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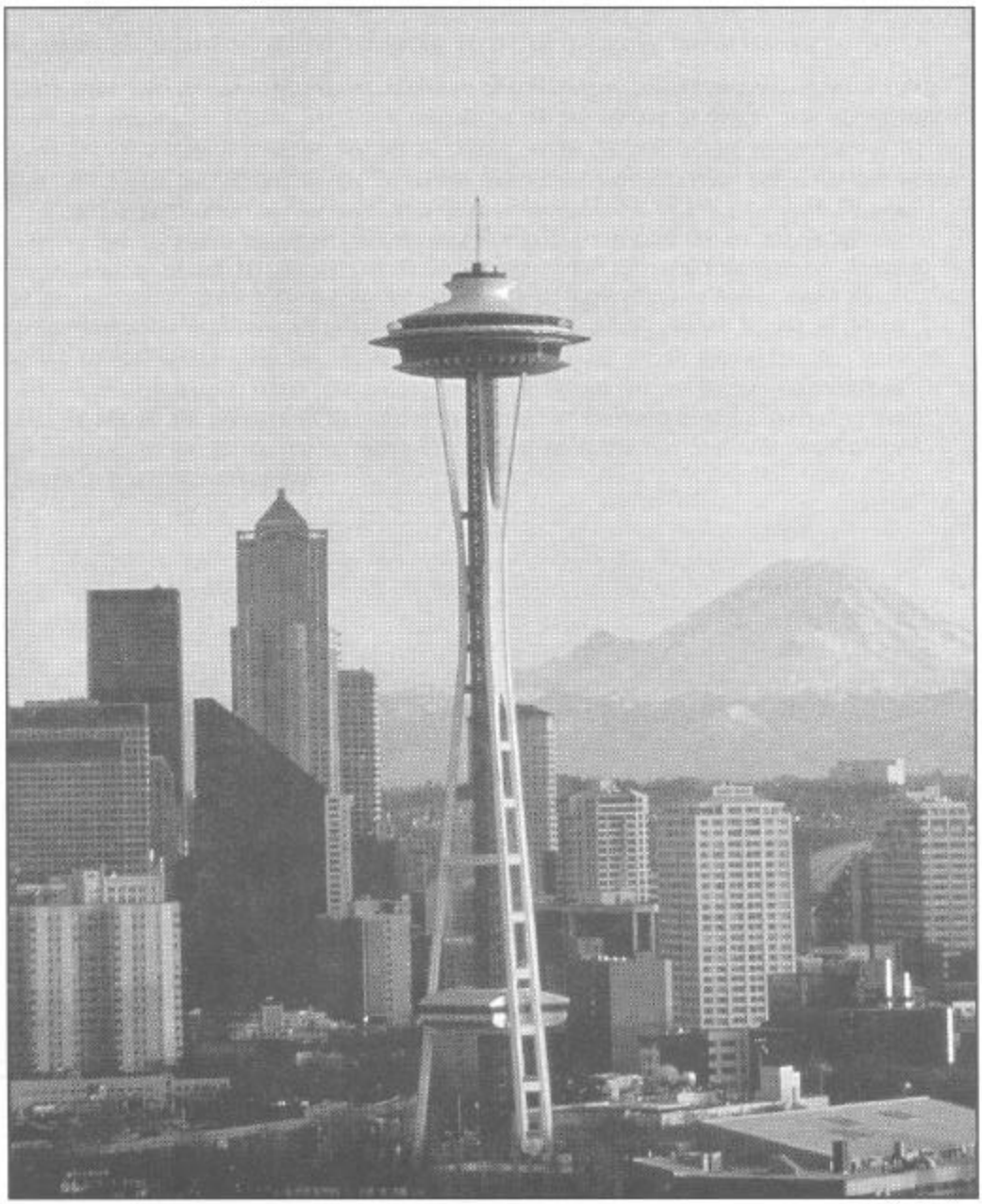
Urban Expansion in the Forests of the Puget Sound Region

Colin D. MacLean and Charles L. Bolsinger



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Abstract

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As part of a 1979 forest resource inventory, over 9,000 points on aerial photographs were sorted into three development zones-primary forest, suburban, and urban. These same points were reexamined in 1989, and zone changes were noted. This report summarizes urban expansion into the primary forest lands of the Puget Sound region (Island, King, Kitsap, Pierce, San Juan, Skagit, Snohomish, Thurston, and Whatcom Counties). In addition, forest statistics for non-industrial private timberlands within the suburban and urban zones are presented.

Keywords: Puget Sound, urban forests, land use planning, forest losses.

Summary

Data from two forest resource inventories of the Puget Sound region-one in 1979 and the second in 1989-provide information on the extent of urban and suburban growth in the region and the impact of urbanization on timberland resources within the urban and suburban zones. The area examined extends from the southern reach of Puget Sound north to Canada, and east to the summit of the Cascade Range. During the 10 years between inventories, the suburban and urban zones have increased by about 10 percent, at the expense of the primary forest zone. Notably, in many cases urban expansion did not progress from primary forest zone to suburban zone and then to urban, but went directly from primary forest to urban. Over 10,000 acres classified as timberlands within the urban and suburban zones were lost annually to urban development in the Puget Sound region--an annual loss of about 1.3 percent of the privately owned timberland in the urbanizing area. In terms of forest productivity, these lands ranked in the top one-fifth of all timber lands in the United States.

Contents

Introduction

Urban development occurs in several localities in western Washington, though it is most noticeable along the I-5 corridor from the Columbia River to British Columbia. The greatest concentration of urban development is in the Puget Sound region between Olympia and Bellingham. Expansion of this urban area into adjacent forest lands is affecting forest resources in the Puget Sound region in several ways:

- Some forest land is being converted to building sites, street networks, and other nonforest use.

- Wildlife habitat values are being changed. Although the habitat is improved for some species -notably birds of the open fields and gardens -the fragmentation of forest land has decreased habitat suitability for others such as cougar *(Fells concolor),* elk *(Cervus elaphus),* and the western gray squirrel (*Sciurus griseus).*

- The increased development increases runoff and adds pollutants to affected watersheds -particularly septic field drainage, herbicides, and pesticides. Thus, water quality declines, and fish habitat is degraded.

- The long-term future of forest land adjacent to urban development is uncertain and, therefore, has become less attractive to investors in long-term timber production but more attractive to developers.

- Urban owners may be more concerned with the amenity value of the forest than with its potential for commodity production.

How rapidly are the urban areas in the Puget Sound region expanding? What is the annual loss of timberland acres to urban use? What is the impact of urban expansion on the availability of timber for commercial use? Results from timber re-inventories done 10 years apart in western Washington may help to answer these questions. In a 1979 inventory (Oswald 1984), aerial photographs were used to classify non Federal lands in the Puget Sound region into three development zones: (1) primary forest, (2) low-density suburban and farming, and (3) urban-residential-industrial. Within each zone, a combination of photo and ground plots was used to estimate the area of timberland. In 1989, the entire area was revisited, and both photo and field plots were reexamined, with special emphasis on identifying change between inventories. The findings that relate to urban expansion in the Puget Sound area are presented in this report.

Methods

The study area extends from Olympia to the Canadian border, west of the Cascade Range and east of the Hood Canal and Puget Sound (fig. 1). It includes all lands in the Washington counties of Island, King, Kitsap, Pierce, San Juan, Skagit, Snohomish, Thurston, and Whatcom except National Forests and lands reserved from timber harvest (for example, national and state parks). Land within the study area was classified in 1979 (Bassett and Oswald 1981, 1982) and in 1989 (MacLean and others 1992) by the Pacific Resource, Inventory, Monitoring, and Evaluation Program (PRIME) of the Pacific Northwest Research Station, USDA Forest Service, as part of

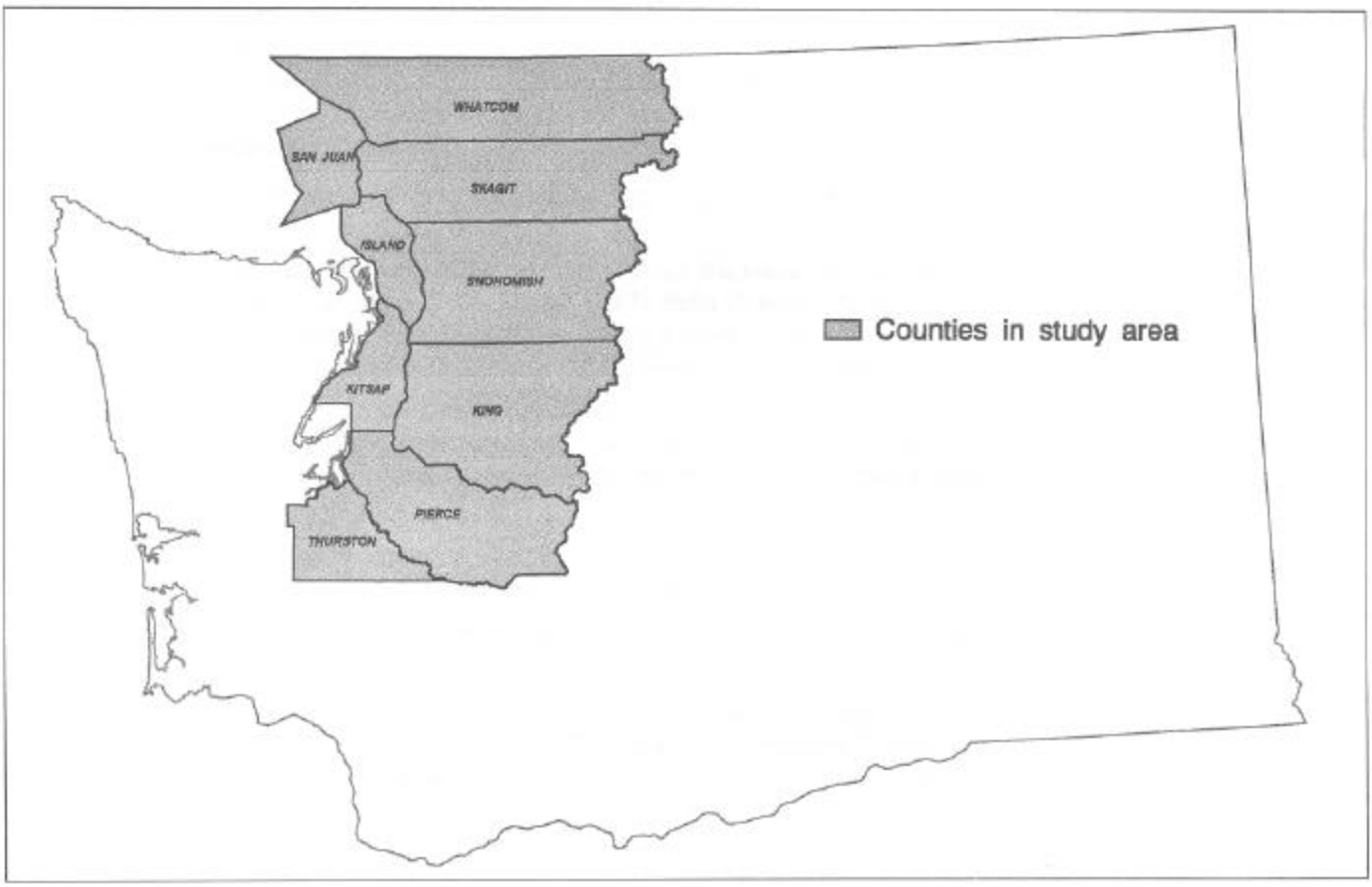

Figure 1—Counties in the Puget Sound study area.

a nationwide forest inventory program. The statistical design used in this study was double sampling for stratification (Cochran 1977). The primary sample was a systematic grid of 9,541 photo points subsampled by 601 field plots arranged on a 3.4-mile square grid. At each photo point, land ownership was determined from public records and classified as shown in tables 1 and 2. Land was classified by a photo-interpreter as timberland, other forest, or nonforest. Native American lands were classified as non-industrial private. Each photo point then was placed in a development zone. For timberland points, additional photo classifications were made to aid in estimating forest condition, timber volume, and wildlife habitat characteristics. All field plots were ground-checked for accuracy of land classification. For timberland plots, trees and other vegetation were tallied and measurements taken.

Table 1—Total land area in the Puget Sound region, 1979 and 1989, by ownership and development zone

	Primary forest zone		Suburban zone		Urban zone	
Ownership	1979	1989	1979	1989	1979	1989
	Thousand acres					
Private	1,681	1,497	1,409	1,518	498	581
Other public	1,483	1,472	128	131	61	66
National Forest	1,938	1,938	—	—	—	—
All ownerships	5,102	4,907	1,537	1,649	559	647

— = All National Forest land is assumed to be in the primary forest zone.

Table 2—Timberland area in private ownership in the Puget Sound region by ownership and development zone, 1989

Ownership	Primary forest zone	Suburban zone	Urban zone	All zones
	Thousand acres			
Forest industry	1,051	28	—	1,079
Nonindustrial private	286	627	65	978
All ownerships	1,337	655	65	2,057

— = less than 3,500 acres.

All photo points and field plots are permanent. Thus classifications made and measurements taken in 1979 were repeated for the same points, plots, and trees in 1989, thereby making accurate estimates of change possible. For this study, we were particularly interested in changes in forest zone and changes, within zone, in land class. Forest zone classification was introduced in the 1979 inventory and is described by Oswald (1984).

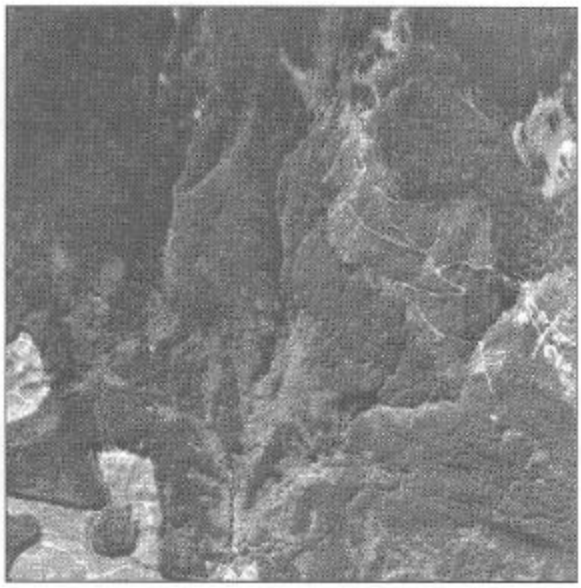

Figure 2—Primary forest zone.

Figure 3—Suburban and farming zone.

Primary forest (zone 1)-- Characterized by large continuous tracts of forested land greater than 640 acres and with little or no nonforest development (fig. 2).

Suburban (zone 2)-- Low-density suburban and farming zone (in this report referred to as the "suburban" zone) characterized by forest land intermingled with nonforest development, including both cultivated farmland, isolated houses, and small subdivisions. Roads in zone 2 are at least one-quarter mile apart (fig. 3).

Figure 4—Urban-residential-industrial zone.

Urban (zone 3)---The urban-residential-industrial zone (in this report referred to as the "urban" zone) includes all land within legal boundaries of cities or towns and all land within areas developed for residential and industrial use. Zone 3 land is characterized by buildings, industrial development, and roads less than one-quarter mile apart (fig. 4).

Zone classifications were based entirely on aerial-photography classification. No attempt was made to check photo classifications on the ground. In fact, our experience has been that the patterns reflected in zone classification are more visible on photos than on the ground. Photo classifications of zone are more reliable than ground classification. Forest land class, however, is more accurately identified on the ground than on aerial photographs. This is particularly true in urban areas where land that appears on the photo to be a timber stand may prove, after ground inspection, to be a developed park or recreation area hidden from the photo-interpreter by dense tree cover. The areas of timberland reported in this study are based on double sample estimates where photo classifications are adjusted by field observations to eliminate bias associated with errors in photo-interpretation. Estimates of area and their variance were calculated from equations 12.1 and 12.24 in Cochran (1977) for double sampling for stratification.

To verify that differences between photo and field classification made in 1979 and those made in 1989 reflected actual change, photo-interpreters in 1989 checked each photo classification against the 1979 classification. If the classifications differed, they compared current photographs with those used in 1979. If this comparison failed to reveal change, they either changed their classification or updated the 1979 classification to imply no change. Ground classifications were treated in the same manner.

Results

Lands in Private Ownership

As expected, the urban area is expanding. By assuming that all National Forest land and all reserved land was in the primary forest zone, we were able to determine how the total area of each of the three zones changed between inventories, as shown in table 1. Between 1979 and 1989, the area in the suburban zone increased by 7.3 percent and the area in the urban zone increased by 15.7 percent. On private land, where almost all the expansion has occurred, the suburban zone increased by 7.7 percent and the urban zone by 16.6 percent. In 1989, 9 percent of the study area was urban and 23 percent suburban.

Changes Within the Suburban Zone

Changes between 1979 and 1989 in the zone classification of private land for each county in the study area are shown in table 3. Increases in the area of the suburban development zone were concentrated in Snohomish County (20 percent) and Kitsap County (46 percent) (fig. 5). Nearly 47 percent of the private land in these two counties is now in the suburban zone, and an additional 21 percent is classified as urban. Increases in the suburban zone averaged 4 percent in Island, King, Pierce, San Juan, and Thurston Counties. Whatcom and Skagit Counties had negligible growth in the suburban zone. Figure 5 shows the percentage of growth change by county within the suburban zone in the Puget Sound region.

Table 3—Total land area in private ownership in the Puget Sound region, 1979 and 1989, by county and development zone

	Primary forest zone		Suburban zone		Urban zone	
County	1979	1989	1979	1989	1979	1989
			Thousand acres			
Island	5	—	98	100	11	14
King	411	367	213	220	162	200
Kitsap	82	45	71	104	51	54
Pierce	312	294	209	217	103	118
San Juan	34	31	66	69	—	—
Snohomish	251	195	203	244	86	102
Skagit	261	257	184	186	21	23
Thurston	189	171	148	159	40	46
Whatcom	137	136	217	218	23	23
All counties	1,681	1,497	1,409	1,518	498	581

— = less than 3,500 acres.

Changes Within the Urban Zone

It should be noted that expansion of the urban zone in King and Pierce Counties (the Seattle-Tacoma metropolitan area) is primarily at the expense of the primary forest zone. This demonstrates that urban expansion does not necessarily follow a succession whereby the primary forest zone first becomes suburban and then urban. Often, the urban area expansion is carved directly from the primary forest zone.

Increases in the urban zone range from no change in Whatcom County to almost 24 percent in King County (fig. 6). In King, Pierce, and Snohomish Counties, the privately owned lands within the urban zone increased an average of 18 percent between inventories. San Juan County had no urban area in either inventory, and the Whatcom County urban area remained stable.

Timberlands

In addition to analyzing the distribution of total land area by development zone, we examined the distribution of privately owned timberland among the three zones. These statistics are shown in table 2.

Change in Timberland

The change in the area of privately owned timberland in each development zone is shown in table 4. Timberland area is declining within both the suburban and urban zones. Within the combined area now classified as suburban or urban, timberland area declined by about 13 percent during the 10-year period between inventories. As might be expected, the conversion of timberland to nonforest use was greatest in the urban zone, amounting to 43 percent between inventories. At 8 percent, the loss of timberland in the suburban zone was less severe. Over half of the former timberland was cleared and subdivided for housing, and most of the rest was converted to horse farms, large gardens, and other uses associated with urban-suburban lifestyles. By contrast, 4 percent of private timberlands in the primary forest zone was converted, mostly to roads.

Non-industrial Private Timber Resource Characteristics

The characteristics of the timber resource in the urban and suburban zones of western Washington were described by Oswald (1984). The current condition of the resource on non-industrial private timberlands in the study area is presented in tables 5 through 9. Less than 4 percent of the timberland in the suburban and urban zones were owned by forest industry and were sampled too lightly to include in the analysis.

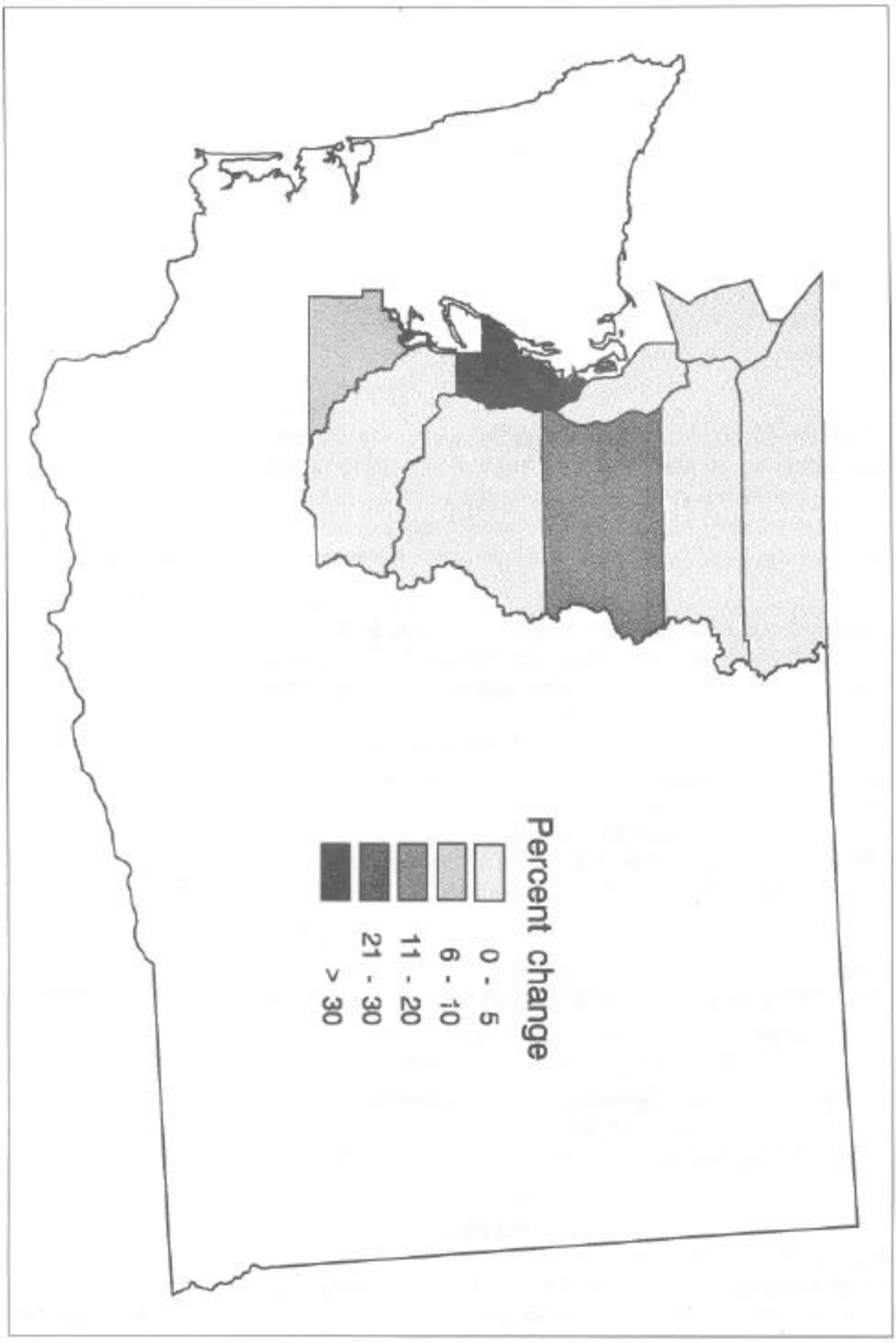

Figure 5—Percentage increase of the suburban zone, by county, 1979-89.

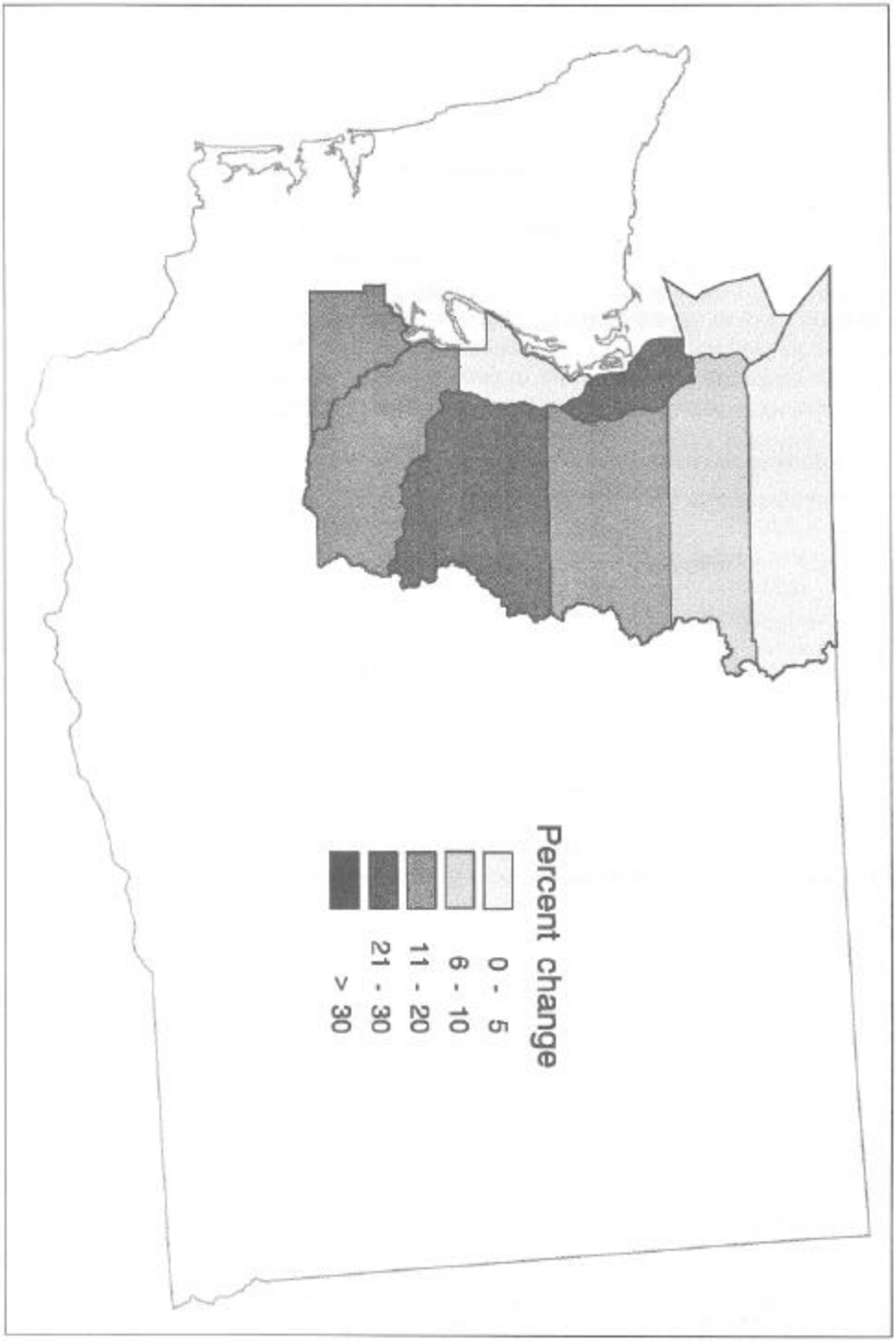

Figure 6—Percentage increase of the urban zone, by county, 1979-89.

Table 4—Change in timberland area in private ownership in the Puget Sound region, 1979 and 1989, by development zone

Year	Primary forest zone	Suburban zone	Urban zone	All zones
		Thousand acres		
1979	1,389	712	115	2,216
1989	1,337	655	65	2,057
Change (1979-89)	-52	-57	-50	-159

Table 5—Area of nonindustrial private timberland in the Puget Sound region by productivity class and development zone

Productivity class[a]	Primary forest zone	Suburban zone	Urban zone	All zones
Cubic feet		*Thousand acres*		
120+	227	473	46	746
20-119	59	154	19	232
All classes	286	627	65	978

[a] The mean annual growth per acre at culmination in fully stocked natural stands.

Productivity

The estimates of area by timber productivity shown in table 5 indicate that 75 percent of the timberland in the urban and suburban zones in the Puget Sound region is capable of producing 120 or more cubic feet of wood per acre per year (in fully stocked natural stands). By comparison, only 10 percent of the timberland in the entire United States is capable of producing this much wood per acre. In the Southern States, which collectively lead the Nation in annual output of forest products, only 17 percent of the timberland is capable of growing 120 cubic feet per acre per year (Powell and others 1993). The forests that are being usurped by urban expansion in the Puget Sound region are among the most productive in the United States.

Table 6—Area of nonindustrial private timberland in the Puget Sound region by forest type and development zone

Forest type	Primary forest zone	Suburban zone	Urban zone	All zones
		Thousand acres		
Softwoods:				
Douglas-fir	97	192	19	308
Pacific silver fir	7	—	—	7
Western hemlock	15	8	—	23
Western redcedar	19	19	—	38
Total softwoods	138	219	19	376
Hardwoods:				
Bigleaf maple	37	44	19	100
Black cottonwood	7	32	—	39
Oregon ash	—	12	—	12
Other hardwoods	4	12	—	16
Pacific madrone	—	12	—	12
Red alder	96	276	27	399
Western paper birch	—	12	—	12
Total hardwoods	144	400	46	590
Nonstocked areas	4	8	—	12
Total, all forest types	286	627	65	978

— = less than 3,500 acres.

Stand Condition

Softwood stands make up slightly less than half of the non-industrial private timberland in the primary forest zone, whereas hardwoods predominate in the suburban and urban areas (table 6). About 57 percent of the non-industrial private timberland in the primary zone is stocked with manageable stands of softwoods (table 7). In the suburban and urban zones, about 37 percent of the area is stocked with manageable stands of softwoods. Forty percent of the non-industrial timberland in the urban and suburban zones is stocked with hardwoods. About 14 percent of the timberland in the primary forest zone and about 22 percent of the timberland in the suburban and urban-zones are less than 20 percent stocked with softwoods, red alder, and cottonwood trees.

Table 7—Area of nonindustrial private timberland in the Puget Sound region by stand condition and development zone

Stand condition	Primary forest zone	Suburban zone	Urban zone	All zones
		Thousand acres		
Softwood stand stocked >20%	163	236	19	418
Hardwood-softwood stand stocked >20%	82	259	23	364
All stands <20% stocked with available trees	41	132	23	196
Total	286	627	65	978

Table 8—Area of nonindustrial private timberland in the Puget Sound region by stand size and development zone

Stand size	Primary forest zone	Suburban zone	Urban zone	All zones
		Thousand acres		
Sawtimber	186	431	50	667
Poletimber	26	104	11	141
Seedlings-saplings	71	84	4	159
Nonstocked areas	4	8	—	12
All stands	286	627	65	978

— = less than 3,500 acres.

Timberland Area

Sawtimber stands predominate in all three zones, accounting for about two-thirds of the timberland area (table 8). Seedling and sapling stands account for one-quarter of the timberland area in the primary forest zone. Within the suburban and urban zones, seedlings and saplings comprise 12 percent of the timberland. Oswald (1984) points out that seedling-sapling stands are established after timber harvest. In the suburban and urban zones, timber harvest often is followed by conversion to nonforest use, thus lowering the rate of establishment for new stands.

Table 9—Net volume of growing stock and sawtimber on nonindustrial private timberland in the Puget Sound region by development zone

Volume type	Primary forest zone	Suburban zone	Urban zone	All zones
	Million cubic feet			
Growing stock:				
Softwoods	711	1,291	145	2,147
Hardwoods	426	1,124	24	1,674
Total growing stock	1,137	2,415	269	3,821
	Million board feet, Scribner scale			
Sawtimber:				
Softwoods	2,675	4,859	563	8,097
Hardwoods	1,542	4,102	462	6,106
Total sawtimber	4,217	8,961	1,025	14,203

Volume

Softwood volume exceeds hardwood volume by a small margin in the urban and suburban zones and by a larger margin in the primary forest zone (table 9). Volume per acre averages about 15,000 board feet per acre in all three zones. A little more than half of that volume is softwood.

Discussion

Is the rate of conversion of timberland for urban use increasing in the Puget Sound region? Between 1945 and 1970, 257,000 acres of timberland were converted to urban use in the State of Washington (Bolsinger 1973). The annual loss in the entire state was 10,000 acres during that period. Between 1979 and 1989, the annual loss of timberland was even greater in the Puget Sound region alone.

Reliability of Data

National Forest area and the area of reserved land, such as national and state parks, were determined from maps. All other area and volume estimates reported here are based on sampling and are subject to sampling error. Land area by owner class by zone was determined from photo-interpretation of 9,541 photo plots. These observations are subject to sampling error and to possible errors in the subjective classifications by photo-interpreters. All timber statistics are based on field observations and are stratified by photo observations combined in a double-sample design (Cochran 1977).

Confidence intervals are quantitative expressions of the reliability of the land area, timberland area, and timber volume statistics. If, for instance, the timberland area by owner or zone is 1 million acres and the confidence interval is plus or minus 23,000 acres, there would be a two-in-three (68-percent) chance that the timberland area was between 977,000 acres and 1,023,000 acres. Confidence intervals vary with the size of the estimate and the variance of the item being estimated. If variance is assumed constant, confidence intervals can be approximated for estimates of various sizes. The confidence guides that follow are based on the assumption that an average relation exists between variance and the size of the estimates, and thus they provide only an approximation of the reliability of individual estimates.

The following tabulation approximates confidence bounds for table cells of various sizes in this report.

	Confidence interval				
		Timberland area			
Area	Land area	By owner or zone	By type or class	Growing-stock volume	Confidence interval
	– – – Thousand acres – – –			*– – Million cubic feet – –*	
3,500	±28	±35	±86	4,000	±290
3,000	±26	±33	±84	2,000	±208
2,500	±24	±31	±78	1,000	±149
2,000	±23	±29	±70	800	±134
1,500	±21	±26	±61	600	±117
1,000	±19	±23	±51	400	±96
800	±17	±21	±46	200	±69
600	±15	±19	±40	100	±49
400	±12	±16	±33	50	±31
200	±9	±13	±24	25	±18
100	±7	±10	±18	15	±13
50	±5	±8	±13	10	±9
25	±4	±6	±9	5	±5
15	±3	±5	±7		
10	±2	±4	±6		

Terminology

Forest industry lands-Lands owned by companies that grow timber for industrial use. Includes companies both with and without wood processing plants.

Forest land-Land at least 10-percent stocked by live trees or land formerly having such tree cover and not currently developed for nonforest use. The minimum area recognized is 1 acre.

Forest types-Stands with 50 percent or more of the stocking in live conifer trees are classed as softwood stands. Stands with more than 50 percent of the stocking in live hardwood trees are classed as hardwood stands. The specific forest type reflects the individual species of live softwood or hardwood tree with the greatest total stocking.

Growing-stock volume-Net volume in cubic feet of live sawtimber and poletimber growing-stock trees from 12-inch stump to a minimum 4-inch top (of central stem) outside the bark. Net volume equals gross volume less deduction for rot and missing bole sections.

Hardwoods-Nonconiferous trees, usually broad-leaved.

Industrial wood-All commercial roundwood products except fuelwood.

Land area-Area reported as land by the Bureau of the Census, U.S. Department of Commerce. Total land area includes dry land and land temporarily or partially covered by water such as marshes, swamps, and river flood plains; streams, sloughs, and canals less than one-eighth of a mile wide; and lakes, reservoirs, and ponds less than 40 acres in area.

Land class-A classification of land by major use. The minimum area for classification is 1 acre.

National Forest lands-Federal lands that have been designated by Executive Order or statute as National Forest or purchase units and other lands under the administration of the Forest Service, U.S. Department of Agriculture, including experimental areas and Bankhead-Jones Title III lands.

Native American lands-Tribal and allotted lands held in trust by the Federal Government. Native American lands are grouped with other privately owned lands as nonindustrial private lands.

Nonforest land-Land that has never supported forest or was formerly forested and is currently developed for nonforest uses. Included are lands used for agricultural crops, Christmas tree farms, improved pasture, residential areas, city parks, constructed roads, operating railroads and their right-of-way clearings, powerline and pipeline clearings, streams more than 30 feet wide, and 1- to 40-acre areas of water classified by the Bureau of the Census, U.S. Department of Commerce, as land. If intermingled in forest area, unimproved roads and other areas must be 1 acre or larger to qualify as nonforest land.

Non-industrial private lands-Privately owned lands not qualifying as forest industry lands. Includes Native American lands.

Nonstocked areas-Timberland less than 10 percent stocked with growing-stock trees. Recent clearcuts scheduled for planting are classed as nonstocked.

Other forest land-Forest land incapable of producing 20 cubic feet per acre per year of industrial wood because of adverse site conditions such as sterile soils, dry climate, poor drainage, high elevation, steepness, or rockiness.

Poletimber stands-Stands with a mean diameter (weighted by basal area) from 5.0 to 9.0 inches in d.b.h. but smaller than sawtimber size.

Sawtimber stands-Stands with a mean diameter (weighted by basal area) larger than 9.0 inches if softwood and larger than 11.0 inches if hardwood.

Sawtimber volume-Net volume of sawtimber trees measured in board feet. Net sawtimber volume equals gross volume less deduction for rot, sweep, crook, and other defects that affect use for lumber.

Scribner rule-The common board-foot log rule used locally in determining volume of sawtimber. Scribner volume is estimated in terms of 32-foot logs for conifers and 16-foot logs for hardwoods.

Seedling and sapling stands-Stands with a mean diameter (weighted by basal area) less than 5.0 inches.

Site class-A classification of the potential productivity of forest land in terms of mean annual increment.

Softwoods-Coniferous trees, usually evergreen, with needles or scale-like leaves.

Stand-size class-A classification of stands based on tree size. Stand-size classes are sawtimber, poletimber, and seedling and sapling stands.

Timberland-Forest land capable of producing 20 cubic feet or more per acre per year of industrial wood and not withdrawn from timber production.

Names of Trees

Common name	Scientific name
Softwoods:	
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
Pacific silver fir	*Abies amabilis* Dougl. ex Forbes
Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
Western redcedar	*Thuja plicata* Donn ex D. Don
Hardwoods:	
Bigleaf maple	*Acer macrophyllum* Pursh
Black cottonwood	*Populus trichocarpa* Torr. & Gray
Oregon ash	*Fraxinus latifolia* Benth.
Pacific madrone	*Arbutus menziesii* Pursh
Red alder	*Alnus rubra* Bong.
Western paper birch	*Betula papyrifera* var. *commutata* (Regel) Fern.

Metric Equivalents

1,000 acres = 404.7 hectares
1,000 cubic feet = 28.3 cubic meters
1 cubic foot per acre = 0.07 cubic meter
1 foot = 0.3048 meter
1 inch = 2.54 centimeters
1 mile = 1.609 kilometers

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