Status and Trends of Land Change in the Western United States—1973 to 2000
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Chapter 16

Blue Mountains Ecoregion

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Ecoregion Description

The Blue Mountains Ecoregion encompasses approximately 65,461 km² (25,275 mi²) of land bordered on the north by the Columbia Plateau Ecoregion, on the east by the Northern Rockies Ecoregion, on the south by the Snake River Basin and the Northern Basin and Range Ecoregions, and on the west by the Cascades and the Eastern Cascades Slopes and Foothills Ecoregions (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). Most of the Blue Mountains Ecoregion is located within Oregon (83.5 percent); 13.8 percent is in Idaho, and 2.7 percent is in Washington. The Blue Mountains are composed of primarily Paleozoic volcanic rocks, with minor sedimentary, metamorphic, and granitic rocks. Lower mountains and numerous basin-and-range areas, as well as the lack of Quaternary-age volcanoes, distinguish the Blue Mountains from the adjacent Cascade Range (Thorson and others, 2003).

The Cascade Range to the west creates a rain-shadow effect in the Blue Mountains Ecoregion, which receives much less rain relative to the Cascade Range and the marine forests of the Pacific Northwest. The rain shadow is most dramatic in the southern reach of the Blue Mountains Ecoregion; the northern part of the ecoregion receives more moisture-bearing air, which passes across the Cascade Range by way of the Columbia Gorge (Heyerdahl and others, 2001). This interregional precipitation gradient contributes to significant vegetation variability across the Blue Mountains Ecoregion. In the northern part of the ecoregion, grasslands thrive at low elevations, and dense forests persist in moist ash soils at high elevations. Much of the southern part of the ecoregion is covered

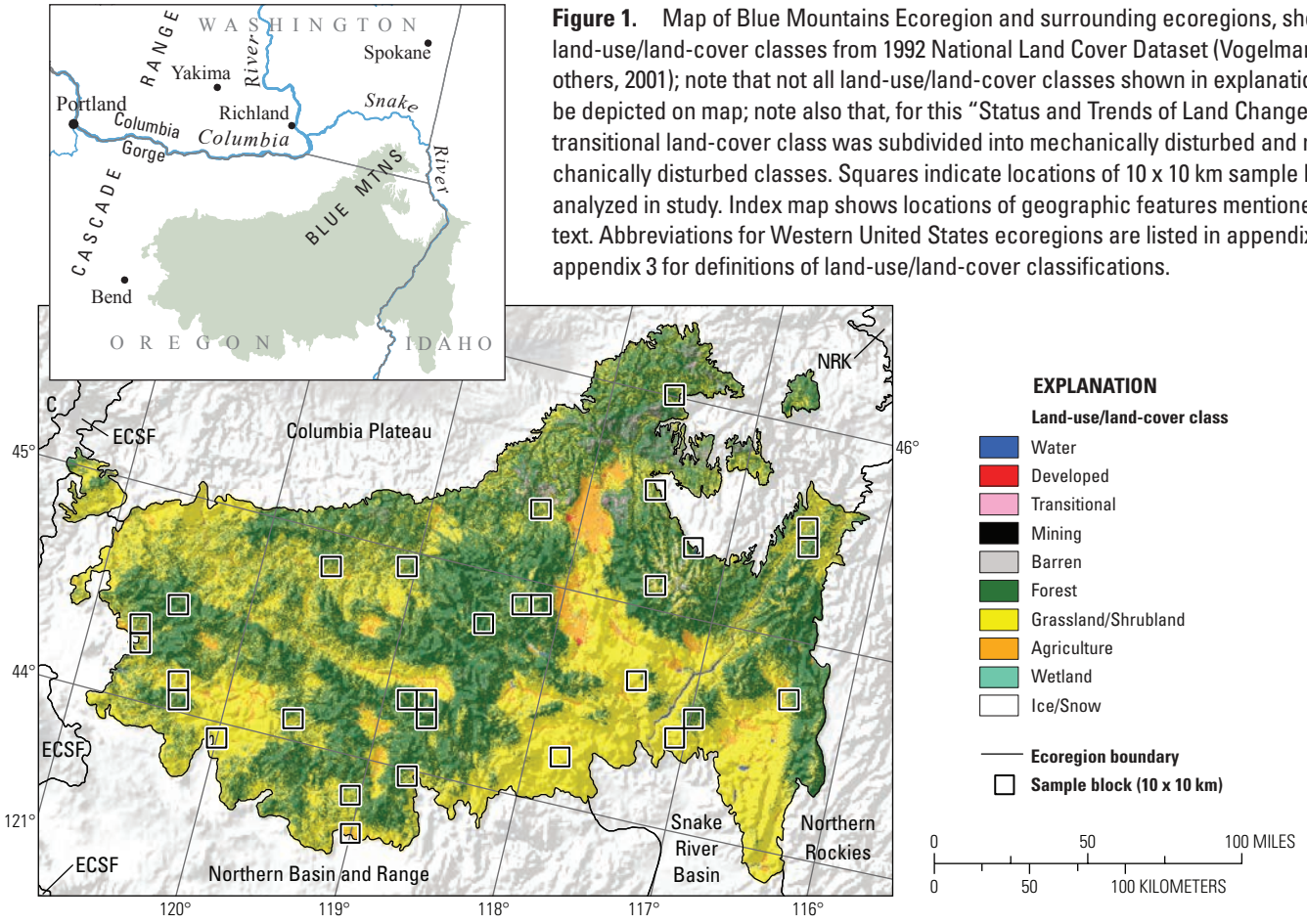

Figure 1. Map of Blue Mountains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and 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.

by drought-tolerant sagebrush (*Artemisia* spp.), shrubland, and juniper woodland (*Juniperus* spp.).

The variety of land covers across the Blue Mountains Ecoregion drives a wide range of land-use patterns in the region. Fertile grasslands support large hay and livestock operations in the northern Blue Mountains Ecoregion where windblown silt has created thick soils. Smaller agricultural operations persist in the dry southern reach of region where soils are less developed (Busacca, 1991). Another contrast is the difference in anthropogenic land disturbances between the northern and southern parts of the Blue Mountains Ecoregion. All mechanical disturbances in the northern forests resulted from logging, but clearings in the southern Blue Mountains Ecoregion resulted primarily from the removal of juniper to improve rangeland. Perhaps the most consistent pattern of land-cover change across the Blue Mountains Ecoregion is that which is caused by nonmechanical disturbances such as fire. Fire has an established history in the Blue Mountains Ecoregion owing to the region's low-to-moderate precipitation and abundant fuel sources (Heyerdahl and others, 2001). However, fire now poses a larger threat in the Blue Mountains Ecoregion (and in the greater western United States) because of vegetation build-up following decades of fire suppression (McCullough and others, 1998). Prescribed burning and forest thinning became increasingly common within much of the Blue Mountains Ecoregion in the latter part of the 20th century to remove dense vegetation and neutralize the threat of large, unmanageable fires that jeopardize wildlife and human habitats.

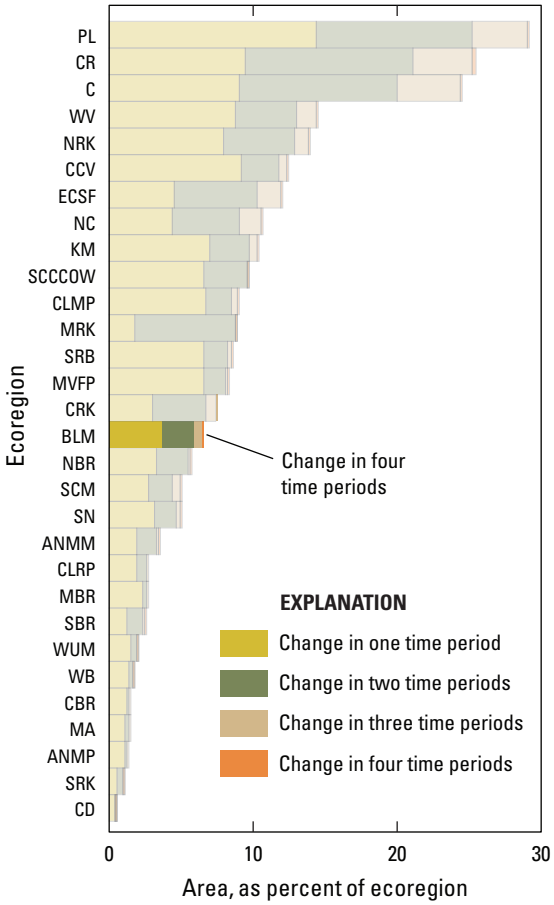

Figure 2. Overall spatial change in Blue Mountains Ecoregion (BLM; darker bars) compared with that of all 30 Western United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Blue Mountains 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.

Contemporary Land-Cover Change (1973 to 2000)

Between 1973 and 2000, the footprint (overall areal extent) of land-use/land-cover change in the Blue Mountains Ecoregion was 6.5 percent, or 4,275 km². The footprint of change can be interpreted as the area that experienced change during at least one of the four time periods that make up the 27-year study period. Of the total change, 2,476 km² (3.8 percent) of the ecoregion changed during one period, 1,367 km² (2.1 percent) changed during two periods, 425 km² (0.6 percent) changed during three periods, and roughly 5 km² (less than 0.1 percent) changed throughout all four periods (table 1). Overall, this level of spatial change is lower than that of most of the western United States ecoregions (fig. 2).

Between 1973 and 2000, the average annual rate of change in the Blue Mountains Ecoregion was roughly 0.4 percent. This measurement, which normalizes the results for each period to an annual scale, indicates that the region averaged roughly 0.4 percent (241 km²) of change each year in the 27-year study period (table 2). However, this annual change varied between each of the four time periods (fig. 3). Between 1973 and 1980, the annual rate of change in the Blue Mountains Ecoregion was 0.1 percent. The annual rate of change steadily increased in each of the following periods, to 0.3 percent between 1980 and 1986, to 0.4 percent between 1986 and 1992, and to 0.6 percent between 1992 and 2000 (table 2).

The results of this study illustrate the estimated dominance of four of the eleven land-use/land-cover classes in the Blue Mountains Ecoregion in 2000: forest (48.4 percent), grassland/shrubland (42.1 percent), agriculture (4.1 percent), and nonmechanically disturbed (2.4 percent). Although six other classes cumulatively made up the remaining 3.0 percent of the Blue Mountains Ecoregion landscape in 2000, each of these classes made up less than one percent of the ecoregion (table 3). Between 1973 and 2000, the land-use/land-cover classes that experienced a noteworthy net change in relation to the total Blue Mountains Ecoregion area include, in descending order, forest (7.9 percent decrease), grassland/shrubland (3.3 percent increase), and nonmechanically disturbed, which occupied no land in 1973 and only 0.2 percent of the total area in 1992 but expanded to 2.4 percent of the sampled area in 2000 (fig. 4).

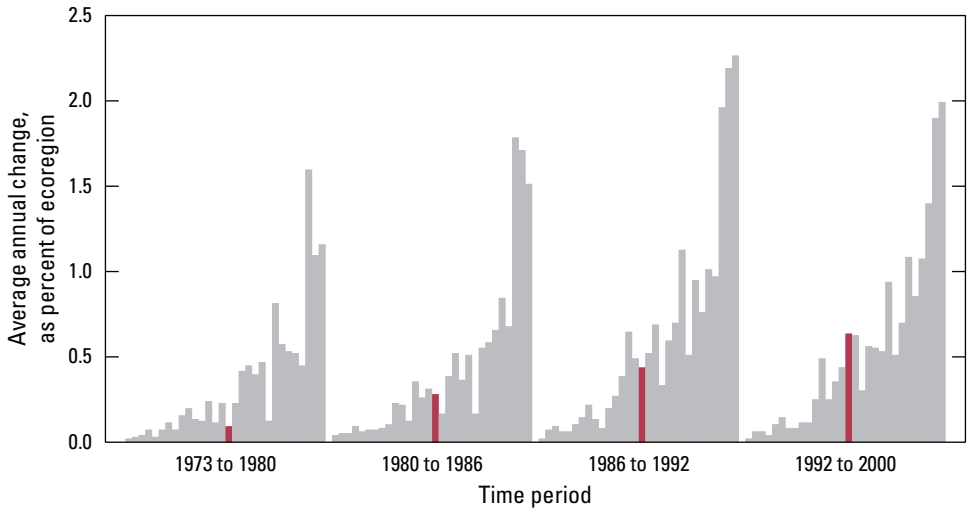

Figure 3. Estimates of land-cover change per time period, normalized to annual rates of change for all 30 Western United States ecoregions (gray bars). Estimates of change for Blue Mountains Ecoregion are represented by red bars in each time period.

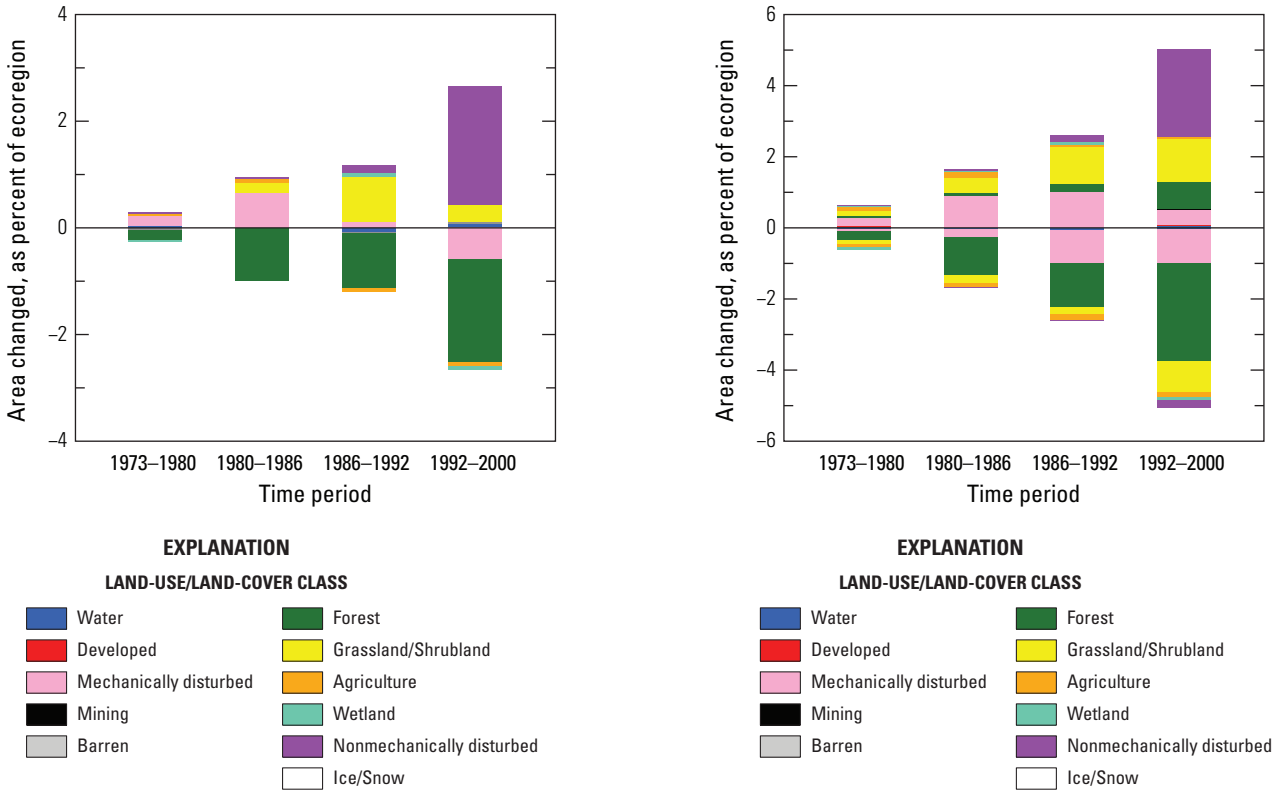

Figure 4. Normalized average net change in Blue Mountains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for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

Figure 5. Gross change (as percent of ecoregion) in Blue Mountains Ecoregion by time period for each land-cover class. Diagram illustrates how net change can mask within-class fluctuations in each period and for entire 27-year study period. Bars above zero axis represent area gained, whereas bars below zero represent area lost. 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.

Net change, however, may not necessarily be the best indicator of within-class variability for those classes experiencing spatiotemporal fluctuations. The net-change metric often masks dynamics of land-use/land-cover change, whereas analysis of gross change (area gained or lost) by individual land-use/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 may indicate (Raumann and others, 2007) (fig. 5). In addition, land-cover classes may experience gains and losses in area both within and between time periods (fig. 5). For example, the mechanically disturbed class increased by more than 600 percent between 1973 and 2000, but gross change relating to mechanical disturbance affected an area greater than 40 times the size of the 1973 classification area. Figure 5 illustrates the dynamic nature of land-use/land-cover change in the Blue Mountains Ecoregion between 1973 and 2000.

The land-use/land-cover change information for each of the four time periods afforded by a postclassification comparison allowed the identification of land-use/land-cover class conversions and the ranking of these conversions according to their magnitude. Table 4 illustrates the most frequent conversions in the Blue Mountains Ecoregion between 1973 and 2000. The largest overall conversion and the largest conversion in each of the first three time periods represented the mechanical disturbance of forest by logging and rangeland improvement (fig. 6). Additionally, the second most common overall conversion and a major conversion in each of the last two time periods were connected to nonmechanical disturbance of forest by fire and to a significantly lesser degree, to insect damage from the Douglas-fir tussock moth (*Orgyia pseudotsugata* McDunnough), the western spruce budworm (*Choristoneura occidentalis* Freeman), and the mountain pine beetle (*Dendroctonus ponderosae*) (Wickman, 1992) (fig. 7). Insect damage to forest land cannot be separated out from other nonmechanical disturbances in the present study; however, it must be stressed that insect-caused declines in forest health are known to exacerbate the effects, spread, and intensity of wildfires (Wickman, 1992). The effect of mechanical disturbance on forest resulted in an estimated 1,663 km² of land-cover loss, whereas the impact of nonmechanical disturbance on grassland/shrubland and forest resulted in an estimated 1,760 km² of vegetated land-cover loss.

Most mechanical disturbances (74.1 percent) occurred between 1980 and 1992, and these changes declined significantly between 1992 and 2000. This decline coincided with the decline in timber harvest in Oregon in the 1990s, when a shift towards forest conservation caused the federal share of Oregon's timber harvest to decrease from approximately 50 percent in 1989 to 10 percent by 2000 (Brandt and others, 2006). Although mechanical forest clearing declined between 1992 and 2000, over 90 percent of all nonmechanical disturbances took place during this period.

Mechanical and nonmechanical disturbances are transitional by definition, so many of these disturbed areas experienced ecological succession, or regrowth, after each disturbance event. The cumulative regrowth following mechanical and nonmechanical disturbances accounts for 1,555 km² of vegetated land-cover gain through 2000; on the basis of field observations, disturbances that occurred in 2000 would also convert to one of the vegetation land-cover classes if mapping efforts had been extended to include a 2007 date. Conversions to and from the agriculture class represent another conversion in the Blue Mountains Ecoregion during the study period. Between 1973 and 2000, 273 km² converted from agriculture to grassland/shrubland and 219 km² converted from grassland/shrubland to agriculture.

The mechanical removal of forest in the Blue Mountains Ecoregion between 1973 and 2000 occurred in over half of the sample-block locations. Most of these conversions were associated with silviculture. Considerable research has been conducted, and policy has been implemented, to establish improved

Figure 6. Young stand of trees in formerly cleared part of Blue Mountains Ecoregion. Standing snags provide nesting and roosting sites for avian species. Land-use/land-cover classes shown are forest and grassland/shrubland.

Figure 7. Cut trees in Blue Mountains Ecoregion during precommercial thinning. Land-use/land-cover classes shown are mechanically disturbed and forest.

Figure 8. Forested area in early-stage succession (regrowth) following fire. Although grasses and shrubs tend to reestablish themselves quite soon after fire, trees take much longer to recover. Land-cover classes shown are grassland/shrubland and forest.

forestry practices such as sustainable stocking levels, thinning practices, and snag preservation (Cochran and others, 1994; Parker and others, 2006; U.S. Department of Agriculture, 1979) (figs. 6,8). The goal of many of these practices has been to replicate old-growth forest conditions and remedy the detrimental effects of logging on forest fauna. For example, protecting tree snags and select trees while cutting is intended to preserve nest and roost sites vital for breeding and winter survival of many avian species (Zarnowitz and Manuwal, 1985; Bryce, 2006; U.S. Department of Agriculture, 1979).

Nonmechanical disturbances, although comparable to mechanical disturbances in terms of the overall footprint of change across the Blue Mountains Ecoregion, were much less frequent than the mapped instances of forest cutting. Despite this lower frequency, nonmechanical disturbances caused by fire had a much larger patch size. Larger fires have become much more common in the Blue Mountains Ecoregion and can be largely attributed to fire-suppression practices that took place over much of 20th century. Fires not only pose an immediate threat to wildlife and human habitats, but they also contribute to future fires by altering forest composition and making damaged

Figure 9. Forested area during prescribed fire, showing warning sign (*A*) and scattered smoldering logs (*B*). Prescribed fires remove undergrowth and prevent large, unmanageable fires from occurring. Land-cover classes shown are nonmechanically disturbed and forest.

trees more vulnerable to insect pests (McCullough and others, 1998). In an effort to reduce the threat of forest fires, prescribed fires are being applied more regularly to remove built-up fuels and excess understory growth within the Blue Mountains Ecoregion (Mutch and others, 1993) (fig. 9).

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

[Most sample pixels remained unchanged (93.5 percent), whereas 6.5 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	3.8	1.9	1.8	5.7	1.3	34.7
2	2.1	0.8	1.3	2.9	0.5	25.8
3	0.6	0.4	0.3	1.0	0.2	38.3
4	0.0	0.0	0.0	0.0	0.0	67.8
Overall spatial change	6.5	2.2	4.3	8.8	1.5	23.0

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

[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	0.6	0.2	0.4	0.8	0.1	18.1	0.1
1980–1986	1.7	0.7	1.0	2.4	0.5	28.0	0.3
1986–1992	2.6	1.1	1.5	3.7	0.8	28.7	0.4
1992–2000	5.0	2.1	3.0	7.1	1.4	27.7	0.6
Estimate of change, in square kilometers							
1973–1980	399	107	292	506	72	18.1	57
1980–1986	1,094	453	641	1,548	306	28.0	182
1986–1992	1,714	727	988	2,441	491	28.7	286
1992–2000	3,300	1,353	1,947	4,653	915	27.7	413

Table 3. Estimated area (and margin of error) of each land-cover class in Blue Mountains 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	0.4	0.3	0.2	0.2	0.1	0.0	0.0	0.0	0.8	0.6	52.5	7.8	40.8	7.6	4.1	2.1	1.0	0.5	0.0	0.0
1980	0.4	0.3	0.2	0.2	0.2	0.1	0.0	0.0	0.8	0.6	52.3	7.7	40.8	7.6	4.1	2.1	0.9	0.5	0.0	0.0
1986	0.4	0.3	0.2	0.2	0.9	0.6	0.0	0.0	0.8	0.6	51.4	7.4	40.9	7.5	4.2	2.1	1.0	0.5	0.0	0.1
1992	0.4	0.3	0.2	0.2	1.0	0.5	0.0	0.0	0.8	0.6	50.3	7.3	41.8	7.3	4.1	2.0	1.0	0.5	0.2	0.2
2000	0.4	0.3	0.3	0.2	0.4	0.2	0.0	0.0	0.8	0.6	48.4	7.0	42.1	7.3	4.1	2.0	0.9	0.5	2.4	2.0
Net change	0.1	0.1	0.0	0.0	0.4	0.2	0.0	0.0	0.0	0.0	−4.2	1.9	1.3	0.7	0.0	0.2	0.0	0.1	2.4	2.0
Gross change	0.2	0.2	0.0	0.0	2.5	1.2	0.0	0.0	0.1	0.1	5.1	2.1	2.5	0.8	0.5	0.3	0.3	0.2	2.9	2.0
Area, in square kilometers																				
1973	250	205	144	99	40	21	26	22	539	420	34,399	5,076	26,677	4,958	2,694	1,360	639	316	0	0
1980	282	212	149	103	153	67	25	21	530	420	34,262	5,046	26,685	4,961	2,704	1,367	612	318	5	7
1986	285	212	157	106	580	404	25	21	530	420	33,626	4,876	26,799	4,892	2,750	1,364	625	325	31	44
1992	236	203	162	110	661	339	26	22	521	420	32,953	4,758	27,337	4,787	2,696	1,299	675	333	140	163
2000	284	210	168	114	284	137	29	27	539	420	31,671	4,573	27,546	4,780	2,667	1,285	618	321	1,602	1,281
Net change	33	34	24	18	244	132	4	4	0	0	−2,728	1,239	868	435	−27	155	−20	36	1,602	1,281
Gross change	140	121	25	18	1,604	811	7	7	36	52	3,363	1,395	1,646	533	329	166	166	112	1,888	1,299

Table 4. Principal land-cover conversions in Blue Mountains 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	152	67	45	0.2	38.0
	Agriculture	Grassland/Shrubland	52	47	32	0.1	13.1
	Grassland/Shrubland	Agriculture	51	49	33	0.1	12.9
	Wetland	Water	31	32	22	0.0	7.7
	Mechanically disturbed	Grassland/Shrubland	30	18	12	0.0	7.4
	Other	Other	83	n/a	n/a	0.1	20.9
		Totals	399			0.6	100.0
1980–1986	Forest	Mechanically disturbed	579	404	273	0.9	52.9
	Mechanically disturbed	Grassland/Shrubland	118	53	36	0.2	10.8
	Grassland/Shrubland	Agriculture	91	64	43	0.1	8.4
	Forest	Grassland/Shrubland	75	107	72	0.1	6.9
	Agriculture	Grassland/Shrubland	63	56	38	0.1	5.8
	Other	Other	168	n/a	n/a	0.3	15.3
		Totals	1,094			1.7	100.0
1986–1992	Forest	Mechanically disturbed	653	340	230	1.0	38.1
	Mechanically disturbed	Grassland/Shrubland	527	363	246	0.8	30.7
	Forest	Nonmechanically disturbed	139	163	110	0.2	8.1
	Grassland/Shrubland	Forest	96	78	53	0.1	5.6
	Agriculture	Grassland/Shrubland	90	111	75	0.1	5.2
	Other	Other	210	n/a	n/a	0.3	12.3
		Totals	1,714			2.6	100.0
1992–2000	Forest	Nonmechanically disturbed	1,471	1,170	791	2.2	44.6
	Mechanically disturbed	Grassland/Shrubland	566	293	198	0.9	17.1
	Grassland/Shrubland	Forest	397	251	170	0.6	12.0
	Forest	Mechanically disturbed	279	137	93	0.4	8.5
	Grassland/Shrubland	Nonmechanically disturbed	125	114	77	0.2	3.8
	Other	Other	462	n/a	n/a	0.7	14.0
		Totals	3,300			5.0	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	1,663	809	547	2.5	25.5
	Forest	Nonmechanically disturbed	1,632	1,178	797	2.5	25.1
	Mechanically disturbed	Grassland/Shrubland	1,240	630	426	1.9	19.0
	Grassland/Shrubland	Forest	554	293	198	0.8	8.5
	Agriculture	Grassland/Shrubland	273	247	167	0.4	4.2
	Other	Other	1,146	n/a	n/a	1.8	17.6
		Totals	6,508			9.9	100.0

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