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
U.S. Geological Survey Professional Paper 1794–A, 2012

Chapter 8
Southern Rockies Ecoregion

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Ecoregion Description

The Southern Rockies Ecoregion is a high-elevation mountainous ecoregion that covers approximately 138,854 km^2 (53,612 mi^2), including much of central Colorado and parts of southern Wyoming and northern New Mexico (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). It abuts six other ecoregions: the Wyoming Basin and Colorado Plateaus Ecoregions on the north and west, the Arizona/New Mexico Plateau Ecoregion on the south, and the Northwestern Great Plains, Western High Plains, and Southwestern Tablelands Ecoregions on the east (fig. 1). The ecoregion receives most of its annual precipitation (25–100 cm) as snowfall, which provides a significant amount of high-elevation snowpack that is an important water source for surrounding ecoregions. The Southern Rockies Ecoregion has a steep elevation gradient from low foothills to high peaks, with several hundred summits higher than 3,660 m (12,000 ft). As a southern extension of the larger Rocky Mountain system, it is composed primarily of seven main north-south trending mountain ranges that are separated by four large intermontane basins. A fifth basin, the San Luis Valley, is outside the ecoregion, forming a northern finger of the Arizona/New Mexico Plateau Ecoregion that lies mostly to the south. To the east, late Tertiary sand and gravel deposits that were eroded from the relatively young Rocky Mountains were carried eastward by streams, forming the nearby Western High Plains Ecoregion and its underlying Ogallala aquifer.

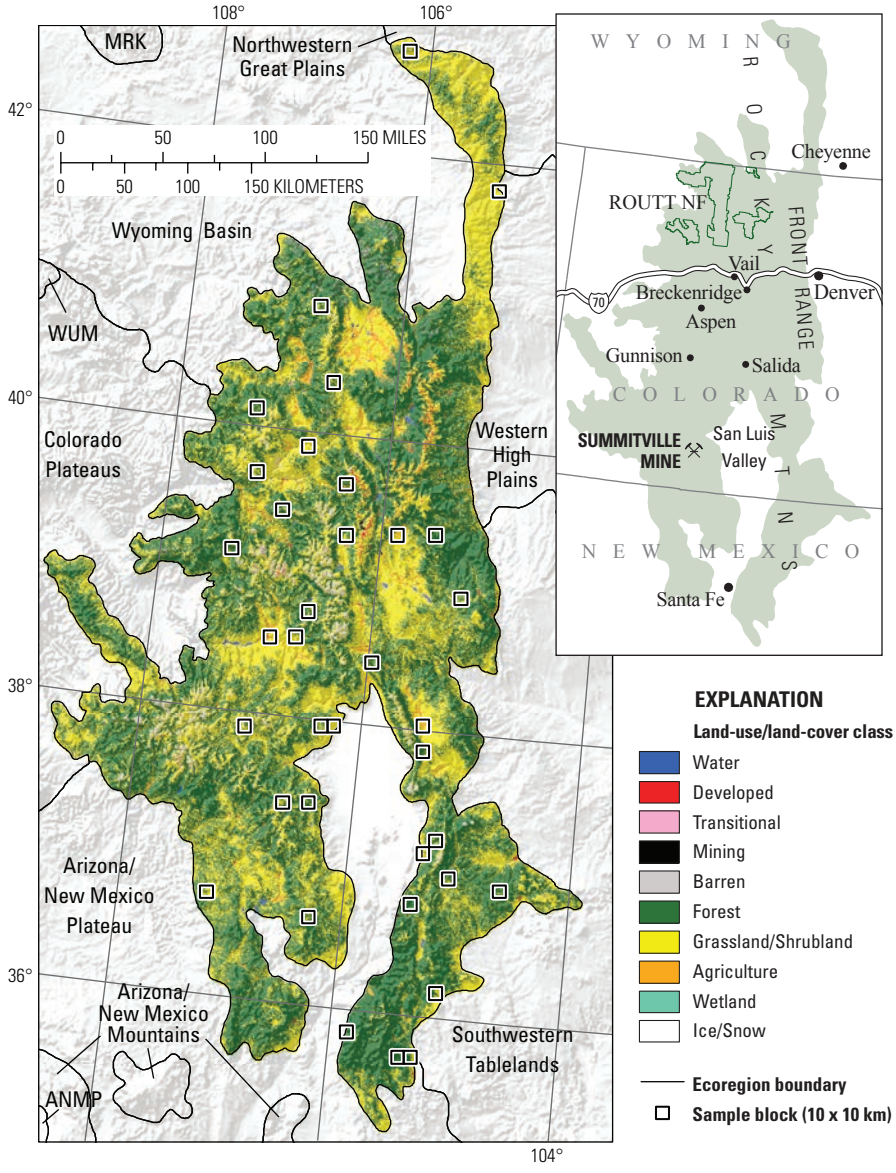

Figure 1. Map of Southern Rockies Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and 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. Also shown on map are three Great Plains ecoregions: Northwestern Great Plains, Western High Plains, and Southwestern Tablelands. See appendix 3 for definitions of land-use/land-cover classifications.

Approximately 56 percent of the ecoregion is forested in a heterogeneous pattern, whereas grassland/shrubland cover makes up nearly 38 percent of the total area (table 1). There are many forest types, including the more prevalent spruce-fir (*Picea* spp. and *Abies* spp.), ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), aspen (*Populus tremuloides*), and pinyon-juniper (*Pinus edulis* and *Juniperus scopulorum*, *monosperma*, and *osteosperma*) types. Vegetation patterns correspond with the steep elevation gradient. In general, grassland and shrubland covers the lower elevation valleys and intermontane basins. Sagebrush (*Artemisia tridentata*), oak (*Quercus* spp.), pinyon-juniper woodland, and blue grama grass (*Bouteloua gracilis*) are common at lower elevations, which range from 1,828 to 2,438 m (Chapman and others, 2006). Ponderosa pine, aspen, juniper, and oak are common at middle elevations. The higher elevation subalpine forests are often dense, consisting of Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). High-elevation alpine zones are above the tree line and support a variety of low shrubs, wildflowers, krummholz (stunted trees), and other vegetation interspersed with exposed rocks, peaks, and permanent snowfields.

Many of the forest systems are heavily influenced by disturbances, particularly those caused by fire and insects, but high winds, avalanches, and disease are also factors. Forests of lodgepole pine, ponderosa pine, and aspen have all been affected by frequent low-intensity fires (Buskirk and others 2000). The low-intensity fire regimes have been altered by historical land-management practices of fire exclusion and suppression, contributing to higher density, even-aged forest stands as well as high-intensity, stand-replacing fires from the resulting heavy fuel loads. Substantial areas of western North American coniferous forest have been affected since 2000 by bark beetle (*Dendroctonus* spp., *Ips* spp., and *Dryocoetes confusus*) outbreaks related to climate variability and change (fig. 2). Drought and warming amplify the effects of insect outbreaks and also cause additional tree mortality and forest dieback (Breshears and others, 2005; van Mantgem and others, 2009). Atmospheric warming and precipitation changes may have a significant effect on the future elevations of upper and lower tree lines. Blowdown events can be substantial—high winds downed an 80-km^2 area of spruce trees in the Routt National Forest in 1997 (Neely and others, 2001).

The human population of the Rocky Mountains is growing three times faster than the national rate (Baron and others, 2000). Despite the high rate of population growth, the Southern Rockies Ecoregion had no towns of more than 15,000 people during the study period. The permanent populations of many of the larger towns range from 3,000 to 6,000 people, including the more agriculturally inclined cities of Gunnison and Salida in central Colorado, as well as the ski towns of Breckenridge, Vail, and Aspen, Colorado. Besides the permanent population, many amenity-rich areas have a significantly higher seasonal population. Breckenridge had 2,366 permanent residents in 2000, but of the 4,229 total housing units, 3,166 were vacant, primarily because of seasonal use patterns

Figure 2. Example of beetle-killed trees (with brown needles) in central Colorado.

Figure 3. Valley development along Interstate 70 corridor near Vail, Colorado.

(U.S. Census Bureau, 2000). Several large cities, including Denver, Colorado, and other Front Range communities lie just outside this ecoregion, and their suburbs and other exurban development has spread into the Southern Rockies Ecoregion. The Interstate 70 corridor that cuts across Colorado is also a central locus of new residential, commercial, and economic development, although growth and tourism reach many rural communities as well.

The steep elevation gradient is important to land-use and land-ownership patterns. Large tracts of high-elevation forest and wilderness are publically owned, whereas many of the small towns characteristic of the ecoregion are located in the valleys and near riparian zones (fig. 3). Approximately 40 percent of the region is privately owned, and 60 percent is managed as public land. More than 80 percent of the public land is managed by the U.S. Forest Service. The numerous amenity-rich rural areas and recreation opportunities, including national parks and monuments, other public lands, and ski resorts, play a role in attracting new development, tourism,

and regional population growth. Land-use changes in the valley bottoms, which are often disproportionately rich in habitat diversity, can affect wildlife and habitat connectivity when grasslands, shrublands, and riparian areas are lost or fragmented by development (Theobald and others, 1996). Similarly, the subdivision of valley ranches into smaller "ranchette" developments is a concern for biodiversity (Mitchell and others, 2002; Theobald and others, 1996). Land-cover changes also occur as residential development spreads into nearby forest edges (fig. 4).

Timber harvesting in the Rocky Mountain region accounts for approximately 5 percent of the national total (Darr, 1995). In the Southern Rockies Ecoregion, forest regeneration after clearcutting is slow compared to many other United States ecoregions because of the shorter growing season and relatively dry climate. This makes the ecoregion less attractive for large-scale industrial silviculture, although the recent forest die-off may cause an increase in timber clearance. Reservoir construction also affects the ecoregion, particularly as agricultural land uses and cities along the drier Front Range require an increasing reliable supply of water. Agriculture in the Southern Rockies Ecoregion is primarily related to livestock grazing (fig. 5), which occurs on both private and public lands, and hay production (fig. 6). Abandoned or reclaimed precious metal mines are a relatively common feature (fig. 7).

Contemporary Land-Cover Change (1973 to 2000)

Land-cover changes between 1973 and 2000 were very low (fig. 8), with no net or gross changes greater than 1.0 percent of ecoregion area for any time period or land-cover class (table 1). Net forest land declined by an estimated 0.6 percent (452 km^2), which is the highest amount of net change in absolute terms (fig. 9). Forest land also had a relatively

Figure 4. Exurban development near Colorado's western slope.

Figure 5. Cattle and maintained pasture in south-central Colorado.

Figure 6. Hay field with aspen and coniferous forest in background in Southern Rockies Ecoregion.

Figure 7. Summitville Mine Superfund Site in southern part of Colorado.

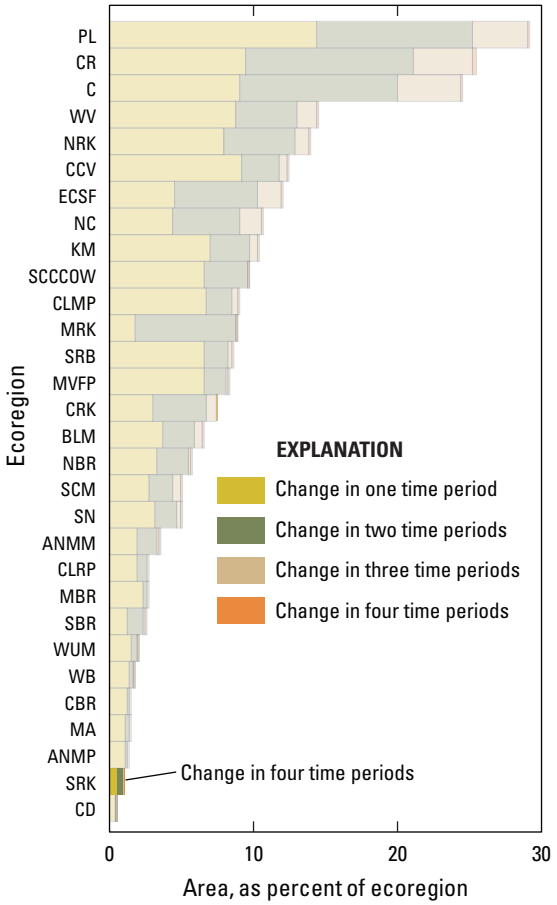

Figure 8. Overall spatial change in Southern Rockies Ecoregion (SRK; darker bars) compared with that of all 30 Western United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Southern Rockies Ecoregion (four time periods) labeled for clarity. See table 4 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

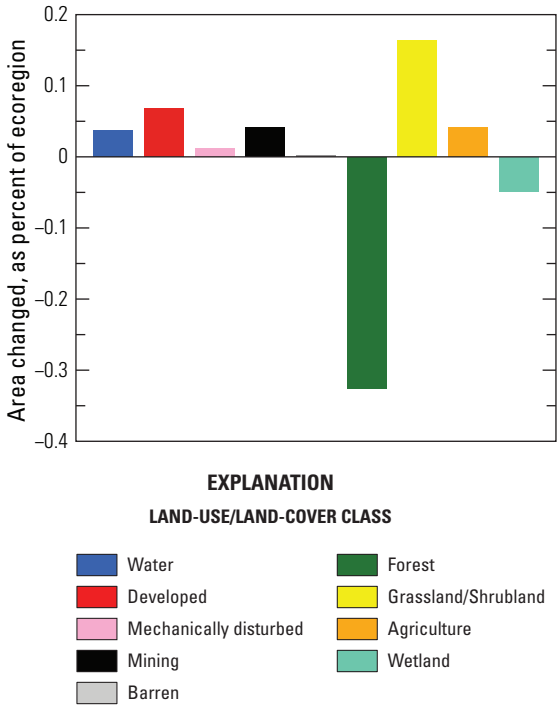

Figure 9. Estimates of net land-cover change in Southern Rockies Ecoregion for each land-cover class between 1973 and 2000. Bars above zero axis represent net gain, whereas bars below zero represent net loss. See appendix 3 for definitions of land-use/land-cover classifications.

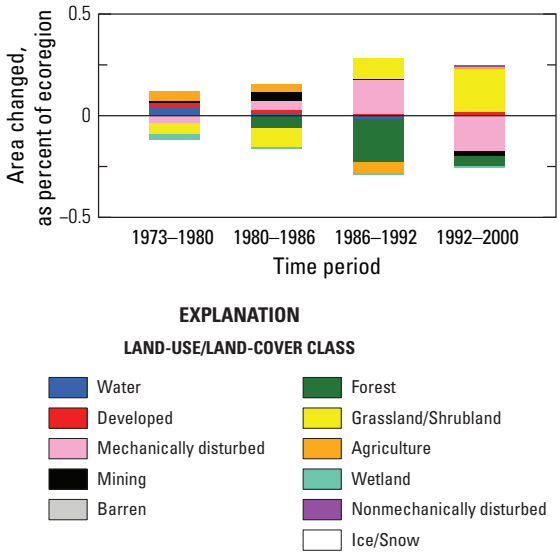

Figure 10. Normalized average net change in Southern Rockies Ecoregion by time period for each land cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use/land-cover classifications.

high level of gross change (684 km^2), in comparison to the other land-cover types. Grassland/shrubland and mechanically disturbed land had the highest gross changes, at 1,021 km^2 and 848 km^2, respectively.

The declines in forest resulted from mechanical disturbance (table 2), which is caused primarily by clearcutting and other timber harvest practices. A smaller amount of forest recovered from mechanical disturbance during the study period, indicating the slow recovery of those forests. Most of the reforestation occurred from an intermediate cover of grassland/shrubland that followed mechanical disturbance. Additional forest land was lost to mining and developed land. The largest extent of forest loss, 299 km^2, occurred between 1986 and 1992 (fig. 10).

The gross changes in grassland/shrubland were related to mechanical disturbance of forest that caused an intermediate stage of vegetated land cover. Switches between

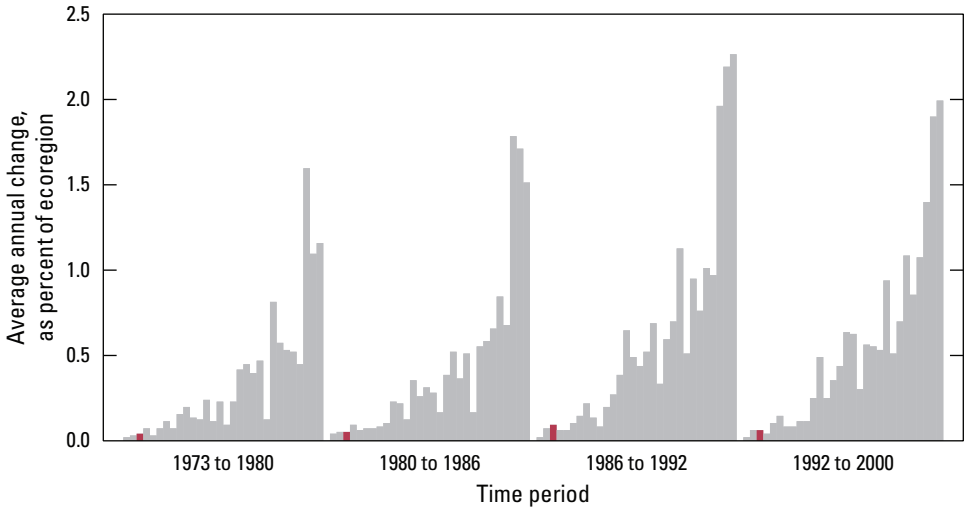

Figure 11. Estimates of land-cover change per time period, normalized to annual rates of change for all 30 Western United States ecoregions (gray bars). Estimates of change for Southern Rockies Ecoregion are represented by red bars in each time period.

grassland/shrubland and agriculture also caused gross change, but these resulted in only a small amount of agricultural expansion (59 km^2). Gains in agriculture between 1973 and 1980 and between 1980 and 1986 were offset somewhat by conversion to grassland/shrubland between 1986 and 1992, when the Conservation Reserve Program (CRP) may have had an impact. The CRP, enacted by Congress in 1985, pays farmers to take marginal cropland out of production and return it to a seminatural grassland condition. Switches between grassland/shrubland and mining, which occur as mining areas expand and are eventually able to recover to vegetated land cover, resulted in minor losses to mining. Development expanded into some grassland/shrubland areas.

The two most common types of land conversion involved mechanical disturbance. Forest to mechanically disturbed, discussed above, was the most common conversion (518 km^2), followed by mechanically disturbed to grassland/shrubland (462 km^2). Because this a transitional land cover, it experienced little net change and a high rate of gross change, which affected 0.6 percent of ecoregion area.

Developed land increased by only 13 percent during the study period but still occupied only 0.6 percent of the ecoregion. The remaining land-cover types had negligible amounts of net change.

Overall, only 1.0 percent of the ecoregion's land cover changed between 1973 and 2000 (table 3). The rates of change during each time period were consistently low (table 4; fig. 11). Compared to other western United States ecoregions, change in the Southern Rockies Ecoregion was very low (fig. 8). Relatively small amounts of change, combined with some variability in the rates of change between the 36 sample sites, resulted in high margins of error. More than one-third of the sample blocks had no change or negligible change during all time periods, which is reflective of a large amount of relatively stable land use. This contrasts with the much smaller area undergoing intense land conversion, such as development in valleys and the suburban and exurban growth associated with the Front Range urban corridor and Interstate 70.

Land use in the West is often cited as undergoing a conversion from a resource-extraction economy to one that is increasingly based on service and technical industries. This is accompanied by population expansion, as technology allows telecommuting and a move towards amenity-rich mountain areas. The change analysis does not target the specific locations where the much-discussed amenity-driven land conversion occurs. However, it does provide a regional overview of land-cover change that reflects the large expanses of land in public ownership, whereas other case studies provide an in-depth understanding of the intensive local-scale changes.

Since 2000, the Southern Rockies Ecoregion has also undergone a substantial amount of forest change. Significant areas of forest are affected by insect outbreaks and the amplifying effects of drought and climate warming. This will likely have a host of consequences affecting fire regimes, logging, carbon sequestration, hydrology, ecosystem function, and tourism.

Table 1. Estimated area (and margin of error) of each land-cover class in Southern Rockies 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	0.1	0.1	0.5	0.4	0.1	0.0	0.1	0.0	1.1	0.6	56.3	6.4	37.5	5.4	2.8	1.7	1.4	1.0	0.0	0.0
1980	0.2	0.1	0.6	0.5	0.0	0.0	0.1	0.0	1.1	0.6	56.3	6.4	37.5	5.4	2.8	1.8	1.4	1.0	0.0	0.0
1986	0.2	0.1	0.6	0.5	0.1	0.0	0.1	0.1	1.1	0.6	56.3	6.4	37.4	5.4	2.9	1.8	1.4	1.0	0.0	0.0
1992	0.2	0.1	0.6	0.5	0.2	0.2	0.1	0.1	1.1	0.6	56.1	6.3	37.5	5.4	2.8	1.7	1.4	1.0	0.0	0.0
2000	0.2	0.1	0.6	0.5	0.1	0.0	0.1	0.1	1.1	0.6	56.0	6.3	37.7	5.3	2.8	1.7	1.4	1.0	0.0	0.0
Net change	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	−0.3	0.2	0.2	0.2	0.0	0.1	0.0	0.0	0.0	0.0
Gross change	0.1	0.1	0.1	0.1	0.6	0.4	0.1	0.1	0.0	0.0	0.5	0.2	0.7	0.3	0.3	0.2	0.1	0.0	0.0	0.0
Area, in square kilometers																				
1973	197	137	731	599	71	55	77	56	1,528	826	78,228	8,857	52,120	7,490	3,887	2,410	1,983	1,349	0	0
1980	244	161	771	627	28	18	88	66	1,529	826	78,221	8,857	52,046	7,481	3,955	2,487	1,940	1,347	0	0
1986	260	166	791	640	95	60	157	138	1,528	826	78,138	8,840	51,919	7,467	4,005	2,491	1,929	1,347	0	0
1992	241	159	805	642	331	248	169	160	1,529	826	77,839	8,763	52,055	7,464	3,936	2,394	1,917	1,347	0	0
2000	249	162	826	646	89	64	137	121	1,529	826	77,776	8,753	52,350	7,388	3,946	2,375	1,915	1,347	4	5
Net change	52	50	94	70	18	87	61	69	1	1	−452	286	230	308	59	102	−68	58	4	5
Gross change	102	80	94	70	848	491	132	149	2	2	684	313	1,021	374	367	249	94	64	4	5

Table 2. Principal land-cover conversions in Southern Rockies 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	Grassland/Shrubland	Agriculture	81	90	61	0.1	24.1
	Mechanically disturbed	Water	42	45	31	0.0	12.4
	Grassland/Shrubland	Forest	33	18	12	0.0	9.9
	Mechanically disturbed	Grassland/Shrubland	29	33	23	0.0	8.6
	Forest	Mechanically disturbed	28	18	12	0.0	8.2
	Other	Other	124	n/a	n/a	0.1	36.8
		Totals	336			0.2	100.0
1980–1986	Forest	Mechanically disturbed	90	61	41	0.1	23.5
	Grassland/Shrubland	Agriculture	77	69	47	0.1	20.3
	Grassland/Shrubland	Mining	41	42	29	0.0	10.9
	Grassland/Shrubland	Forest	38	26	18	0.0	10.0
	Mechanically disturbed	Grassland/Shrubland	28	18	12	0.0	7.2
	Other	Other	107	n/a	n/a	0.1	28.1
		Totals	381			0.3	100.0
1986–1992	Forest	Mechanically disturbed	319	248	169	0.2	44.9
	Mechanically disturbed	Grassland/Shrubland	94	60	41	0.1	13.3
	Agriculture	Grassland/Shrubland	93	116	79	0.1	13.1
	Grassland/Shrubland	Forest	58	44	30	0.0	8.1
	Forest	Mining	21	31	21	0.0	3.0
	Other	Other	125	n/a	n/a	0.1	17.7
		Totals	711			0.5	100.0
1992–2000	Mechanically disturbed	Grassland/Shrubland	311	246	167	0.2	50.0
	Forest	Mechanically disturbed	82	64	43	0.1	13.1
	Grassland/Shrubland	Agriculture	46	29	19	0.0	7.5
	Agriculture	Grassland/Shrubland	39	31	21	0.0	6.3
	Mining	Grassland/Shrubland	37	40	27	0.0	5.9
	Other	Other	107	n/a	n/a	0.1	17.3
		Totals	622			0.4	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	518	295	201	0.4	25.3
	Mechanically disturbed	Grassland/Shrubland	462	285	194	0.3	22.5
	Grassland/Shrubland	Agriculture	223	133	90	0.2	10.9
	Agriculture	Grassland/Shrubland	162	148	100	0.1	7.9
	Grassland/Shrubland	Forest	150	74	50	0.1	7.3
	Other	Other	536	n/a	n/a	0.4	26.1
		Totals	2,051			1.5	100.0

Table 3. Percentage of Southern Rockies Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (99.0 percent), whereas 1.0 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	0.6	0.2	0.4	0.8	0.1	22.4
2	0.4	0.2	0.2	0.6	0.1	35.2
3	0.0	0.0	0.0	0.0	0.0	62.5
4	0.0	0.0	0.0	0.0	0.0	98.7
Overall spatial change	1.0	0.3	0.7	1.4	0.2	20.3

Table 4. Raw estimates of change in Southern Rockies 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	0.2	0.1	0.1	0.3	0.1	26.2	0.0
1980–1986	0.3	0.1	0.2	0.4	0.1	25.3	0.0
1986–1992	0.5	0.2	0.3	0.7	0.2	29.5	0.1
1992–2000	0.4	0.2	0.3	0.6	0.1	29.1	0.1
Estimate of change, in square kilometers							
1973–1980	336	129	207	466	88	26.2	48
1980–1986	381	142	239	523	96	25.3	64
1986–1992	711	309	402	1,019	210	29.5	118
1992–2000	622	267	356	889	181	29.1	78

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