

Chapter 15

Sierra Nevada Ecoregion

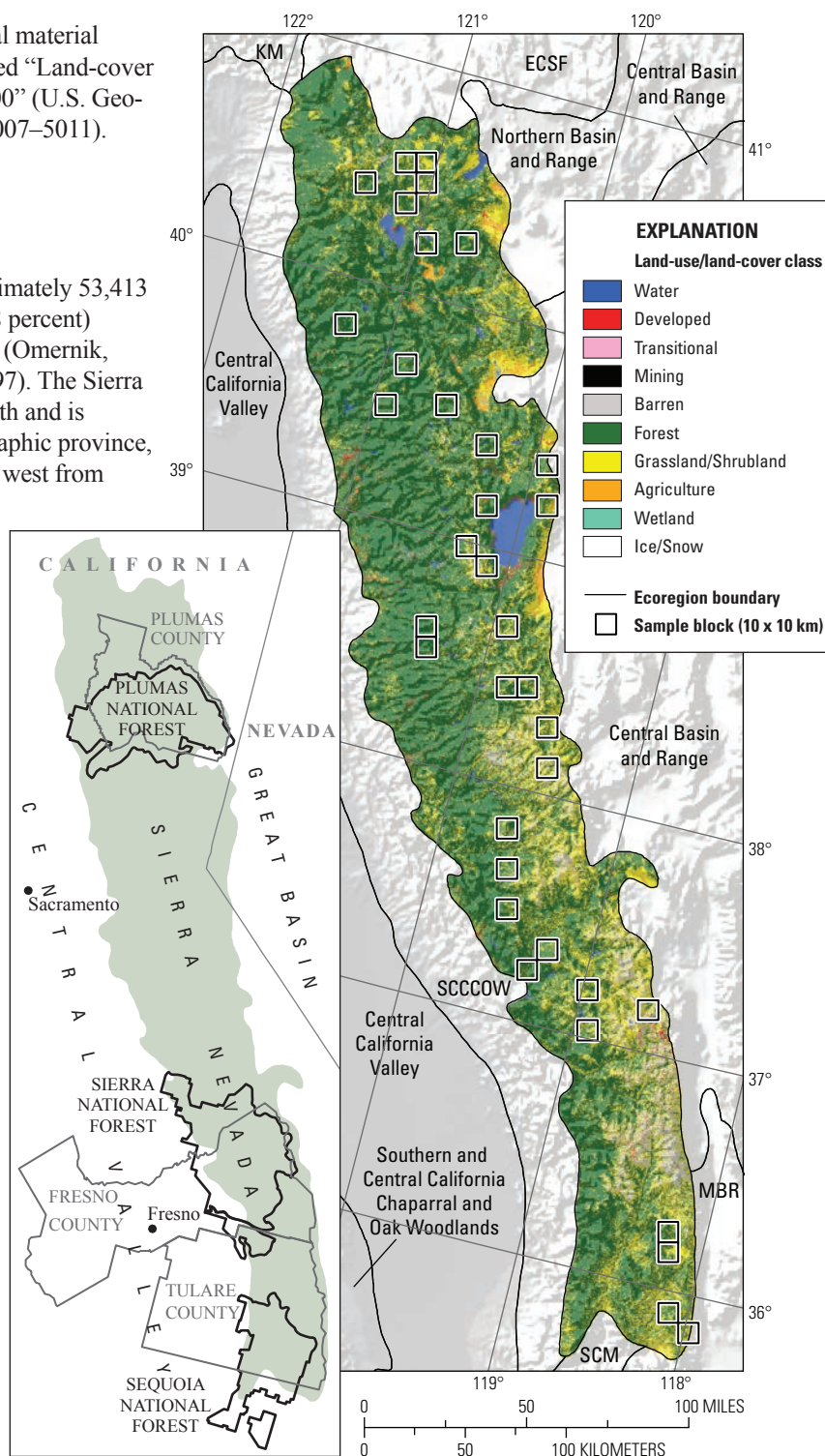
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Ecoregion Description

The Sierra Nevada Ecoregion covers approximately 53,413 km² (20,623 mi²) with the majority of the area (98 percent) in California and the remainder in Nevada (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). The Sierra Nevada Ecoregion is generally oriented north-south and is essentially defined by the Sierra Nevada physiographic province, which separates California’s Central Valley to the west from the Great Basin to the east. It is bounded by seven other ecoregions: Southern and Central California Chaparral and Oak Woodlands Ecoregion on the west; Klamath Mountains and Eastern Cascades Slopes and Foothills Ecoregions on the north; Southern California Mountains Ecoregion on the south; and Northern Basin and Range, Central Basin and Range, and Mojave Basin and Range Ecoregions on the east (fig. 1). The Sierra Nevada range is a granitic batholith, much of which is exposed at higher elevations, with a gradual western slope and a generally steep eastern escarpment.

Figure 1. Map of Sierra Nevada 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.



The climate of the Sierra Nevada Ecoregion is primarily Mediterranean, characterized by cool, wet winters and long, dry summers. Most areas of elevation above 2,100 m have a Boreal climate, and the highest elevations, typically above 3,600 m, have an Alpine climate. Precipitation increases with elevation from west to east as storm systems moving from the west are subject to orographic uplift, causing rain and snowfall. Because most precipitation from storm systems falls on the western slope of the Sierra Nevada range, a strong rainshadow limits precipitation on the steep eastern slope. This climatic gradient plays a significant role in determining the type and distribution of ecological communities. In order to provide water resources for the growing populations in low-elevation areas of California and Nevada, numerous reservoirs on the western and eastern slopes of the Sierra Nevada range collect runoff from the winter snow pack.

Before the 20th century, resource use within the Sierra Nevada Ecoregion was largely unregulated. However, laws and administrative policies such as the Wilderness Act of 1964, National Environmental Policy Act of 1969, and National Forest Management Act of 1976 provided a mechanism for managing national forests. Furthermore, other environmental laws, annual appropriations legislation, and administrative policies relating to fire and fuels management have guided resource use and likely have had significant environmental effects in the Sierra Nevada Ecoregion (Ruth, 1996). Today, public lands make up 74.6 percent (39,433 km²) of the ecoregion, with the majority (57.8 percent of the ecoregion) managed by the U.S. Forest Service as National Forests and Wilderness Areas.

Despite resource regulation, California's growing urban population has greatly increased the demand for wood, water, hydroelectricity, and recreational opportunities from the Sierra Nevada Ecoregion. Timber harvesting surged in the 1950s to 1970s but decreased substantially after the economic recession in the early 1980s. Water is considered the region's most valuable resource, and it is controlled in nearly every major river basin in the region and also managed to provide municipal water supplies and hydroelectric power (Sierra Nevada Ecosystem Project Science Team and Special Consultants, 1996). Major highways and ski resorts were constructed in the 1950s and 1960s to meet the demand for year-round recreation (Sierra Nevada Ecosystem Project Science Team and Special Consultants, 1996). Over the past several decades, the demand for natural resources within the Sierra Nevada Ecoregion has altered ecological communities in the region by changing land-use/land-cover patterns.

In terms of nonmechanical land-cover change components, frequent fires of low to moderate intensity are an integral driver of change within the region's ecological communities. Fires create a cycle of disturbance and succession that floral and faunal communities have adapted to and often require to propagate and thrive (Skinner and Chang, 1996). By the late 20th century the regional fire regime had greatly changed, primarily as a result of logging during the settlement period of the 1950s and 1960s and effective fire

suppression activities mandated by State and Federal policies since the 1920s. Consequently, fires were less frequent and more severe than before (Skinner and Chang, 1996). Forest density increased and contributed to higher tree mortality because of greater intertree competition, insect attack, disease, and storm damage (Oliver and others, 1996). These conditions led to an increased supply of fuel which, in turn, resulted in an increased fire hazard, including the likelihood of high-severity fire (Manley and others, 2000). A shift to a warmer and moister climate may also have contributed to this altered fire regime by reducing winter severity and providing a longer growing season (McKelvey and others, 1996; Stine, 1996).

Contemporary Land-Cover Change (1973 to 2000)

The overall areal extent, or "footprint," of land-cover change between 1973 and 2000 was 5.0 percent (2,645 km²), which means that 5.0 percent of the Sierra Nevada Ecoregion underwent change over at least one of the four time periods that make up the entire 27-year study period. Areas totaling 3.1 percent of the ecoregion changed during only one period, 1.6 percent changed during two periods, and 0.3 percent changed during three periods (table 1). This footprint of change in the Sierra Nevada Ecoregion was low to moderate when compared to other ecoregions in the western United States (fig. 2).

The estimated average annual rate of land-cover change is calculated by normalizing each period's gross change by the number of years in that period. Normalizing gross change by year allows comparison of the amount of change in each period when periods are of varying length. It is important to note that the resulting rates of change, although presented as per-year rates, are only an estimate and should be viewed as a description of the period and not of the individual years within the period. The estimated average annual rate of change for the entire 27-year study period between 1973 and 2000 was 0.3 percent/year, which means that on average 0.3 percent (or roughly 144 km²) of the Sierra Nevada Ecoregion changed each year. However, the annual rate of change has not been constant during the 27-year study period, as shown by the estimated average annual rates for the four periods. Between 1973 and 1980 and between 1980 and 1986, change occurred at 0.1 percent/year. The annual rate of change increased to 0.3 percent/year between 1986 and 1992 and continued to increase to 0.5 percent/year between 1992 and 2000 (table 2; fig. 3).

Results show that in 2000 the Sierra Nevada Ecoregion was dominated by forest (70.1 percent), with grassland/shrubland (20.4 percent), barren (2.7 percent), nonmechanically disturbed (2.4 percent), wetland (2.2 percent), and water (1.1 percent) making up almost all the remainder of land cover (table 3). Developed, mining, agriculture, ice/snow, and mechanically disturbed classes each made up less than one percent of the region (table 3). Land-use/land-cover classes

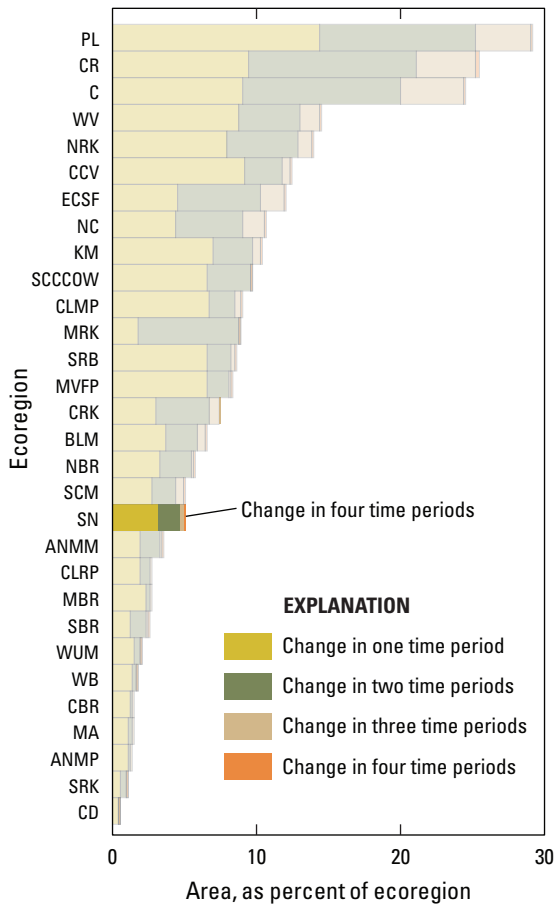


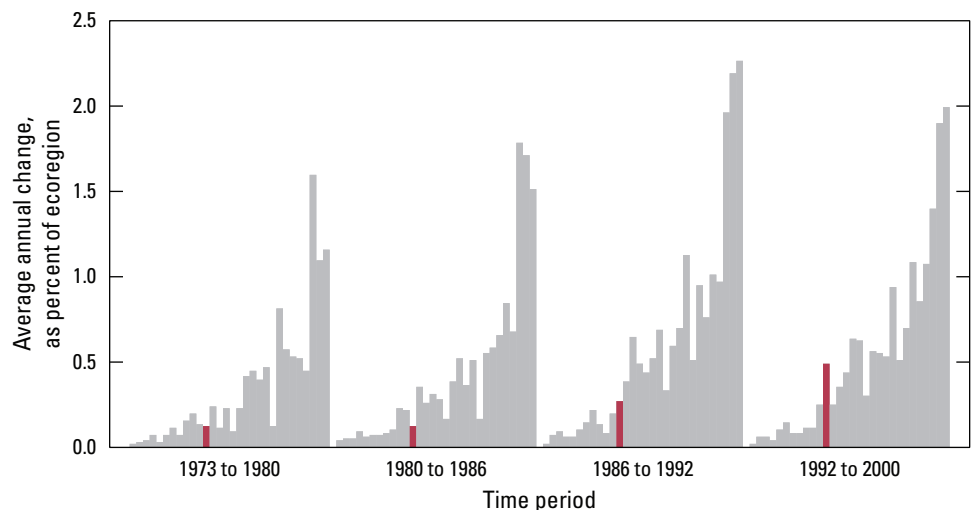
Figure 2. Overall spatial change in Sierra Nevada Ecoregion (SN; darker bars) compared with that of all 30 Western United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change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

that underwent the greatest net change (that is, total area gained minus total area lost) in relation to their area in 1973 were forest (4.7 percent decrease), grassland/shrubland (6.0 percent increase), and nonmechanically disturbed (which accounted for 0.2 percent or less of the ecoregion’s area in each year between 1973 and 1992 but increased to 2.4 percent of the classified area in 2000). Although the developed and agriculture classes each made up less than 1 percent of the Sierra Nevada Ecoregion, the developed class underwent the greatest relative increase in area (16.6 percent), and agriculture underwent the greatest relative decrease in area (5.2 percent). However, it is important to note that considerable uncertainty is associated with estimates for very rare land-cover classes.

The net change values as a percentage of ecoregion area at the beginning (1973) and end (2000) dates of the study period in table 3 show little variability and may seem to indicate stability (fig. 4). Net change values, however, often mask land-use/land-cover dynamics. For example, a class may gain 100 km² and at the same time lose 100 km², which would yield a net change of 0 km². Reporting the net change value of 0 km² misses much of the story of landscape change. However, analysis of gross change (that is, area gained and area lost) by individual land-cover classes by period shows that classes have fluctuated throughout the 27-year study period to a greater degree than net change values may indicate. Figure 5 shows that the forest, grassland/shrubland, mechanically disturbed, and nonmechanically disturbed classes were the most dynamic between 1973 and 2000. The transitional characteristic of the mechanically disturbed class is also illustrated by the fact that area gained (809 km²) nearly equals area lost (753 km²) between 1973 and 2000. Land-cover change was clearly at its peak during the period between 1992 and 2000 when gains and losses were generally greatest for the four most dynamic classes.

All individual land-cover conversions between classes were ranked by summing the total area changed during each of the four periods. Each conversion documents land changing from one class to another (for example, forest to

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 Sierra Nevada Ecoregion are represented by red bars in each time period.



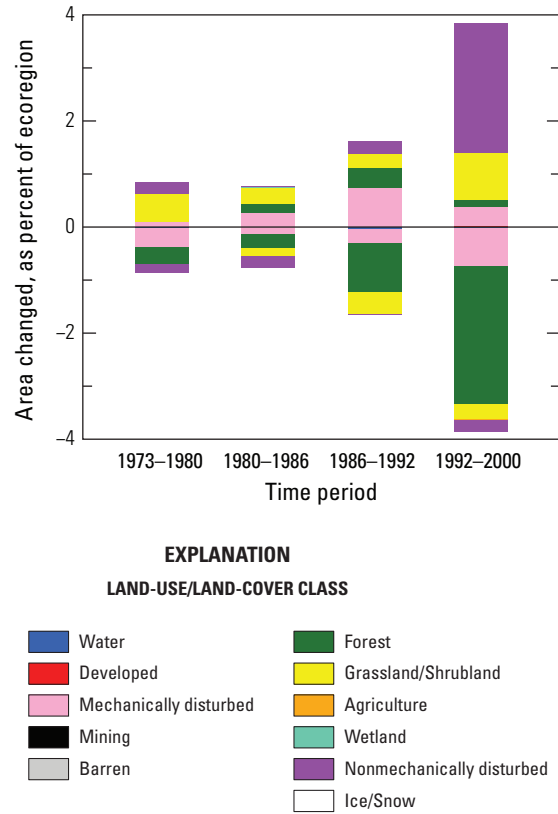
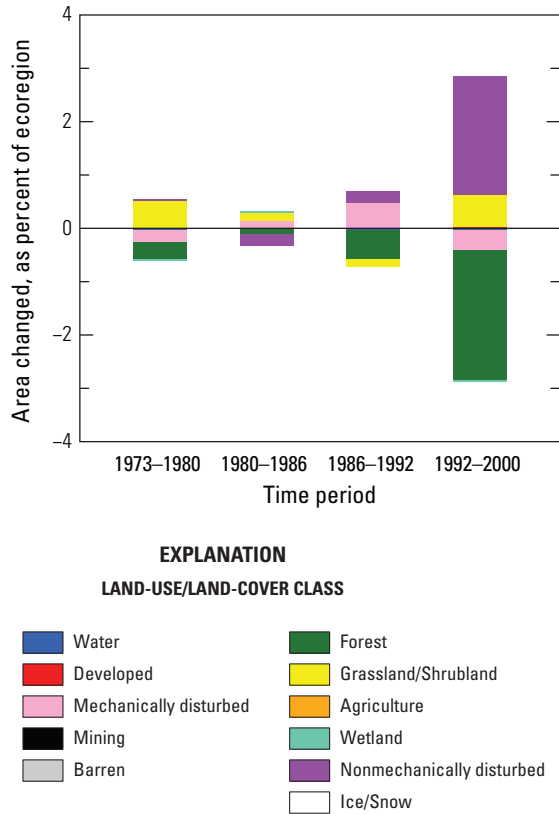


Figure 4. Normalized average net change in Sierra Nevada Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for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

Figure 5. Gross change (area gained and lost) in Sierra Nevada 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.

developed) and shows the direction of change. Table 4 shows the individual conversions ranked from greatest to least area converted. The most common individual conversions describe the disturbance of forest land by mechanical (that is, clearcuts) and nonmechanical (that is, fire) means. Overall, the most common conversion was that of 1,404 km² of forest to the nonmechanically disturbed class, which accounted for 37.1 percent of all conversions (fig. 6). The second most common conversion was that of 784 km² of forest to the mechanically disturbed class, accounting for 20.7 percent of all changes (fig. 7). Conversion of mechanically and nonmechanically disturbed land to the grassland/shrubland class (753 km² and 307 km², respectively) were the two next most common conversions and represented the process of vegetation regeneration after clearcutting or fire (fig. 8). Similarly, conversion of grassland/shrubland to forest (303 km²) represented the final stage of the regeneration cycle. A much less common but noteworthy conversion was that of water to mechanically disturbed (26 km²), which accounted for 0.7 percent of all individual conversions (fig. 9). This conversion indicates surface-level fluctuations of reservoirs in the ecoregion.

More insight can be provided by aggregating the conversions listed in table 4 to identify how a single land-use class was affected. Between 1973 and 2000, 1,540 km² of vegetation (forest, grassland/shrubland, and wetland) area was converted to the nonmechanically disturbed class. Fire caused all of these conversions, and almost all of this change (1,302 km²) took place between 1992 and 2000. Regeneration after disturbance was captured as the conversion of nonmechanically disturbed land to vegetation classes (forest and grassland/shrubland) and conversion of mechanically disturbed land to vegetation classes (forest and grassland/shrubland) for aggregated totals of 307 km² and 753 km², respectively.

The land-use/land-cover change patterns measured in the Sierra Nevada Ecoregion between 1973 and 2000 are consistent with information in the literature. Much of the clearcutting and reservoir water-level change in the region has been driven by the demand for wood, water, hydroelectricity, and recreational opportunities associated with California’s growing urban population. As for fires, many of the severe contemporary fires in the Sierra Nevada Ecoregion are likely the result of a fuel buildup caused by fire suppression activities mandated by State and Federal policies since the 1920s.



Figure 6. September 2004 appearance of area (intermediate background slopes) undergoing regeneration following Manter Fire at southern end of Sierra Nevada Ecoregion in Sequoia National Forest, Tulare County, California. Manter Fire ignited on July 22, 2000, and burned about 300 km². Land-cover types shown are forest, grassland/shrubland, and wetland.



Figure 8. Forest regeneration after seeding, Plumas National Forest, near northern end of Sierra Nevada Ecoregion. Land-cover types shown are forest and grassland/shrubland.



Figure 7. Recently clearcut area near northern end of Sierra Nevada Ecoregion in Plumas National Forest, Plumas County, California. Land-cover types shown are forest and mechanically disturbed.



Figure 9. Courtright Reservoir in Sierra National Forest, Fresno County, California, in southern part of Sierra Nevada Ecoregion, showing lowered surface levels in late summer (September 2004). Land-cover types shown are forest, barren, and mechanically disturbed (latter is due to reservoir drawdown).

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

[Most sample pixels remained unchanged (95.0 percent), whereas 5.0 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	3.1	2.5	0.6	5.6	1.7	55.1
2	1.6	0.5	1.1	2.1	0.4	22.2
3	0.3	0.3	0.0	0.5	0.2	77.6
4	0.0	0.0	0.0	0.0	0.0	90.3
Overall spatial change	5.0	2.5	2.4	7.5	1.7	34.9

Table 2. Raw estimates of change in Sierra Nevada 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	0.9	0.5	0.4	1.3	0.3	36.0	0.1
1980–1986	0.7	0.4	0.4	1.1	0.2	33.2	0.1
1986–1992	1.6	0.5	1.1	2.1	0.4	21.6	0.3
1992–2000	3.9	2.5	1.3	6.4	1.7	44.3	0.5
Estimate of change, in square kilometers							
1973–1980	454	241	213	695	164	36.0	65
1980–1986	400	196	205	596	133	33.2	67
1986–1992	868	276	592	1,144	188	21.6	145
1992–2000	2,059	1,344	715	3,404	913	44.3	257

Table 3. Estimated area (and margin of error) of each land-cover class in Sierra Nevada 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	1.1	0.5	0.2	0.3	0.4	0.3	0.1	0.2	2.7	1.5	73.5	4.6	19.2	4.0	0.3	0.4	2.2	1.2	0.2	0.0
1980	1.1	0.5	0.2	0.3	0.1	0.1	0.1	0.2	2.7	1.5	73.2	4.6	19.7	3.9	0.3	0.4	2.2	1.2	0.2	0.0
1986	1.1	0.5	0.2	0.3	0.3	0.2	0.1	0.2	2.7	1.5	73.1	4.6	19.9	3.9	0.3	0.4	2.2	1.2	0.0	0.2
1992	1.1	0.5	0.2	0.3	0.8	0.3	0.1	0.2	2.7	1.5	72.5	4.5	19.8	3.9	0.3	0.4	2.2	1.2	0.2	0.3
2000	1.1	0.5	0.3	0.3	0.4	0.2	0.1	0.2	2.7	1.5	70.1	4.6	20.4	3.8	0.3	0.4	2.2	1.2	2.4	0.1
Net change	0.0	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-3.5	2.3	1.1	0.6	0.0	0.0	0.0	0.0	2.3	0.1
Gross change	0.0	0.1	0.0	0.0	1.9	0.7	0.0	0.0	0.0	0.0	4.5	2.3	2.6	0.9	0.0	0.0	0.0	0.0	3.2	0.8
Area, in square kilometers																				
1973	612	288	127	134	191	144	73	100	1,446	799	39,274	2,477	10,259	2,143	160	223	1,176	666	84	109
1980	606	287	127	134	65	39	73	100	1,446	799	39,104	2,466	10,534	2,093	160	223	1,175	665	114	152
1986	606	287	127	134	153	89	73	100	1,446	799	39,046	2,455	10,616	2,074	160	223	1,176	666	0	1
1992	592	287	129	137	411	156	73	100	1,446	799	38,741	2,384	10,550	2,093	160	223	1,176	666	125	127
2000	586	287	148	150	215	106	73	100	1,446	799	37,427	2,477	10,872	2,043	152	212	1,176	666	1,307	1,345
Net change	-26	30	21	23	23	129	0	0	0	0	-1,847	1,241	613	319	-8	12	0	0	1,223	1,354
Gross change	26	30	21	23	1,016	368	0	0	0	0	2,412	1,249	1,367	468	8	12	3	3	1,690	1,362

Table 4. Principal land-cover conversions in Sierra Nevada 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	Mechanically disturbed	Grassland/Shrubland	191	144	98	0.4	42.1
	Forest	Nonmechanically disturbed	112	152	103	0.2	24.6
	Nonmechanically disturbed	Grassland/Shrubland	84	109	74	0.2	18.6
	Forest	Mechanically disturbed	58	38	26	0.1	12.9
	Water	Mechanically disturbed	6	9	6	0.0	1.4
	Other	Other	2	n/a	n/a	0.0	0.5
	Totals			454			0.9
1980–1986	Forest	Mechanically disturbed	146	89	60	0.3	36.5
	Nonmechanically disturbed	Grassland/Shrubland	110	152	103	0.2	27.4
	Grassland/Shrubland	Forest	81	78	53	0.2	20.3
	Mechanically disturbed	Grassland/Shrubland	54	37	25	0.1	13.5
	Mechanically disturbed	Forest	4	6	4	0.0	1.0
	Other	Other	4	n/a	n/a	0.0	1.1
Totals			400			0.7	100.0
1986–1992	Forest	Mechanically disturbed	391	154	105	0.7	45.1
	Grassland/Shrubland	Forest	190	171	116	0.4	21.9
	Mechanically disturbed	Grassland/Shrubland	146	89	60	0.3	16.8
	Forest	Nonmechanically disturbed	102	96	65	0.2	11.8
	Grassland/Shrubland	Nonmechanically disturbed	23	32	22	0.0	2.6
	Other	Other	16	n/a	n/a	0.0	1.8
Totals			868			1.6	100.0
1992–2000	Forest	Nonmechanically disturbed	1,190	1,230	835	2.2	57.8
	Mechanically disturbed	Grassland/Shrubland	361	135	92	0.7	17.6
	Forest	Mechanically disturbed	188	104	71	0.4	9.1
	Nonmechanically disturbed	Grassland/Shrubland	112	119	81	0.2	5.4
	Grassland/Shrubland	Nonmechanically disturbed	112	116	79	0.2	5.4
	Other	Other	96	n/a	n/a	0.2	4.7
Totals			2,059			3.9	100.0
1973–2000 (overall)	Forest	Nonmechanically disturbed	1,404	1,244	845	2.6	37.1
	Forest	Mechanically disturbed	784	299	203	1.5	20.7
	Mechanically disturbed	Grassland/Shrubland	753	323	219	1.4	19.9
	Nonmechanically disturbed	Grassland/Shrubland	307	214	145	0.6	8.1
	Grassland/Shrubland	Forest	303	195	132	0.6	8.0
	Other	Other	231	n/a	n/a	0.4	6.1
Totals			3,782			7.1	100.0

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