Preservation	Preservation & Controlled Burn	Preservation & Salvage
<b>National Forest</b>						
Acres Managed (million)	6.7 <sup>1</sup>	36.4	36.4	0	36.4	36.4
Returns (million)	445	1,210	959	0	0	527
Mgmt. Costs (million)	32 <sup>1</sup>	175	325	0	291	183
Net (million)	413	1,035	633	0	-291	343
"Tax Surrogate"(\$)	103	259	158	0	0	86
Road & Fire Cost (million)	63 <sup>1</sup>	100	0	55	146	113
Federal Net(million)	247	676	475	-55	-437	145
<b>Local Government</b>						
Employment (million)	278 <sup>1</sup>	996	880	116	116	699
"Tax Surrogate" (million)	103	259	158	0	0	86
Net (million)	382	1,255	1,038	116	116	785
<b>Other</b>						
Volume Flow (MBF/AC)(bill)	2	11	11	0	0	6
Timber Supply	Medium	High	High	Low	Low	Medium
CO2 Change(Pres.)	4%	22%	21%	0%	0%	12%
Road Access	Some	Yes	Yes	No	Yes	Yes
Employed (Person Years (7 hours))	1	100	88	12	12	70

<sup>1</sup> Commodity management on 6.7 million acres; preservation on 29.7 million acres.

Table 4. —Changes in values of objectives if all non-reserved, productive national forest lands were managed by different management scenarios compared to present (see Table 3). Values would be less if less area were managed.

Changes in Values	Expanded Commodity	Landscape Management	Preservation	Preservation & Controlled Burn	Preservation & Salvage
Biodiversity	+ <sup>1</sup>	+++	+ <sup>1</sup>	++	+ <sup>1</sup>
Global Environment	+18	+17	-4%	-4%	+8%
Employment (thousand person years)	+72	+60	-16	-16	+42
Return to Public (negative value = cost)					
Federal (million)	+429	+228	-302	-611	-102
% Change	+17%	+9%	-12%	-24%	-4%
Local (million)	+873	+656	-266	-266	+403
Consumer Cost of Wood	Low	Low	Hi	Hi	Med

<sup>1</sup>The relative benefits of these three management approaches on biodiversity are uncertain; however, their benefits are less than Preservation with controlled burn (if it is possible) and much less than Landscape Management.

In addition, three variations of the preservation approach are compared, since these approaches have been actively proposed in light of fires in the eastern Washington Cascades. The variations are: Preservation with no activities; Controlled burning with no harvest of timber; Salvage of burned trees for timber production.

The effects of each management approach on each objective are compared in Tables 2, 3, and 4. Table 2 shows per acre values; Table 3 expands the analysis to the entire 36.4 million acres of national forests in the Inland West. For this expansion, the values for each site are used in proportion to their amount in the Inland West (e.g., 49% on low sites [capable of growing between 20 and 49 cubic feet annually], 44% on medium sites [capable of growing between 50 and 119 cubic feet annually], and 7% on high sites [capable of growing over 120 cubic feet annually]; Powell et al. 1993). To keep the range of assumptions manageable, it is assumed that even-age harvest rotations are 100 years, uneven-age harvest cycles are 25 years. When a given silvicultural regime is considered, it is also assumed that 1/100th of the acres will be treated for each activity each year. In fact, the present distribution of stand conditions would require that more lands be treated in the next few decades (Lippke et al., paper in this volume).

Although calculations are shown here for national forest land, similar trends apply to other public and private forest lands as well. On these other lands, however, costs of various operations are often lower and so change the values. Also, private landowners pay taxes instead of a surrogate to counties, even if they do not harvest timber.

## Commodity Management Alternatives

Historically, forests have been managed primarily for specific commodities, such as grazing, water, or timber—except for the extreme preservation approach toward fire management. Values such as biodiversity were often not considered, or human impacts were assumed to be so insignificant to forest ecosystems that they would not affect such values. Commodity management has become institutionalized on public forest lands in the United States (and elsewhere in the world) where national forest management practices are funded by timber sales receipts, and where various thinning and harvesting operations need to be economically justified. Commodity management has essentially been required on private forest lands, since landowners must make enough profit to pay taxes or their land will be confiscated.

For this commodity management analysis, the forests are managed by a highly profitable silvicultural regime for its productivity class—with historic factors taken into account (Larson 1982; Oliver and Larson 1990). Commodity management, therefore, is considered in this paper as uneven-aged management on all unproductive and medium productivity sites, and even-aged management (with no thinning) on all highly productive sites. It is estimated that fire fighting costs are less expensive under regimes of no active management (Table 1). Even-aged management with thinning included prescribed burning, so fire fighting costs are assumed to be negligible. This effect of management may vary somewhat regionally but seems reasonable (O'Laughlin et al. 1993; O'Laughlin 1994).

Table 4. —Changes in values of objectives if all non-reserved, productive national forest lands were managed by different management scenarios compared to present (see Table 3). Values would be less if less area were managed.

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Although calculations are shown here for national forest land, similar trends apply to other public and private forest lands as well. On these other lands, however, costs of various operations are often lower and so change the values. Also, private landowners pay taxes instead of a surrogate to counties, even if they do not harvest timber.

## Commodity Management Alternatives

Historically, forests have been managed primarily for specific commodities, such as grazing, water, or timber—except for the extreme preservation approach toward fire management. Values such as biodiversity were often not considered, or human impacts were assumed to be so insignificant to forest ecosystems that they would not affect such values. Commodity management has become institutionalized on public forest lands in the United States (and elsewhere in the world) where national forest management practices are funded by timber sales receipts, and where various thinning and harvesting operations need to be economically justified. Commodity management has essentially been required on private forest lands, since landowners must make enough profit to pay taxes or their land will be confiscated.

For this commodity management analysis, the forests are managed by a highly profitable silvicultural regime for its productivity class—with historic factors taken into account (Larson 1982; Oliver and Larson 1990). Commodity management, therefore, is considered in this paper as uneven-aged management on all unproductive and medium productivity sites, and even-aged management (with no thinning) on all highly productive sites. It is estimated that fire fighting costs are less expensive under regimes of no active management (Table 1). Even-aged management with thinning included prescribed burning, so fire fighting costs are assumed to be negligible. This effect of management may vary somewhat regionally but seems reasonable (O'Laughlin et al. 1993; O'Laughlin 1994).

human activities that human intervention, other than to preserve forests, will be irrevocably harmful to the natural system. Large preserves are advocated where natural patterns and processes are assumed to grow and maintain this old growth condition with limited human activities. Species dependent on habitat other than old-growth are assumed either not to exist, to be able to survive in old-growth structures, or to exist in geographically distant areas.

***Preservation with no activities:*** For this example, no silvicultural operations or road maintenance is done under this preservation approach. Wildfires are assumed to occur on each acre once every 100 years, with associated fire fighting costs.

Fires in eastern Washington in the summer of 1994 led to suggested modifications of the preservation approach to allow controlled burning or salvage of burned timber. Because of the potential impact of these two alternatives, they are considered as separate alternatives:

***Controlled burning with no harvest of timber:*** Controlled burning would attempt to restore pre-European fire regimes to forested areas by actively burning, but other human activities would be excluded. Controlled fires may not be possible in unthinned and unharvested areas because of the extremely high buildup of fuels. However, for this analysis they are assumed to be possible, to cost an estimated \$200/acre, and are to be conducted once every 25 years on each acre (Table 1). In fact, they would probably be done more frequently on each acre, with each subsequent fire costing less. Road maintenance would be necessary in burn areas to be able to control the fires.

***Salvage of burned trees for timber production:*** Salvage represents another alternative within a preservation approach and entails removal of some timber burned in natural fires. This timber would be used for manufacture of wood products. Salvage logging is assumed to remove 60% of the timber which would otherwise be harvested if even-age management with no thinning were done on all sites (Table 1), since some timber would deteriorate before it could be salvaged. Salvage logging would pay for one half of the road maintenance costs.

## TRADEOFFS BETWEEN OBJECTIVES AND MANAGEMENT ALTERNATIVES

The impacts of each management alternative on each objective are described below and shown in Tables 2, 3, and 4. These values could be put into a matrix, normalized, and weighted to allow policy makers to understand and select options. Determining weights for such a matrix is beyond the scope of this paper and remains an important aspect of policy decision-making.

### Impacts on Biodiversity

***Commodity-based management (present approach):*** has generally promoted just those forest habitats and structures compatible with efficient commodity production. The same economic basis which has led to even-aged management on highly productive sites has led to uneven-aged management on low-productivity sites in the Inland West. Carried to extremes, both can threaten biodiversity. Excessive even-aged manage-

ment can lead to a shortage of old-growth forests, and excessive uneven-aged management has created a shortage of open structures in the Inland West. In fact, the species being threatened in the Inland West are the ones needing stand initiation structures: Canadian lynx, wolves, bighorn sheep, and several plant species. Commodity-based management has, to a degree, contributed to biodiversity by reducing extreme insect, disease, and fire conditions sometimes found on more preserved lands (O'Laughlin et al. 1993).

***Expanded commodity-based management:*** Most areas will be in either stem exclusion or old-growth structures except for the few, very productive sites under even-aged management. Commodity-based management, therefore, leads to relatively stable proportions of certain stand structures. It is uncertain whether this stability of a few structures is more conducive to biodiversity than the instability of structures produced by preservation management.

***Landscape ecosystem management*** will create the greatest biodiversity according to the dynamic ecological theory by actively maintaining a balance of habitats (Oliver 1992a,b and Everett et al. 1993). Landscape ecosystem management will ensure greater biodiversity than commodity-based management.

***Preservation with no activities*** will provide the greatest biodiversity under the steady-state ecological theory; however, under the dynamic theory, it will cause the least biodiversity because open (stand initiation) habitats will be greatly diminished until very large catastrophic fires occur, after which "old growth" habitats will be diminished. Such catastrophic fires as the Foothills Fire (over 140,000 acres) on the Boise National Forest in 1992 (Sampson et al. 1994) are significant examples of the fallacy of assuming natural processes would maintain a steady state and protect all species.

***Controlled burning with no harvest of trees*** will provide a variety of habitats, similar to the landscape management approach provided the treated area is large enough. The large fuel base, however, means even the controlled fires will be hot and not produce the structure that follows frequent cooler fires. In addition, trees killed in the fires may lead to very hot reburns when later controlled or natural fires occur.

***Salvage of burned trees for timber production*** will be similar to preservation management in the maintenance of biodiversity, since natural processes create similar patterns and sizes of disturbances and regrowth.

Ranking of each management approach for its biodiversity value based on the above descriptions is shown in Table 4. Progress in refining habitat suitability indices and other measures of biodiversity will ultimately lead to less subjective biodiversity measures. Rankings would be different under the steady state ecological theory; however, under the presently-accepted dynamic theory, landscape management is best. Controlled fires rank second since they create a mosaic of all structures and (even with the high fuel buildup) has some resemblance to forest conditions under Native American habitation. It is uncertain what the relative biodiversity benefits are of expanded commodity management, preservation with no activities, and preserva-

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60% of the rate of even-aged management without thinning (see Table 1), so the global impacts will be the equivalent of a reduction of carbon output to the atmosphere from the U.S. by about 8% of President Clinton's emissions reduction target.

## Impact on Employment

The present condition of commodity/ management provides a moderate number of jobs in rural areas (Table 3).

Commodity-based management will provide nearly a four-fold increase in jobs in the woods, lumber mills, and in rural infrastructures supporting these workers if it is applied to all 36.4 million acres of non-reserved, productive national forest land. There may actually be an immigration of workers to these rural areas to fill these jobs.

Landscape ecosystem management will provide nearly 90% of the employment of commodity management, both in forest operations to maintain the balance of stand structures, and through remanufacture of the high-quality wood produced through this management (Oliver 1992a,b).

Preservation with no activities will provide very few jobs, except those provided through fighting wildfires and their supporting infrastructure of hotels, etc. Since no timber is being produced or processed, woods and mill jobs associated with this industry will not exist.

Controlled burning with no harvest will still only provide those direct and indirect jobs associated with fire management.

Salvage of burned trees for timber production will provide jobs, however, the irregular nature of fires will mean the jobs will be sporadic, result in hauling of logs to more distant mills, and therefore probably not support a sustained local infrastructure.

## Impact on Cost to the Public

The differences in cost to the public of various management approaches is significant (Tables 3 and 4). Many costs of national forest management are masked, since some costs and benefits are borne by the federal government and others by local governments.

Present condition of commodity management is estimated (using figures in Table 3) to yield \$247 million per year revenue to the U.S. Forest Service (when payments to local governments and other costs are subtracted). Local communities benefit by receiving \$103 million as surrogate taxes, and \$178 million in employment or reduced unemployment.

Expanded commodity-based management of the Inland West's national forests will net \$676 million to the U.S. Forest Service and contribute \$996 million in direct jobs to local communities. In addition, payment of 25% of timber receipts to counties in lieu of taxes will contribute another \$259 million to local governments in the Inland West.

Landscape ecosystem management will contribute about 10% less than commodity-based management to the local economy in direct and indirect jobs, and will offset U.S. Forest Service expenses by \$475 million. It will also contribute somewhat less as a tax surrogate to local governments.

Preservation with no activities will contribute no Forest Service income and will only contribute \$116 million in direct and indirect jobs to local governments. This employment will be from fire fighting. It will increase the U.S. Forest Service expenses about 12% (Table 4). With no timber receipts, it will make no contributions to local governments in lieu of taxes.

Controlled burning with no harvesting of timber will contribute about the same to the local government as preservation without prescribed fires, since the direct and indirect jobs from creating prescribed fires will be about the same as fighting fires. No contributions will be made to local governments in timber receipts, and Forest Service expenses will increase about 24%.

Salvage of burned trees for timber production will contribute an intermediate amount of direct and indirect employment, surrogate taxes to local governments, and will reduce the Forest Service expenses about 4%.

## Discussion

The direct costs and receipts for managing national forests are borne by the federal government, but ultimately the consumer pays these costs in taxes. Landscape management on all unreserved, productive forests will still leave over 57% of the federal forests in the Inland West unmanaged or managed as wilderness or national parks. The higher costs of landscape management, coupled with payments to local governments in lieu of taxes will mean \$201 million less return to the U.S. Forest Service compared to commodity management on the same lands. This will still be \$228 million more in revenue than is currently being generated. In fact, research and other programs funded by the U.S. Forest Service make its expenses greater than its revenue each year. The other management approaches do not change the net expenses of the U.S. Forest Service extremely: from 24% per year increased expense (controlled burning with no harvest of timber) to a 17% per year reduced expense (expanded commodity-based management) (Table 4).

The costs to the public have dramatic impacts at the local government levels. The differences in revenue to local governments, as surrogate taxes, are masked by the impact on employment benefits and unemployment costs by the different management regimes. Local governments can benefit or be negatively impacted by management regimes, from a maximum cost increase of \$266 million to a maximum cost reduction of over \$873 million, depending on federal policies.

There are additional costs and benefits to the public. Additional costs of preservation management involve increasing the cost of wood products and reducing the buying power of the U.S. economy by importing wood or its substitutes. The price of lumber has already increased because of harvest reduction in the Pacific Northwest but may not increase more; instead, more polluting substitute products such as steel studs may be used.

## CHOOSING AN ALTERNATIVE

There may not be a management alternative which is optimum for all objectives (Tables 3 and 4). The choice of how to weigh

each objective, and which alternative to implement, is the responsibility of policy makers. However, their decision will only be effective if they understand this broad range of alternatives and have a clear understanding of the consequences of each.

Preservation management alternatives provide the least risk to biodiversity only if the steady-state ecological theory is assumed. All other objectives are negatively affected if the preservation approach is adopted. Preservation management is also very expensive, although the costs are primarily borne by local governments rather than by the federal government, even though the decision is not under the control of local governments.

Landscape ecosystem management provides higher values for more of the other objectives. Landscape management also provides the least risk to biodiversity if the effective ecological theory is uncertain, since this value is high under either theory. If preservation ecosystem management is used, and the dynamic ecological theory assumed, the results characterize a worst case for almost all values, including biodiversity. The preponderance of recent scientific studies favors the dynamic ecological theory (Botkin 1990; Oliver and Larson 1990; Sprugel 1991), which would support the landscape approach to ecosystem management of Johnson and Agee (1987), Salwasser et al. (1992), Oliver (1992a,b), Everett et al. (1993), and Boyce and McNab (1994).

History has shown that governments and their policies are sustained by their ability to provide a certain quality of life for the citizens: stable social structures and high standards of living at low costs (Lee 1994). Other values will only be supported if they can be achieved in ways which are not too costly to the public. Most people do not study the subtle differences between the steady-state and dynamic ecological theories, or the impact of wood vs. steel on the global environment. They do become concerned about the amount of unemployment, the price of houses and building materials, and the costs of unemployment. If a management system is implemented which increases these hardships, the public may reject trying to manage for biodiversity and the global environment by any means.

A parallel example to management based on incorrect scientific theories may be found in the collapse of the Soviet agricultural system and government. The people did not realize (or even care) that Lysenko's theory of evolution was incorrect and the government's agricultural policy therefore theoretically wrong. The people only knew that failed agriculture and constantly importing grain was making their lives unnecessarily difficult (Khrushchev 1990).

Landscape management is an approach to achieving biodiversity and helping the global environment which is scientifically sound and does not require the public to pay a harsh penalty. It does require a change in policy. Preservation management will probably not achieve biodiversity, will harm the global environment, and will require the public to reduce its standard of living.

## ORGANIZATION AND MANAGEMENT SYSTEM FOR IMPLEMENTING THE CHOSEN ALTERNATIVE

Even an appropriate management approach will be effective only if implemented through an effective organization and management system. The U.S. Forest Service and other public and private forest management entities have generally been effective and could be adapted to manage for the changed objectives. Several specific changes which would be effective in managing public lands in the Inland West by landscape management are detailed below.

### Decentralized Decision Structure

Over the past few decades, scientists and managers have found that the management organization needed to accomplish complex desires is not top-down, central planning, but the decentralized approach based on the enfranchisement of workers to make site-specific decisions (Reich 1983). With decentralized management, upper levels of management do not compete with lower levels for authority; rather, the upper levels coordinate decisions among various groups at the lower levels.

The Forest Service management system and laws, court orders, and executive decisions have made national forest management very centrally planned. Management will probably not be effective until this management is reversed and local managers are allowed to make site-specific management decisions based on specific, local conditions. An added benefit to letting many local groups make local decisions is that a single wrong decision cannot impact a large area—as it can when centrally mandated to a large area.

Centralized management on private lands takes the form of fairly uniform forest practice regulations. The objectives will be achieved more effectively if these regulations are exchanged for more target-driven incentives, which encourage the private landowner to produce for the various public values (Lippke and Oliver 1993b).

### Decouple Dependencies on Timber Harvests

A decision of nearly 200 years ago exempted federal government property from paying local taxes. About 85 years ago, the Forest Service was mandated to pay part of its timber receipts to the local government to compensate for having national forest land from which it could not collect taxes (Steen 1976).

The timber base of the revenue has made each county an advocate for timber harvest to help with its tax base. If the payments to counties were based on something other than the timber harvest, there would be less tendency for timber counties to favor commodity management. Since mills and woods workers do reside in one place, these would be somewhat stable even if the location of forest management and timber harvest moved as necessary to maintain balanced ecosystems.

The funds for many forest operations, necessary to landscape ecosystem management on national forests, are budgeted based

on the revenue from timber. If the operations prescribed for each area were separated from the timber revenue base, a wider variety of operations could be done to maintain stable ecosystems. To avoid spending too much public money, a balance between expenses on forest operations and revenue from timber could be maintained at the district, forest, or national level. Maintaining this balance while reporting on the objectives achieved vs. the costs absorbed would be an appropriate job for upper management levels in a decentralized organization system, described above.

The requirement that private landowners pay taxes necessitates management operations based on timber revenue. Private landowners are penalized where they are mandated, through regulations, to provide public values for which they receive no income, such as biodiversity. Giving these landowners an incentive to provide these values will allow the public to pay for these social values on the private lands (Lippke and Oliver 1993b).

### Modernize Landscape Management Tools

Until recently, management over broad areas and long time frames was limited by the ability of managers to coordinate the necessary data and analyses. Recent advances in computers, satellite images, spatial data management, and forest growth projections have allowed landscape management tools to be developed which allow visualization of forest conditions across the landscape and through time under a variety of management choices. These tools allow planning, policy making, and management to be more integrated.

Tools developed by Boyce (1985) and Sessions and Sessions (1992) are being combined and refined. An effort under way at the University of Washington College of Forest Resources Silviculture/Engineering Laboratories integrates Geographic Information Systems, stand inventories, landscape visualization, stand projections, stand visualization, hazard ratings, and silvicultural decision keys into a landscape management system (Oliver et al. 1992).

### Separate Logging and Selling Operations

Selling standing timber gives an incentive for the buyer to remove the timber with minimal regard for the condition of the remaining trees, soil, etc. Instead, woods operations could be contracted to deliver logs harvested in a certain manner to a designated concentration yard, from which they could then be sorted and sold. This would also allow thinnings to benefit forest health and return some money to the Forest Service even though the thinning may not be profitable to a buyer if sold on the stump.

### Increase Efficiencies and Utilization

The temporary increase in price for small diameter timber presently allows many such trees to be thinned, however, this price increase will probably be temporary. Creating more shortages of timber through preserves will not continue to reduce the cost of thinning the stands. Instead, it will lead to more use of

wood from other areas of the world, as well as use of more polluting substitutes for wood.

Thinning operations beneficial to ecosystem health in the Inland West will be done if ways are found to reduce the cost of thinning and increase the value of the thinned wood. Costs can be reduced by increasing the efficiency of thinning and harvesting equipment and techniques, and through technical training of forest workers to operate such equipment most efficiently. A technical institute both for training forest workers in the use of advanced equipment and for testing the equipment is presently being developed on the Olympic Peninsula (contact Ms. Harriette Buckmann, Port Angeles, Washington, for more details).

Landowners might evaluate broadening the range of goods and benefits produced from forest holdings, increasing the value of commodity products and their returns from all stages (e.g., Figure 1) using a portfolio approach to management (Oliver 1994a,b). This approach would strengthen incentives to manage for and through these stages and, thus, help reduce the cost of jointly produced non-commodity values (Lippke and Oliver 1993b). Such products might include timber products, fish, wildlife, mushrooms, berries, floral boughs, and others (Oliver 1992a).

Of these, timber brings by far the most revenue to the landowner. Promoting research in wood utilization and marketing would not only increase the ability to manage the forests for ecosystem health, it would also promote the use of an environmentally sound product.

The tradeoffs shown in Table 1 through 4 are based on the 36.4 million acres of productive, non-reserved federal forest land in the Inland West being managed by each scenario—with the remaining 55 million acres of federal forest land there being unmanaged. If only a proportion of the 36.4 million acres were managed by a scenario other than “preservation,” as is presently done, the benefits or costs would be proportionately changed and the remaining land would be managed as “preservation, no activities” by default.

## LITERATURE CITED

- Adams, D. L. 1980. The northern Rocky Mountain region. *In*: J. W. Barrett, ed., *Regional Silviculture of the United States*, Second Edition. John Wiley and Sons, New York. pp. 341-389
- Agee, J. K. 1993. *Fire ecology of Pacific Northwest forests*. Island Press, Washington DC. 493 pp.
- Botkin, D. B. 1990. *Discordant harmonies: A new ecology for the twenty-first century*. Oxford Univ. Press, New York. 241 pp.
- Boyce, S. G. 1985. *Forestry decisions*. USDA Forest Service, Gen. Tech. Report SE-35, Southeastern Forest Exp. Sta., Asheville, NC.
- Boyce, S. G. and W. H. McNab. 1994. *Management of forested landscapes: Simulations of three alternatives*. *J. For.* 92: 27-32.

- Boyce, S. G. and W. H. McNab. 1994. Management of forested landscapes: simulations of three alternatives. *J. For.* 92: 27-32.
- Burk, D. A. 1970. *The clear-cut crisis: Controversy in the Bitterroot*. Jursnick Press, Great Falls, MT. 152 pp.
- Clinton, W. J. and A. Gore, Jr. 1993. *The climate change action plan*. U.S. Department of the Interior, Washington DC. 49 pp.
- Covington, W. W. and M. M. Moore. 1994. Southwestern ponderosa pine forest structure: Changes since Euro-American settlement. *J. For.* 92:39
- Daniel, T. W. 1980. The middle and southern Rocky Mountain region. *In: J. W. Barrett, ed., Regional Silviculture of the United States, Second Edition*. John Wiley and Sons, New York. pp. 377-340.
- Everett, R. L., P. Hessburg, M. Jensen, and B. Bormann. 1993. *Eastside forest ecosystem health assessment*. USDA Forest Service, National Forest System, Forest Service Research, Wenatchee WA. 5 Volumes.
- FEMAT. 1993. *Draft 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. (Volume and Appendix A)* USDA Forest Service, USDI Bureau of Land Management.
- Fry, M. and N. R. Money. 1994. Biodiversity conservation in the management of utility rights-of-way. *In: Proceedings of the 15th Annual Forest Vegetation Management Conference*, Redding CA. pp. 94-103.
- Johnson, C. G., R. R. Clausnitzer, P. J. Mehringer, and C. D. Oliver. 1993. Biotic and abiotic processes of eastside ecosystems: The effects of management on plant and community ecology, and on stand and landscape vegetation dynamics. *In: P. F. Hessburg, compiler, Eastside forest ecosystem health assessment—Volume III: Assessment*. Portland, Oregon. USDA Forest Service, PNW Research Station. pp. 35-100.
- Johnson, D. R. and J. K. Agee. 1987. Introduction to ecosystem management. *In: J. K. Agee and D. R. Johnson, eds., Ecosystem Management for Parks and Wilderness*. Univ. Washington Press, Seattle. pp. 3-14.
- Khrushchev, S. 1990. *Khrushchev on Khrushchev*. Little, Brown, and Company, New York. 423 pp.
- Koch, P. 1991. Wood vs. non-wood materials in U.S. residential construction: Some energy-related international implications. Univ. Washington, College of Forest Resources CINTRAFOR Working Paper 36. 38 pp.
- Larson, B. C. 1982. Development and growth of even-aged and multi-aged mixed stands of Douglas-fir and grand fir on the east slope of the Washington Cascades. Ph.D. dissertation, Univ. Washington, Seattle. 219 pp.
- Lee, R. G. 1994. *Broken land, broken trust*. Book Partners, Wilsonville OR. 210 pp.
- Lippke, B. and C. D. Oliver. 1993a. Aneconomic tradeoff system for ecosystem management. *In: M. A. Jensen and P. S. Bourgeron, eds. Eastside Forest Ecosystem Health Assessment, Volume II. Ecosystem Management: Principles and Applications*. USDA Forest Service. National Forest System, Forest Service Research. pp. 337-345.
- Lippke, B. and C. D. Oliver. 1993b. Managing for multiple values. *J. For.* 91:14-18.
- O'Laughlin, J. 1994. Assessing forest health conditions in Idaho with forest inventory data. *J. Sustain. For.* 2:221-247.
- O'Laughlin, J., J. G. MacCracken, D. L. Adams, S. C. Bunting, K. A. Blatner, and C. E. Keegan, III. 1993. *Forest health conditions in Idaho: Executive summary*. Idaho Forest, Wildlife and Range Policy Analysis Group. Report No. 11. 37 pp.
- Oliver, C. D. 1992a. Enhancing biodiversity and economic productivity through a systems approach to silviculture. *In: The Silviculture Conference*. Forestry Canada, Ottawa, Ontario. pp. 287-293.
- Oliver, C. D. 1992b. A landscape approach: Achieving biodiversity and economic productivity. *J. For.* 90:20-25.
- Oliver, C. D. 1994a. A portfolio approach to landscape management: An economically, ecologically, and socially sustainable approach to forestry. *In: Innovative Silvicultural Systems in Boreal Forests, Proceedings of a conference held on October 4-8, 1994, Mayfield Inn, Edmonton AL, Canada*. Canadian Forest Service, Edmonton, Alberta. In press.
- Oliver, C. D. 1994b. Ecosystem and landscape management: How do they affect timber supply? Paper presented at the Canadian Council of Forest Ministers Conference: "Timber Supply in Canada: Challenges and Choices." November 16-18, 1994. Kananaskis, Alberta, Canada. Proceedings to be published.
- Oliver, C. D. and B. C. Larson. 1990. *Forest Stand Dynamics*. McGraw-Hill, NY. 467 pp.
- Oliver, C. D., D. E. Ferguson, A. E. Harvey, H. S. Malany, J. M. Mandzak, and R. W. Mutch. 1994. Managing ecosystems for forest health: An approach and the effects of uses on values. *J. Sustain. For.* 2(1/2):113-133.
- Oliver, C. D., D. R. Berg, D. R. Larsen, and K. L. O'Hara. 1992. Integrating management tools, ecological knowledge, and silviculture. *In: R. Naiman, ed., New perspectives for watershed management*. Springer-Verlag, NY. p. 361-382.
- Perez-Garcia, J. M. 1993. Global forestry impacts of reducing softwood supplies from North America. CINTRAFOR Working Paper 43. Univ. Washington, College of Forest Resources Center for International Trade in Forest Products. 35 pp.

- Powell, D. S., J. L. Faulkner, D. R. Darr, Z. Zhu, and D. W. MacCleery. 1993. Forest resources of the United States, 1992. USDA Forest Service Gen. Tech. Rep. RM-234. 132 pp.
- Reich, R. B. 1983. The next American frontier. The New York Times Book Co., New York, NY. 324 pp.
- Salwasser, H., D. MacCleery, and T. Snellgrove. 1992. New perspectives for managing the U.S. national forest system. Report to the North American Forestry Commission, 16th Session, Cancun, Mexico. February, 1992.
- Sampson, R. N., D. L. Adams, S. Hamilton, S. P. Mealey, R. Steele, and D. Van De Graff. 1994. Assessing forest ecosystem health in the Inland West. *J. Sustain. For.* 2(1/2):3-10.
- Sessions, J., and J. B. Sessions. 1992. Scheduling and network analysis program (SNAPII) User's guide, Version 2.02. Corvallis, OR.
- Sprugel, D. G. 1991. Disturbance, equilibrium, and environmental variability: What is natural vegetation in and changing environment? *Biol. Conserv.* 58:1-18.
- Steen, H. K. 1976. The U.S. Forest Service: A history. Univ. Washington Press, Seattle. 356 pp.
- Stevens, W. K. 1990. New eye on nature: The real constant is eternal turmoil. *New York Times*, July 31, 1990, pp. B5-6.
- Walkinshaw, L. H. 1983. Kirtland's warbler. Cranbrook Institute of Science, Bloomfield Hills MI. 207 pp.

## Authors

Chadwick D. Oliver  
 Professor of Silviculture and Forest Ecology  
 College of Forest Resources  
 University of Washington  
 Seattle WA 98195

Bruce R. Lippke  
 Professor and Director  
 Center for International Trade of Forest Products  
 College of Forest Resources  
 University of Washington  
 Seattle, Washington 98195