Marine West Coast Forests Ecoregions

Status and Trends of Land Change in the Western United States—1973 to 2000
Edited by Benjamin M. Sleeter, Tamara S. Wilson, and William Acevedo
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Chapter 1
Coast Range Ecoregion

By Terry L. Sohl

Ecoregion Description

The Coast Range Ecoregion, which covers approximately 57,338 km^2 (22,138 mi^2), is a thin, linear ecoregion along the Pacific Coast, stretching roughly 1,300 km from the Olympic Peninsula, in northwest Washington, to an area south of San Francisco, California (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). It is bounded on the east by the Puget Lowland, the Willamette Valley, the Klamath Mountains, and the Southern and Central California Chaparral and Oak Woodlands Ecoregions.

Almost the entire Coast Range Ecoregion lies within 100 km of the coast. Topography is highly variable, with coastal mountain ranges and valleys ranging from sea level to over 1,000 m in elevation (fig. 2). A maritime climate, along with high topographic relief, results in substantial, but regionally variable, amounts of rainfall, ranging from 130 cm to more than 350 cm per year. The favorable climate of the Coast Range Ecoregion has supported forests of Sitka spruce (*Picea sitchensis*) along its northern coast and coast redwoods (*Sequoia sempervirens*) along its southern coast, as well as Douglas-fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), and western hemlock (*Tsuga heterophylla*) inland (Omernik, 1987). Today, however, much of the forest is heavily managed for logging (fig. 3), although the ecoregion still

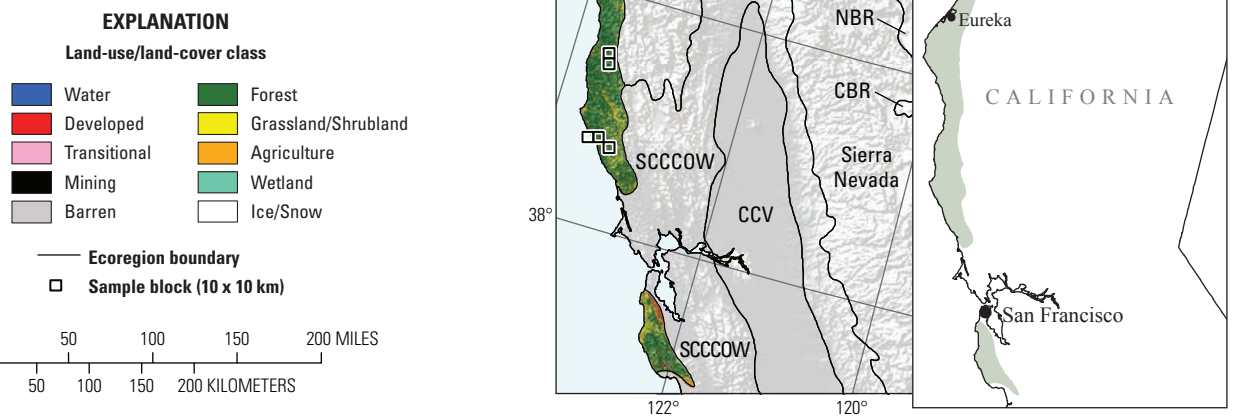

Figure 1. Map of Coast Range Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Western United States ecoregions are listed in appendix 2. See appendix 3 for definitions of land-use/land-cover classifications.

Figure 2. Pacific Coast and forested coastal mountains of Coast Range Ecoregion.

Figure 3. Clearcut area and subsequent regrowth of planted trees in Coast Range Ecoregion.

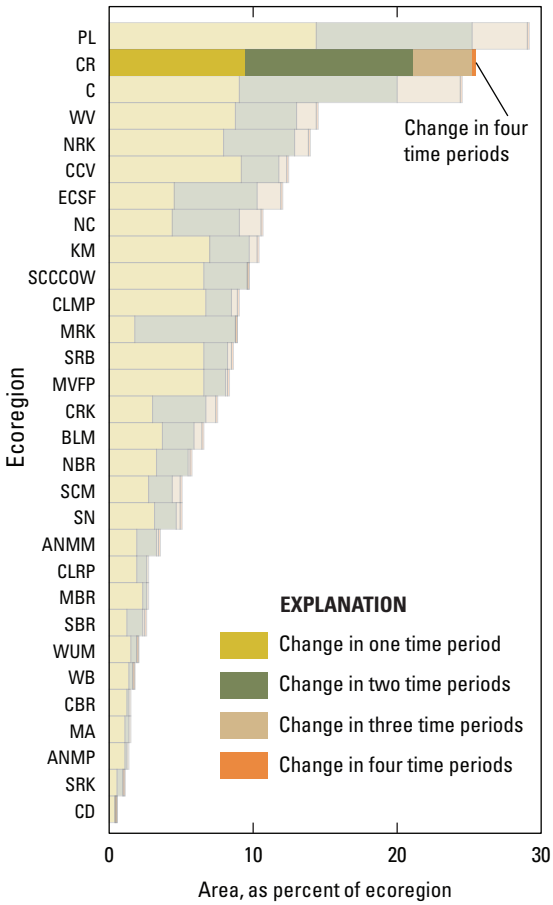

Figure 4. Overall spatial change in Coast Range Ecoregion (CR; darker bars) compared with that of all 30 Western United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during time periods 1, 2, 3, or 4; highest level of spatial change in Coast Range Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

supports some of the largest remaining areas of old-growth forest in the Pacific Northwest. Agriculture is a minor component of the landscape, present locally in flat lands and valleys near the coast. Urban development is minimal; Eureka, California, is the only urban center in the ecoregion, with a population of over 26,000 (U.S. Census Bureau, 2000).

Contemporary Land-Cover Change (1973 to 2000)

The footprint of change (the percentage of area that changed at least one time between 1973 and 2000) in the ecoregion was 25.5 percent (table 1), indicating that the Coast Range Ecoregion had one of the highest levels of change in the western United States (fig. 4). When normalized to account for varying lengths of study periods, annual rates of change increased through the first three time periods, peaking between 1986 and 1992, and then they declined slightly in the last period, between 1992 and 2000 (table 2; fig. 5).

A statistically significant negative trend was determined for forest land, which had a decline of 5.0 percent between 1973 and 2000 (table 3). Balancing the decline in forest land were corresponding statistically significant positive trends in the mechanically disturbed (51.3 percent) and grassland/shrubland (36.9 percent) classes. However, these gains were not constant over the four time periods. Both mechanically disturbed and grassland/shrubland experienced two periods of net gain and two periods of net loss (fig. 6).

In the Coast Range Ecoregion, the vast majority of mechanically disturbed land and grassland/shrubland were associated with the logging and subsequent replanting and regrowth of forest (fig. 7). Clearcut forest patches are initially mapped as mechanically disturbed. Depending upon local site conditions and the length of time between initial cutting and the next mapped time period, these mechanically disturbed patches typically are mapped either as an intermediate grassland/shrubland class in subsequent time periods or as forest once regrowth has

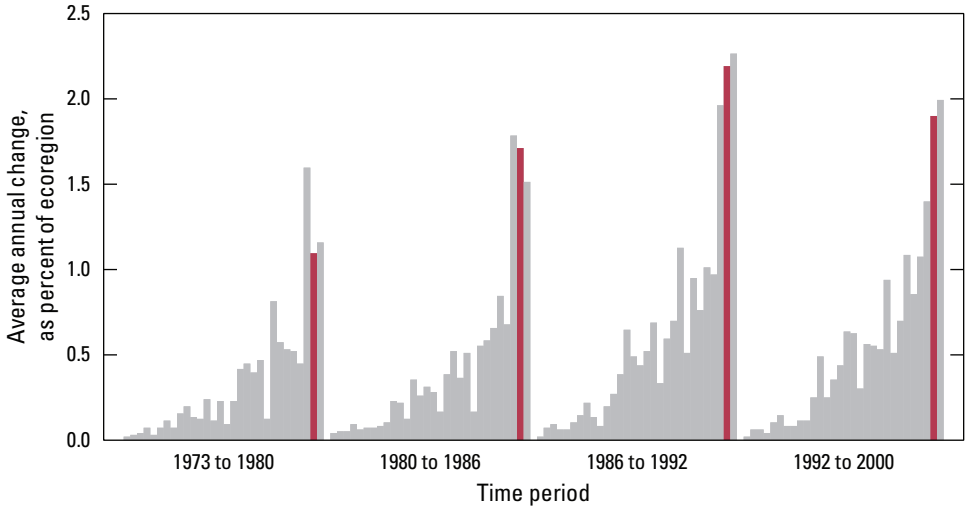

Figure 5. Estimates of land-cover change per time period, normalized to annual rates of change for all 30 Western United States ecoregions (gray bars). Estimates of change for Coast Range Ecoregion are represented by red bars in each time period.

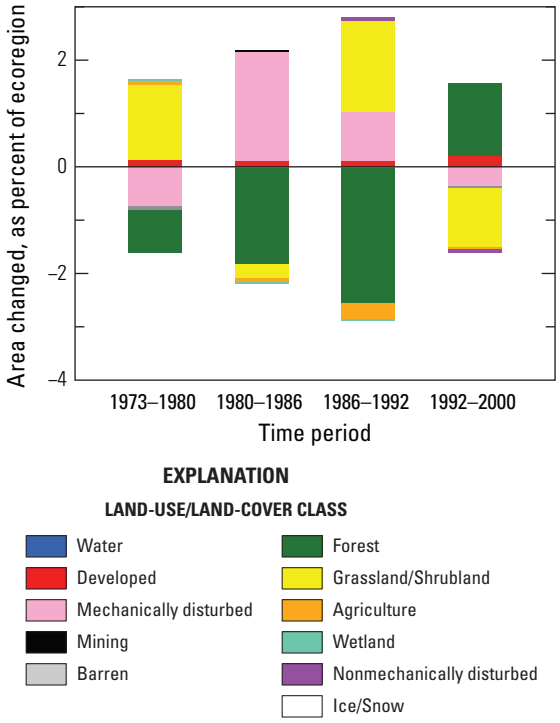

Figure 6. Normalized average net change in Coast Range Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use/land-cover classifications.

Figure 7. Clearcut (mechanically disturbed) forest in Coast Range Ecoregion and subsequent regrowth.

Figure 8. Lumberyard in Coast Range Ecoregion.

advanced sufficiently. Overall, while per-period trends in forest, mechanically disturbed, and grassland/shrubland land-cover classes fluctuated throughout the study period, total forest use (defined as the sum of forest land, mechanically disturbed land, and grassland/shrubland) remained remarkably constant (table 4).

The timber industry's effect on the landscape dominated the story of change in the ecoregion (fig. 8). For every time period, forest cutting (forest to mechanically disturbed) was the most common type of land-cover change, whereas each of the next three most common changes were related to forest regeneration (mechanically disturbed to grassland/shrubland, mechanically disturbed to forest, or grassland/shrubland to forest) (table 5). For the whole ecoregion, over 95 percent of change was associated with the timber-cutting cycle, with nearly 11,000 km^2 of cutting occurring between 1973 and 2000. Large swaths of forest land in the Coast Range Ecoregion were cut between 1973 and 2000, and they now are in a forest-regeneration stage because of the coalescence of individual patches of cut forest (fig. 9).

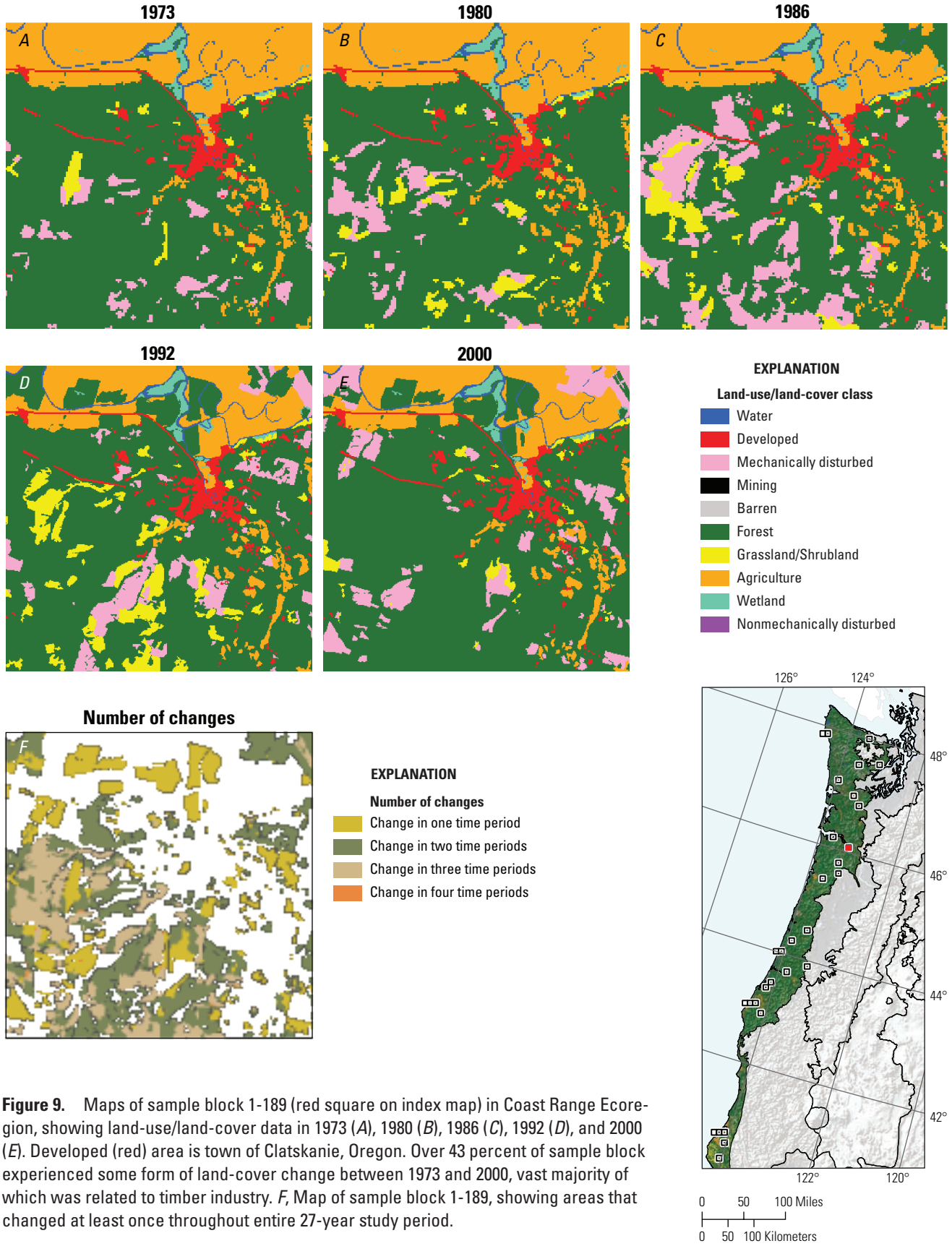

Figure 9. Maps of sample block 1-189 (red square on index map) in Coast Range Ecoregion, showing land-use/land-cover data in 1973 (*A*), 1980 (*B*), 1986 (*C*), 1992 (*D*), and 2000 (*E*). Developed (red) area is town of Clatskanie, Oregon. Over 43 percent of sample block experienced some form of land-cover change between 1973 and 2000, vast majority of which was related to timber industry. *F*, Map of sample block 1-189, showing areas that changed at least once throughout entire 27-year study period.

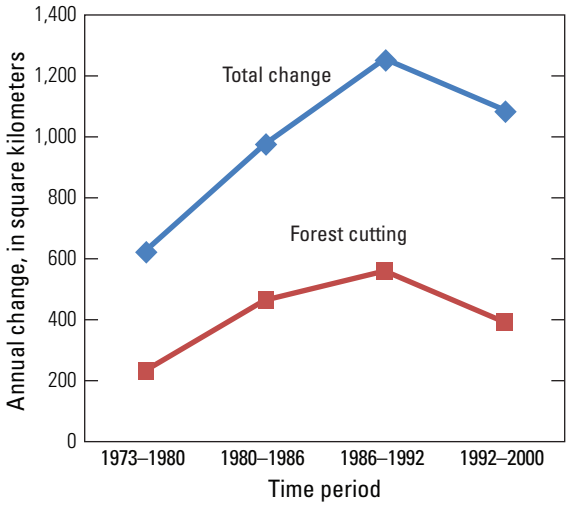

Figure 10. Annual land-cover change related to forest cutting in Coast Range Ecoregion, compared to that of total land-use/land-cover changes, for each of four time periods. Both change related to forest cutting and total change peaked between 1986 and 1992 and then declined between 1992 and 2000.

From the 1940s through the 1980s, forestry activity in the area generally focused on the cutting of natural forests and the establishment of Douglas-fir plantations on these lands (Swanson and Franklin, 1992). The annual rate of forest cutting steadily rose during the first three time periods, peaking between 1986 and 1992, and then declined between 1992 and 2000 (fig. 10). Although multiple drivers are responsible for the declines in forest cutting after 1992, the status and protection of the Northern Spotted Owl (*Strix occidentalis caurina*) likely had the biggest influence. In 1990, the Northern Spotted Owl was listed as "threatened" under the Endangered Species Act. In February 1991, an interagency scientific committee published a report addressing conservation of the Northern Spotted Owl (Thomas and others, 1990), leading U.S. District Court Judge Dwyer to block timber sales in national forest lands in the area to protect the species. In December 1994, Judge Dwyer accepted the Northwest Forest Plan, a comprehensive document directing coordinated management activities for lands administered by the U.S. Forest Service and the Bureau of Land Management. The plan permitted the cutting of 1 billion board feet of timber from public lands per year, only one-fourth the timber-harvest levels of the 1980s (Espy and Babbitt, 1994).

Another contributing factor responsible for the 1990s decline in forest cutting was the very high rate of logging in the 1980s, which may have been unsustainable over the long term given the 40- to 60-year cutting cycle that is typical for Douglas-fir in the ecoregion. In addition, Pacific Northwest forestry as a whole has been increasingly outcompeted by forestry operations in the southeastern United States and the interior of Canada, and the ecoregion has been at a competitive disadvantage for providing wood products to markets in the eastern and southern United States. Siberian larch (*Larix sibirica*) and Norway spruce (*Picea abies*) from Russian plantations, as well as Monterey pine (*Pinus radiata*) from more recently established plantations in New Zealand and Chile, also strongly increased their presence in the softwood lumber market in the 1990s (Gataulina and Waggener, 1998; Center for International Trade in Forest Products, 1993). At the same time, once-strong Pacific Northwest exports of wood products to large Asian markets (primarily Japan, South Korea, and China) declined throughout the 1990s (fig. 11). Changes in the Japanese housing industry, along

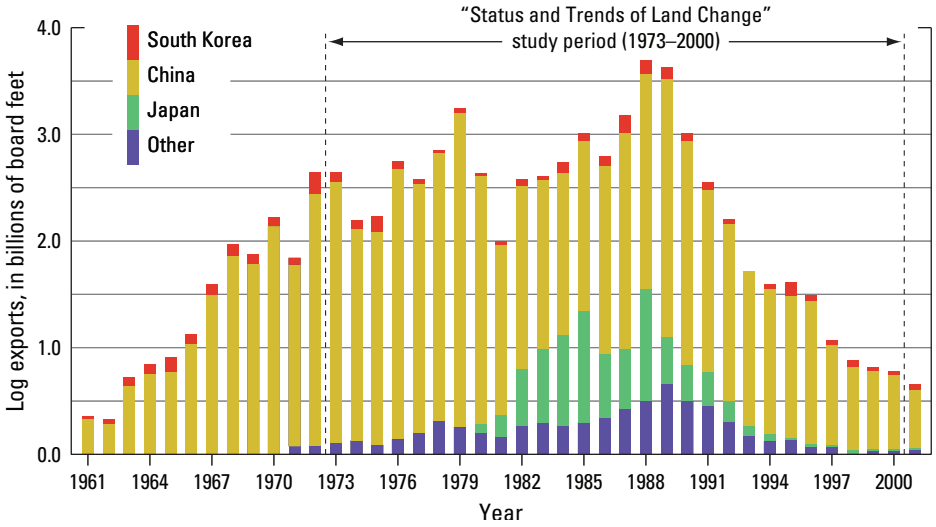

Figure 11. Exports of Pacific Northwest logs between 1961 and 2001 (from Daniels, 2005). Note how exports to all areas fell dramatically during 1990s.

with the Asian economic collapse of the 1990s, were major factors in declining exports (Daniels, 2005).

Land-cover changes in the ecoregion, other than those related to logging, were relatively minor. A statistically significant trend occurred in developed lands, which increased from 2.5 to 3.1 percent of the ecoregion between 1973 and 2000 (table 3). Most of the observed development was associated with the largest cities in the ecoregion: Eureka, California (population over 26,128 in 2000); Aberdeen, Washington (population, 16,461 in 2000); and Coos Bay, Oregon (population, 15,374) (U.S. Census, 2000). In addition, scattered high-value developments were found in areas with recreational amenities.

Table 1. Percentage of Coast Range Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (74.5 percent), whereas 25.5 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	9.5	1.5	7.9	11.0	1.0	10.9
2	11.6	1.9	9.7	13.5	1.3	11.1
3	4.2	1.1	3.1	5.4	0.8	18.2
4	0.2	0.1	0.1	0.3	0.1	27.5
Overall spatial change	25.5	3.9	21.7	29.4	2.6	10.3

Table 2. Raw estimates of change in Coast Range Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each time period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	7.6	1.2	6.4	8.8	0.8	10.6	1.1
1980–1986	10.3	2.0	8.2	12.3	1.4	13.4	1.7
1986–1992	13.1	2.3	10.9	15.4	1.5	11.8	2.2
1992–2000	15.2	2.9	12.3	18.1	2.0	13.0	1.9
Estimate of change, in square kilometers							
1973–1980	4,380	688	3,692	5,068	465	10.6	626
1980–1986	5,880	1,168	4,712	7,047	789	13.4	980
1986–1992	7,535	1,312	6,223	8,848	887	11.8	1,256
1992–2000	8,700	1,668	7,032	10,369	1,128	13.0	1,088

Table 3. Estimated area (and margin of error) of each land-cover class in Coast Range Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	5.1	3.0	2.5	1.3	3.7	0.9	0.0	0.0	1.2	0.6	76.2	4.1	4.6	1.4	5.7	2.1	1.0	0.7	0.0	0.0
1980	5.1	3.0	2.6	1.3	3.0	0.5	0.0	0.0	1.1	0.6	75.4	4.2	6.0	1.0	5.7	2.1	1.0	0.7	0.0	0.0
1986	5.1	3.0	2.8	1.4	5.0	1.2	0.0	0.0	1.1	0.6	73.5	4.1	5.7	1.1	5.7	2.1	1.0	0.7	0.0	0.0
1992	5.1	3.0	2.9	1.4	6.0	1.2	0.0	0.0	1.1	0.6	71.0	3.9	7.4	1.2	5.4	2.0	1.0	0.7	0.1	0.1
2000	5.1	3.0	3.1	1.5	5.6	1.4	0.0	0.0	1.0	0.5	72.4	4.0	6.3	1.2	5.4	2.0	1.0	0.7	0.0	0.0
Net change	0.0	0.0	0.6	0.3	1.9	1.5	0.0	0.0	−0.2	0.1	−3.8	1.9	1.8	1.0	−0.3	0.4	0.0	0.0	0.0	0.0
Gross change	0.1	0.0	0.6	0.3	10.4	2.1	0.0	0.0	0.2	0.1	12.9	2.1	8.2	2.1	0.8	0.5	0.0	0.0	0.1	0.2
Area, in square kilometers																				
1973	2,941	1,696	1,438	744	2,142	493	18	17	673	364	43,676	2,349	2,627	782	3,245	1,215	562	406	0	0
1980	2,937	1,695	1,516	770	1,723	314	21	17	641	348	43,208	2,382	3,422	595	3,288	1,211	565	407	0	0
1986	2,941	1,699	1,579	789	2,890	698	23	19	633	335	42,165	2,368	3,284	610	3,247	1,181	558	406	0	0
1992	2,940	1,699	1,647	823	3,423	688	25	19	614	329	40,720	2,226	4,270	672	3,087	1,136	557	406	39	56
2000	2,947	1,707	1,772	845	3,227	794	25	20	584	307	41,504	2,270	3,636	680	3,073	1,139	553	398	0	0
Net change	7	15	334	162	1,085	850	7	6	−89	79	-2,172	1,074	1,009	594	−172	246	-9	10	0	0
Gross change	38	23	335	162	5,977	1,203	8	6	120	79	7,397	1,177	4,719	1,194	445	287	20	13	77	111

Table 4. Percentages of forest use, defined as sum of forest, mechanically disturbed, and grassland/shrubland land-cover classes, in Coast Range Ecoregion, showing that forest use remained remarkably constant over study period.

Year	Forest use (% of ecoregion)
1973	84.5
1980	84.3
1986	84.3
1992	84.4
2000	84.4

Table 5. Principal land-cover conversions in Coast Range Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for "other" class are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km^2)	Margin of error (+/– km^2)	Standard error (km^2)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mechanically disturbed	1,638	282	191	2.9	37.4
	Mechanically disturbed	Grassland/Shrubland	1,195	309	209	2.1	27.3
	Mechanically disturbed	Forest	863	288	195	1.5	19.7
	Grassland/Shrubland	Forest	451	228	154	0.8	10.3
	Forest	Agriculture	60	63	42	0.1	1.4
	Other	Other	174	n/a	n/a	0.3	4.0
		Totals	4,380			7.6	100.0
1980–1986	Forest	Mechanically disturbed	2,796	686	464	4.9	47.6
	Grassland/Shrubland	Forest	1,094	304	206	1.9	18.6
	Mechanically disturbed	Grassland/Shrubland	920	215	146	1.6	15.6
	Mechanically disturbed	Forest	734	177	120	1.3	12.5
	Agriculture	Forest	61	59	40	0.1	1.0
	Other	Other	274	n/a	n/a	0.5	4.7
		Totals	5,880			10.3	100.0
1986–1992	Forest	Mechanically disturbed	3,362	675	456	5.9	44.6
	Mechanically disturbed	Grassland/Shrubland	1,801	543	367	3.1	23.9
	Mechanically disturbed	Forest	1,049	344	232	1.8	13.9
	Grassland/Shrubland	Forest	911	203	137	1.6	12.1
	Agriculture	Forest	124	142	96	0.2	1.6
	Other	Other	288	n/a	n/a	0.5	3.8
		Totals	7,535			13.1	100.0
1992–2000	Forest	Mechanically disturbed	3,147	780	527	5.5	36.2
	Mechanically disturbed	Forest	2,173	557	376	3.8	25.0
	Grassland/Shrubland	Forest	1,847	560	378	3.2	21.2
	Mechanically disturbed	Grassland/Shrubland	1,178	327	221	2.1	13.5
	Forest	Developed	92	45	31	0.2	1.1
	Other	Other	263	n/a	n/a	0.5	3.0
		Totals	8,700			15.2	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	10,943	1,973	1,334	19.1	41.3
	Mechanically disturbed	Grassland/Shrubland	5,093	1,116	755	8.9	19.2
	Mechanically disturbed	Forest	4,820	975	659	8.4	18.2
	Grassland/Shrubland	Forest	4,303	926	626	7.5	16.2
	Forest	Developed	236	117	79	0.4	0.9
	Other	Other	1,100	n/a	n/a	1.9	4.2
		Totals	26,495			46.2	100.0

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Chapter 2
Puget Lowland Ecoregion

By Daniel G. Sorenson

Ecoregion Description

The Puget Lowland Ecoregion covers an area of approximately 18,009 km² (6,953 mi²) within northwestern Washington (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). The ecoregion is located between the Coast Range Ecoregion to the west, which includes the Olympic Mountains, and the North Cascades and the Cascades Ecoregions to the east, which include the Cascade Range. From the north, the ecoregion follows the Interstate 5 corridor, from the Canadian border south through Bellingham, Seattle, Olympia, and Longview, Washington, to the northern border of the Willamette Valley Ecoregion. The Puget Lowland Ecoregion borders the shoreline of the greater Puget Sound, a complex bay and saltwater estuary fed by spring freshwater runoff from the Olympic Mountains and Cascade Range watersheds. The ecoregion is situated in a continental glacial trough that has many islands, peninsulas, and bays. Relief is moderate, with elevations ranging from sea level to 460 m but averaging approximately 150 m (DellaSala and others, 2001).

Proximity to the Pacific Ocean gives the Puget Lowland Ecoregion its mild maritime climate (U.S. Environmental Protection Agency, 1999). Mean annual temperature is 10.5°C, with an average of 4.1°C in January and 17.7°C in July (Guttman and Quayle, 1996). Average annual precipitation ranges from 800 to 900 mm, but some areas in the rain shadow of the Olympic Mountains receive as little as 460 mm (DellaSala and

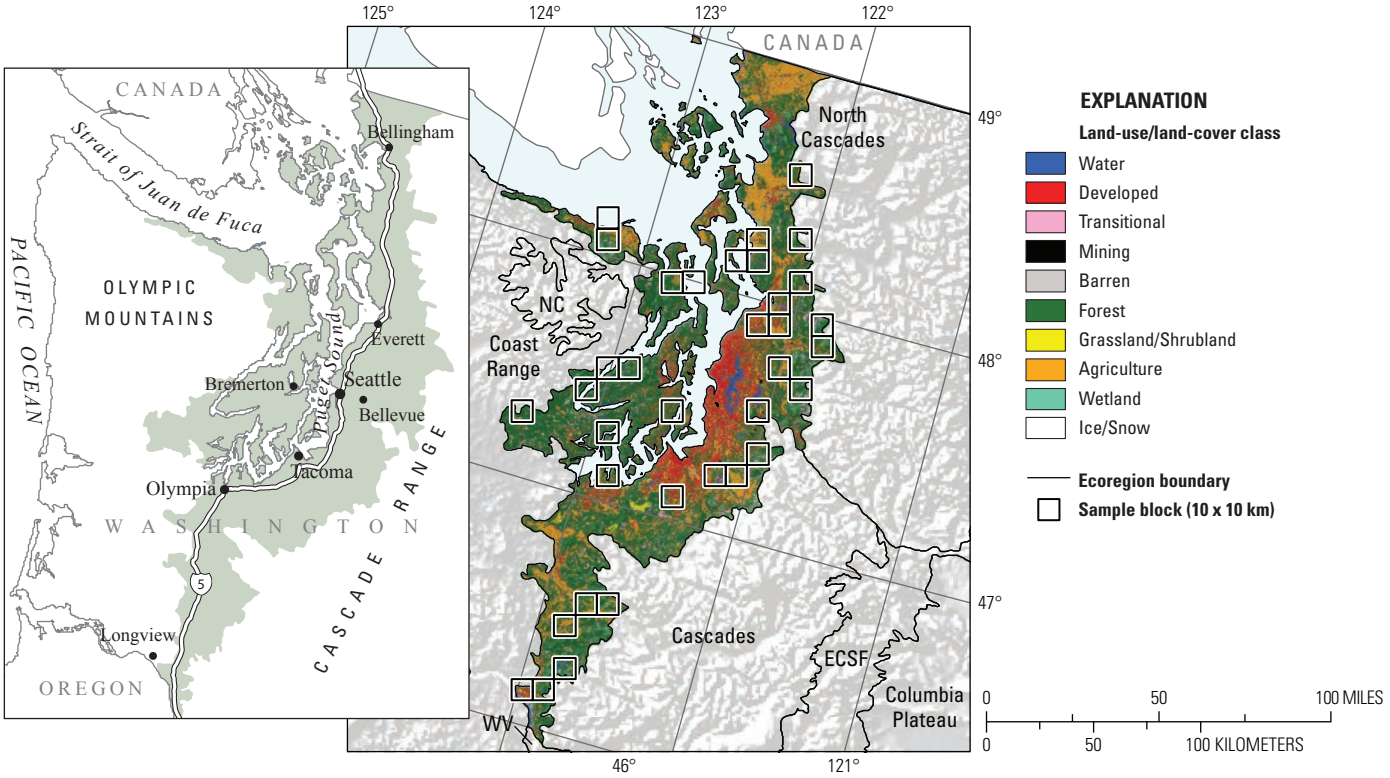

Figure 1. Map of Puget Lowland Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Western United States ecoregions are listed in appendix 2. See appendix 3 for definitions of land-use/land-cover classifications.

others, 2001). Varying annual average precipitation greatly influences vegetation and soil type in the ecoregion. In the Puget Lowland Ecoregion, soils are dominated by Inceptisols in the north and Ultisols in the south (Jones, 2003). Before European settlement, most of the ecoregion was covered by coniferous forests, with species composition dependent on local climate (U.S. Environmental Protection Agency, 1999). The World Wildlife Fund places the Puget Lowland Ecoregion in the Western Hemlock Vegetation Zone. Although this vegetation zone is named after the western hemlock (*Tsuga heterophylla*), Douglas-fir (*Pseudotsuga menziesii*) is the dominant tree species.

Seattle, which had an estimated population of 563,376 in 2000, is the largest city in the Puget Lowland Ecoregion (Puget Sound Regional Council, 2001). The greater Seattle metropolitan area, comprising Seattle, Tacoma, Bellevue, and Bremerton, had an estimated population of 3.5 million people in 2000 (U.S. Census Bureau, 2000). Other sizable cities in the ecoregion include the state capital Olympia, as well as Tacoma, Bellingham, and Everett, Washington. The center of the Puget Lowland Ecoregion is dominated by the Seattle metropolitan area and developed land cover, whereas agriculture occurs mainly on river floodplains in the north and south. The remainder of the ecoregion area is dominated by forest land cover (fig. 1).

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change in the Puget Lowland Ecoregion (that is, the percentage of the land cover that changed at least once between 1973 and 2000) was estimated at 28.0 percent (5,041 km²) (table 1). When compared with other ecoregions in the western United States, the Puget Lowland Ecoregion had the highest percentage of change in the last two of the four time periods analyzed (fig. 2). Between 1992 and 2000 alone, 16.0 percent of the ecoregion changed from one land-cover class to another (table 2). However, when the change estimates are normalized to an annual average to account for varying lengths of study periods, the normalized annual average rate of change was highest in the third time period between 1986 and 1992, at 2.3 percent (table 2). Compared to other western ecoregions, Puget Lowland Ecoregion experienced the most overall change of any ecoregion in the West (fig. 3).

Land-cover estimates in 2000 for the Puget Lowland Ecoregion show forest as the most common land-cover class (47.1 percent), followed by developed (18.8 percent), water (12.9 percent), and agriculture (10.4 percent). All other land-cover classes were estimated at less than 5 percent of the ecoregion's land cover (table 3). Land-cover classes with the highest estimates of change were the forest, developed, mechanically disturbed, and grassland/shrubland. Between 1973 and 2000, the largest net change in land cover occurred in the forest class, with an estimated loss of 17.2 percent (1,767 km²). The second largest absolute net change in the ecoregion was the 53.8 percent (1,186 km²) increase in developed lands. Mechanical disturbance played a large role in land-cover change in the Puget Lowland Ecoregion. This transitional land-cover class, attributed primarily to forest cutting in this ecoregion, affected an estimated 3,591 km², with the highest estimates recorded between 1986 and 1992 (6 percent of ecoregion area; 1,084 km²). Agriculture decreased by 5.4 percent (107 km²), with all losses occurring in the last two time periods. Grassland/shrubland more than doubled, increasing by 327 km² during the study period, but still accounted for only 3.1 percent of the ecoregion in 2000. All other classes increased or decreased less than 50 km² (table 3; fig. 4).

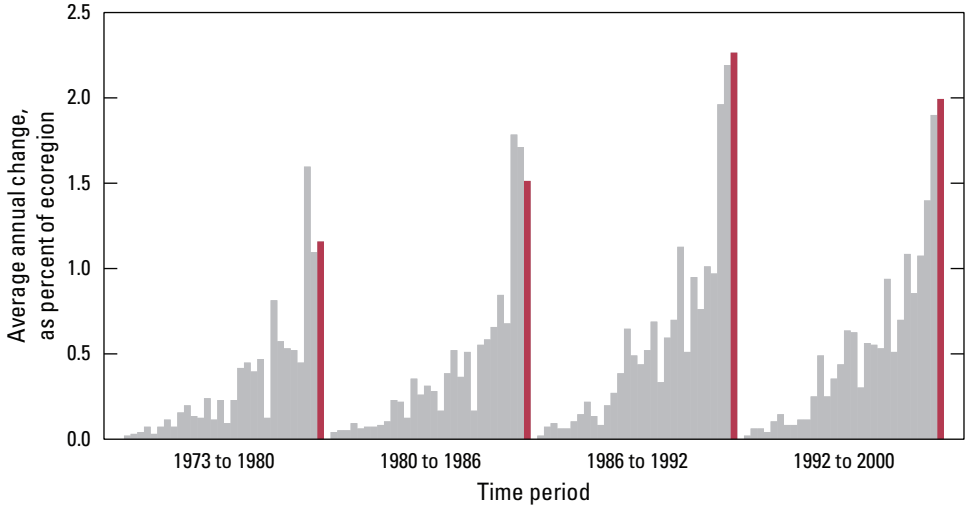

Figure 2. Estimates of land-cover change per time period, normalized to annual rates of change for all 30 Western United States ecoregions (gray bars). Estimates of change for Puget Lowland Ecoregion are represented by red bars in each time period.

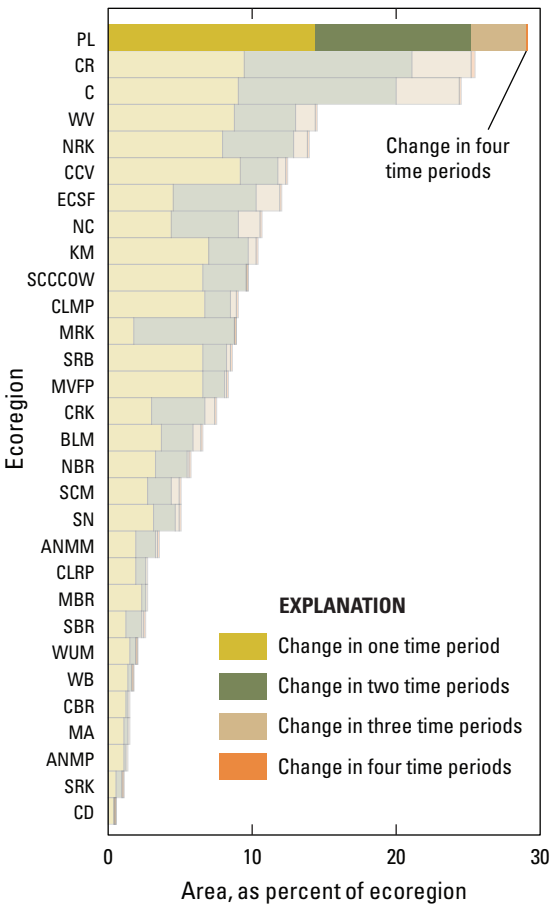

Figure 3. Overall spatial change in Puget Lowland Ecoregion (PL; darker bars) compared with that of all 30 Western United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Puget Lowland Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

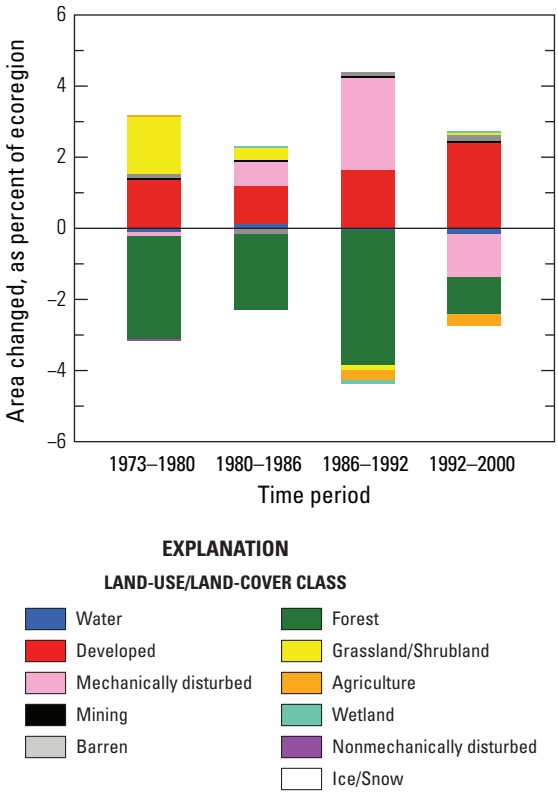

Figure 4. Normalized average net change in Puget Lowland Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use/land-cover classifications.

Four of the top five largest land-cover conversions in the ecoregion were associated with timber harvest and forest regeneration (table 4; figs. 5,6). Timber harvesting is generally accepted as a change from forest to mechanically disturbed, with forest regrowth occurring either rapidly (mechanically disturbed directly back to forest) or more slowly (mechanically disturbed to grassland/shrubland and then grassland/shrubland to forest). The only leading land-cover conversion not related to timber harvest and forest regeneration was losses of forest to developed land. In each time period except the last, the conversion from forest to other land-cover classes accounted for at least half of all land-cover change.

Regrowth of forest here occurs at a moderate pace, aided by mandated replanting efforts (fig. 6). Since 1975, the Washington State Department of Natural Resources (WADNR) has required land owners to plant seedlings of desirable species within 3 years of forest harvest to prevent the spread of invasive species (Washington State Department of Natural Resources, 2001). This requirement also helps establish steady forest regrowth rates after harvest. Logging declines estimated in the last time period between 1992 and 2000 coincide with notable declines in lumber and wood exports from Washington in the 1990s (fig. 7). The export market suffered as a result of market downturns in Japan and Asia, reducing demand for wood-based products. At the same time, forests in the Pacific Northwest also faced increasing competition from other wood-producing countries, such as Russia, Canada, and New Zealand.

The 1990s also ushered in an era of federal forest protection in the Pacific Northwest. The Northwest Forest Plan was implemented to protect the old-growth forest habitat of the threatened Northern Spotted Owl (*Strix occidentalis caurina*). (Daniels, 2005). The Northern Spotted Owl prefers to roost, forage, and nest in old growth forests that have moderate to high canopy enclosure and many large trees (Tesky, 1992). Under the Northwest Forest Plan, timber harvest was banned on 10 million of the 17 million acres (40,000 of 69,000 km²) of national forest land in the Pacific Northwest. Before the Northwest Forest Plan, timber sales from these national forests were approximately 4 to 5 billion board feet per year. After

Figure 5. Transportation of logged trees in Puget Lowland Ecoregion.

Figure 6. Logging activity and various stages of forest regrowth in Puget Lowland Ecoregion, including recently replanted seedlings in addition to reestablished forest stand next to older growth trees.

Figure 7. Logging exports at one of many shipping ports along Puget Sound.

1990, sales dropped to less than a billion board feet per year. The WADNR changed its regulatory rules for State forests in the 1990s as well, to ensure sustainable logging practices and protect critical wildlife habitat. In 1999, the Forests and Fish Law was enacted in Washington, protecting critical salmon (*Oncorhynchus* spp.) habitat by requiring tree buffers along stream banks, even on private land (Daniels, 2005).

The second most important driver of land-cover change in the Puget Lowland Ecoregion was the increase in developed land. Most of the developed land (73.4 percent) was in areas that were previously forest land (fig. 8). The largest gain in developed land occurred between 1992 and 2000, and the slowest growth occurred between 1980 and 1986. During the 1980s, the Puget Lowland Ecoregion experienced an economic downturn. By 1982, the unemployment rate was above 10 percent. Net migration of people into the ecoregion dropped to zero in 1983 but remained above 20,000 per year for the rest of the study period (Puget Sound Regional Council, 2007). By the 1990s, the economic situation in Puget Lowland Ecoregion improved, and the population increased, led by employment opportunities and growth in the technology sector, including the biotechnology, computer, electronic equipment, software, and telecommunications industries. The ecoregion experienced a 65.4 percent increase in technology jobs between 1995 and 2001, adding more than 60,000 jobs at a 7.8 percent rate

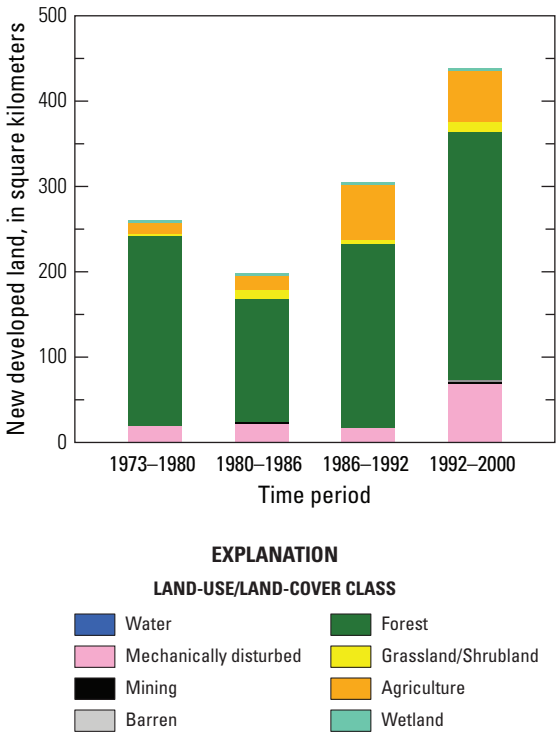

Figure 8. Gains in developed land-cover class in Puget Lowland Ecoregion. Values are areas in square kilometers that converted into developed land. Colors indicate which land-cover class converted to developed land.

Figure 9. New developed land along forest margin in Puget Lowland Ecoregion, with agricultural land preserved.

annually (Puget Sound Regional Council, 2006). By 1999, the technology sector of manufacturing (excluding transportation equipment) and industrial machinery surpassed lumber and wood products as Washington's third leading export commodity (Lin and Schmidt, 2000).

With a substantial growth in developed land in Puget Lowland Ecoregion, one might expect a large decline in agricultural land, but this was not the case (table 3; fig. 9). Only 12.8 percent of new developed land came at the expense of agriculture. Although western Washington makes up only 5 percent of the state's farmland, it contributed 23 percent of the agricultural earnings in 1992. Small farms tend to grow high-value crops such as fruits, vegetables, and greenhouse products. To prevent the loss of large amounts of agriculture land to developed land, the Washington State legislature enacted the Washington State Growth Management Act (GMA) in 1990. The GMA requires the fastest growing and most populated counties to adopt broad land-use plans. One of GMA's provisions is the protection of agricultural lands of long-term commercial significance for the safeguarding of food production (Klein and Reganold, 1997). A principal goal of the GMA was to reduce the conversion of undeveloped and agricultural land into sprawling, low-density developed land. The intention was to direct new development to urban growth areas (UGA) that are usually located adjacent to existing cities and towns. The Puget Sound Regional Council reported that, between 1995 and 2000, 87 percent of the population growth in the region occurred inside the UGAs. Directing growth within UGAs allowed natural resource lands, such as farms and forests, to be conserved and to retain their rural character (Washington State Department of Community Trade and Economic Development, 2003).

The Puget Lowland Ecoregion experienced some of the highest estimates of land-cover change that occurred in the western United States over the entire study period (1973–2000). The largest proportion of change was attributed to land-cover conversions related to forestry and forest regeneration. Clearcut areas tend to be large, and the successional regrowth takes many years, depending on replanting times and local climate. Along with the changes in forests, the Puget Lowland Ecoregion had a notable increase in developed land. The aerospace and computer technology industries fostered an economic boom in the Puget Lowland Ecoregion in the 1990s, with associated population expansion and increased housing demand. Agricultural land cover remained fairly stable, with a slight net decline.

Table 1. Percentage of Puget Lowland Ecoregion that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (72.0 percent), whereas 28.0 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	13.1	1.1	12.2	14.5	0.8	5.7
2	10.7	1.9	8.8	12.6	1.3	12.1
3	3.7	0.9	2.8	4.5	0.6	15.7
4	0.2	0.1	0.2	0.3	0.0	15.2
Overall spatial change	28.0	3.1	24.9	31.1	2.1	7.4

Table 2. Raw estimates of change in Puget Lowland Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each time period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	8.1	1.0	7.1	9.1	0.7	8.1	1.2
1980–1986	9.1	1.5	7.6	10.6	1.0	11.3	1.5
1986–1992	13.6	2.2	11.4	15.8	1.5	10.9	2.3
1992–2000	16.0	2.4	13.6	18.4	1.6	10.2	2.0
Estimate of change, in square kilometers							
1973–1980	1,463	175	1,287	1,638	119	8.1	209
1980–1986	1,639	273	1,366	1,911	185	11.3	273
1986–1992	2,454	395	2,058	2,849	268	10.9	409
1992–2000	2,877	433	2,444	3,310	293	10.2	360

Table 3. Estimated area (and margin of error) of each land-cover class in Puget Lowland Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	13.1	5.3	12.2	2.6	2.9	0.7	0.2	0.1	0.4	0.1	56.9	4.0	1.3	0.4	11.0	2.6	1.9	0.5	0.0	0.1
1980	13.1	5.3	13.6	2.8	2.8	0.7	0.2	0.1	0.5	0.2	54.0	4.0	2.9	0.7	11.0	2.6	1.9	0.5	0.0	0.0
1986	13.2	5.3	14.7	3.0	3.4	0.9	0.3	0.1	0.3	0.1	51.9	3.9	3.2	0.7	11.0	2.6	1.9	0.5	0.0	0.0
1992	13.1	5.3	16.4	3.2	6.0	1.3	0.3	0.1	0.4	0.1	48.1	3.7	3.1	0.7	10.7	2.6	1.8	0.5	0.0	0.0
2000	12.9	5.3	18.8	3.4	4.8	1.0	0.4	0.1	0.6	0.2	47.1	3.9	3.1	0.7	10.4	2.6	1.9	0.5	0.0	0.0
Net change	−0.2	0.1	6.6	1.3	1.9	0.9	0.2	0.1	0.2	0.1	−9.8	1.3	1.8	0.6	−0.6	0.5	0.0	0.1	0.0	0.1
Gross change	0.8	0.4	6.6	1.3	10.6	2.1	0.2	0.1	0.7	0.4	13.1	1.8	7.2	1.4	1.4	0.5	0.3	0.1	0.0	0.1
Area, in square kilometers																				
1973	2,367	958	2,204	461	523	125	31	11	71	25	10,254	721	233	79	1,974	466	345	87	8	11
1980	2,352	958	2,457	499	498	120	41	15	88	32	9,733	721	523	130	1,979	471	339	85	0	0
1986	2,373	960	2,653	532	619	159	48	18	61	21	9,345	705	583	123	1,981	473	347	87	0	0
1992	2,361	958	2,954	579	1,084	243	58	21	76	24	8,667	659	550	127	1,929	477	332	84	0	0
2000	2,329	954	3,390	617	867	183	68	27	104	35	8,487	695	561	121	1,867	469	337	84	0	0
Net change	−38	23	1,186	231	344	154	37	17	33	24	−1,767	239	327	115	−107	95	−8	13	−8	11
Gross change	144	72	1,186	231	1,916	371	43	16	124	69	2,360	328	1,298	255	245	88	58	26	8	11

Table 4. Principal land-cover conversions in Puget Lowland Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for "other" class are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km^2)	Margin of error (+/– km^2)	Standard error (km^2)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mechanically disturbed	485	120	81	2.7	33.2
	Mechanically disturbed	Grassland/Shrubland	361	100	68	2.0	24.7
	Forest	Developed	222	62	42	1.2	15.2
	Mechanically disturbed	Forest	137	57	38	0.8	9.3
	Grassland/Shrubland	Forest	76	32	22	0.4	5.2
	Other	Other	182	n/a	n/a	1.0	12.5
		Totals	1,463			8.1	100.0
1980–1986	Forest	Mechanically disturbed	611	158	107	3.4	37.3
	Mechanically disturbed	Grassland/Shrubland	315	90	61	1.7	19.2
	Grassland/Shrubland	Forest	244	61	41	1.4	14.9
	Mechanically disturbed	Forest	153	48	32	0.8	9.3
	Forest	Developed	144	56	38	0.8	8.8
	Other	Other	172	n/a	n/a	1.0	10.5
		Totals	1,639			9.1	100.0
1986–1992	Forest	Mechanically disturbed	1,067	243	165	5.9	43.5
	Grassland/Shrubland	Forest	363	97	66	2.0	14.8
	Mechanically disturbed	Grassland/Shrubland	335	93	63	1.9	13.7
	Mechanically disturbed	Forest	260	90	61	1.4	10.6
	Forest	Developed	215	52	35	1.2	8.8
	Other	Other	214	n/a	n/a	1.2	8.7
		Totals	2,454			13.6	100.0
1992–2000	Forest	Mechanically disturbed	851	183	124	4.7	29.6
	Mechanically disturbed	Forest	559	183	124	3.1	19.4
	Mechanically disturbed	Grassland/Shrubland	442	112	76	2.5	15.4
	Grassland/Shrubland	Forest	425	113	76	2.4	14.8
	Forest	Developed	290	43	29	1.6	10.1
	Other	Other	310	n/a	n/a	1.7	10.8
		Totals	2,877			16.0	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	3,013	598	405	16.7	35.7
	Mechanically disturbed	Grassland/Shrubland	1,453	278	189	8.1	17.2
	Grassland/Shrubland	Forest	1,109	226	153	6.2	13.1
	Mechanically disturbed	Forest	1,108	314	213	6.2	13.1
	Forest	Developed	871	186	126	4.8	10.3
	Other	Other	878	n/a	n/a	4.9	10.4
		Totals	8,432			46.8	100.0

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Status and Trends of Land Change in the Western United States—1973 to 2000
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Chapter 3
Willamette Valley Ecoregion

By Tamara S. Wilson and Daniel G. Sorenson

Ecoregion Description

The Willamette Valley Ecoregion (as defined by Omernik, 1987; U.S. Environmental Protection Agency, 1997) covers approximately 14,458 km² (5,582 mi²), making it one of the smallest ecoregions in the conterminous United States. The long, alluvial Willamette Valley, which stretches north to south more than 193 km and ranges from 32 to 64 km wide, is nestled between the sedimentary and metamorphic Coast Ranges (Coast Range Ecoregion) to the west and the basaltic Cascade Range (Cascades Ecoregion) to the east (fig. 1). The Lewis and Columbia Rivers converge at the ecoregion's northern boundary in Washington state; however, the majority of the ecoregion falls within northwestern Oregon. Interstate 5 runs the length of the valley to its southern boundary with the Klamath Mountains Ecoregion. Topography here is relatively flat, with elevations ranging from sea level to 122 m. This even terrain, coupled with mild, wet winters, warm, dry summers, and nutrient-rich soil, makes the Willamette Valley the most important agricultural region in Oregon. Population centers are concentrated along the valley floor. According to estimates from the Oregon Department of Fish and Wildlife (2006), over 2.3 million people lived in Willamette Valley in 2000. Portland, Oregon, is the largest city, with 529,121 residents (U.S. Census Bureau, 2000). Other sizable cities include Eugene, Oregon; Salem (Oregon's state capital); and Vancouver, Washington.

Despite the large urban areas dotting the length of the Willamette Valley Ecoregion, agriculture and forestry products are its economic foundation (figs. 2,3). The valley is a major producer of grass seed, ornamental plants, fruits, nuts, vegetables, and grains, as well as poultry, beef, and dairy

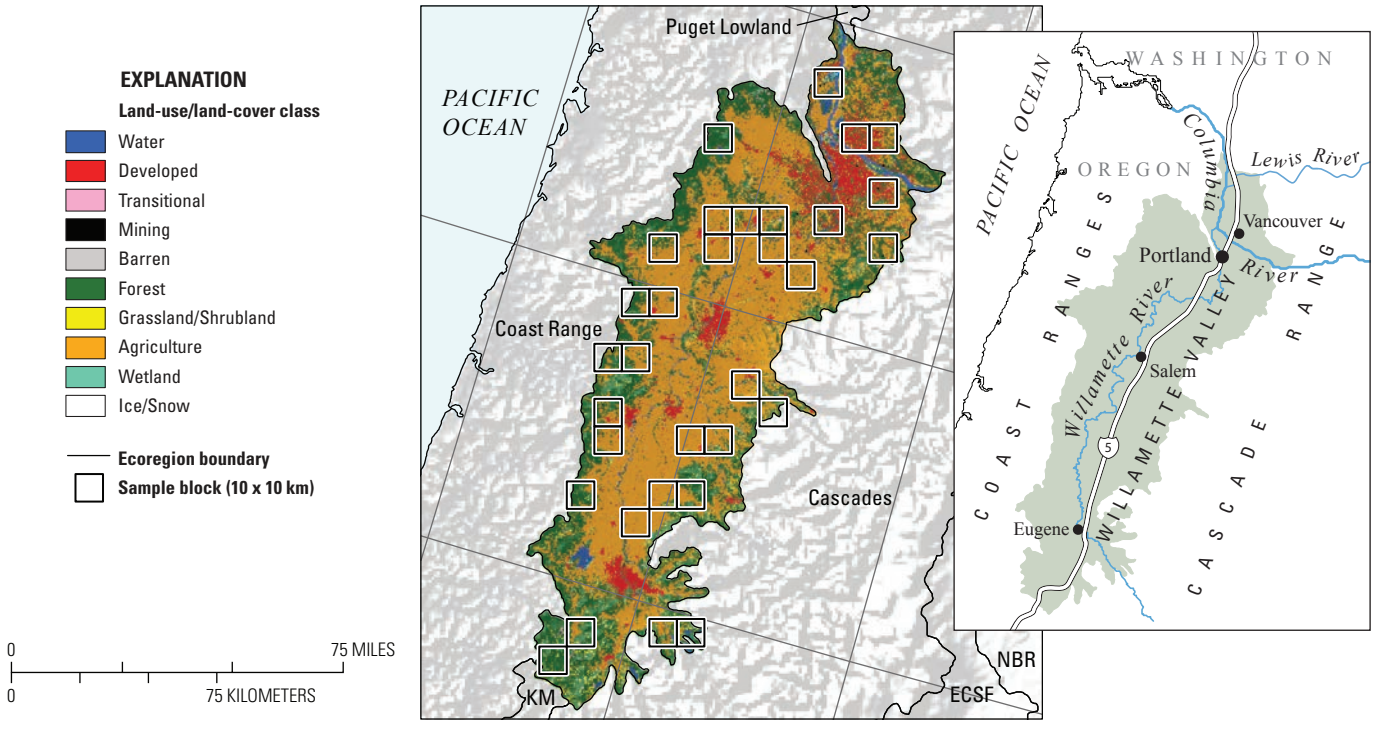

Figure 1. Map of Willamette Valley Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Western United States ecoregions are listed in appendix 2. See appendix 3 for definitions of land-use/land-cover classifications.

Figure 2. Vineyard adjacent to forested foothills in Willamette Valley Ecoregion. Note recovering clearcut hillside (upper left).

Figure 3. Livestock grazing in Willamette Valley Ecoregion.

products. The forestry and logging industries also are primary employers of the valley's rural residents (Rooney, 2008). These activities have affected the watershed significantly, with forestry and agricultural runoff contributing to river sedimentation and decreased water quality in the Willamette River and its tributary streams (Oregon Department of Fish and Wildlife, 2006).

Recent years have seen a marked decline in forest health related to the increased frequency of multiyear droughts. Insect damage and other diseases also are present; however, drought-related water stress is the primary factor in coniferous-tree mortality (Oregon Department of Forestry, 2008). Trees most at risk include Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), and western red cedar (*Thuja plicata*). Overstocking by timber companies and planting on sites with poor conditions increase susceptibility. Over time, these problems may lead to changes in planting practices and the use of more drought-tolerant species such as ponderosa pine (*Pinus ponderosa*).

Contemporary Land-Cover Change (1973 to 2000)

Between 1973 and 2000, the footprint (overall areal extent) of land-use/land-cover change in the Willamette Valley Ecoregion was 14.5 percent, or approximately 2,090 km² of area changed (table 1). This change is high when compared to land-cover change in other Western United States ecoregions (fig. 4). The footprint of change can be interpreted as the area that changed during at least one of the four multiyear periods in the 27-year study period. Overall, an estimated 1,240 km² in the ecoregion changed in at least one of the time periods, 594 km² changed during two time periods, 195 km² changed during three periods, and less than 7 km² changed in all four time periods (table 1).

The average annual rate of change in the Willamette Valley Ecoregion between 1973 and 2000 was 0.8 percent (table 2). This measurement, which normalizes the results for each period to an annual scale, indicates that the region averaged an estimated 113.6 km² of change each year in the 27-year study period. A closer look at successive time periods reveals a steady increase in annual change during the study period (fig. 5). Between 1973 and 1980, the annual rate of

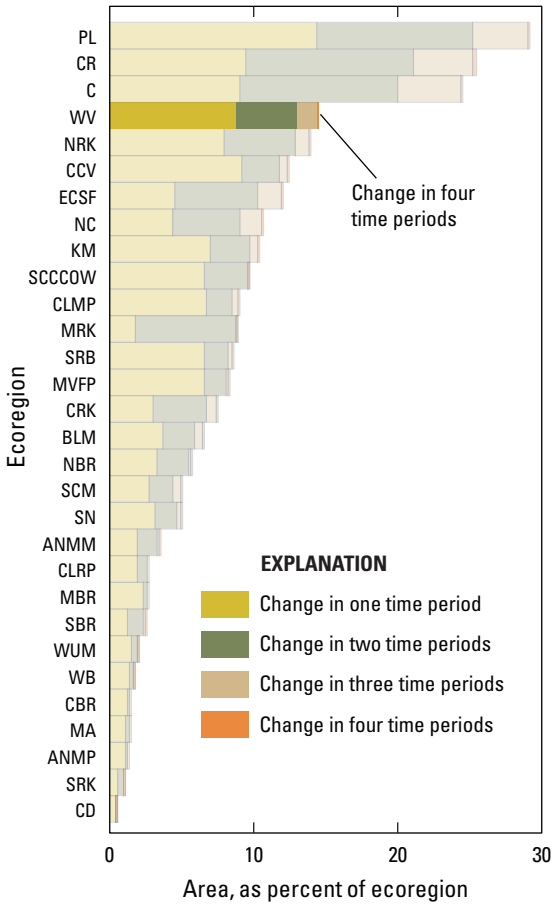

Figure 4. Overall spatial change in Willamette Valley Ecoregion (WV; darker bars) compared with that of all 30 Western United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Willamette Valley Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

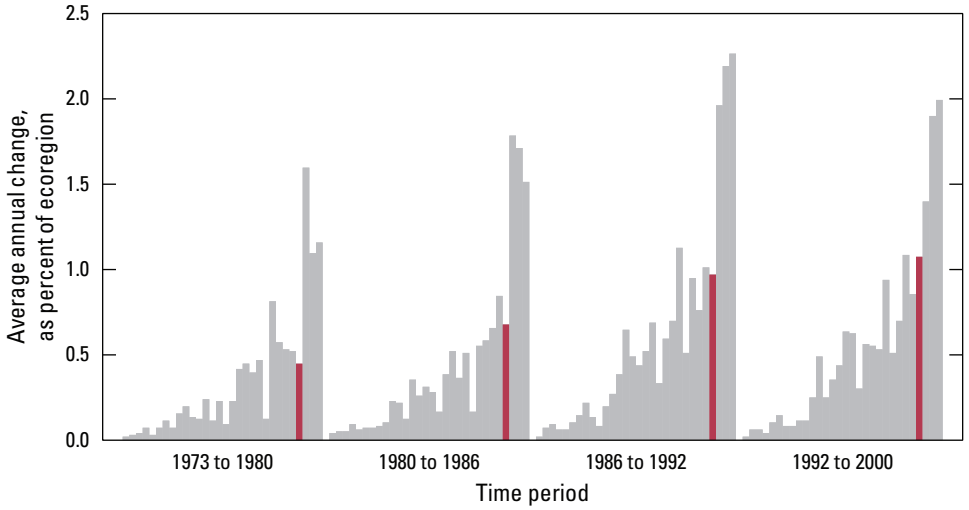

Figure 5. Estimates of land-cover change per time period, normalized to annual rates of change for all 30 Western United States ecoregions (gray bars). Estimates of change for Willamette Valley Ecoregion are represented by red bars in each time period.

change was 0.4 percent (65 km²), increasing to 0.7 percent (98 km²) from 1980 to 1986. This rate continued to rise to 1.0 percent (140 km²) between 1986 and 1992 and again to 1.1 percent (155 km²) between 1992 and 2000 (table 2).

Results from 2000 illustrate an estimated dominance of four of the ten land-cover classes in the Willamette Valley Ecoregion: agriculture (45.1 percent), forest (33.5 percent), developed (12.5 percent), and mechanically disturbed (4.0 percent) (table 3). These estimates from the sampled area are extraordinarily similar to land-cover percentages reported for the entire ecoregion (Oregon Department of Fish and Wildlife, 2006). The remaining six classes together accounted for the final 4.8 percent of the classified area in 2000, and each of these classes alone represents less than two percent of the sampled area (table 3). Between 1973 and 2000, there were considerable net losses in the areas of forest land (-11.0 percent) and agricultural land (-4.7 percent), along with net gains in developed land (33.4 percent) and mechanically disturbed land (236 percent, from 1.2 to 4.0 percent of the total ecoregion area) (fig. 6).

Net change, however, represents only changes between the first and final time periods, or the difference between land cover in 1973 and that in 2000. Net change is not the best indicator of within-class variability for those classes experiencing spatial and temporal fluctuations. The net-change metric does not reveal dynamics of change within and between time periods. Analysis of gross change (area gained and lost) by individual land-cover classes by time period shows that classes have fluctuated throughout the 27-year study period to a greater degree than net-change values indicate (Raumann and others, 2007). Classes may experience gains and losses in area between time periods. For example, mechanically disturbed land experienced a net increase of 2.8 percent between 1973 and 2000, but variable rates of forest cutting and other disturbances throughout the study period show a gross change of 3.3 percent. This equates to a net change in mechanically disturbed land of 404.7 km² (area in 2000 minus area in 1973) compared with a gross change of 476.3 km² over the entire study period.

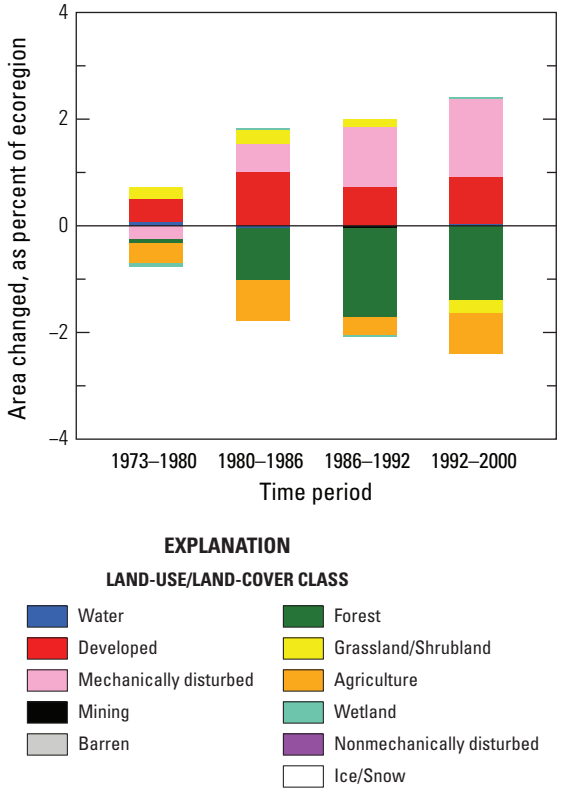

Figure 6. Normalized average net change in Willamette Valley Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use/land-cover classifications.

The "from class–to class" information afforded by a postclassification comparison was used to identify land-cover class conversions and rank them according to their magnitude. Table 4 illustrates the most frequent conversions between 1973 and 2000. Nearly 80 percent of land-cover class conversions were related to timber harvest and successional regrowth. The mechanical disturbance of forests accounted for 51.1 percent of the changes related to timber harvesting, with 18.2 percent recovering directly back to forest and 16.3 percent converting to grassland/shrubland. Overall, the cumulative effect of forest clearing represents 1,254 km^2 of disturbed landscape. The majority of changes occurred along the ecoregion periphery within higher elevation forests. Another important conversion somewhat masked by the dominance of forestry is the loss of agricultural land to developed land (table 4). In the first change period (1973–1980), only 10.3 percent of all changes were from agriculture to developed, but between 1980 and 1986, this land-cover conversion more than doubled to 22.3 percent (132 km^2).

Table 1. Percentage of Willamette Valley Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (85.5 percent), whereas 14.5 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	8.8	1.7	7.1	10.5	1.2	13.4
2	4.2	1.2	3.0	5.5	0.8	20.0
3	1.4	0.5	0.9	1.9	0.3	23.6
4	0.0	0.0	0.0	0.1	0.0	33.5
Overall spatial change	14.5	3.0	11.5	17.4	2.0	13.9

Table 2. Raw estimates of change in Willamette Valley Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	3.1	0.9	2.2	4.1	0.6	20.4	0.4
1980–1986	4.1	1.0	3.1	5.0	0.6	15.9	0.7
1986–1992	5.8	1.4	4.4	7.2	0.9	16.0	1.0
1992–2000	8.6	2.1	6.5	10.6	1.4	16.2	1.1
Estimate of change, in square kilometers							
1973–1980	454	137	317	591	93	20.4	65
1980–1986	590	138	452	728	94	15.9	98
1986–1992	841	198	642	1,039	134	16.0	140
1992–2000	1,238	296	942	1,535	201	16.2	155

Table 3. Estimated area (and margin of error) of each land-cover class in Willamette Valley Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	1.8	0.8	9.4	3.6	1.2	0.5	0.2	0.1	0.0	0.0	37.7	6.0	0.8	0.4	47.3	6.2	1.6	0.9	0.0	0.0
1980	1.8	0.8	9.8	3.8	0.9	0.4	0.2	0.1	0.0	0.0	37.6	6.0	1.1	0.3	47.0	6.3	1.5	0.8	0.0	0.0
1986	1.8	0.8	10.9	4.0	1.4	0.4	0.2	0.1	0.0	0.0	36.6	5.9	1.3	0.4	46.2	6.3	1.5	0.8	0.0	0.0
1992	1.8	0.8	11.6	4.3	2.6	0.8	0.2	0.1	0.0	0.0	34.9	5.6	1.5	0.4	45.9	6.3	1.5	0.8	0.0	0.0
2000	1.8	0.8	12.5	4.5	4.0	1.2	0.2	0.1	0.1	0.0	33.5	5.3	1.2	0.4	45.1	6.3	1.5	0.8	0.0	0.0
Net change	0.1	0.1	3.1	1.4	2.8	1.0	0.0	0.0	0.0	0.0	−4.1	1.4	0.4	0.6	−2.2	1.2	−0.1	0.1	0.0	0.0
Gross change	0.2	0.1	3.1	1.4	4.8	1.3	0.1	0.0	0.0	0.0	6.1	1.4	2.6	0.8	3.1	1.1	0.2	0.1	0.0	0.0
Area, in square kilometers																				
1973	253	116	1,359	524	172	76	29	13	6	4	5,450	870	120	59	6,842	902	226	123	0	0
1980	264	116	1,422	544	136	53	31	15	6	4	5,440	874	153	50	6,790	908	216	118	0	0
1986	260	116	1,574	579	207	60	32	14	6	4	5,298	853	189	55	6,676	904	216	117	0	0
1992	261	115	1,681	615	371	110	30	14	6	4	5,051	813	210	58	6,631	905	216	117	0	0
2000	265	116	1,813	651	578	180	31	14	7	4	4,851	770	174	59	6,521	905	218	117	0	0
Net change	12	13	454	205	407	142	2	5	1	1	−600	196	54	80	−322	175	−8	15	0	0
Gross change	25	18	454	205	694	193	12	5	4	4	876	207	376	115	444	161	28	14	0	0

Table 4. Principal land-cover conversions in Willamette Valley Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for "other" class are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km^2)	Margin of error (+/– km^2)	Standard error (km^2)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mechanically disturbed	127	53	36	0.9	28.0
	Mechanically disturbed	Grassland/Shrubland	85	42	28	0.6	18.8
	Mechanically disturbed	Forest	85	44	30	0.6	18.6
	Grassland/Shrubland	Forest	52	38	26	0.4	11.4
	Agriculture	Developed	45	26	18	0.3	10.0
	Other	Other	60	n/a	n/a	0.4	13.2
		Totals	454			3.1	100.0
1980–1986	Forest	Mechanically disturbed	201	59	40	1.4	34.1
	Agriculture	Developed	132	81	55	0.9	22.3
	Mechanically disturbed	Grassland/Shrubland	94	35	23	0.6	15.9
	Grassland/Shrubland	Forest	60	30	20	0.4	10.2
	Mechanically disturbed	Forest	34	23	15	0.2	5.7
	Other	Other	70	n/a	n/a	0.5	11.8
		Totals	590			4.1	100.0
1986–1992	Forest	Mechanically disturbed	360	110	74	2.5	42.8
	Mechanically disturbed	Grassland/Shrubland	119	39	27	0.8	14.2
	Grassland/Shrubland	Forest	102	45	30	0.7	12.1
	Agriculture	Developed	77	35	24	0.5	9.2
	Mechanically disturbed	Forest	73	30	20	0.5	8.7
	Other	Other	109	n/a	n/a	0.8	13.0
		Totals	841			5.8	100.0
1992–2000	Forest	Mechanically disturbed	566	182	123	3.9	45.7
	Mechanically disturbed	Forest	256	96	65	1.8	20.7
	Grassland/Shrubland	Forest	138	51	35	1.0	11.1
	Mechanically disturbed	Grassland/Shrubland	101	37	25	0.7	8.2
	Agriculture	Developed	93	39	27	0.6	7.5
	Other	Other	84	n/a	n/a	0.6	6.7
		Totals	1,238			8.6	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	1,255	369	250	8.7	40.2
	Mechanically disturbed	Forest	447	176	120	3.1	14.3
	Mechanically disturbed	Grassland/Shrubland	399	126	86	2.8	12.8
	Grassland/Shrubland	Forest	352	131	89	2.4	11.3
	Agriculture	Developed	347	164	111	2.4	11.1
	Other	Other	322	n/a	n/a	2.2	10.3
		Totals	3,122			21.6	100.0

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