Cold Deserts 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 20

Central Basin and Range Ecoregion

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This chapter has been modified from original material published in Soulard (2006), entitled “Land-cover trends of the Central Basin and Range Ecoregion” (U.S. Geological Survey Scientific Investigations Report 2006–5288).

Ecoregion Description

The Central Basin and Range Ecoregion (Omernik, 1987; U.S. Environmental Protection Agency, 1997) encompasses approximately 343,169 km² (132,498 mi²) of land bordered on the west by the Sierra Nevada Ecoregion, on the east by the Wasatch and Uinta Mountains Ecoregion, on the north by the Northern Basin and Range and the Snake River Basin Ecoregions, and on the south by the Mojave Basin and Range and the Colorado Plateaus Ecoregions (fig. 1). Most of the Central Basin and Range Ecoregion is located in Nevada (65.4 percent) and Utah (25.1 percent), but small segments are also located in Idaho (5.6 percent), California (3.7 percent), and Oregon (0.2 percent). Basin-and-range topography characterizes the Central Basin and Range Ecoregion: wide desert valleys are bordered by parallel mountain ranges generally oriented north-south. There are more than 33 peaks within the Central Basin and Range Ecoregion that have summits higher than 3,000 m

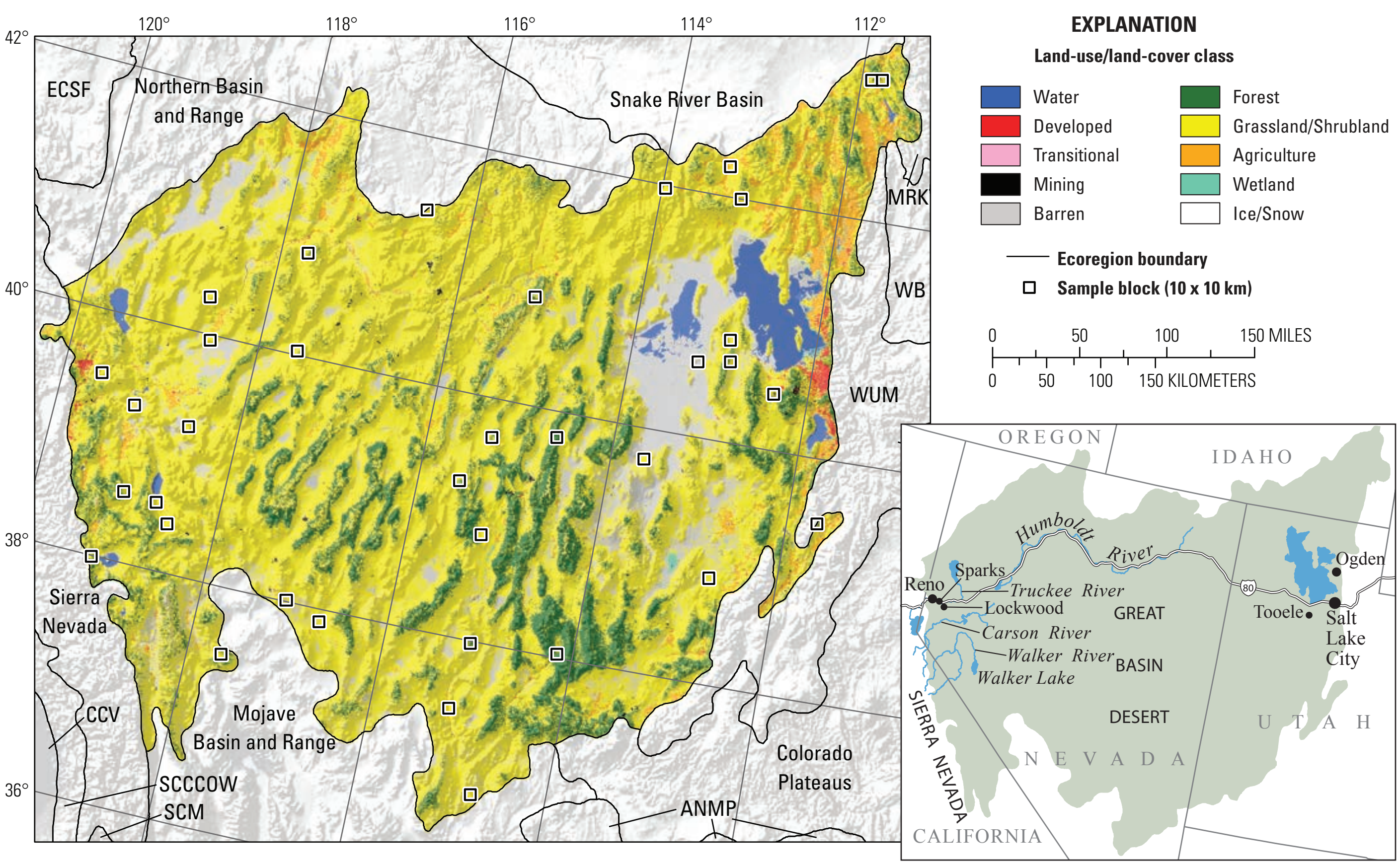

Figure 1. Map of Central Basin and Range Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this “Status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

(10,000 ft), but valleys in the ecoregion are also high, most having elevations above 1,200 m (4,000 ft) (Grayson, 1993).

The Central Basin and Range Ecoregion's high elevation and location between mountain ranges influences regional climate. The Sierra Nevada to the west produces a rain shadow effect that blocks moisture from the Pacific Ocean, and the Rocky Mountains to the east creates a barrier effect that restricts moisture from the Gulf of Mexico (Rogers, 1982). This lack of moisture creates the Great Basin Desert (encompassed within the Central Basin and Range Ecoregion), which is one of the four biologically distinct deserts in North America, along with the Mojave, Sonoran, and Chihuahuan Deserts (Grayson, 1993). The Great Basin has the coldest climate of these deserts. As opposed to the other North American deserts, precipitation within the Great Basin regularly falls in winter as snow (Mac and others, 1998). Because no natural drainages exist within the Central Basin and Range Ecoregion, the little precipitation that does fall either drains to ephemeral or saline lakes by means of streams or disappears through evaporation and (or) absorption into the soil (Grayson, 1993).

Inhospitable conditions, such as harsh climate, infertile soils, and lack of viable resources, have been a formidable barrier to human land use in the Central Basin and Range Ecoregion. These conditions also restrict ecoregion resilience, which results in lasting impacts from most land-use practices. This ecoregion is very sensitive to those land-use changes that do occur (Mac and others, 1998; Pellant and others, 2004; Chambers and Miller, 2004). Much as with the historical land-use legacies of the ecoregion, factors that have driven contemporary change in the ecoregion have the potential to produce long-term consequences. For example, the poor soil quality and low rainfall characteristic of the ecoregion make successful farming difficult. As a way to overcome these obstacles, farmers either establish irrigation-dependent crops near rare riparian segments or rely on groundwater pumping and water diversions. Water diversions from the Carson, Humboldt, Truckee, and Walker Rivers have shifted to accommodate irrigation demand (particularly to support the ranching industry), municipal-water demand in regional cities (for example, Reno, Nevada), and government-mandated water conservation. Shifts in agricultural land use across the Central Basin and Range Ecoregion degrade ecosystems vital to the fitness of many vertebrates and invertebrates. This degradation is manifested as livestock trampling of native vegetation (in wetlands and grasslands) and lowered water tables in places like Walker Lake (Mac and others, 1998).

The arid climate and abundance of dry fuel sources also make the ecoregion naturally susceptible to fire. This susceptibility has been magnified since European settlement in the late 1800s. Early settlers changed the composition of grasslands and shrublands by introducing livestock grazing and fire-suppression practices within the sagebrush-dominated landscape. Grazing and fire suppression have continued to the present day and have shaped the grassland/shrubland landscape by degrading sagebrush plant communities and enabling nonnative annual grasses to invade much of the ecoregion (Miller and others, 2001). These grasses, most notably cheatgrass (*Bromus tectorum*), not only contribute to a rise in fire susceptibility across the ecoregion by increasing dry fuel sources but also reestablish themselves more easily than native plants following fires, thereby perpetuating and magnifying the cycle of fires (Pellant and others, 2004). Historical and contemporary land-use practices have produced lasting impacts in the Central Basin and Range Ecoregion by changing the fire regime and making the ecoregion more susceptible to fire. The increased probability of fire poses long-term risks for human and natural systems.

Contemporary Land-Cover Change (1973 to 2000)

Land-use/land-cover change between 1973 and 2000 that was discernable using a 60-m mapping unit was minimal, especially when compared to other ecoregions of the western

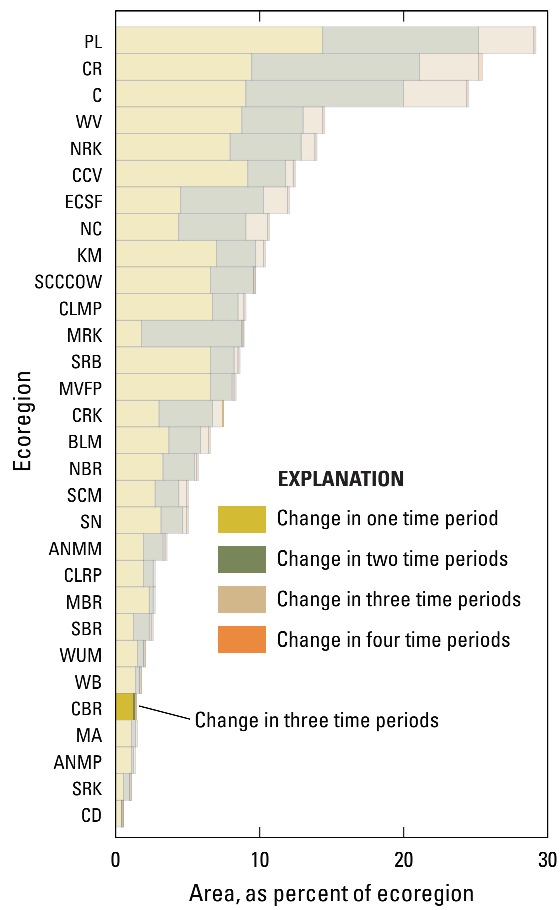

Figure 2. Overall spatial change in Central Basin and Range Ecoregion (CBR; darker bars) compared with that of all 30 Western United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of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

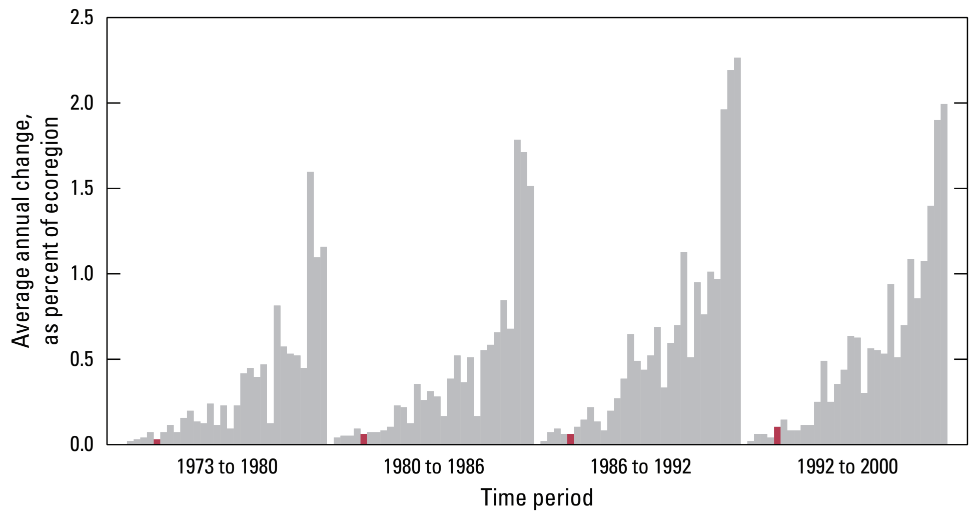

Figure 3. Estimates of land-cover change per time period, normalized to annual rates of change for all 30 Western United States ecoregions (gray bars). Estimates of change for Central Basin and Range Ecoregion are represented by red bars in each time period.

United States (fig. 2). Between 1973 and 2000, the footprint (overall areal extent) of land-cover change in the Central Basin and Range Ecoregion was only 1.5 percent, or 4,979 km². The footprint of change can be interpreted as the area in the Central Basin and Range Ecoregion that experienced change during at least one of the four multiyear periods that make up the 27-year study period; it does not account for the frequency of change in any given location. This overall spatial change translates to 4,461 km² that changed in one period, 343 km² that changed in two periods, and 166 km² that changed in three periods (table 1).

The normalized annual rate of land-cover change in the Central Basin and Range Ecoregion between 1973 and 2000 was less than 0.1 percent per year. This means that the ecoregion averaged less than 0.1 percent (206 km²) of change each year in the 27-year study period. Between 1973 and 1980, the annual rate of change in the Central Basin and Range Ecoregion was less than 0.1 percent per year, while the annual rate of change increased to about 0.1 percent per year between 1980 and 1986, 1986 and 1992, and 1992 and 2000 (table 2; fig. 3).

Of the 11 land-use/land-cover classes, 4 dominated the landscape of the Central Basin and Range Ecoregion in 2000: grassland/shrubland (75.4 percent), forest (15.3 percent), barren (3.9 percent), and agriculture (2.9 percent). The remaining seven classes cumulatively made up the remaining 2.5 percent of the Central Basin and Range Ecoregion landscape in 2000 (table 3).

Between 1973 and 2000, the land-cover classes that experienced a measurable net change include grassland/shrubland (0.8 percent decrease), forest (1.9 percent decrease), developed (43 percent increase), wetland (12.2 percent decrease), mining (159 percent increase, but still representing just 0.2 percent of the ecoregion), and nonmechanically disturbed (which was not present until the 2000 classification, when it occupied 0.5 percent of the sampled area). Net change by temporal period is illustrated in figure 4.

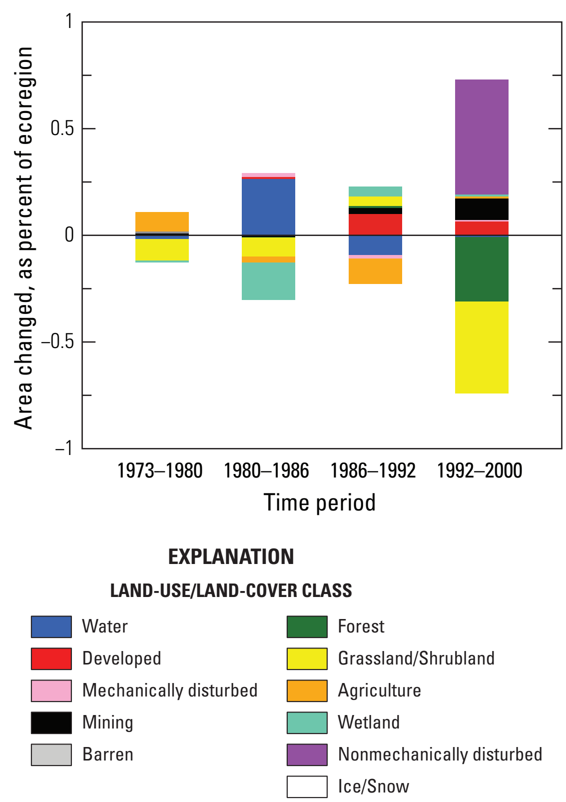

Figure 4. Normalized average net change in Central Basin and Range Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 2 for definitions of land-use/land-cover classifications.

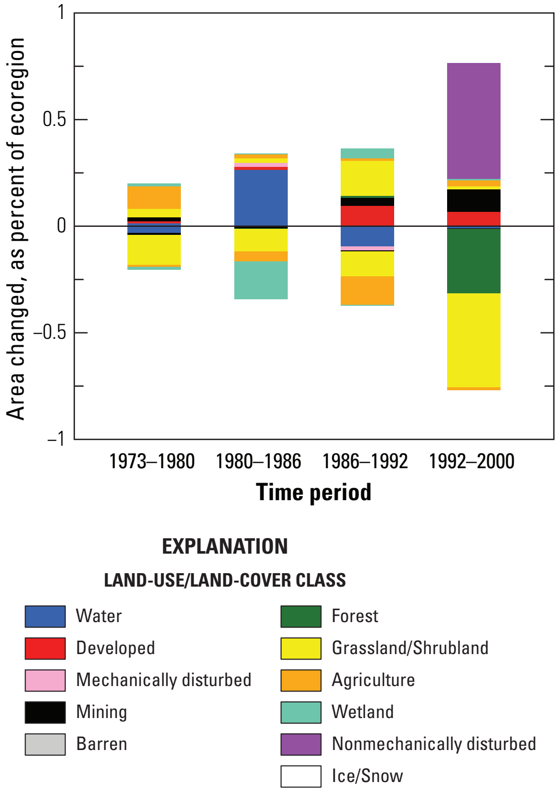

Figure 5. Gross change (area gained and lost) in Central Basin and Range Ecoregion by time period for each land-cover class. Area gained is shown by positive values, and area lost is shown by negative values. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 2 for definitions of land-use/land-cover classifications.

Figure 6. Instances of agriculture in Central Basin and Range Ecoregion. *A*, Livestock grazing on rangeland. *B*, Irrigated fields growing livestock feed.

Net change, however, is not necessarily the best indicator of within-class variability for those classes experiencing spatio-temporal fluctuations (fig. 5). For instance, areas classified as water fluctuated wildly between 259 km^2 (1980) and 1,168 km^2 (1986) because of the ephemeral nature of desert lakes. Between 1973 and 2000, a net areal gain of 172 percent (518 km^2) in water was measured, but gross change over the entire study period reached 1,420 km^2, nearly five times the area that water occupied in 1973.

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 for each individual time period and also between 1973 and 2000. Although fieldwork confirmed the presence of many of the conversions listed in table 4, the ability to report these changes on the basis of interpretations was accomplished with varying degrees of uncertainty (as illustrated by the statistical error values in the table). In general, higher uncertainty arose where sampled changes were clustered within certain parts of the ecoregion rather than distributed evenly across the ecoregion.

The two most prominent conversions reflect the natural, or nonmechanical, disturbance of natural land cover by fire. Cumulatively, the effect of nonmechanical disturbance on grassland/shrubland and forest resulted in 1,872 km^2 (32.5 percent of all changes) loss of vegetated land cover. As discussed earlier, the increase in fire seen within the Central Basin and Range Ecoregion is largely attributable to the invasion of annual grasses like cheatgrass (*Bromus tectorum*), which has increased dry fuels on the landscape. The changes in the agriculture and water classes represent other common conversions. Prominent changes in agricultural lands include 527 km^2 of conversion from grassland/shrubland to agriculture and 503 km^2 from agriculture to grassland/shrubland (fig. 3). Similarly, the water class experienced a variety of conversions within the Central Basin and Range Ecoregion, including 640 km^2 from wetland to water, 255 km^2 from water to grassland/shrubland, 222 km^2 from grassland/shrubland to water, and 178 km^2 from water to wetland (note that water conversions account for changes in both natural and manmade water bodies). Ultimately, these land-use dynamics vary across the ecoregion and, as noted earlier, are associated with irrigation demand (to support the ranching industry), municipal-water demand in cities (for

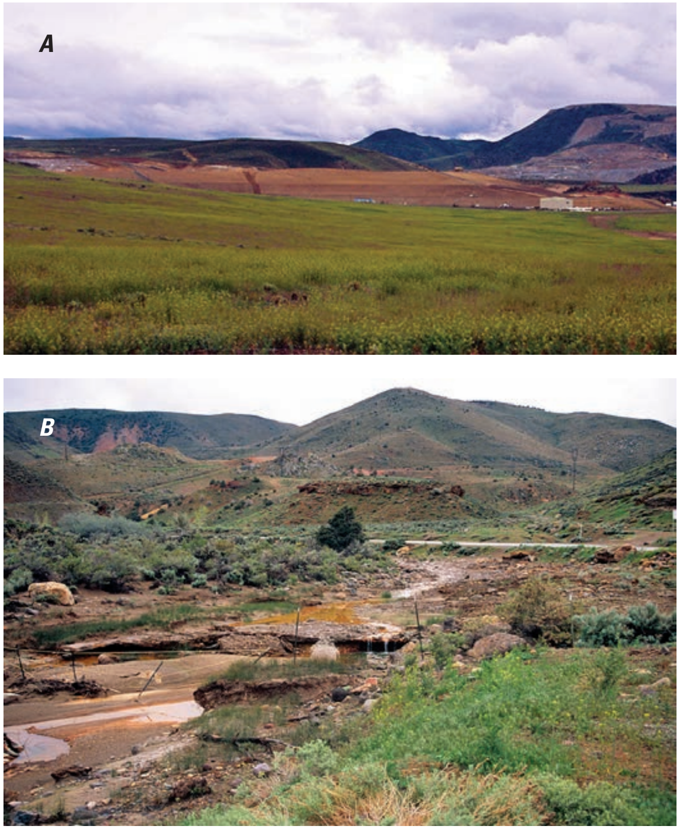

Figure 7. Hillside municipal-waste facility (*A*) and its downhill stream drainage (*B*) near Lockwood, Nevada.

example, Reno, Nevada), and government-mandated water conservation. Changes from grassland/shrubland to both developed (538 km²) and mining (526 km²) were predominantly unidirectional and permanent (figs. 6,7,8).

Contemporary land-use/land-cover change has been minimal throughout the Central Basin and Range Ecoregion. However, landscape changes that result from increased fire frequency, rising demand for water and mineral resources, and growing highway development can have far-reaching consequences despite the small spatial extent of change. For example, increased fire frequency in the Central Basin and Range Ecoregion has ultimately contributed to the loss of sagebrush plant communities in favor of invasive annual grasses (Miller and others, 2001), resulting in possible impacts on biological diversity and human health. Much of the wildlife that depends on this vegetated landscape may become more vulnerable as a result of loss of habitat following a fire. Fire also directly threatens human communities and indirectly affects humans by jeopardizing traditional ranging practices (U.S. Geological Survey, 2003). Agricultural and developed land-use changes also have possible impacts, including pollution from agricultural and municipal sources as well as mechanical disturbances associated with water and mineral-resource use. Although wildlife has proven to be resilient to anthropogenic land use, the loss of natural vegetation resulting

Figure 8. Different elements of mining in Central Basin and Range Ecoregion. *A*, Gravel-extraction site near Tooele, Utah. *B*, Piles of gravel aggregate awaiting transport. *C*, Mineral-processing facility along Interstate 80 near Reno, Nevada. *D*, Old tailings pile undergoing reestablishment of vegetation.

from the afore-mentioned changes has both eliminated and polluted ecosystems used by endangered species such as the Greater Sage Grouse (*Centrocercus urophasianus*).

The growth of human populations in the Reno–Sparks and Salt Lake City–Ogden metropolitan areas will likely dictate the rate of future land-use conversions in the Central Basin and Range Ecoregion. The findings from the present study can be used in conjunction with existing literature to explore how, and to what extent, current land-use/land-cover trends will affect the Central Basin and Range Ecoregion into the future, and they also can provide insights into how policy change may alter current landscape conditions.

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

[Most sample pixels remained unchanged (98.5 percent), whereas 1.5 percent changed at least once throughout study period. Two dashes (--) indicate that, because zero pixels changed four times during study period, relative error is not calculable]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	1.3	0.7	0.6	1.9	0.4	35.0
2	0.1	0.1	0.0	0.2	0.1	59.7
3	0.0	0.0	0.0	0.1	0.0	65.9
4	0.0	0.0	0.0	0.0	0.0	--
Overall spatial change	1.5	0.7	0.7	2.2	0.5	34.2

Table 2. Raw estimates of change in Central Basin and 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 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	48.2	0.0
1980–1986	0.3	0.3	0.0	0.7	0.2	69.5	0.1
1986–1992	0.4	0.2	0.2	0.5	0.1	34.1	0.1
1992–2000	0.8	0.6	0.2	1.3	0.4	49.4	0.1
Estimate of change, in square kilometers							
1973–1980	698	495	202	1,193	337	48.2	100
1980–1986	1,163	1,190	–27	2,354	808	69.5	194
1986–1992	1,254	629	624	1,883	428	34.1	209
1992–2000	2,638	1,918	721	4,556	1,303	49.4	330

Table 3. Estimated area (and margin of error) of each land-cover class in Central Basin and 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		Nonmechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	0.1	0.1	0.4	0.4	0.0	0.0	0.1	0.1	3.9	3.6	15.6	5.1	75.9	5.7	2.9	2.1	1.0	0.7	0.0	0.0
1980	0.1	0.1	0.4	0.4	0.0	0.0	0.1	0.1	3.9	3.6	15.6	5.1	75.8	5.7	3.0	2.2	1.0	0.7	0.0	0.0
1986	0.3	0.4	0.5	0.4	0.0	0.0	0.1	0.1	3.9	3.6	15.6	5.1	75.8	5.7	3.0	2.2	0.8	0.7	0.0	0.0
1992	0.2	0.3	0.6	0.4	0.0	0.0	0.1	0.1	3.9	3.6	15.6	5.1	75.8	5.7	2.9	2.1	0.9	0.7	0.0	0.0
2000	0.2	0.3	0.6	0.4	0.0	0.0	0.2	0.2	3.9	3.6	15.3	4.8	75.4	5.6	2.9	2.1	0.9	0.7	0.5	0.6
Net change	0.2	0.3	0.2	0.1	0.0	0.0	0.1	0.1	0.0	0.0	−0.3	0.4	−0.6	0.5	0.0	0.1	−0.1	0.2	0.5	0.6
Gross change	0.4	0.5	0.2	0.1	0.0	0.1	0.2	0.1	0.0	0.0	0.3	0.4	1.0	0.5	0.3	0.2	0.2	0.3	0.5	0.6
Area, in square kilometers																				
1973	302	278	1,510	1,256	0	0	312	317	13,320	12,282	53,407	17,337	260,616	19,717	10,060	7,371	3,509	2,405	0	0
1980	259	246	1,530	1,261	0	0	345	307	13,323	12,282	53,407	17,337	260,266	19,706	10,401	7,401	3,506	2,403	0	0
1986	1,168	1,219	1,581	1,262	61	89	336	280	13,323	12,282	53,384	17,341	259,975	19,699	10,302	7,396	2,906	2,281	0	0
1992	847	968	1,922	1,308	0	0	454	328	13,323	12,282	53,400	17,343	260,129	19,580	9,905	7,150	3,055	2,281	0	0
2000	820	930	2,159	1,368	12	18	806	520	13,323	12,282	52,366	16,615	258,664	19,382	9,932	7,131	3,082	2,283	1,872	1,916
Net change	518	925	649	484	12	18	494	349	3	5	−1,041	1,471	−1,952	1,580	−128	434	−428	628	1,872	1,916
Gross change	1,420	1,575	649	484	134	179	570	375	3	5	1,074	1,470	3,311	1,578	1,150	629	782	1,133	1,872	1,916

Table 4. Principal land-cover conversions in Central Basin and 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	Grassland/Shrubland	Agriculture	352	353	240	0.1	50.5
	Water	Grassland/Shrubland	101	148	101	0.0	14.5
	Grassland/Shrubland	Mining	62	51	34	0.0	8.9
	Wetland	Water	39	57	38	0.0	5.5
	Grassland/Shrubland	Wetland	37	55	37	0.0	5.3
	Other	Other	106	n/a	n/a	0.0	15.2
		Totals	698			0.2	100.0
1980–1986	Wetland	Water	600	874	594	0.2	51.6
	Grassland/Shrubland	Water	202	234	159	0.1	17.3
	Agriculture	Water	108	158	107	0.0	9.3
	Grassland/Shrubland	Agriculture	55	57	39	0.0	4.8
	Grassland/Shrubland	Developed	51	46	31	0.0	4.4
	Other	Other	147	n/a	n/a	0.0	12.7
		Totals	1,163			0.3	100.0
1986–1992	Agriculture	Grassland/Shrubland	399	320	218	0.1	31.8
	Grassland/Shrubland	Developed	243	193	131	0.1	19.4
	Water	Grassland/Shrubland	154	225	153	0.0	12.3
	Water	Wetland	149	214	145	0.0	11.9
	Grassland/Shrubland	Mining	126	117	79	0.0	10.1
	Other	Other	182	n/a	n/a	0.1	14.5
		Totals	1,254			0.4	100.0
1992–2000	Forest	Nonmechanically disturbed	1,005	1,471	1,000	0.3	38.1
	Grassland/Shrubland	Nonmechanically disturbed	867	1,269	862	0.3	32.9
	Grassland/Shrubland	Mining	328	252	171	0.1	12.4
	Grassland/Shrubland	Developed	224	198	135	0.1	8.5
	Grassland/Shrubland	Agriculture	85	124	84	0.0	3.2
	Other	Other	130	n/a	n/a	0.0	4.9
		Totals	2,638			0.8	100.0
1973–2000 (overall)	Forest	Nonmechanically disturbed	1,005	1,471	1,000	0.3	17.5
	Grassland/Shrubland	Nonmechanically disturbed	867	1,269	862	0.3	15.1
	Wetland	Water	640	932	633	0.2	11.1
	Grassland/Shrubland	Developed	538	386	262	0.2	9.4
	Grassland/Shrubland	Agriculture	527	413	281	0.2	9.2
	Other	Other	2,177	n/a	n/a	0.6	37.8
		Totals	5,753			1.7	100.0

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Chapter 21

Colorado Plateaus Ecoregion

By Michael P. Stier

Ecoregion Description

The Colorado Plateaus Ecoregion covers approximately 129,617 km^2 (50,045 mi^2) within southern and eastern Utah, western Colorado, and the extreme northern part of Arizona (fig. 1). The terrain of this ecoregion is characterized by broad plateaus, ancient volcanoes, and deeply dissected canyons (Booth and others, 1999; fig. 2). The ecoregion is bounded on the east by the Wyoming Basin and Southern Rockies Ecoregions in Colorado and on the northwest by the Wasatch and Uinta Mountains Ecoregion in northern and central Utah. To the south, the ecoregion borders the Arizona/New Mexico Plateau Ecoregion, which has a higher elevation and more grasslands than the Colorado Plateaus Ecoregion (Omernik, 1987; U.S. Environmental Protection Agency, 1997).

The climate in the ecoregion is arid to semiarid, with only 15 to 40 cm of annual precipitation. Higher elevation areas such as the La Sal Mountains receive more precipitation and support a mixed forest of ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), quaking aspen (*Populus tremuloides*), and Engelmann spruce (*Picea engelmannii*). Most other locations of the ecoregion are covered by an extensive woodland zone, which is dominated by a “pygmy forest” of pinyon pine (*Pinus edulis*) and several species of juniper (*Juniperus* spp.; fig. 3). The ground between these trees is sparsely covered by blue grama (*Bouteloua gracilis*), shrubs such as big sagebrush (*Artemisia tridentata*) and alderleaf cercocarpus (*Cercocarpus montanus*), and various herbs (McGinley, 2007). Grassland/shrubland land cover accounts for approximately 63 percent of the

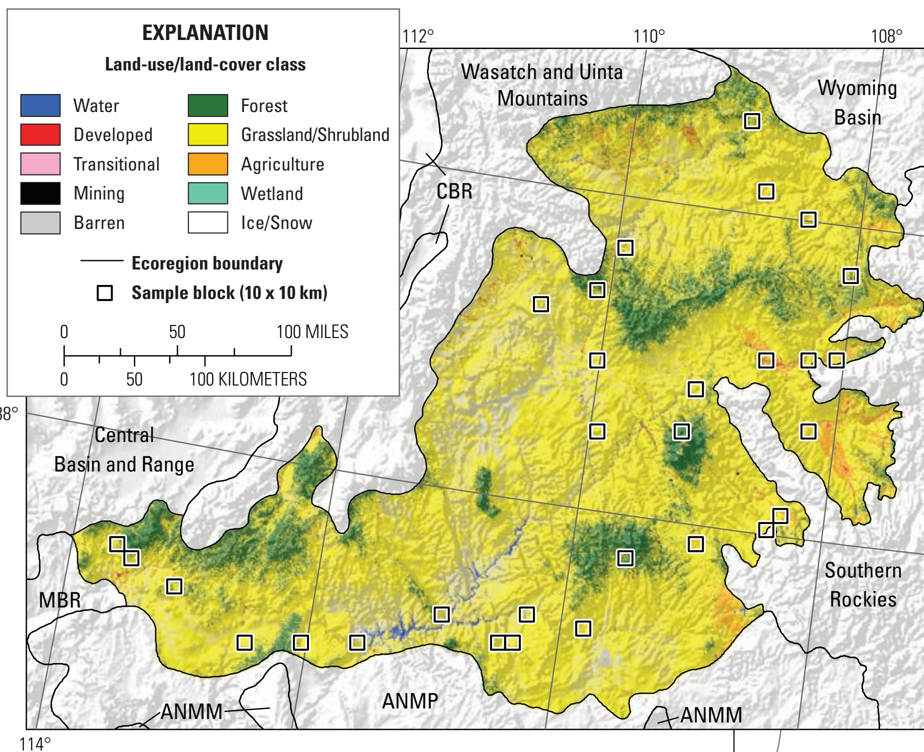

Figure 1. Map of Colorado Plateaus Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this “Status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

Figure 3. Mix of junipers and pinyon pine in eastern part of Colorado Plateaus Ecoregion.

ecoregion, whereas the remainder is covered by forest (25 percent), agriculture (6 percent), barren (4 percent), developed (1 percent), water (0.5 percent), wetland (0.4 percent), and mining (0.1 percent). The land-cover makeup of the ecoregion is summarized in table 3, which shows the percent land cover by type in the year 2000 (see appendix 3 for definitions of land-cover classifications).

From the Paleozoic into the Mesozoic era (600 to 300 million years ago), thick layers of limestone, sandstone, siltstone, and shale were deposited in shallow marine waters and then overlain by eolian deposits. Layers of sediment accumulated for millions of years on a thick crustal block that became the foundation of the Colorado Plateaus Ecoregion. As the plateau started to rise because of tectonic activity about 10 million years ago, streams that would become the present-day Colorado and Green Rivers carved down through the colorful (reds, purples, and oranges, stained by iron and other minerals) sedimentary rocks (Booth and others, 1999). Erosional processes created the arroyos, canyons, mesas, buttes, monuments, towers, and cliffs that make up the dramatic landscape we see today (fig. 4).

Because the Colorado Plateaus Ecoregion has been stable geologically (in other words, little rock deformation by faulting and folding) within the last 500 million years, conditions were ideal to create, preserve, and then reveal the unique rock formations and landforms (Wheeler, 1990). As a result of extensive conservation efforts, numerous U.S. National Parks, Forests, and Monuments have been established to protect, and preserve access to, these unique features. These extensive federal lands, coupled with Bureau of Land Management rangelands, account for nearly 55 percent of the ecoregion area. The remaining public land in the ecoregion is tribal land (24 percent) or held by state and local governments (6 percent). Private lands account for an estimated 15 percent of the entire ecoregion (Booth and others, 1999).

Today (2012), with the easy access provided by Interstate Highways 15 and 70 and secondary roads through the ecoregion to numerous wilderness areas and National Parks and Monuments, the area has become a tourist mecca. National Park visits increased 94 percent between 1981 and 1994, and recreation and tourism has become one of the ecoregion’s largest industries (Hecox and Ack, 1996). Other major economic activities include ranching, farming, timber harvesting, and mining. From the late 1800s to the 1950s, gold, silver, and uranium mining were the major economic drivers in the region. Since the 1970s, increased demands have made coal, oil, and

Figure 4. Mesas, towers, and monuments just east of Moab, Utah.

Figure 5. Coal power plant in eastern part of Colorado Plateaus Ecoregion near Grand Junction, Colorado.

gas the primary targets of mining and energy exploration in the Colorado Plateaus Ecoregion (fig. 5).

As the tourism and energy-exploration industries grew, the number of new jobs increased 225 percent between 1970 and 2000, 140 percent faster than the national average (van Riper and Mattson, 2005). Approximately 95 percent of all new jobs were service based. Resource-based employment in farming and mining only made up 2 percent of this growth (8,728 jobs), whereas manufacturing provided the remaining 3 percent (14,038 jobs) during this period (van Riper and Mattson, 2005). Service-based employment accounted for nearly 90 percent of all jobs within the Colorado Plateaus Ecoregion by 2000. All these factors indicate a rapid conversion from resource-extractive to service-based industries in the ecoregion during the study period.

Contemporary Land-Cover Change (1973 to 2000)

An estimated 2.6 percent of the land cover in the Colorado Plateaus Ecoregion changed at least once between 1973 and 2000 (table 1). Overall, the ecoregion experienced a low amount of land-cover conversion when compared to other western ecoregions (fig. 6). An estimated 0.6 percent of the ecoregion experienced change in more than one of the four time periods analyzed (table 2). Much of the land-cover change involved the expansion of developed land that accompanied employment increases and population growth. Change within the four individual time periods ranged from a low of 0.6 percent between 1980 and 1986 to a high of 1.1 percent between 1973 and 1980 (table 2). When the estimates are normalized to an annual average, accounting for varying lengths of study periods, the period between 1973 and 1980 experienced the highest normalized annual rate of change, at 0.15 percent (196 km^2; fig. 7). The other three time periods were relatively stable, at approximately 0.1 percent change per year.

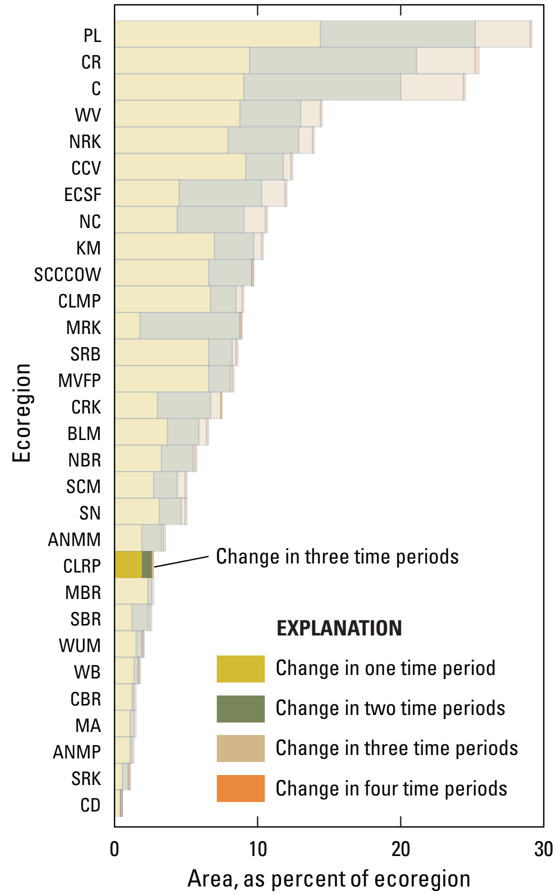

Figure 6. Overall spatial change in Colorado Plateaus Ecoregion (CLRP; darker bars) compared with that of all 30 Western United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Colorado Plateaus Ecoregion (three time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

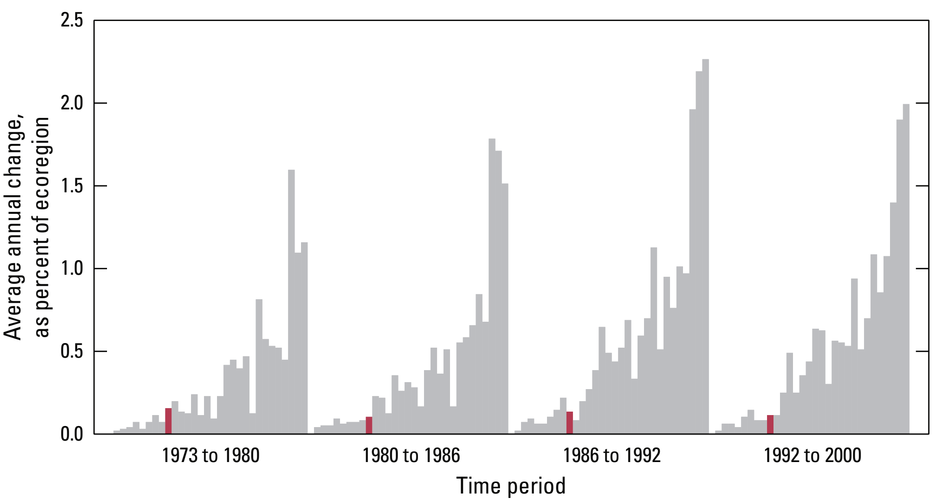

Figure 7. Estimates of land-cover change per time period, normalized to annual rates of change for all 30 Western United States ecoregions (gray bars). Estimates of change for Colorado Plateaus Ecoregion are represented by red bars in each time period.

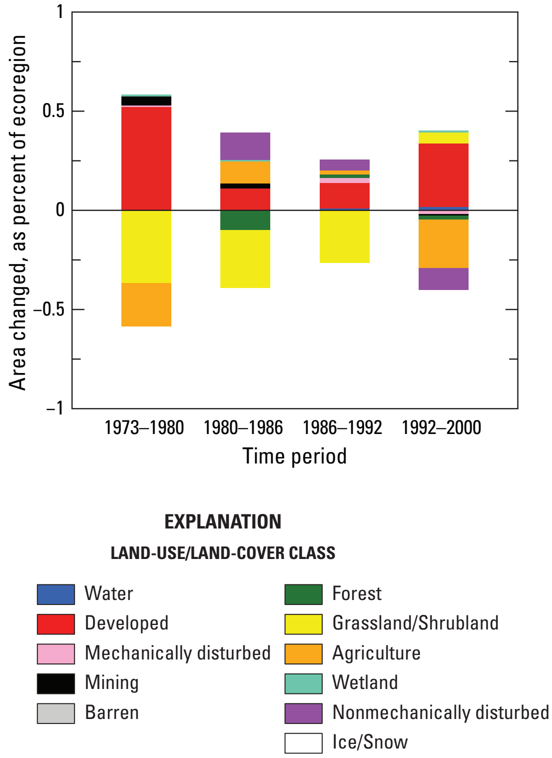

Figure 8. Normalized average net change in Colorado Plateaus Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use/land-cover classifications.

The largest amounts of net change that occurred over the entire study period (1973–2000) were an estimated 430 percent (1,408 km^2) increase in developed land and a 1.3 percent (1,121 km^2) decrease in grassland/shrubland (table 3). The largest net change in developed land occurred between 1973 and 1980 (fig. 8), almost all new developed land resulting from losses in either agriculture (756 km^2) or grassland/shrubland (644 km^2; table 4).

Although developed land only accounted for a small percentage of the ecoregion, nearly 43 percent of the land that changed became new developed land. Developed land is estimated to account for 0.3 percent (326 km^2) of the ecoregion in 1973, increasing to just over 1.3 percent (1,735 km^2) by 2000 (table 3). New developed land primarily was found near the ecoregion's urban centers of Saint George, Utah, and Grand Junction, Colorado, which had respective population estimates of 49,663 and 41,986 in 2000 (U.S. Census Bureau, 2000). Both of these cities have seen substantial population increases because of flourishing tourism and energy-mining industries. For example, Saint George's population increased 600 percent, from 7,097 in 1970 to 49,728 in 2000, whereas Grand Junction's increased 108 percent, from 20,170 in 1970 to 41,986 in 2000 (U.S. Census Bureau, 2000). The Interstate 15 and 70 corridors near these two cities also attracted new development, especially north from Saint George along Interstate 15 to Cedar City, Utah, and west from Grand Junction along Interstate 70 to Fruita, Colorado (fig. 9).

The grassland/shrubland land-cover class had the largest net loss in the ecoregion, decreasing by approximately 1,121 km^2. New developed land accounted for most of this decline, but land-cover conversions between agriculture and grassland/shrubland between 1973 and 2000 also affected the net change of grassland/shrubland. Considerable areas of land fluctuated between these two classes in all time periods between 1973 and 2000 (table 4). The overall trend from 1973 to 1992 indicated that more grassland/shrubland converted to agriculture than agriculture to grassland/shrubland. As a result, a net loss of grassland/shrubland to agriculture of approximately 327 km^2 occurred between 1973 and 1992. Irrigation needed to grow crops in the Colorado Plateaus Ecoregion's arid and relatively warm climate expanded in the counties of southeastern Utah and southwestern Colorado, causing agricultural lands to increase at the expense of grassland/shrubland. Irrigation water was drawn from the Dakota–Glen Canyon aquifer and the Colorado, White, San Juan, and Green Rivers to grow corn, wheat, barley, dry beans, hay, and alfalfa (U.S. Department of Agriculture, 2002). From 1992 to 2000, the exchange between grassland/shrubland and agricultural lands was balanced.

Even though agricultural lands increased at the expense of grassland/shrubland, the increase was not enough to offset agricultural lands lost to new developed land and mining between 1973 and 2000. As a result, agricultural lands in the Colorado Plateaus Ecoregion had a net decrease of 5.6 percent. Agricultural lands were estimated to account for 6.2 percent (8,004 km^2) of the ecoregion in 1973, decreasing to 5.8 percent (7,555 km^2) by 2000 (table 3). The largest net loss in agricultural lands occurred between 1992 and 2000, at 321 km^2, most of which went to developed land and grassland/shrubland (table 3). Increased municipal-water demands, as well as water scarcity in the arid Colorado Plateaus Ecoregion, may leave limited water available to farmers growing irrigated

Figure 9. Development in Redlands, between Fruita and Grand Junction, Colorado.

crops, further contributing to this decline. Additionally, because of cyclic changes in the extent of grassland/shrubland and agricultural lands, the gross land-cover change for agriculture and grassland/shrubland were the greatest among the other land-cover categories, totaling 1.2 percent (1,606 km^2) and 1.7 percent (2,204 km^2) of the ecoregion, respectively (table 3).

Periodic wildfires (classified as nonmechanically disturbed) affected nearly 1 percent (983 km^2) of the ecoregion's land between from 1973 and 2000 (table 3). These fires created common land-cover conversions involving forest and grassland/shrubland categories, especially between 1980 and 1986 and between 1986 and 1992. Between 1980 and 1986, conversion from forest to nonmechanically disturbed was the second greatest land change, whereas conversion from grassland/shrubland to nonmechanically disturbed was the top land-cover change between 1986 and 1992 (table 4). As burned areas recovered, land-cover conversion from nonmechanically disturbed to grassland/shrubland was common. For example, between 1986 and 1992, approximately 253 km^2 of grassland/shrubland burned, becoming nonmechanically disturbed, and then, by 2000, returned to grassland/shrubland. Because of this sequence of events, the return of nonmechanically disturbed lands to grassland/shrubland was the fifth most common conversion between 1973 and 2000, at 434 km^2 (table 4). As some burned areas have recovered by 2000, nonmechanically disturbed lands covered an estimated 115 km^2 of the ecoregion in 2000 (table 3).

Forest, the second most common land-cover class at approximately 25 percent of the Colorado Plateaus Ecoregion, generally was confined to the higher elevations of the ecoregion in the La Sal, Abajo, and Henry Mountains. Changes associated with forests were relatively small in the Colorado Plateaus Ecoregion. Forests had a small net decrease of 132 km^2 between 1973 and 2000 (table 3). Much of the forest loss is attributed to wildfires that occurred between 1980 and 1986, which caused an estimated loss of 178 km^2 in forest land to nonmechanically disturbed. Forest areas did expand in some locations of the ecoregion between 1980 and 1986 but not enough to make up for losses caused by wildfires. Slight forest gains in the ecoregion may be a result of the forest-management practice of fire suppression, as well as the dissemination of juniper seeds by grazing cattle while they simultaneously remove the competing grasses that inhibit juniper expansion (Allen, 1998). Both factors caused grasses to decline, whereas dense woodlands of pinyon pine and juniper expanded.

Other land-cover classes that changed very little are water, mining, and mechanically disturbed. Gross and net land change between 1973 and 2000 for each of these land categories affected no more than 0.1 percent (approximately 100 km^2) of the ecoregion. Mining lands had a net increase of 91 km^2 between 1973 and 2000 (table 3).

In Grand Junction and in many locations of the western slope of Colorado, new development expanded at a brisk pace, especially between 1973 and the early 1980s as people came to work in the energy-exploration business. An economic boom occurred during this time as major oil companies began investing large sums of money in the oil-shale industry (Gulliford, 2003). Grand Junction had its largest population increase (approximately 39 percent) between 1970 and 1980 (U.S. Census Bureau, 2000). This increase likely contributed to the large expansion of developed land in Colorado Plateaus Ecoregion between 1973 and 1980 (table 2).

As oil and gas exploration increased in the eastern part of the Colorado Plateaus Ecoregion during the energy crisis of the mid-1970s, the amount of new mining land increased between 1973 and 1992 (71 km^2 to 175 km^2, respectively; table 3). Mining of aggregate for the new Interstate 70 also accelerated mining land expansion in the 1970s. Nearly 78 percent of all new mining land was converted from grassland/shrubland. After 1982, however, the energy industry declined dramatically as the value of oil, coal, and uranium decreased, causing a "bust" economic condition in many small communities (notably, the towns of Rifle and Parachute, Colorado) that relied on the energy industry in the Colorado Plateaus Ecoregion (Gulliford, 2003). Mining land stabilized between 1986 and 1992 before decreasing from 175 km^2 in 1992 to 162 km^2 in 2000 (table 3).

Population gains continued in the Grand Junction area following the departure of major oil companies, causing a continuation of new developed lands. The economy in this part of the ecoregion became more diversified as a stable health care industry, tourism, agriculture (orchards and vineyards), livestock, and oil-and-gas extraction became major economic contributors. As oil and natural-gas prices increased in the 1990s, major energy companies once again invested large amounts of money into the area (van Riper and Mattson, 2005). In the 1990s, many Americans, especially well-educated retirees, were attracted to the western slope area of Colorado near Grand Junction because of outdoor amenities such as access to public lands and high mountain meadows. New developed land expanded as numerous second homes were built for the retirees (Gulliford, 2003).

The Saint George, Utah, area (known informally as "Utah's Dixie") also expanded for similar reasons. Outdoor recreational areas and nearby Zion and Bryce Canyon National Parks helped the tourism and recreation industry to grow there, attracting workers. The mild climate, access to high-quality health care, and natural amenities in the Saint George area attracted numerous retirees from other parts of the country. In addition, some large corporations such as SkyWest Airlines and Intermountain Health Care made their home in Saint George (Hecox and Ack, 1996). All these factors played an important role in expanding developed lands within the Colorado Plateaus Ecoregion.

Consequences of land change within the Colorado Plateaus Ecoregion became especially apparent between 1973 and 2000. Many agents of change are related to population growth in the ecoregion. As new development, tourism, mining, and heavy grazing increased, habitats that support wildlife and native plants have been greatly degraded. Approximately 85 percent of the ecoregion's habitat has been altered by human activity

(McGinley, 2007). Hardest-hit areas include riparian ecosystems and areas where mineral resources have been extracted. Habitat destruction caused by dam building (fig. 10) and other forms of development threaten native fish, including the humpback chub (*Gila cypha*), bluehead sucker (*Catostomus discobolus*), and the Colorado pikeminnow (*Ptychocheilus lucius*) (McGinley, 2007). Demand for water by growing municipalities also is having an effect on riparian areas as the water needs of wildlife, vegetation, and riparian systems become secondary (Booth and others, 1999). Today (2012), land managers are charged with accommodating land uses that can be sustained without degrading the health of the land and water. As a result, timber harvesting, mining, and livestock grazing all have been reduced in the ecoregion (Booth and others, 1999). Land managers increasingly are relying on science to balance commodity extraction and public recreation use while, at the same time, protecting ecosystem health within the Colorado Plateaus Ecoregion.

Figure 10. Glen Canyon Dam in southwestern part of Colorado Plateaus Ecoregion, near Page, Arizona.

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

[Most sample pixels remained unchanged (97.4 percent), whereas 2.6 percent changed at least once throughout study period. Two dashes (--) indicate that, because zero pixels changed four times during study period, relative error is not calculable]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	2.0	1.7	0.2	3.7	1.2	59.2
2	0.6	0.4	0.2	1.1	0.3	47.6
3	0.0	0.0	0.0	0.0	0.0	82.3
4	0.0	0.0	0.0	0.0	0.0	--
Overall spatial change	2.6	2.1	0.6	4.7	1.4	53.2

Table 2. Raw estimates of change in Colorado Plateaus 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	1.1	1.2	−0.2	2.3	0.8	78.4	0.2
1980–1986	0.6	0.3	0.3	0.9	0.2	37.0	0.1
1986–1992	0.8	0.5	0.4	1.3	0.3	37.5	0.1
1992–2000	0.9	0.7	0.1	1.6	0.5	56.2	0.1
Estimate of change, in square kilometers							
1973–1980	1,369	1,589	−219	2,958	1,074	78.4	196
1980–1986	738	404	334	1,142	273	37.0	123
1986–1992	1,053	584	469	1,637	395	37.5	175
1992–2000	1,135	943	191	2,078	638	56.2	142

Table 3. Estimated area (and margin of error) of each land-cover class in Colorado Plateaus 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	0.3	0.3	0.0	0.0	0.1	0.1	4.3	2.5	24.9	6.8	63.5	7.5	6.2	3.7	0.4	0.2	0.0	0.0
1980	0.4	0.3	0.8	1.0	0.0	0.0	0.1	0.1	4.3	2.5	24.9	6.8	63.1	7.5	6.0	3.5	0.4	0.2	0.0	0.0
1986	0.4	0.3	0.9	1.1	0.0	0.0	0.1	0.1	4.3	2.5	24.8	6.7	62.8	7.6	6.1	3.6	0.4	0.2	0.1	0.2
1992	0.4	0.3	1.0	1.2	0.0	0.0	0.1	0.1	4.3	2.5	24.8	6.7	62.6	7.6	6.1	3.6	0.4	0.2	0.2	0.3
2000	0.5	0.3	1.3	1.7	0.0	0.0	0.1	0.1	4.3	2.5	24.8	6.7	62.6	7.7	5.8	3.5	0.4	0.2	0.1	0.1
Net Change	0.0	0.0	1.1	1.4	0.0	0.0	0.1	0.1	0.0	0.0	−0.1	0.3	-0.9	0.6	−0.3	1.2	0.0	0.0	0.1	0.1
Gross Change	0.1	0.1	1.1	1.4	0.1	0.1	0.1	0.1	0.0	0.0	0.3	0.2	1.7	0.8	1.2	1.1	0.0	0.0	0.8	0.8
Area, in square kilometers																				
1973	547	389	326	394	0	0	71	72	5,545	3,186	32,302	8,771	82,281	9,680	8,004	4,750	541	268	0	0
1980	547	387	1,011	1,360	2	3	135	127	5,542	3,186	32,306	8,767	81,815	9,754	7,718	4,524	541	271	0	0
1986	546	386	1,155	1,450	2	3	175	163	5,544	3,186	32,173	8,702	81,437	9,837	7,859	4,650	546	275	181	265
1992	561	390	1,319	1,612	43	40	175	188	5,544	3,186	32,194	8,698	81,097	9,888	7,876	4,696	555	281	253	370
2000	589	409	1,735	2,189	18	27	162	169	5,544	3,186	32,170	8,689	81,161	9,928	7,555	4,599	568	281	115	168
Net Change	42	54	1,408	1,795	18	27	91	97	−1	5	−132	328	−1,121	840	−449	1,513	27	23	115	168
Gross Change	69	71	1,408	1,795	112	82	168	148	9	8	332	318	2,204	1,091	1,606	1,456	42	22	983	999

Table 4. Principal land-cover conversions in Colorado Plateaus 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	Developed	343	478	323	0.3	25.0
	Agriculture	Developed	342	489	331	0.3	24.9
	Grassland/Shrubland	Agriculture	305	198	134	0.2	22.3
	Agriculture	Grassland/Shrubland	246	349	236	0.2	18.0
	Grassland/Shrubland	Mining	57	52	35	0.0	4.1
	Other	Other	77	n/a	n/a	0.1	5.7
		Totals	1,369			1.1	100.0
1980–1986	Grassland/Shrubland	Agriculture	235	202	136	0.2	31.8
	Forest	Nonmechanically disturbed	178	0	0	0.1	24.1
	Grassland/Shrubland	Developed	92	82	56	0.1	12.4
	Grassland/Shrubland	Forest	50	69	47	0.0	6.7
	Agriculture	Developed	50	65	44	0.0	6.7
	Other	Other	138	n/a	n/a	0.1	18.8
		Totals	738			0.6	100.0
1986–1992	Grassland/Shrubland	Nonmechanically disturbed	253	266	180	0.2	24.1
	Nonmechanically disturbed	Grassland/Shrubland	181	265	179	0.1	17.2
	Grassland/Shrubland	Agriculture	162	153	103	0.1	15.4
	Grassland/Shrubland	Developed	102	95	65	0.1	9.7
	Agriculture	Grassland/Shrubland	76	71	48	0.1	7.3
	Other	Other	278	n/a	n/a	0.2	26.4
		Totals	1,053			0.8	100.0
1992–2000	Agriculture	Developed	305	445	301	0.2	26.9
	Nonmechanically disturbed	Grassland/Shrubland	253	370	250	0.2	22.3
	Grassland/Shrubland	Developed	108	130	88	0.1	9.5
	Agriculture	Grassland/Shrubland	98	103	70	0.1	8.6
	Grassland/Shrubland	Agriculture	90	83	56	0.1	8.0
	Other	Other	280	n/a	n/a	0.2	24.7
		Totals	1,135			0.9	100.0
1973–2000 (overall)	Grassland/Shrubland	Agriculture	793	534	361	0.6	18.5
	Agriculture	Developed	756	1,085	733	0.6	17.6
	Grassland/Shrubland	Developed	644	711	481	0.5	15.0
	Agriculture	Grassland/Shrubland	466	533	360	0.4	10.9
	Nonmechanically disturbed	Grassland/Shrubland	434	448	303	0.3	10.1
	Other	Other	1,201	n/a	n/a	0.9	28.0
		Totals	4,295			3.3	100.0

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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 22

Columbia Plateau Ecoregion

By Benjamin M. Sleeter

Ecoregion Description

Located in eastern Washington and northern Oregon, the Columbia Plateau Ecoregion is characterized by sagebrush steppe and grasslands with extensive areas of dryland farming and irrigated agriculture. The ecoregion, which is approximately 90,059 km^2 (34,772 mi^2), is surrounded on all sides by mountainous ecoregions: to the west, the North Cascades Ecoregion and the Eastern Cascades Slopes and Foothills Ecoregion (and to the west of it, the Cascades Ecoregion); to the south, the Blue Mountains Ecoregion; and to the east, the Northern Rockies Ecoregion (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). The climate is Mediterranean, with cool wet winters and hot dry summers.

The ecoregion was formed by Miocene (17 to 6 million year old) flood basalts covering approximately 200,000 km^2 in what is currently central and eastern Washington, northern Oregon, and western Idaho (Hooper, 1982). Other notable processes

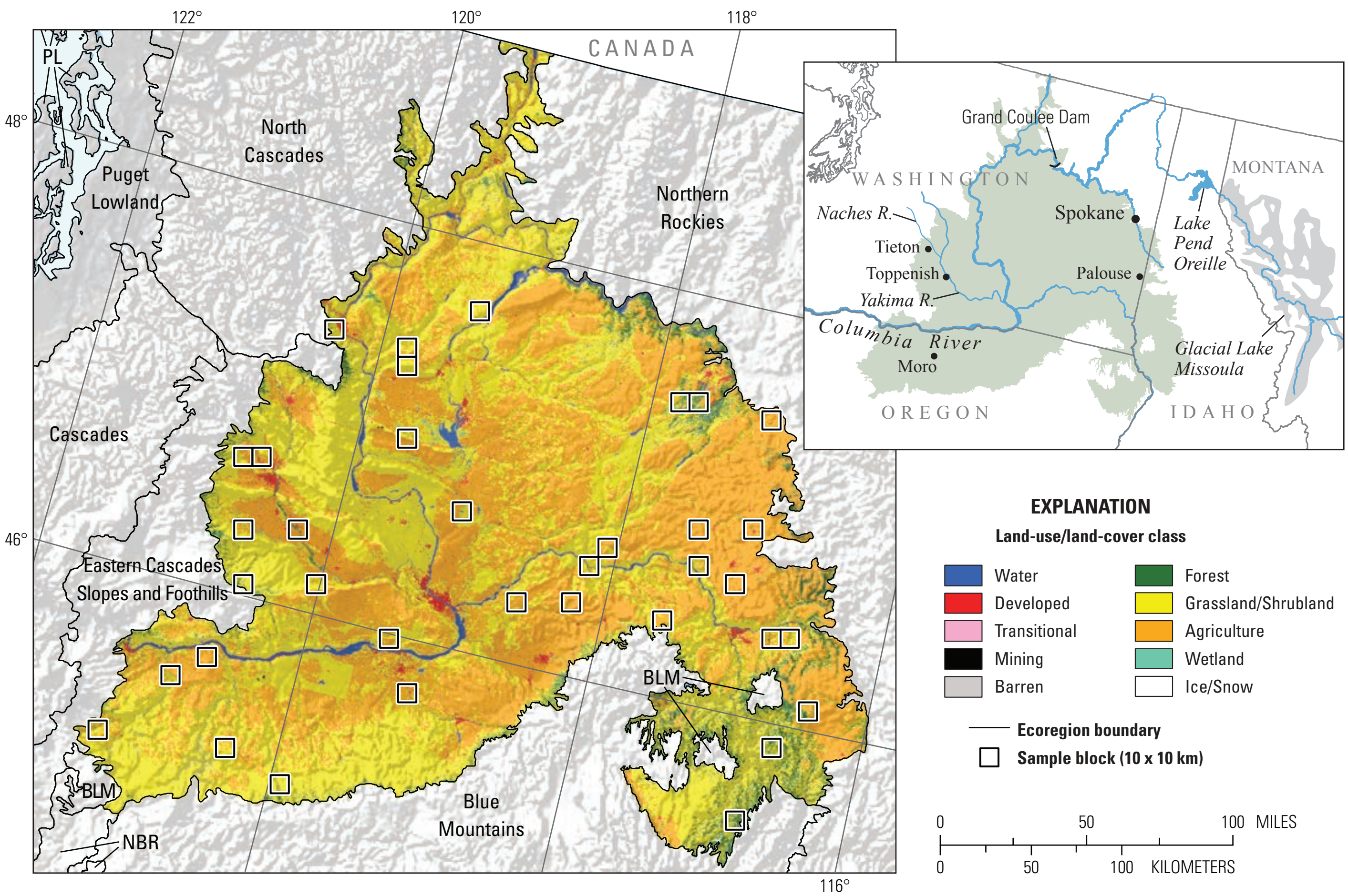

Figure 1. Map of Columbia Plateau Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and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

that shaped the Columbia Plateau Ecoregion were the great Missoula floods caused by catastrophic failures of glacial dams that blocked Montana's Glacial Lake Missoula 10 to 15 thousand years ago. Massive amounts of water rushing westward from the vicinity of the present-day east end of Lake Pend Oreille, Idaho, transformed a dendritic preglacial drainage pattern into the channeled scablands of today (Bretz, 1969; Smith, 2006). The great floods resulted in the loss of loess soils that covered much of the region. The only areas spared were those not in the path of flood waters or that had high enough elevations, such as the fertile Palouse region in eastern Washington. Today (2012) these areas support vast amounts of grain farming.

Since European settlement in the mid-19th century, the region has been heavily used for agricultural production. Much of the Columbia Plateau Ecoregion is used for dryland winter wheat production (fig. 2), the typical pattern being winter-wheat, followed by summer-fallow, cultivation. Soil moisture is accumulated throughout the winter; most growth occurs in the spring, and the harvest takes place in the summer. The hot and dry summer climate is ideal for maturation of dryland grains and cereals, but without irrigation little else can flourish (Schillinger and Papendick, 2008).

The Columbia Basin Project, a large engineered irrigation network serving eastern Washington, began in the 1930s with the construction of Grand Coulee Dam, originally designed to provide irrigation to the region's farmers. World War II caused the project to shift its focus to providing hydroelectric power; the irrigation component was not functional again until the 1950s. In 2009 alone, water from the Columbia Basin Project irrigated approximately 670,000 acres of crops valued at over $600 million annually (U.S. Bureau of Reclamation, 2009) (fig. 3).

Figure 2. Wheat fields near Moro, Oregon (*A*) and outside of Spokane, Washington (*B*).

Figure 3. Hops planted in Yakima Valley, Washington (*A*) and corn field near Toppenish, Washington (*B*).

Development in the Columbia Plateau Ecoregion generally is rural with only a few major urban areas. Population growth was slow in the 1980s, increasing only 4.9 percent. In the 1990s the ecoregion population increased by 20 percent to just under one million people (U.S. Census Bureau, 2000) (table 1).

Contemporary Land-Cover Change (1973 to 2000)

An estimated 9.2 percent of the Columbia Plateau Ecoregion land cover changed at least once between 1973 and 2000 (table 2). Compared to other ecoregions, change in the

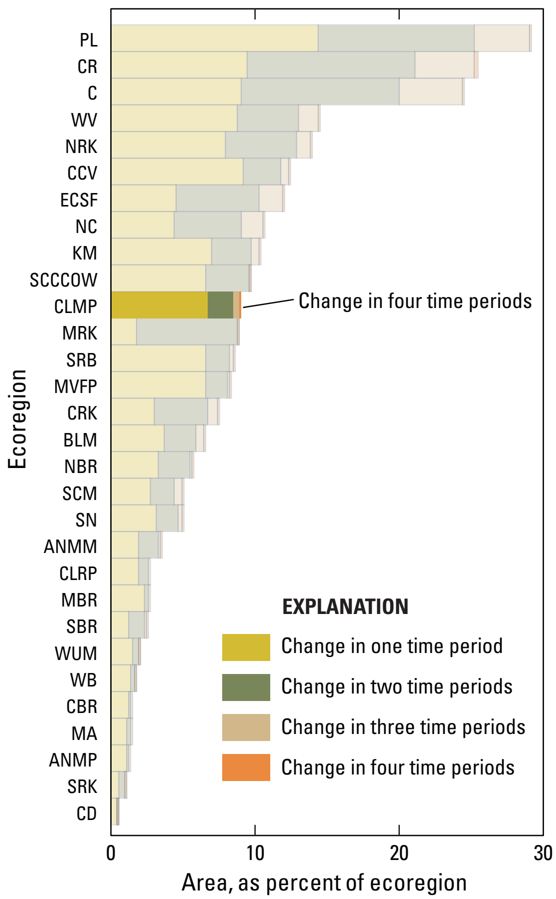

Figure 4. Overall spatial change in Columbia Plateau Ecoregion (CLMP; darker bars) compared with that of all 30 Western United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial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

Columbia Plateau Ecoregion is considered modest (fig. 4). Of the total area, 2.3 percent changed in more than one of the four time periods analyzed (table 3), mostly a result of farmland cycling in and out of production. Changes to ecoregion land cover were not spread evenly throughout the entire 27-year study period. As is the case in many other agricultural regions, the period between 1986 and 1992 experienced the greatest amount of change, owing, in large part, to the conversion of marginal agricultural lands to grassland/shrubland (see appendix 3 for definitions of land-cover classes). The average annual rate of change during this period was 0.7 percent, whereas the other three periods experienced rates roughly one-half that amount (table 3; fig. 5).

Agricultural lands made up approximately 48.8 percent of the ecoregion in 1973 (table 4). By 1986 the agriculture land-cover class had increased an estimated 1,475 km^2 to make up 50.4 percent of the ecoregion. Between 1986 and 1992, agricultural lands declined by an estimated 1,531 km^2 (fig. 6), decreasing to approximately 48.7 percent of total ecoregion land cover. By 2000, agriculture had once again increased to account for 49.4 percent of the ecoregion (table 4). The Conservation Reserve Program (CRP), a federal policy to encourage landowners to convert marginal farmlands to native vegetation, played an important role in the Columbia Plateau Ecoregion. After the onset of the program, the ecoregion reversed the prior trend of increasing agricultural land use, and by 1997 enrollment in the CRP program totaled 3,311 km^2 (U.S. Department of Agriculture, 1999). Expiration of 10-year CRP contracts in the late 1990s contributed to 0.6 percent of the ecoregion converting back into agricultural land use by 2000. During the study period, dryland wheat farming experienced a sharp decline, whereas other areas of agriculture intensified with the addition of new irrigated lands. Historical levels of dryland wheat, irrigated cropland, and CRP enrollments are summarized in figure 7.

Trends in grassland/shrubland mirrored those of the agriculture class. Grassland/shrubland made up 41.0 percent of the ecoregion in 1973 and 39.9 percent in 2000, a net

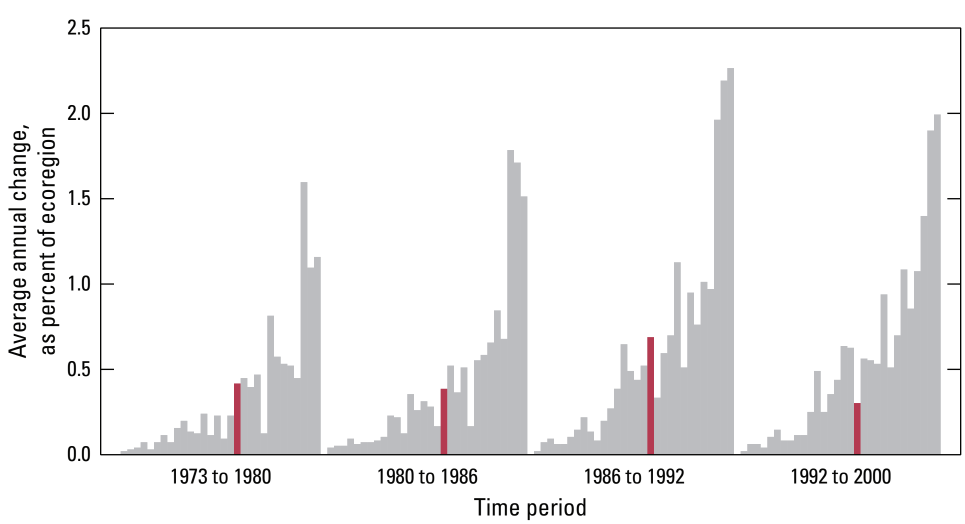

Figure 5. Estimates of land-cover change per time period, normalized to annual rates of change for all 30 Western United States ecoregions (gray bars). Estimates of change for Columbia Plateau Ecoregion are represented by red bars in each time period.

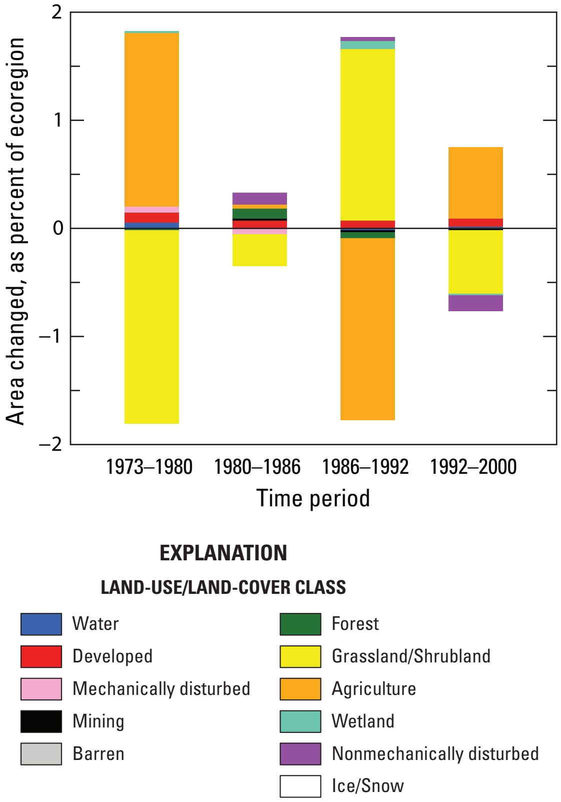

Figure 6. Normalized average net change in Columbia Plateau Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for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

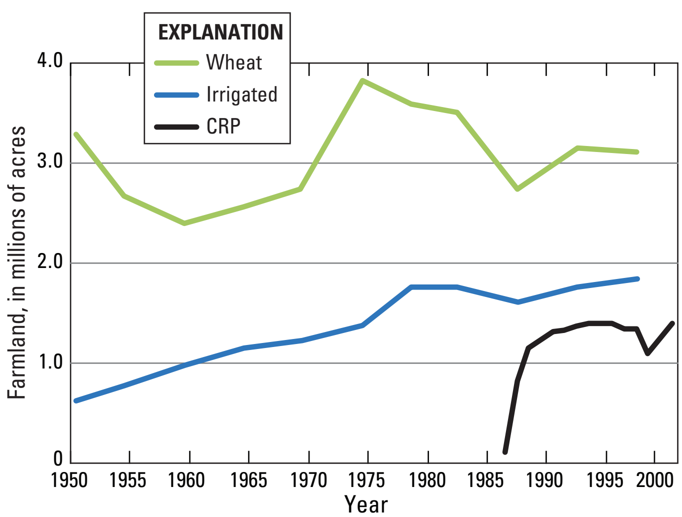

Figure 7. Historical trends in acreage for irrigated agriculture, dryland wheat, and Conservation Reserve Program enrollments (CRP). Total annual values were summed for all counties that have their centroid within Columbia Plateau Ecoregion. Data from United States Department of Agriculture's agriculture census (U.S. Department of Agriculture, 1999).

loss of 973 km^2. Developed land accounted for a very small proportion of the ecoregion (about 1.0 percent), an estimated net increase of approximately 284 km^2 over the 27-year period. All other land-cover classes remained relatively stable (table 4).

As expected, the most common land-cover conversions were between the agriculture and grassland/shrubland classes. In all four time periods, these were the two most common land-cover conversions. In three of the four periods, increases in conversions from agriculture to grassland/shrubland outpaced losses. The exception was between 1986 and 1992, when 2,342 km^2 changed from agriculture to grassland/shrubland, and only 886 km^2 converted from grassland/shrubland to agriculture. Other conversions of note were grassland/shrubland to nonmechanically disturbed (by fire) and agriculture to developed (table 5).

Irrigation technology, infrastructure development, federal conservation efforts, and population growth all acted as drivers of change on Columbia Plateau Ecoregion land cover. In the 1960s and 1970s, the spread of center-pivot irrigation technology enhanced the ability to bring marginal lands into agricultural production. The spread of irrigation was facilitated by the expansion and utilization of water-delivery infrastructure from the Columbia Basin Project, designed to irrigate more than 1 million acres of marginal lands. Estimates indicate that this period resulted in the greatest rate of change from sagebrush steppe (grassland/shrubland class) to new agriculture, adding an average of 290 km^2 per year between 1973 and 1980.

Whereas new lands were being added to the Columbia Plateau Ecoregion's agriculture mosaic in each time period, in only one period, 1986 to 1992, were these additions outpaced by the reversion back to natural vegetative conditions, largely as a result of the CRP (fig. 8). In the western United States, CRP had its most substantial effect in the Columbia Plateau Ecoregion. Estimates reveal that this period (1986–1992) experienced the only net decline in agriculture land cover during the 27-year land-cover study.

Figure 8. Agricultural land converted to grassland/shrubland under Conservation Reserve Program.

Regional population growth also has had an effect on regional land-cover change. Although developed land-cover areas accounted for approximately 1 percent of the total ecoregion area, a measured increase in developed lands of approximately 32 percent occurred between 1973 and 2000. Demand for new housing and infrastructure to support an additional 200,000 people resulted in the conversion of a relatively small amount of agricultural land and, to a lesser extent, grassland/shrubland to new developed uses (fig. 9).

Figure 9. New home construction and orchard near Naches River and town of Tieton, Washington.

Table 1. Columbia Plateau Ecoregion population estimates by state for 1980, 1990, and 2000 censuses (U.S. Census Bureau, 2000). Population estimates are calculated using census tracts that have their centroid within ecoregion. Total population estimates are sums of all three states for each year.

[--, no significant change]

Census year	State	Population	Percent change from previous decade
1980	Total	777,166	
	Oregon	90,051	
	Washington	618,055	
	Idaho	69,060	
1990	Total	814,979	+4.9
	Oregon	90,861	--
	Washington	654,062	+5.8
	Idaho	70,056	+1.4
2000	Total	978,069	+20.0
	Oregon	107,212	+18.0
	Washington	792,260	+21.1
	Idaho	78,597	+12.2

Table 2. Percentage of Columbia Plateau Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (90.8 percent), whereas 9.2 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	7.0	2.3	4.8	9.3	1.6	22.2
2	1.7	0.6	1.2	2.3	0.4	22.2
3	0.4	0.2	0.2	0.5	0.1	32.0
4	0.0	0.1	0.0	0.1	0.0	84.6
Overall spatial change	9.2	2.7	6.3	11.9	1.8	20.4

Table 3. Raw estimates of change in Columbia Plateau 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	2.9	1.4	1.5	4.3	1.0	32.8	0.4
1980–1986	2.3	0.6	1.7	3.0	0.4	18.9	0.4
1986–1992	4.1	1.4	2.7	5.5	0.9	23.0	0.7
1992–2000	2.4	0.7	1.7	3.2	0.5	21.0	0.3
Estimate of change, in square kilometers							
1973–1980	2,641	1,275	1,366	3,915	866	32.8	377
1980–1986	2,080	579	1,501	2,659	393	18.9	347
1986–1992	3,702	1,251	2,451	4,954	850	23.0	617
1992–2000	2,174	671	1,504	2,845	456	21.0	272

Table 4. Estimated area (and margin of error) of each land-cover class in Columbia Plateau 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		Nonmechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	0.8	0.4	1.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	7.6	3.1	41.0	6.4	48.8	7.4	0.9	0.3	0.0	0.0
1980	0.8	0.4	1.1	0.7	0.0	0.1	0.0	0.0	0.0	0.0	7.6	3.0	39.2	6.1	50.4	7.3	0.9	0.3	0.0	0.0
1986	0.8	0.4	1.1	0.7	0.0	0.0	0.0	0.1	0.0	0.0	7.7	3.1	38.9	5.9	50.4	7.1	0.9	0.3	0.1	0.2
1992	0.8	0.4	1.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	7.6	3.0	40.5	6.1	48.7	7.2	0.9	0.3	0.1	0.2
2000	0.8	0.4	1.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	7.6	3.0	39.9	6.1	49.4	7.2	0.9	0.3	0.0	0.0
Net change	0.1	0.1	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	−1.1	2.5	0.6	2.5	0.1	0.1	0.0	0.0
Gross change	0.1	0.1	0.3	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.4	0.4	7.6	2.4	7.3	2.4	0.1	0.1	0.5	0.5
Area, in square kilometers																				
1973	680	360	878	580	0	0	7	8	1	1	6,836	2,754	36,943	5,742	43,946	6,674	768	291	0	0
1980	730	390	967	612	41	59	18	18	0	1	6,817	2,728	35,331	5,455	45,387	6,532	768	288	0	0
1986	738	394	1,025	647	0	0	40	46	1	2	6,894	2,779	35,068	5,350	45,421	6,435	775	288	96	139
1992	718	387	1,095	682	8	9	36	43	1	1	6,847	2,679	36,495	5,464	43,889	6,447	840	291	131	189
2000	740	388	1,162	734	5	5	29	28	4	5	6,843	2,678	35,970	5,486	44,480	6,525	826	289	0	0
Net change	61	71	284	172	5	5	21	25	3	4	7	224	-973	2,270	534	2,223	58	63	0	0
Gross change	113	83	284	172	94	118	57	61	5	7	381	325	6,881	2,166	6,561	2,144	111	74	455	463

Table 5. Principal land-cover conversions in Columbia Plateau 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	1,960	1,139	774	2.2	74.2
	Agriculture	Grassland/Shrubland	440	301	204	0.5	16.7
	Agriculture	Developed	61	50	34	0.1	2.3
	Grassland/Shrubland	Water	51	73	50	0.1	1.9
	Forest	Mechanically disturbed	41	59	40	0.0	1.5
	Other	Other	88	n/a	n/a	0.1	3.3
		Totals	2,641			2.9	100.0
1980–1986	Grassland/Shrubland	Agriculture	944	363	246	1.0	45.4
	Agriculture	Grassland/Shrubland	822	419	285	0.9	39.5
	Grassland/Shrubland	Nonmechanically disturbed	94	135	92	0.1	4.5
	Agriculture	Developed	47	37	25	0.1	2.3
	Agriculture	Forest	42	60	41	0.0	2.0
	Other	Other	132	n/a	n/a	0.1	6.3
		Totals	2,080			2.3	100.0
1986–1992	Agriculture	Grassland/Shrubland	2,342	1,155	785	2.6	63.3
	Grassland/Shrubland	Agriculture	880	470	319	1.0	23.8
	Forest	Nonmechanically disturbed	131	189	129	0.1	3.5
	Nonmechanically disturbed	Grassland/Shrubland	96	138	94	0.1	2.6
	Grassland/Shrubland	Forest	89	76	52	0.1	2.4
	Other	Other	165	n/a	n/a	0.2	4.5
		Totals	3,702			4.1	100.0
1992–2000	Grassland/Shrubland	Agriculture	1,276	527	358	1.4	58.7
	Agriculture	Grassland/Shrubland	634	313	212	0.7	29.1
	Nonmechanically disturbed	Grassland/Shrubland	131	188	128	0.1	6.0
	Agriculture	Developed	49	44	30	0.1	2.3
	Wetland	Water	19	20	14	0.0	0.9
	Other	Other	66	n/a	n/a	0.1	3.0
		Totals	2,174			2.4	100.0
1973–2000 (overall)	Grassland/Shrubland	Agriculture	5,060	2,075	1,410	5.6	47.7
	Agriculture	Grassland/Shrubland	4,238	1,621	1,101	4.7	40.0
	Nonmechanically disturbed	Grassland/Shrubland	226	230	156	0.3	2.1
	Agriculture	Developed	211	149	102	0.2	2.0
	Forest	Nonmechanically disturbed	134	189	129	0.1	1.3
	Other	Other	729	n/a	n/a	0.8	6.9
		Totals	10,597			11.8	100.0

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Chapter 23

Northern Basin and Range Ecoregion

By Christopher E. Soulard

Ecoregion Description

The Northern Basin and Range Ecoregion (Omernik, 1987; U.S. Environmental Protection Agency, 1997) is located in eastern Oregon (58.7 percent), northern Nevada (20.6 percent), southwestern Idaho (14.8 percent), and northeastern California (5.9 percent), encompassing the northern extent of the hydrographic Great Basin (Grayson, 1993). The ecoregion, which covers approximately 110,039 km² (42,486 mi²) of land, is bordered on the west by the Eastern Cascades Slopes and Foothills and the Sierra Nevada Ecoregions, on the north by the Blue Mountains and the Snake River Basin Ecoregions, and on the south by the Central Basin and Range Ecoregion (fig. 1). Much like the other Basin and Range ecoregions in the western United States (for example, Central Basin and Range, Mojave Basin and Range, and Sonoran Basin and Range Ecoregions), the Northern Basin and Range Ecoregion is characterized by basin-and-range topography. The ecoregion contains several wide basins bordered by scattered low mountains. Big sagebrush (*Artemisia tridentata*), the predominant vegetation, is intermixed with grasslands. Despite regional aridity, natural springs and spring-fed wetlands

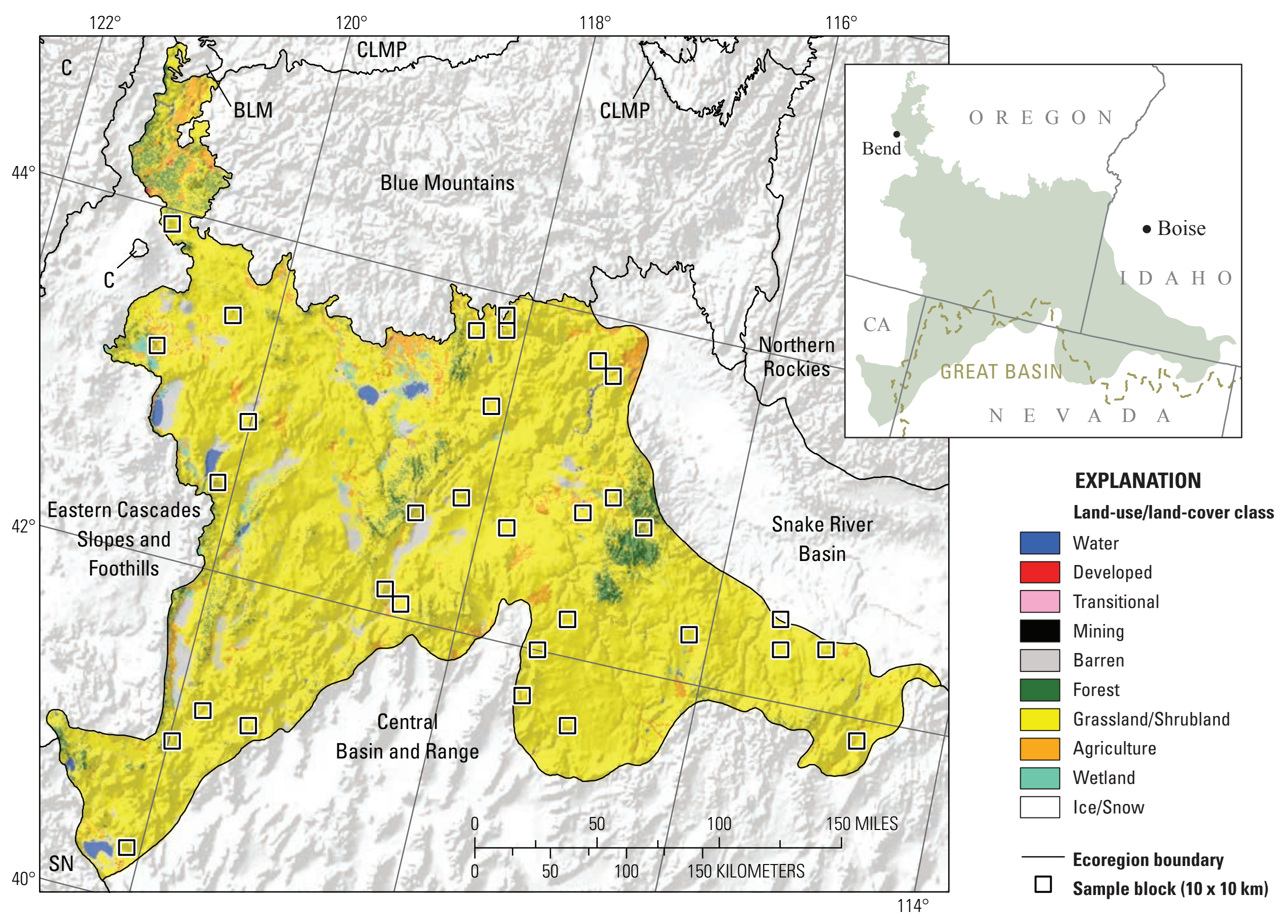

Figure 1. Map of Northern Basin and Range Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status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

are scattered around the landscape, sustaining much of the region's wildlife (Oregon Department of State Lands, 2000).

Because most of the Northern Basin and Range Ecoregion is arid and soil development generally is poor, viable economic land uses are limited. Livestock (cattle and sheep) grazing, the predominant land use, occurs mostly in the grassland/shrubland landscapes (fig. 2). Some agriculture (mostly hay farming) occurs where reservoirs have been constructed along regional waterways. Mining and recreation also account for small fragments of local economy. Ultimately, the scarcity of economic activity explains the absence of any large municipalities and the general lack of developed land across the ecoregion's landscape.

Land-cover change in the ecoregion is caused primarily by livestock grazing. Grazing activity has effectively modified the contemporary fire regime, contributing to the loss of native-plant communities in the region (Miller and others, 2001) (fig. 3). Historical land-management practices of unregulated grazing and fire suppression have led to increased fuel loads and nonnative-species invasion of rangelands (Oregon Department of State Lands, 2000). The most notable of these invasive species is cheatgrass (*Bromus tectorum*), which was introduced by settlers intending to feed domestic livestock by seeding areas devoid of native vegetation (Pellant and others, 2004). Cheatgrass and other introduced annuals not only outcompete native plants but also alter the fire regime by providing a denser, more continuous fuel source, which can extend the fire season (Pyke, 2002). Increased fire frequency eliminates native sagebrush in the short term, as the highly prolific seed-production capability of cheatgrass allows it to reestablish before sagebrush can take hold (Keeley, 2006; Pellant and others, 2004). Cheatgrass has ultimately created a positive-feedback mechanism for its own colonization, quickly expanding its range owing to frequent fires and its early reestablishment success in burned landscapes formerly occupied by sagebrush.

Figure 2. Area undergoing livestock grazing and hay farming in Northern Basin and Range Ecoregion. Land-use/land-cover classes shown are grassland/shrubland and agriculture.

Figure 3. Shrubland being used as open rangeland for cattle in Northern Basin and Range Ecoregion. Charred shrubs illustrate nonmechanical disturbance of land cover by fire. Land-use/land-cover classes shown are grassland/shrubland and nonmechanically disturbed.

Contemporary Land-Cover Change (1973 to 2000)

Between 1973 and 2000, the footprint (overall areal extent) of land-use/land-cover change in the Northern Basin and Range Ecoregion was 5.8 percent, or 6,430 km². This can be interpreted as the amount of land that experienced change during at least one of the four time periods that make up the entire 27-year study period. This footprint of change translates to an estimated 3,631 km² of land that changed during one time period, 2,421 km² that changed during two time periods, 110 km² that changed during three time periods, and 220 km² that changed throughout all four time periods (table 1; fig. 4).

The average annual rate of change between 1973 and 2000 was 0.3 percent per year. This measurement, which normalizes the results for the 27-year study period to an annual scale, means that the region averaged 363 km² of change each year between 1973 and 2000 (table 2); however, this annual change varied between each of the four time periods. Between 1973 and 1980, the annual rate of change was 0.1 percent per year; this rate increased to 0.3 percent annually between 1980 and 1986 and 0.6 percent annually between 1986 and 1992. The normalized annual rate dropped back to 0.3 percent between 1992 and 2000 (table 2). Compared to the other ecoregions in the western United States, land-cover change in the Northern Basin and Range Ecoregion was relatively low (fig. 5).

In 2000, five of the eleven land-use/land-cover classes made up the majority of the Northern Basin and Range Ecoregion: grassland/shrubland (89.3 percent), forest (3.7 percent), nonmechanically disturbed (2.5 percent), agriculture (2.3 percent), and wetland (1.1 percent). Five other classes cumulatively made up the remaining 1 percent of the Northern Basin and Range Ecoregion landscape in 2000 (table 3).

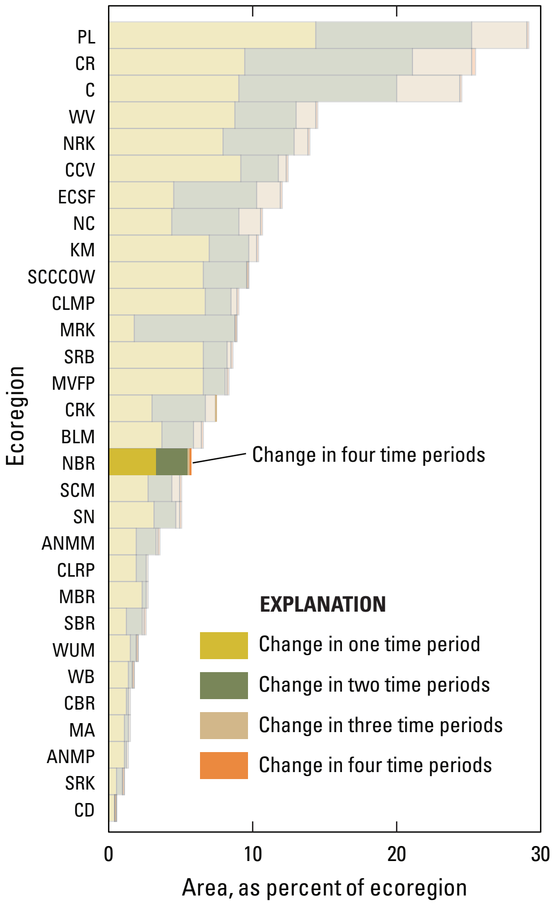

Figure 4. Overall spatial change in Northern Basin and Range Ecoregion (NBR; darker bars) compared with that of all 30 Western United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during time periods 1, 2, 3, or 4; highest level of spatial change in Northern Basin and 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.

Between 1973 and 2000, the land-cover classes that experienced a measurable net change in relation to total ecoregion area include grassland/shrubland (2.6 percent decrease) and nonmechanically disturbed (which occupied 194 km^2 in 1973 and 2,713 km^2 in 2000, owing to fires) (fig. 6).

The “from class–to class” information afforded by a postclassification comparison was used to identify land-cover class conversions and to rank these conversions from highest to lowest (table 4). Although fieldwork confirmed the presence of many of the conversions listed in table 4, the ability to report these changes on the basis of interpretations was accomplished with varying degrees of uncertainty (as illustrated by the statistical error values in the table). In general, higher uncertainty arose where sampled changes were clustered spatially within the ecoregion rather than distributed evenly across the ecoregion.

Four of the top ten most prominent conversions are connected to nonmechanical disturbance of land cover by fire (fig. 7). Cumulatively, nonmechanical disturbance of grassland/shrubland resulted in the loss of an estimated 5,016 km^2; however, much of this land experienced ecological succession, or regrowth, and by the end of the study period, 2,530 km^2 had converted back to grassland/shrubland (fig. 7; table 4). Areas that experienced fires in consecutive periods accounted for an additional 1,491 km^2 (table 4). The conversions to and from the water class also were common in the Northern Basin and Range Ecoregion (1,016 km^2 of gross change). Less common were the conversions from grassland/shrubland to agriculture and to mining.

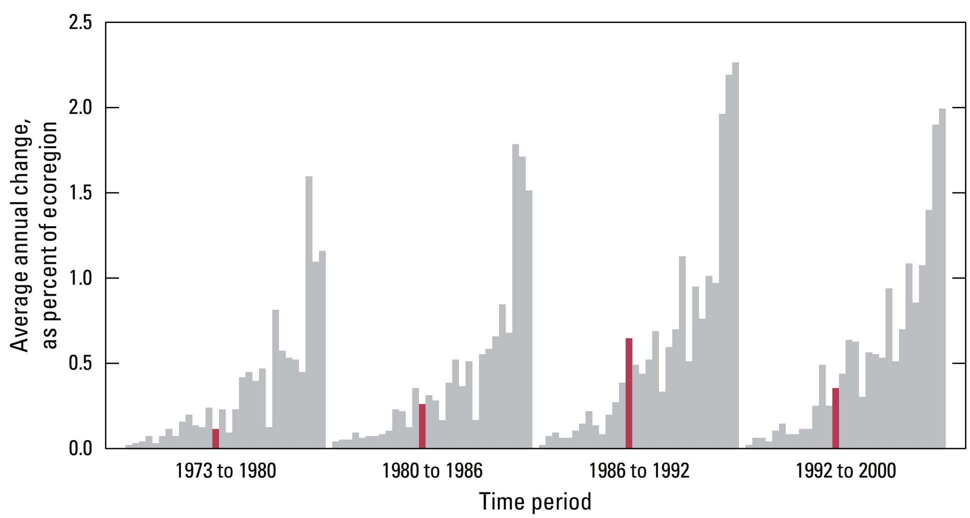

Figure 5. Estimates of land-cover change per time period, normalized to annual rates of change for all 30 Western United States ecoregions (gray bars). Estimates of change for Northern Basin and Range Ecoregion are represented by red bars in each time period.

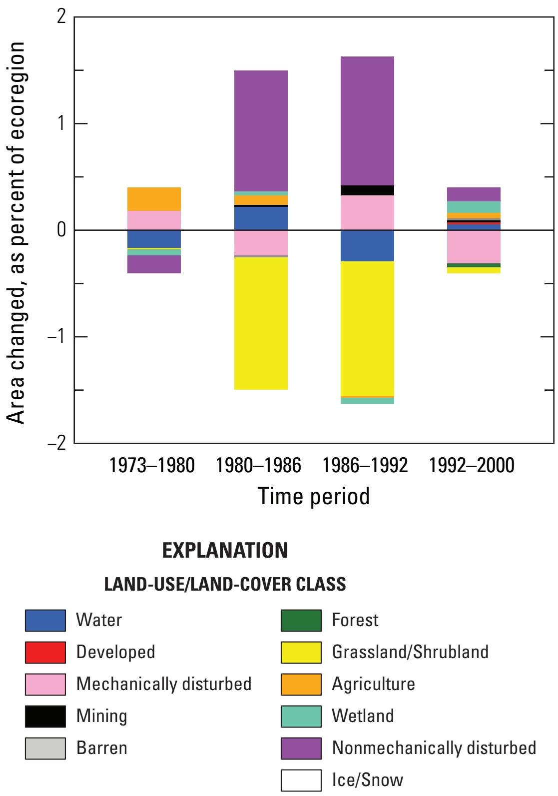

Figure 6. Normalized average net change in Northern Basin and Range Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix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

Figure 7. Area experiencing active nonmechanical disturbance of land cover by fire in Northern Basin and Range Ecoregion. Land-use/land-cover classes shown are grassland/shrubland, forest, and nonmechanically disturbed.

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

[Most sample pixels remained unchanged (94.2 percent), whereas 5.8 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	3.3	3.2	0.0	6.5	2.2	67.0
2	2.2	2.1	0.1	4.4	1.5	65.3
3	0.1	0.1	0.0	0.3	0.1	52.7
4	0.2	0.3	−0.1	0.5	0.2	97.7
Overall spatial change	5.8	3.9	2.0	9.7	2.6	44.7

Table 2. Raw estimates of change in Northern Basin and 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 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	0.8	0.5	0.3	1.2	0.3	42.8	0.1
1980–1986	1.6	1.0	0.6	2.6	0.7	43.3	0.3
1986–1992	3.9	2.7	1.2	6.5	1.8	47.2	0.6
1992–2000	2.8	2.1	0.7	4.8	1.4	50.2	0.3
Estimate of change, in square kilometers							
1973–1980	828	523	305	1,351	354	42.8	118
1980–1986	1,727	1,104	624	2,831	748	43.3	288
1986–1992	4,249	2,957	1,292	7,207	2,004	47.2	708
1992–2000	3,055	2,263	792	5,319	1,533	50.2	382

Table 3. Estimated area (and margin of error) of each land-cover class in Northern Basin and 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	0.5	0.4	0.1	0.0	0.1	0.1	0.1	0.1	0.4	0.2	3.8	2.5	91.9	2.6	2.0	0.9	1.0	0.5	0.2	0.3
1980	0.3	0.2	0.1	0.0	0.2	0.3	0.1	0.1	0.4	0.2	3.8	2.5	91.9	2.7	2.2	1.0	1.0	0.5	0.0	0.0
1986	0.6	0.4	0.1	0.0	0.0	0.0	0.1	0.1	0.4	0.2	3.8	2.5	90.7	2.7	2.3	1.0	1.0	0.5	1.1	1.0
1992	0.3	0.2	0.1	0.0	0.3	0.3	0.2	0.1	0.4	0.2	3.8	2.5	89.4	3.2	2.2	1.0	1.0	0.5	2.3	2.4
2000	0.3	0.2	0.1	0.1	0.0	0.0	0.2	0.1	0.4	0.2	3.7	2.5	89.3	3.9	2.3	1.1	1.1	0.5	2.5	3.2
Net change	−0.2	0.3	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.1	−2.6	3.3	0.3	0.3	0.1	0.2	2.3	3.3
Gross change	0.9	0.9	0.0	0.0	1.2	1.2	0.1	0.1	0.0	0.0	0.0	0.1	6.7	4.5	0.4	0.3	0.3	0.4	6.1	4.6
Area, in square kilometers																				
1973	551	401	62	49	59	84	73	57	463	183	4,156	2,792	101,150	2,908	2,177	964	1,152	526	194	282
1980	374	223	64	50	267	342	79	58	461	182	4,158	2,792	101,139	2,947	2,401	1,070	1,091	524	5	8
1986	619	386	68	53	1	1	97	65	458	182	4,157	2,791	99,752	2,974	2,492	1,132	1,145	523	1,250	1,060
1992	307	215	69	53	372	337	188	118	449	181	4,157	2,790	98,361	3,527	2,474	1,127	1,078	523	2,584	2,616
2000	378	229	80	65	30	25	219	133	451	181	4,111	2,783	98,309	4,301	2,538	1,178	1,210	548	2,713	3,571
Net change	−173	356	18	16	−29	89	146	116	−12	10	−45	60	−2,841	3,589	361	348	58	179	2,519	3,582
Gross change	1,016	997	18	16	1,305	1,340	152	116	28	21	48	60	7,387	4,965	444	342	381	404	6,670	5,066

Table 4. Principal land-cover conversions in Northern Basin and 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	Water	Mechanically disturbed	256	341	231	0.2	30.9
	Grassland/Shrubland	Agriculture	226	183	124	0.2	27.2
	Nonmechanically disturbed	Grassland/Shrubland	193	280	190	0.2	23.3
	Mechanically disturbed	Water	59	84	57	0.1	7.2
	Wetland	Grassland/Shrubland	44	50	34	0.0	5.3
	Other	Other	51	n/a	n/a	0.0	6.1
		Totals	828			0.8	100.0
1980–1986	Grassland/Shrubland	Nonmechanically disturbed	1,250	1,060	718	1.1	72.4
	Mechanically disturbed	Water	237	315	213	0.2	13.7
	Grassland/Shrubland	Agriculture	95	96	65	0.1	5.5
	Grassland/Shrubland	Wetland	34	40	27	0.0	2.0
	Grassland/Shrubland	Mining	21	28	19	0.0	1.2
	Other	Other	90	n/a	n/a	0.1	5.2
		Totals	1,727			1.6	100.0
1986–1992	Grassland/Shrubland	Nonmechanically disturbed	2,482	2,528	1,713	2.3	58.4
	Nonmechanically disturbed	Grassland/Shrubland	1,139	961	651	1.0	26.8
	Water	Mechanically disturbed	313	330	224	0.3	7.4
	Wetland	Grassland/Shrubland	70	68	46	0.1	1.6
	Grassland/Shrubland	Mechanically disturbed	49	72	49	0.0	1.2
	Other	Other	195	n/a	n/a	0.2	4.6
		Totals	4,249			3.9	100.0
1992–2000	Grassland/Shrubland	Nonmechanically disturbed	1,279	1,558	1,055	1.2	41.9
	Nonmechanically disturbed	Grassland/Shrubland	1,193	1,669	1,131	1.1	39.0
	Mechanically disturbed	Wetland	152	220	149	0.1	5.0
	Mechanically disturbed	Grassland/Shrubland	144	127	86	0.1	4.7
	Grassland/Shrubland	Agriculture	73	104	70	0.1	2.4
	Other	Other	215	n/a	n/a	0.2	7.0
		Totals	3,055			2.8	100.0
1973–2000 (overall)	Grassland/Shrubland	Nonmechanically disturbed	5,016	4,243	2,875	4.6	50.9
	Nonmechanically disturbed	Grassland/Shrubland	2,530	2,450	1,660	2.3	25.7
	Water	Mechanically disturbed	569	662	449	0.5	5.8
	Grassland/Shrubland	Agriculture	407	345	234	0.4	4.1
	Mechanically disturbed	Water	354	345	234	0.3	3.6
	Other	Other	983	n/a	n/a	0.9	10.0
		Totals	9,860			9.0	100.0

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Chapter 24

Snake River Basin Ecoregion

By Benjamin M. Sleeter

Ecoregion Description

Located in south-central Idaho, the Snake River Basin Ecoregion spans 66,063 km^2 (25,507 mi^2) of mostly sagebrush-steppe (*Artemisia tridentata*) with some areas of saltbush-greasewood (*Atriplex* spp. and *Sarcobatus* spp.) and barren lava fields (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). The Snake River is the dominant hydrographic feature extending the full length (east to west) of the ecoregion. Elevation ranges from approximately 640 m in the "Treasure Valley" (Canyon County, near Nampa, Idaho) to 2,000 m in the semiarid foothills and eastern Snake River Plain. Mean annual precipitation ranges from 15 to 50 cm annually, and highest precipitation occurs in the high elevations of the dissected plateaus and Teton Basin along the eastern edge of the ecoregion. Mean January temperatures range from –14 to 4°C, with mean July temperatures ranging from 8 to 32°C.

Land cover in the Snake River Basin Ecoregion is dominated by grassland/shrubland, which covered approximately two-thirds of the landscape in 2000 (fig. 2). The sagebrush-steppe ecosystems of the Snake River Plain consist of a mosaic of sagebrush and perennial grass species, including Wyoming big sagebrush (*Artemisia tridentata*), bluebunch wheatgrass (*Pseudoroegneria spicata*), basin wildrye (*Leymus cinereus*), rabbitbrush (*Chrysothamnus viscidiflorus*), Thurber needlegrass (*Achnatherum thurberianum*), Idaho fescue (*Festuca*

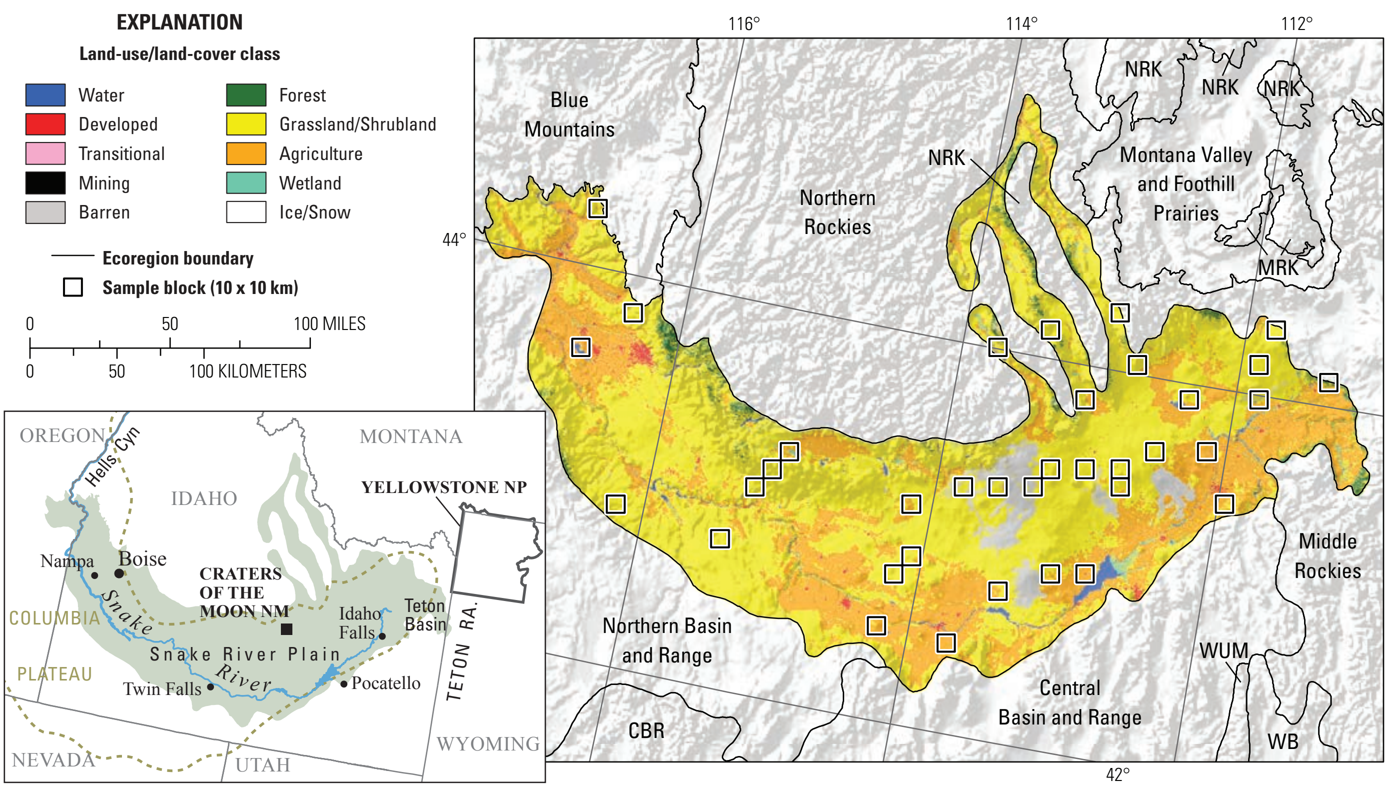

Figure 1. Map of Snake River Basin Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status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

Figure 3. Road serving as fire break in Snake River Basin Ecoregion. Area on right recently burned and has been revegetated with grasslands. Area to left of road was not burned and is dominated by sagebrush steppe.

idahoensis), threetip sagebrush (*Artemisia tripartita*), Gardner's saltbush (*Atriplex gardneri*), black greasewood (*Sarcobatus vermiculatus*), Indian ricegrass (*Achnatherum hymenoides*), fourwing saltbush (*Atriplex canescens*), crested wheatgrass (*Agropyron cristatum*), alkali sagebrush (*Artemisia longiloba*), and cheatgrass (*Bromus tectorum*) (McGrath and others, 2001). Disturbance from fire occurs at relatively long periods with low severity burns most common. However, due to the introduction of exotic species, such as cheatgrass, and managed burns to clear sagebrush for rangeland improvements, fire regimes have been altered, resulting in decreased fire-return periods with higher severity (fig. 3). Whisenant (1990) found fire-return periods had decreased from more than 75 years to as little as 5 to 10 years in some areas. The result on the landscape is a reduced ability of sagebrush species to recover postdisturbance, which may impact the long-term viability of sage-dependent species (Knick and Rotenberry, 1995).

Agriculture was the second most common land-use/land-cover type, accounting for approximately one-quarter of the ecoregion's area (fig. 4). Barren lands, primarily volcanic basalt flows, cover 2.6 percent of the ecoregion (fig. 5), and wetlands cover an additional 1.9 percent. Developed lands accounted for only 0.5 percent of the Snake River Basin Ecoregion. Whereas developed lands were limited, five of Idaho's largest cities are found within the Snake River Basin Ecoregion, including Boise (population 185,787), Nampa (population 51,867), Pocatello (population 51,466), Idaho Falls (population 50,730), and Twin Falls (population 34,469) (U.S. Census Bureau, 2010).

The high-elevation mountains surrounding the eastern Snake River Basin Ecoregion provide abundant high-quality water to the region. The absence of large settlements and industry contribute to the high quality of the water entering the basin. The Snake River derives as much as 50 percent of its annual flow from natural spring discharge (Miller and others, 2003). Surface water feeds the Snake River Basin aquifer, which is as much as 400 m thick, underlies 26,000 km^2 of the ecoregion, and contains about 1.23 x 10^{12} m^3 (100 million acre-ft) of water (Smith, 2004). Johnson and Cosgrove (1997) estimated that total groundwater storage declined on average about 350,000 acre-ft per year between 1975 and 1995, a cumulative decrease of 7 million acre-ft. Drought conditions caused declines in spring discharge and subsequent declines in groundwater levels as recharge capability dropped while withdrawals continued (Kjelstrom, 1986). However, in certain areas of the ecoregion, declines may be predominantly the result of a single factor (Idaho Department of Water Resources, 1999). For example, groundwater declines of 10 ft or more in Minidoka County were attributed to increased groundwater pumping in that area (Lindholm and others, 1988). Agricultural activities, urban runoff, and historical disposal practices at the Idaho National Engineering and Environmental Laboratory are major threats to groundwater quality (Smith, 2004).

Base flow of the Snake River was reduced, in part, owing to the introduction of more efficient irrigation technologies and a conversion from surface water to groundwater irrigation sources (Idaho Department of Water Resources, 1999; Miller and others, 2003). The net effect of efficiency improvements and pumpage by 1992 was an annual decrease in aquifer recharge of more than 2.1 million acre-ft, leading to groundwater-level and springflow declines (Idaho Department of Water Resources, 1999). Demands for Snake River water are diverse and include competition among agriculture, municipal users, industry, hydroelectric-power-generating utilities, recreation, and fish and wildlife. Federal and state management agencies are attempting to adjust to changing values while maintaining most of the traditional demands (Miller and others, 2003).

Contemporary Land-Cover Change (1973 to 2000)

Overall spatial change in the Snake River Basin Ecoregion, or the area that changed at least one time between 1973 and 2000, was 8.5 percent (5,604 km^2) (table 1). Compared to other western ecoregions, the Snake River Basin Ecoregion experienced a modest amount of change (fig. 6). Of the

Figure 4. Irrigated potato field near Twin Falls, Idaho.

Figure 5. Lava field at Craters of the Moon National Monument and Preserve, Idaho.

total area that changed, 6.6 percent of the ecoregion changed in only one time period, while 1.8 percent of the ecoregion changed in two periods. Changes in multiple dates are primarily attributed to fire disturbance and subsequent revegetation in following periods.

Change by time period ranged from 1.0 percent to 5.0 percent (table 2). When the time periods are normalized to account for the varying lengths of time, the highest rate of change was an estimated 411 km^2 of change per year between 1992 and 2000. The second highest rate of change was 343 km^2 per year between 1986 and 1992. The first two periods (1973–1980, 1980–1986) were relatively stable at an estimated 0.2 percent change per year. Rates of overall land-cover change in the Snake River Basin Ecoregion are unique from surrounding ecoregions (fig. 7). Ecoregions to the north are characterized by changes associated with forest disturbance from both natural and anthropogenic sources, whereas to the south change was relatively low in the basin-and-range ecoregions. The Snake River Basin Ecoregion contains a mix of land-cover changes that are generally associated with three themes: rangeland fire, agricultural expansion and contraction, and urbanization.

Grassland/shrubland declined 2.3 percent over the 27-year period, from 66.3 percent of the ecoregion in 1973 to 64.8 percent of the ecoregion in 2000. This amounts to a loss of 988 km^2. The period of greatest decline was between 1992 and 2000—an estimated loss of 1,232 km^2 over the 8-year period. The first three time periods were relatively stable in terms of net changes in grassland/shrubland (table 3; fig. 8). The large loss of grassland/shrubland between 1992 and 2000 was primarily a result of fire disturbance. During that period, an estimated 1,907 km^2 of grassland/shrubland were disturbed by fire, whereas 500 km^2 converted from a disturbed state back to grassland/shrubland (table 4).

The Snake River Basin Ecoregion is one of five key agricultural regions in the western United States along with the Columbia Plateau, Willamette Valley, Central California Valley, and Southern and Central California Chaparral and Oak Woodlands Ecoregions. Compared to these other agricultural

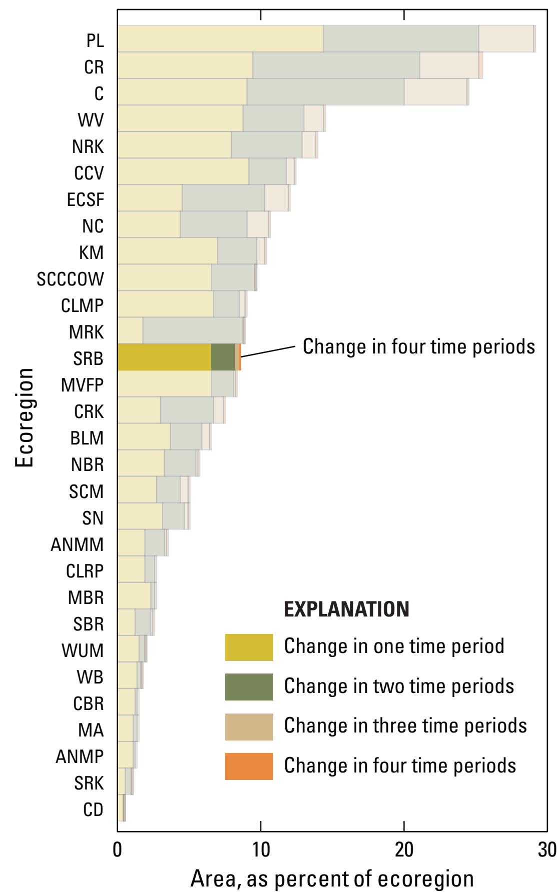

Figure 6. Overall spatial change in Snake River Basin Ecoregion (SRB; darker bars) compared with that of all 30 Western United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Snake River Basin 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.

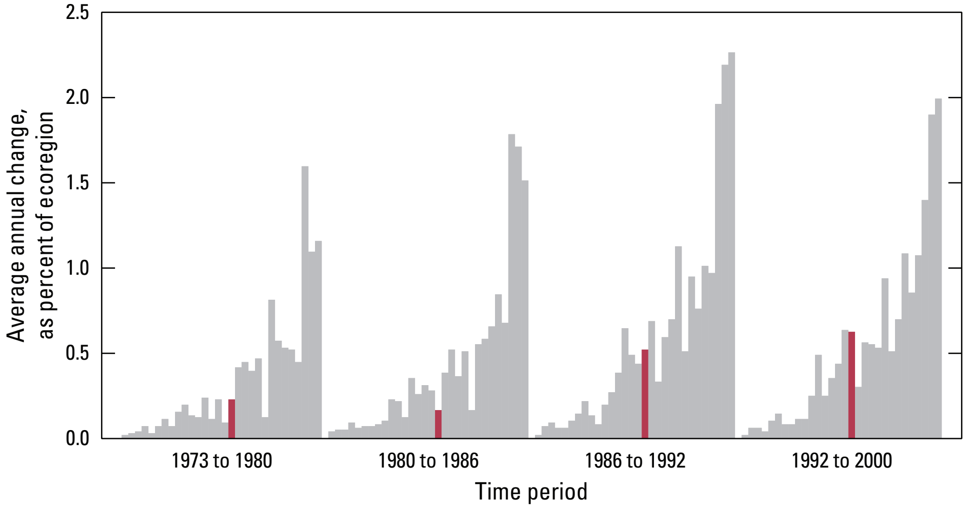

Figure 7. Estimates of land-cover change per time period normalized to annual rates of change for all 30 Western United States ecoregions (gray bars). Estimates of change for Snake River Basin Ecoregion are represented by red bars in each time period.

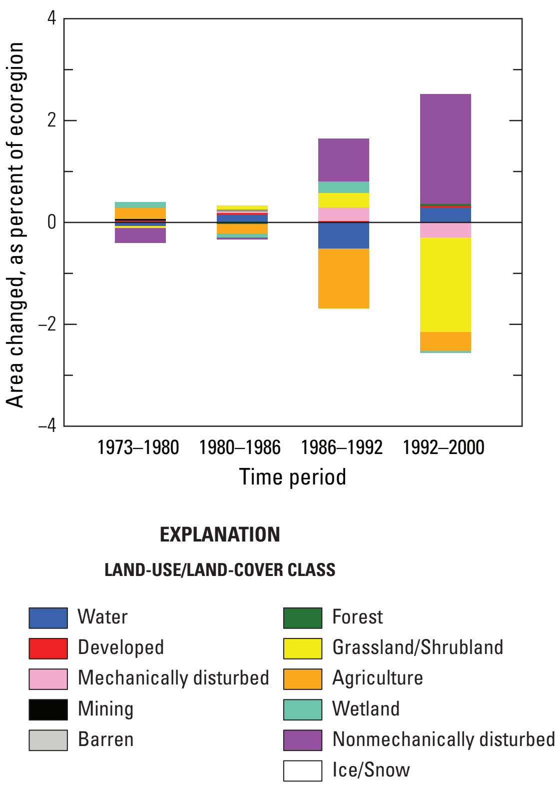

Figure 8. Normalized average net change in Snake River Basin Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use/land-cover classifications.

ecoregions, the Snake River Basin Ecoregion had the lowest overall spatial change but lost the largest amount of agriculture over the 27-year period (table 5).

The 1973 to 1980 period was the only period that realized a net increase (153 km^2) of agricultural land. Following 1980, agriculture began to decline and reached its largest period of loss between 1986 and 1992—a net loss of 773 km^2. Between 1992 and 2000, there was a net decline of 260 km^2 of agriculture. Driving the high amount of net loss in agriculture between 1986 and 1992 was the establishment of the Conservation Reserve Program (CRP). CRP enrollments began in 1986 and provided incentives for landowners to convert marginal and highly erodible croplands into natural vegetation. Based on county data from the U.S. Department of Agriculture (1999), counties in the Snake River Basin Ecoregion enrolled a total of 147,787 acres (598 km^2) into CRP by 1992. The main counties in Idaho that contributed to the program were Clark, Elmore, Madison, Teton, Bingham, and Twin Falls. Combined, they accounted for over three-quarters of all Snake River Basin Ecoregion CRP enrollments in 1992 (fig. 9).

Over the 27-year study period, developed land increased 47 percent. However, developed land uses make up less than 1 percent of the total ecoregion area. In 1973, an estimated 0.4 percent of the ecoregion was developed land, including the largest developed areas in the western part of the ecoregion associated with the cities of Boise and Nampa, Idaho. By 2000, developed land had increased to account for approximately 0.5 percent of the ecoregion—a gain of 112 km^2. Over the same three-decade period, population of counties that intersect the Snake River Basin Ecoregion increased from 561,641 in 1970 to 1,041,398 in 2000, an increase of 85 percent (U.S. Census Bureau, 2010).

Wetlands accounted for slightly less than 2 percent of the ecoregion and experienced a statistically significant

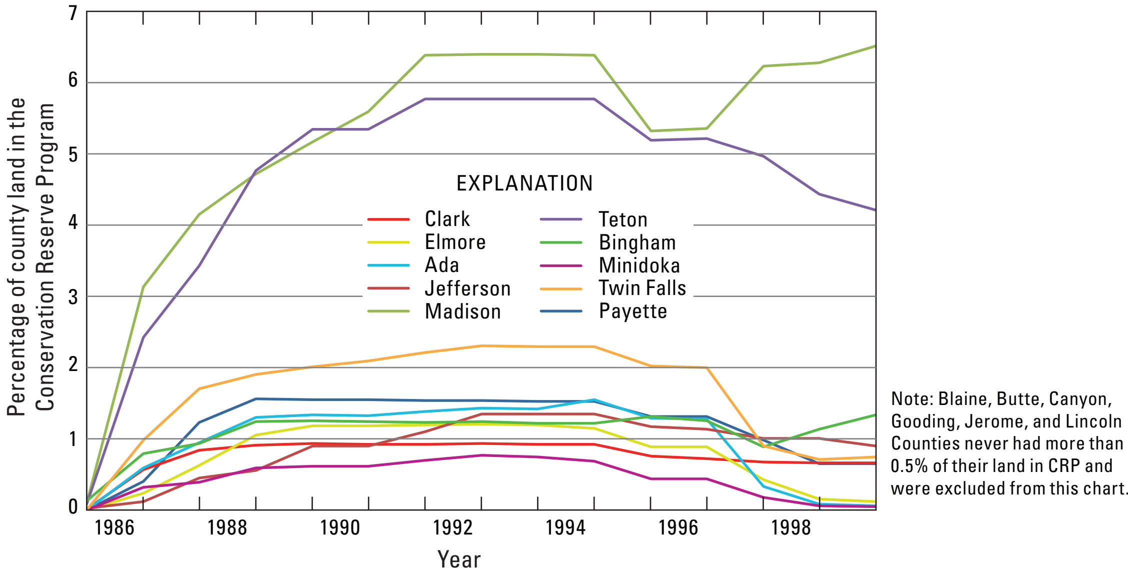

Figure 9. Enrollments in Conservation Reserve Program (CRP) for counties in Idaho that intersect Snake River Basin Ecoregion.

increasing trend throughout the study period. In 1973, wetlands accounted for 1.7 percent of the ecoregion, and by 2000 they accounted for 1.9 percent, an increase of 156 km^2.

As with many western ecoregions, ecosystem disturbance played an important role in the Snake River Basin Ecoregion. Nonmechanical disturbance, primarily from fire, accounted for an estimated 2,517 km^2 over the 27-year study period (table 4). Between 1973 and 1992, fire disturbance was relatively low with less than one percent of the ecoregion experiencing a disturbance in any of the periods. However, between 1992 and 2000, fire disturbance affected an estimated 3.0 percent of the ecoregion. Introduction of nonnative species and managed burns to remove sagebrush for range improvement are largely the cause of increased fire frequency (Pellant, 1990; Whisenant, 1990; Billings, 1994).

Land-cover change in the Snake River Basin Ecoregion generally involved land conversions into and out of the grassland/shrubland class (table 4). Conversions from grassland/shrubland to and from agriculture were most common and ranked in the top five conversions in each of the four time periods. Conversion from agricultural land to grassland/shrubland between 1980 and 1992 were especially common and were the top-ranked conversion during that time. From 1973 to 1980 and 1980 to 1986, conversion of grassland/shrubland to agriculture was the first and second most common conversion, respectively. Irrigation projects and technology advances, such as the adoption of center-pivot irrigation, likely resulted in the increase in agricultural land during this time. Changes associated with fire were most common in the last two time periods. Between 1992 and 2000 an estimated 1,907 km^2 converted from grassland/shrubland to nonmechanically disturbed, whereas an additional 500 km^2 of area classified as nonmechanically disturbed in the previous time period converted back to grassland/shrubland.

Drivers of land-cover and land-use change in the Snake River Basin Ecoregion are primarily associated with anthropogenic alteration of the sagebrush-steppe ecosystem. In the 1970s, areas of new agriculture outpaced areas converted out of agriculture by a 2:1 margin. With the implementation of the federal CRP program in the late 1980s, the trend reversed and nearly six times as much land ceased to be used for agriculture as there was new agricultural land. Historic management practices and the introduction of cheatgrass have influenced land change by promoting a change in historic fire regimes to more frequent and higher intensity burns. Managed burning to remove sagebrush for range improvement has also contributed to changes in land cover.

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

[Most sample pixels remained unchanged (91.5 percent), whereas 8.5 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	6.6	2.7	3.8	9.3	1.9	28.4
2	1.8	1.1	0.6	2.9	0.8	43.5
3	0.2	0.1	0.1	0.2	0.1	29.5
4	0.0	0.0	0.0	0.0	0.0	61.2
Overall spatial change	8.5	3.0	5.5	11.5	2.1	24.3

Table 2. Raw estimates of change in Snake River Basin 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	1.6	0.4	1.1	2.0	0.3	18.6	0.2
1980–1986	1.0	0.4	0.6	1.4	0.3	27.7	0.2
1986–1992	3.1	1.6	1.6	4.7	1.1	33.9	0.5
1992–2000	5.0	2.6	2.4	7.6	1.8	35.9	0.6
			Estimate of change, in square kilometers				
1973–1980	1,024	280	744	1,305	190	18.6	146
1980–1986	665	271	394	936	184	27.7	111
1986–1992	2,056	1,026	1,030	3,082	697	33.9	343
1992–2000	3,292	1,738	1,553	5,030	1,181	35.9	411

Table 3. Estimated area (and margin of error) of each land-cover class in Snake River Basin 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		Nonmechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
									Area, in percent stratum											
1973	1.0	0.9	0.4	0.2	0.0	0.0	0.1	0.0	2.6	1.9	3.1	2.7	66.3	8.3	24.5	7.5	1.7	1.2	0.4	0.3
1980	1.0	0.9	0.4	0.3	0.0	0.0	0.1	0.1	2.6	1.9	3.1	2.7	66.2	8.4	24.7	7.5	1.8	1.3	0.1	0.1
1986	1.1	0.9	0.4	0.3	0.1	0.1	0.1	0.1	2.6	1.9	3.1	2.6	66.3	8.4	24.5	7.5	1.7	1.2	0.0	0.0
1992	0.7	0.5	0.5	0.3	0.3	0.3	0.1	0.1	2.6	1.9	3.1	2.6	66.6	8.2	23.3	7.3	1.9	1.4	0.9	1.1
2000	0.9	0.8	0.5	0.3	0.0	0.0	0.1	0.1	2.6	1.9	3.2	2.7	64.8	8.2	22.9	7.2	1.9	1.4	3.0	2.6
Net change	−0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	−1.5	2.9	−1.5	1.5	0.2	0.2	2.7	2.4
Gross change	1.1	0.9	0.2	0.1	0.7	0.7	0.0	0.0	0.0	0.0	0.1	0.1	7.8	3.5	3.3	1.5	0.6	0.5	5.0	3.4
									Area, in square kilometers											
1973	678	592	237	138	27	27	41	30	1,704	1,272	2,074	1,755	43,775	5,491	16,154	4,964	1,126	818	248	181
1980	644	591	277	166	23	20	48	35	1,698	1,269	2,072	1,752	43,764	5,561	16,307	4,981	1,191	866	42	59
1986	758	618	297	178	41	42	56	43	1,699	1,269	2,063	1,735	43,825	5,577	16,177	4,961	1,148	823	0	0
1992	429	337	329	198	206	229	51	35	1,704	1,270	2,065	1,735	44,019	5,441	15,404	4,812	1,288	925	569	711
2000	622	555	349	213	27	24	56	41	1,706	1,270	2,089	1,767	42,787	5,385	15,144	4,787	1,282	917	2,000	1,718
Net change	−56	69	112	91	1	32	15	15	2	7	15	16	−988	1,930	−1,009	1,010	156	140	1,752	1,613
Gross change	732	568	116	90	476	450	33	29	14	14	46	57	5,160	2,299	2,154	1,016	409	343	3,319	2,256

Table 4. Principal land-cover conversions in Snake River Basin 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	382	157	107	0.6	37.3
	Nonmechanically disturbed	Grassland/Shrubland	248	180	123	0.4	24.2
	Agriculture	Grassland/Shrubland	169	102	69	0.3	16.5
	Water	Wetland	54	54	36	0.1	5.2
	Grassland/Shrubland	Nonmechanically disturbed	42	59	40	0.1	4.1
	Other	Other	130	n/a	n/a	0.2	12.7
		Totals	1,024			1.6	100.0
1980–1986	Agriculture	Grassland/Shrubland	200	124	84	0.3	30.1
	Grassland/Shrubland	Agriculture	151	83	56	0.2	22.6
	Wetland	Water	109	129	88	0.2	16.4
	Agriculture	Wetland	49	71	48	0.1	7.4
	Nonmechanically disturbed	Grassland/Shrubland	42	59	40	0.1	6.2
	Other	Other	114	n/a	n/a	0.2	17.1
		Totals	665			1.0	100.0
1986–1992	Agriculture	Grassland/Shrubland	890	721	490	1.3	43.3
	Grassland/Shrubland	Nonmechanically disturbed	569	711	483	0.9	27.7
	Water	Mechanically disturbed	182	225	153	0.3	8.8
	Grassland/Shrubland	Agriculture	143	122	83	0.2	7.0
	Water	Wetland	138	137	93	0.2	6.7
	Other	Other	134	n/a	n/a	0.2	6.5
		Totals	2,056			3.1	100.0
1992–2000	Grassland/Shrubland	Nonmechanically disturbed	1,907	1,635	1,111	2.9	57.9
	Nonmechanically disturbed	Grassland/Shrubland	500	706	480	0.8	15.2
	Agriculture	Grassland/Shrubland	375	261	177	0.6	11.4
	Mechanically disturbed	Water	178	225	153	0.3	5.4
	Grassland/Shrubland	Agriculture	173	71	48	0.3	5.3
	Other	Other	158	n/a	n/a	0.2	4.8
		Totals	3,292			5.0	100.0
1973–2000 (overall)	Grassland/Shrubland	Nonmechanically disturbed	2,517	1,831	1,244	3.8	35.8
	Agriculture	Grassland/Shrubland	1,634	1,030	700	2.5	23.2
	Grassland/Shrubland	Agriculture	849	276	187	1.3	12.1
	Nonmechanically disturbed	Grassland/Shrubland	789	720	489	1.2	11.2
	Mechanically disturbed	Water	208	229	156	0.3	3.0
	Other	Other	1,039	n/a	n/a	1.6	14.8
		Totals	7,036			10.7	100.0

Table 5. Overall spatial change and net agricultural change in five main agricultural ecoregions of western United States.

Ecoregion	Overall spatial change (percent of ecoregion)	Agricultural change (km^2)	Agricultural change (percent ecoregion)
Snake River Basin	8.5	−1,022	−1.6
Southern and Central California Chaparral and Oak Woodlands	9.7	−862	−0.8
Willamette Valley	14.5	−322	−2.2
Central California Valley	12.4	+358	+0.8
Columbia Plateau	9.0	+534	+0.6

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Chapter 25

Wyoming Basin Ecoregion

By Todd J. Hawbaker

Ecoregion Description

The Wyoming Basin Ecoregion (Omernik 1987; U.S. Environmental Protection Agency, 1999) covers approximately 128,914 km^2 (49,774 mi^2) in Wyoming and parts of northwestern Colorado, northeastern Utah, southeastern Idaho, and southern Montana (fig. 1). The ecoregion is bounded on the east by the Northwestern Great Plains Ecoregion; on the south and east by the Southern Rockies Ecoregion; on the south by the Colorado Plateaus Ecoregion; on the south and west by the Wasatch and Uinta Mountains Ecoregion; and on the north by the Middle Rockies Ecoregion and parts of the Montana Valley and Foothill Prairies Ecoregion (fig. 1). The ecoregion generally consists of broad intermountain basins dominated by arid

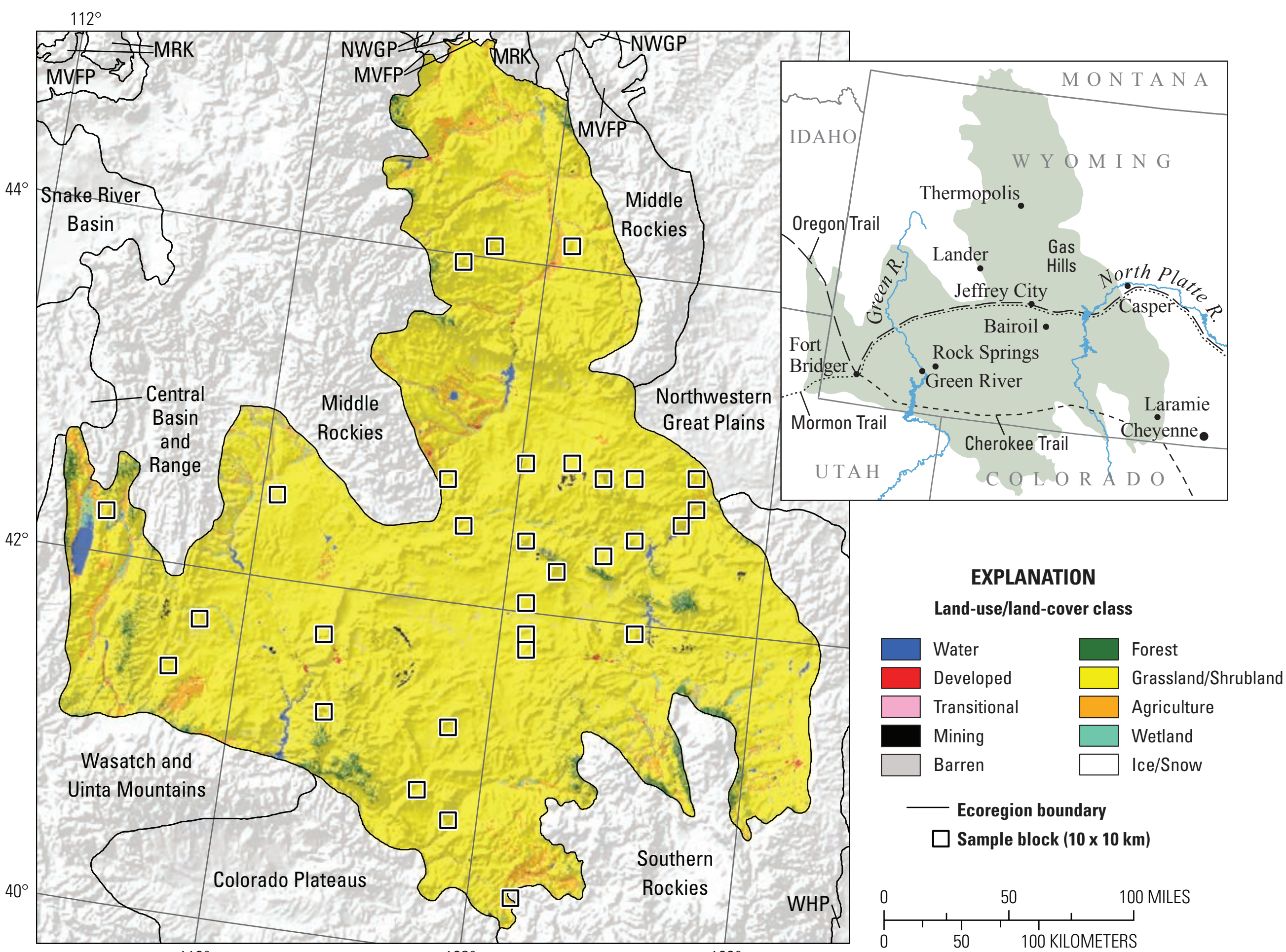

Figure 1. Map of Wyoming Basin Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this “Status and 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 parts of two Great Plains ecoregions: Northwestern Great Plains (NWGP) and Western High Plains (WHP). See appendix 3 for definitions of land-use/land-cover classifications.

grasslands and shrublands, as well as isolated hills and low mountains that merge to the south into a dissected plateau.

The climate in the Wyoming Basin Ecoregion is semi-arid continental, and it is drier and windier than most places in the United States. The average annual precipitation from rain is 20 cm in Green River, Wyoming, 28 cm in Thermopolis, Wyoming, and 30 cm in Casper, Wyoming. The average annual snowfall is 74 cm in Green River, 76 cm in Thermopolis, and 198 cm in Casper. Average maximum monthly temperatures range from 32°C and above in July to near −17°C in January (Desert Research Institute, 2011). Nearly surrounded by forest-covered mountains, the region is somewhat drier than the Northwestern Great Plains Ecoregion to the northeast.

Vegetation consists of grasses interspersed among big sagebrush (*Artemisia tridentata*). Higher elevations harbor some quaking aspen (*Populus tremuloides*) and patches of coniferous forest. Open water is rare in this ecoregion, consisting mainly of reservoirs on the North Platte and Green Rivers, as well as on smaller rivers that traverse the area. Many minor waterways have been dammed to provide water for livestock. Stream beds are often dry in these riparian areas. Wetlands are especially rare and typically are riparian.

This ecoregion has a rich history in the settlement of the American West. Several major trails cross through the ecoregion, as it provides a low pass across the Rocky Mountains (fig. 1). The Oregon Trail was used by settlers heading west during the 1840s to 1890s. The northern route of the Cherokee Trail, which crosses through southern Wyoming, was used primarily by travelers heading west to the California gold fields. The Mormon Trail was used between 1846 and 1857 by Mormons fleeing to Utah after persecution in the Midwest (Hill, 1987). The short-lived Pony Express also had stations lining an east-to-west route near the Oregon Trail (Di Certo, 2002). Evidence of many of these old trails is still visible. The Pony Express and overland movement along wagon trails started to decline with the increase in rail travel and telegraph use starting in the mid- to late-1800s.

Human population in the Wyoming Basin Ecoregion is sparse. The largest cities in the ecoregion are Casper (population, 49,644 in 2000), Laramie (27,204), and Rock Springs (18,708), Wyoming (U.S. Census Bureau, 2011). Much of the ecoregion is used for cattle and sheep grazing, often in managed pastures, and ranches are common, but many areas lack sufficient vegetation to support grazing. Agriculture is limited primarily to irrigated hay, corn, and sugar beets along river bottoms (fig. 2). Much of the land is owned by the Bureau of Land Management and is leased to ranches for cattle grazing.

The Wyoming Basin Ecoregion has a long history of energy development, as it holds large reserves of minerals, oil, and natural gas (fig. 3). Wyoming accounts for roughly 40 percent of all coal production in the United States, the most of any state (Freme, 2009). Much of the coal mined in Wyoming is shipped to the Midwest, producing approximately 30 percent of the electricity consumed in the United States.

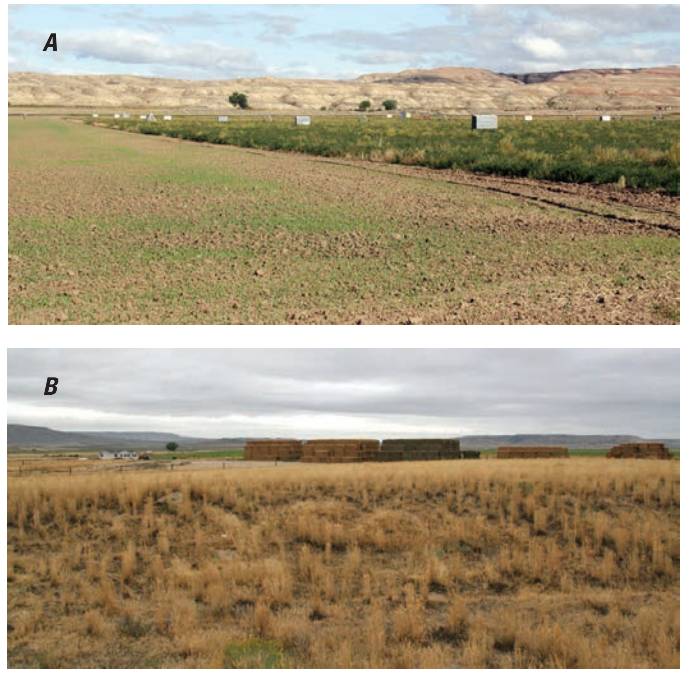

Figure 2. Agriculture in Wyoming Basin Ecoregion. *A*, Irrigated crops. *B*, Hay production.

Figure 3. Energy development in south-central Wyoming.

Figure 4. Reclaimed mine in Gas Hills District of Wyoming.

Figure 5. Oil well near Bairoil, Wyoming, and warning sign for hydrogen-sulfide gas.

Coal-fired power plants are scattered throughout the ecoregion, and large transmission lines radiate from them. Uranium mining once was common but decreased in the 1980s after the incidents at Three Mile Island and Chernobyl nuclear power plants. Many of those once-active mines have been reclaimed (fig. 4). Towns associated with uranium mining, such as Jeffrey City, Wyoming, are largely deserted. Today, uranium is mined in place using chemicals to dissolve the minerals before pumping them to the surface (Gregory, 2011).

Wyoming's first oil well was drilled in 1885, just southeast of Lander, Wyoming (Roberts, 2011). As of 2006, Wyoming ranked second in the United States for proven natural-gas reserves and fourth for proven crude-oil reserves (fig. 5). The most recent period of energy development started in the late 1990s and has intensified with rising energy prices during the 2000s. In some places, the density of recent energy development has produced a nearly continuous matrix of wells and their associated transportation networks. There is growing concern about how intensifying energy development will affect the populations and migration patterns of wildlife species that use parts of the Wyoming Basin Ecoregion (Bowen and others, 2009).

Contemporary Land-Cover Change (1973 to 2000)

Between 1973 and 2000, 1.8 percent of the Wyoming Basin Ecoregion changed land-use/land-cover classes at least once (table 1; fig. 6). In 1.4 percent of the ecoregion, change occurred in land-use/land-cover in one time period. Overall, the average annual rate of land-cover change in the Wyoming Basin Ecoregion was very low, at only 0.1 percent (fig. 7; table 2). Rates of change varied little among the different time periods analyzed. Even though the rate of change appeared low, the Wyoming Basin Ecoregion's size meant that it amounted to nearly 92 to 181 km^2 per year of total change, depending on the time period (table 2). Overall, this ecoregion's level of change was one of the lowest among western United States ecoregions (table 1).

The extent of agriculture increased until 1986 and then started to decline, although it remained at 2 percent of ecoregion in 2000. The extent of grassland/shrubland was negatively correlated to agriculture, and it was at its lowest point in 1986. In contrast, the amount of area classified as water, wetland, and mechanically disturbed (primarily reservoir drawdown) fluctuated during each time period (table 3). Conversions between grassland/shrubland and agriculture and between water, wetland, and mechanically disturbed account for the majority of change observed in the ecoregion (table 4).

During the 27-year study period, the extent of urban developed land increased from 39 km^2 to 61 km^2, with most expansion occurring near cities such as Cheyenne and Rock Springs, Wyoming. The amount of forest land decreased by

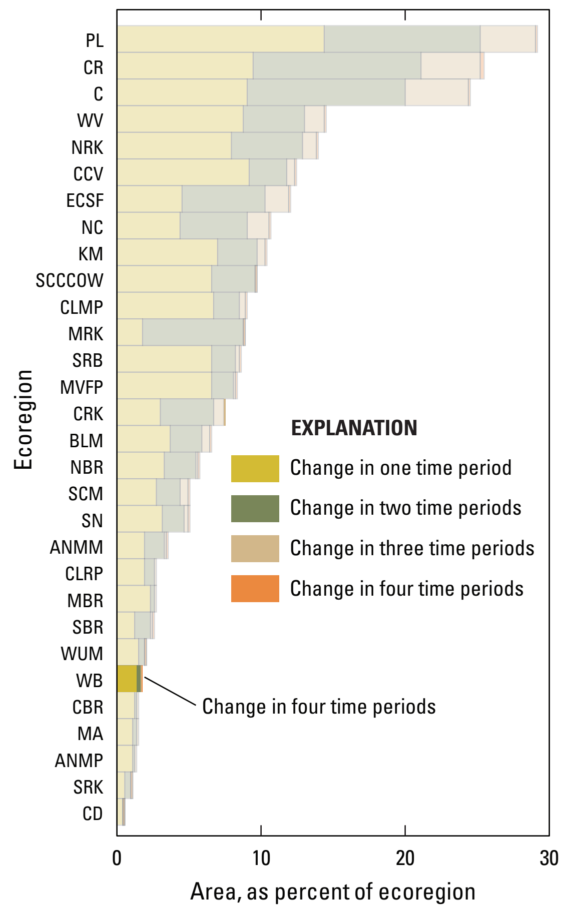

Figure 6. Overall spatial change in Wyoming Basin Ecoregion (WB; darker bars) compared with that of all 30 Western United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Wyoming Basin 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.

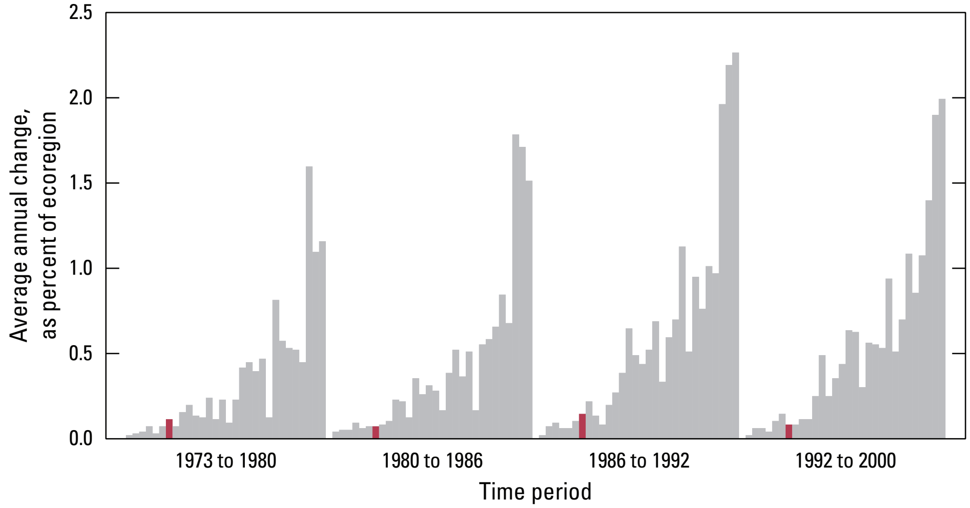

Figure 7. Estimates of land-cover change per time period, normalized to annual rates of change for all 30 Western United States ecoregions (gray bars). Estimates of change for Wyoming Basin Ecoregion are represented by red bars in each time period.

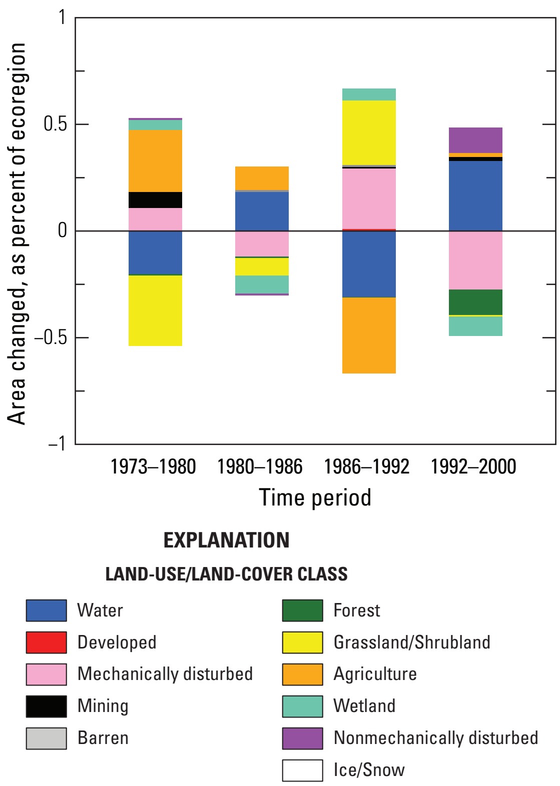

Figure 8. Normalized average net change in Wyoming Basin Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use/land-cover classifications.

4.2 percent, from 4,205 km^2 in 1973 to 4,027 km^2 in 2000. Nonmechanical disturbances were rare (table 3; figure 8).

The area covered by energy-related development (mining land-cover class) also was relatively low (0.3 percent in 2000; table 3); however, this area increased substantially, from 301 km^2 in 1973 to 435 km^2 in 2000 (table 3). Thus, a 44 percent increase occurred in the area impacted by energy development during the 27-year study period. Most of the mining increases took place between 1973 and 1980, during which time mining land cover is estimated to have increased by nearly 30 percent (fig. 8) following the energy boom that occurred in the 1970s.

The amount of area affected by mining may be underestimated, owing to the study's sampling design and the random sample-block selection process, as well as the 60-m resolution of the data. Almost all of the blocks fell outside areas experiencing major energy development. Some sample blocks (143, 533, 622) contained some energy development, but major oil and gas fields such as the Jonah and Pinedale fields were not sampled in the random selection process. Many oil- and gas-well pads are less than 60 m^2 and, thus, did not meet the minimum mapping-unit size in this study. Additionally, the extensive transportation networks required to access the oil- and gas-well pads have not been mapped. Thus, the measures of area in the mining and developed land-use/land-cover classes can be interpreted as highly conservative estimates of the true area affected.

Today (2012), Wyoming is in the midst of another energy boom. High demand and increasing prices for oil and gas since 2000 have rapidly transformed Wyoming's economy and landscape. Information from this project and other USGS projects that are examining the impacts of energy development, as well as from anecdotal accounts, indicates that the current rate of energy development is greatly outpacing past rates.

The fact that a large proportion of the Wyoming Basin Ecoregion is public land will constrain certain types of land-use/land-cover change. Energy exploration and grazing are extensive on both public and private lands, but intensive agricultural and urban development is limited to private lands. This constraint, in addition to a harsh and dry climate, generally limits agriculture to riparian areas where water is directly available for irrigation. The extent of agriculture fluctuated during the study period and is likely to continue to fluctuate as demand for agricultural products changes over time.

Urban development also will be both constrained and driven by land-ownership patterns. On the one hand, public lands preclude housing and urban development. On the other hand, public lands provide natural amenities that often attract low-density-housing development. The greatest increases in developed land occurred between 1986 and 1992, following the energy boom of the mid-1970s, and between 1992 and 2000 (fig. 8). Just as this study provides a conservative estimate of the area impacted by mining, it is probably providing a highly conservative estimate of the area impacted by development.

Most of the Wyoming Basin Ecoregion has not experienced substantial land-use/land-cover change during the past three decades. Large expanses of land remain largely free of development and agriculture; however, Wyoming's mineral resources are abundant, and the only limit to energy development may be the cost of extraction. As demands for energy increase with population growth, energy-related landscape change in the Wyoming Basin Ecoregion will increase. The overall footprint of energy development may be small, but the impacts on wildlife and water quality from mines, well pads, and related transportation infrastructure may extend out for some distance. Balancing wildlife and habitat conservation with the economic and social benefits of agricultural land uses and energy development will become increasingly challenging as the landscape in the Wyoming Basin Ecoregion continues to change.

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

[Most sample pixels remained unchanged (98.2 percent), whereas 1.8 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	1.4	0.7	0.6	2.1	0.5	35.6
2	0.3	0.2	0.1	0.5	0.1	41.9
3	0.0	0.0	0.0	0.0	0.0	56.4
4	0.2	0.3	−0.1	0.5	0.2	97.5
Overall spatial change	1.8	0.9	1.0	2.7	0.6	32.0

Table 2. Raw estimates of change in Wyoming Basin 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	0.8	0.4	0.4	1.2	0.3	34.7	0.1
1980–1986	0.4	0.3	0.1	0.7	0.2	47.1	0.1
1986–1992	0.8	0.7	0.2	1.5	0.5	54.0	0.1
1992–2000	0.7	0.5	0.2	1.1	0.3	46.5	0.1
Estimate of change, in square kilometers							
1973–1980	1,018	523	495	1,541	354	34.7	145
1980–1986	550	383	167	933	259	47.1	92
1986–1992	1,087	868	219	1,955	587	54.0	181
1992–2000	858	591	267	1,449	399	46.5	107

Table 3. Estimated area (and margin of error) of each land-cover class in Wyoming Basin 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	0.5	0.4	0.0	0.0	0.0	0.0	0.2	0.2	0.6	0.5	3.3	1.9	92.3	2.4	1.9	1.4	1.2	0.5	0.0	0.0
1980	0.3	0.2	0.0	0.0	0.1	0.2	0.3	0.3	0.6	0.5	3.3	1.9	92.0	2.5	2.2	1.5	1.2	0.5	0.0	0.0
1986	0.5	0.4	0.0	0.0	0.0	0.0	0.3	0.3	0.6	0.5	3.2	1.9	91.9	2.5	2.3	1.5	1.1	0.5	0.0	0.0
1992	0.2	0.1	0.0	0.0	0.3	0.3	0.3	0.3	0.6	0.5	3.2	1.9	92.2	2.3	2.0	1.1	1.2	0.5	0.0	0.0
2000	0.5	0.4	0.0	0.0	0.0	0.0	0.3	0.3	0.6	0.5	3.1	1.7	92.2	2.3	2.0	1.2	1.1	0.5	0.1	0.2
Net change	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	−0.1	0.2	−0.1	0.7	0.1	0.7	−0.1	0.1	0.1	0.2
Gross change	1.1	1.4	0.0	0.0	0.8	0.9	0.1	0.1	0.0	0.0	0.1	0.2	1.1	0.6	0.9	0.6	0.5	0.4	0.1	0.2
Area, in square kilometers																				
1973	659	576	39	40	6	9	301	289	749	581	4,205	2,426	118,962	3,124	2,511	1,812	1,483	642	0	0
1980	403	276	40	40	152	219	390	371	751	581	4,193	2,423	118,539	3,192	2,886	1,917	1,548	620	13	19
1986	638	545	42	41	1	1	397	369	755	581	4,184	2,421	118,426	3,206	3,028	1,967	1,444	608	0	0
1992	234	164	57	43	362	397	416	371	759	581	4,183	2,421	118,825	2,958	2,570	1,476	1,508	603	0	0
2000	660	566	61	44	10	7	435	380	760	581	4,027	2,229	118,822	2,947	2,595	1,498	1,388	586	157	229
Net change	1	21	23	13	4	11	134	95	10	16	−178	230	−140	857	85	845	−96	69	157	229
Gross change	1,412	1,769	23	13	1,033	1,221	140	101	22	16	179	231	1,422	807	1,113	831	589	560	183	231

Table 4. Principal land-cover conversions in Wyoming Basin 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	423	339	229	0.3	41.6
	Water	Mechanically disturbed	150	219	148	0.1	14.8
	Water	Wetland	122	170	115	0.1	11.9
	Grassland/Shrubland	Mining	89	84	57	0.1	8.7
	Agriculture	Grassland/Shrubland	82	109	74	0.1	8.1
	Other	Other	152	n/a	n/a	0.1	14.9
		Totals	1,018			0.8	100.0
1980–1986	Grassland/Shrubland	Agriculture	135	88	59	0.1	24.6
	Mechanically disturbed	Water	133	195	132	0.1	24.3
	Wetland	Water	107	155	105	0.1	19.5
	Grassland/Shrubland	Wetland	43	41	28	0.0	7.9
	Wetland	Grassland/Shrubland	40	29	19	0.0	7.2
	Other	Other	91	n/a	n/a	0.1	16.6
		Totals	550			0.4	100.0
1986–1992	Agriculture	Grassland/Shrubland	498	716	484	0.4	45.8
	Water	Mechanically disturbed	333	397	269	0.3	30.6
	Water	Wetland	82	113	77	0.1	7.5
	Grassland/Shrubland	Agriculture	39	33	22	0.0	3.6
	Grassland/Shrubland	Mechanically disturbed	23	32	22	0.0	2.1
	Other	Other	112	n/a	n/a	0.1	10.3
		Totals	1,087			0.8	100.0
1992–2000	Mechanically disturbed	Water	336	397	268	0.3	39.2
	Forest	Nonmechanically disturbed	157	229	155	0.1	18.3
	Wetland	Water	88	121	82	0.1	10.3
	Grassland/Shrubland	Agriculture	77	75	50	0.1	9.0
	Agriculture	Grassland/Shrubland	59	54	37	0.0	6.8
	Other	Other	141	n/a	n/a	0.1	16.5
		Totals	858			0.7	100.0
1973–2000 (overall)	Grassland/Shrubland	Agriculture	675	456	309	0.5	19.2
	Agriculture	Grassland/Shrubland	641	874	591	0.5	18.3
	Water	Mechanically disturbed	486	611	413	0.4	13.8
	Mechanically disturbed	Water	472	587	397	0.4	13.4
	Wetland	Water	217	277	187	0.2	6.2
	Other	Other	1,022	n/a	n/a	0.8	29.1
		Totals	3,513			2.7	100.0

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Chapter 26

Arizona/New Mexico Plateau Ecoregion

By Jana Ruhlman, Leila Gass, and Barry Middleton

Ecoregion Description

Situated between ecoregions of distinctly different topographies and climates, the Arizona/New Mexico Plateau Ecoregion represents a large area of approximately 192,869 km^2 (74,467 mi^2) that stretches across northern Arizona, central and northwestern New Mexico, and parts of southwestern Colorado; in addition, a small part extends into southeastern Nevada (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). Forested, mountainous terrain borders the ecoregion on the northeast (Southern Rockies Ecoregion) and southwest (Arizona/New Mexico Mountains Ecoregion). Warmer and drier climates exist to the south (Chihuahuan Deserts Ecoregion) and west (Mojave Basin and Range Ecoregion). The semiarid grasslands of the western Great Plains are to the east (Southwestern Tablelands Ecoregion), and the tablelands of the Colorado Plateau in Utah and western Colorado lie to the north (Colorado Plateaus Ecoregion). The Arizona/New Mexico Plateau Ecoregion occupies a significant portion of the southern half of the Colorado Plateau.

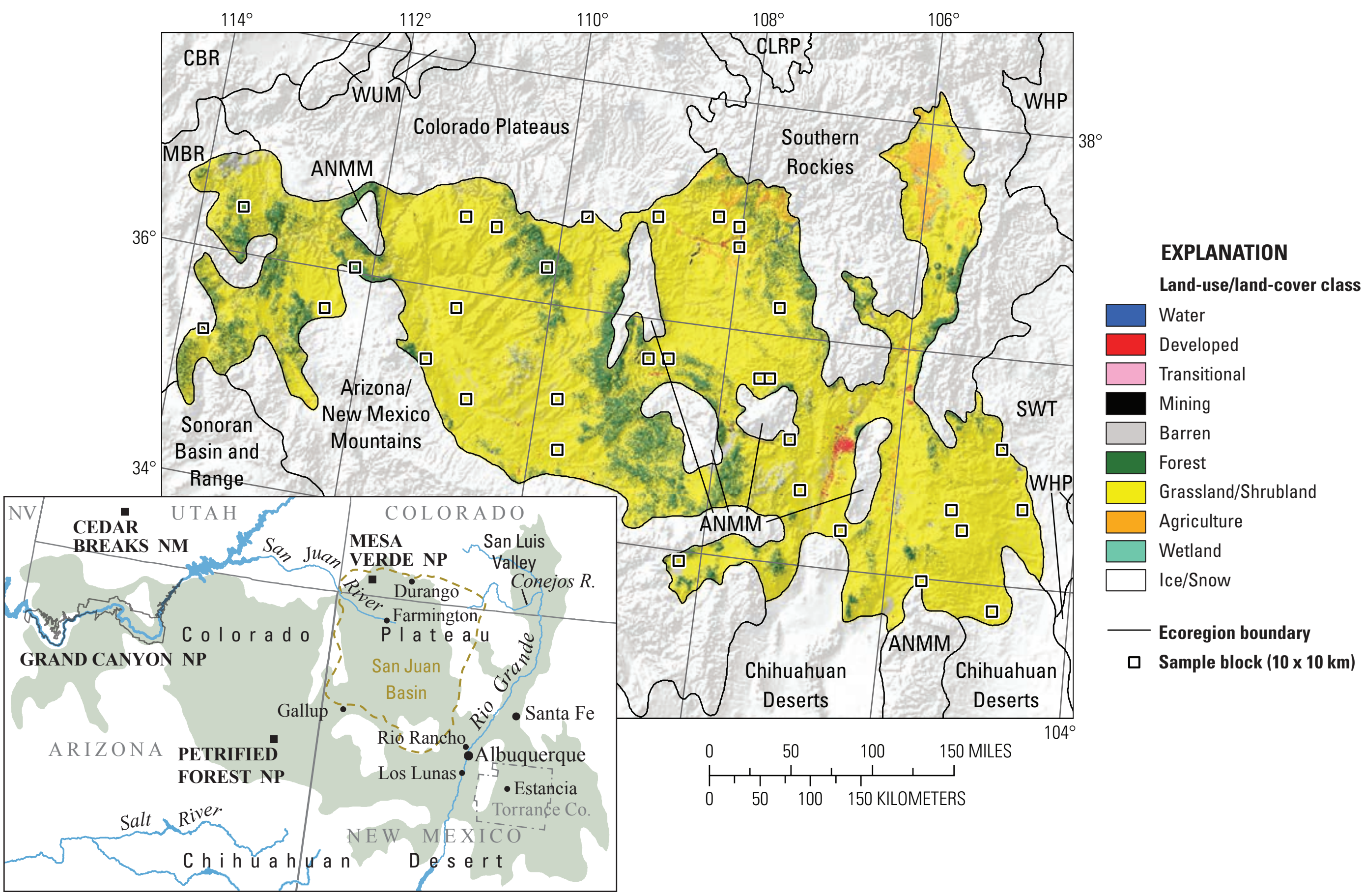


Figure 1. Map of Arizona/New Mexico Plateau Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "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 parts of two Great Plains ecoregions: Southwestern Tablelands (SWT) and Western High Plains (WHP). See appendix 3 for definitions of land-use/land-cover classifications.

The Arizona/New Mexico Plateau Ecoregion is covered predominantly in a mosaic of sparse semiarid grassland and desert-scrub species. Major washes and river courses often contain riparian canopies of cottonwood (*Populus deltoides*), desert willow (*Chilopsis linearis*), and salt cedar (*Tamarix* spp.). Juniper (*Juniperus* spp.) and pinyon (*Pinus* spp.) trees are located in the upland areas, with ponderosa pine (*Pinus ponderosa*) forests present at the highest elevations. The climate in the ecoregion is mostly semiarid, but regional topography causes annual precipitation to vary substantially, ranging from 127 to 890 mm (Daly and others, 2002). Most of the ecoregion, however, averages between 152 and 254 mm of precipitation from southwestern monsoonal summer thunderstorms and winter frontal storms. The coldest areas can dip below −17.8°C in winter, and the hottest summer temperatures can exceed 36°C (Western Regional Climate Center, 2009).

Albuquerque, New Mexico, is the largest urban area, with a 2000 census population of 448,607, followed by Santa Fe, New Mexico, with a population of 62,203. Numerous smaller communities exist within the ecoregion, but only five municipalities had a 2000 census count greater than 10,000: Rio Rancho, Farmington, Gallup, and Los Lunas, New Mexico, and Durango, Colorado (U.S. Census Bureau, 2001a, 2001b). Over 55 percent of the ecoregion is federal land, with the majority occupying one of 29 different Indian reservations and pueblos. The largest of these tribal lands is the Navajo Nation, with 41,562 km^2 within the Arizona/New Mexico Plateau Ecoregion. The next largest federal landholders in the ecoregion are the Bureau of Land Management, Forest Service, and National Park Service. There are 15 National Park Service areas within the ecoregion; many of the national parks and monuments are dedicated to preserving the rich history and remnants from the Southwest's ancient native cultures. Prominent national parks in the ecoregion are the Grand Canyon and the Petrified Forest in Arizona and Mesa Verde in Colorado.

Because of limited rainfall in the ecoregion, crop production is found primarily in close proximity to natural water sources such as the Rio Grande, San Juan River, and Conejos River. The high mountains surrounding the fertile San Luis Valley in south-central Colorado and northern New Mexico provide snowmelt, which supports extensive farming in that area (McNoldy and Doesken, 2007). Likewise, there is considerable agriculture in the closed Estancia basin region in Torrance County, New Mexico, which is "one of the most productive agricultural counties in the United States" (Torrance County, New Mexico, 2009).

With over 33 percent of the Arizona/New Mexico Plateau Ecoregion designated as tribal lands, sheep ranching, cattle ranching, and farming (dry and some irrigated) continue to be the primary traditional economic activities for many Native Americans (Grahame and Sisk, 2002). The effect of low regional precipitation levels that can support only scant forage has been exacerbated by a long-term trend toward aridity in this part of the ecoregion (Karl and others, 2009). Combined with historical overgrazing and desertification, the condition of the rangeland in many areas is poor. As early as 1933, the Bureau of Indian Affairs determined that two-thirds of the Navajo rangeland had been overgrazed (Grahame and Sisk, 2002). Increases in wind erosion and sand-dune mobility that have resulted from current drought conditions across northeastern Arizona have further degraded rangelands (Ferguson and Crimmins, 2009).

Mining also contributes to local economies in parts of the Arizona/New Mexico Plateau Ecoregion. The San Juan Basin in northwestern New Mexico and southwestern Colorado was at one time the second largest natural-gas reserve in the United States (La Plata County Energy Council, 2009), having 20,000 producing wells (Ortega, 2009). Additionally, the Peabody Western Coal Company mines about 8.5 million tons of coal annually through lease agreements with the Navajo Nation and Hopi Tribe (U.S. Office of Surface Mining, 2008). As the ecoregion's largest city, Albuquerque is also its largest economy. Located at the crossroads of Interstate Highways 25 and 70, Albuquerque has a "diverse economic base consisting of government, services, trade, agriculture, tourism, manufacturing, and research and development" (City-Data.com, 2009). Kirtland Air Force Base is the largest employer in the Albuquerque metropolitan area (Albuquerque Economic Development, Inc., 2010).

Contemporary Land-Cover Change (1973 to 2000)

The Arizona/New Mexico Plateau Ecoregion experienced very little land-cover change during the study period (fig. 2). An estimated 1.2 percent of the ecoregion (2,380 km^2) converted to other land-cover classes during the study period. Estimates reveal that 1.1 percent of the ecoregion changed only once during the study period, and 0.1 percent changed twice (table 1). However, standard error is high as a proportion of overall spatial change, which is not unusual for an ecoregion with little change. Compared to other western United States ecoregions, the Arizona/New Mexico Plateau Ecoregion had the lowest amount of change other than the Chihuahuan Deserts Ecoregion and the Southern Rockies Ecoregion. Low estimates of land-cover change are consistent with other ecoregions in the Southwest (figs. 2, 3).

Estimated land-cover change per time period started with 0.2 percent between 1973 and 1980, and it increased 0.1 percent each time period thereafter, to reach 0.5 percent between 1992 and 2000. When the change estimates are normalized to account for the varying lengths of time between satellite imagery dates, the average rate of change per year was less than 100 km^2 between 1973 and 1980 and between 1980 and 1986, 131 km^2 between 1986 and 1990, and 111 km^2 between 1992 and 2000 (table 2; fig. 3).

Results showed that grassland/shrubland and forest were the predominant land-cover classes within the ecoregion. Grassland/shrubland encompassed approximately 78 percent of the land cover in each time period, whereas forest covered

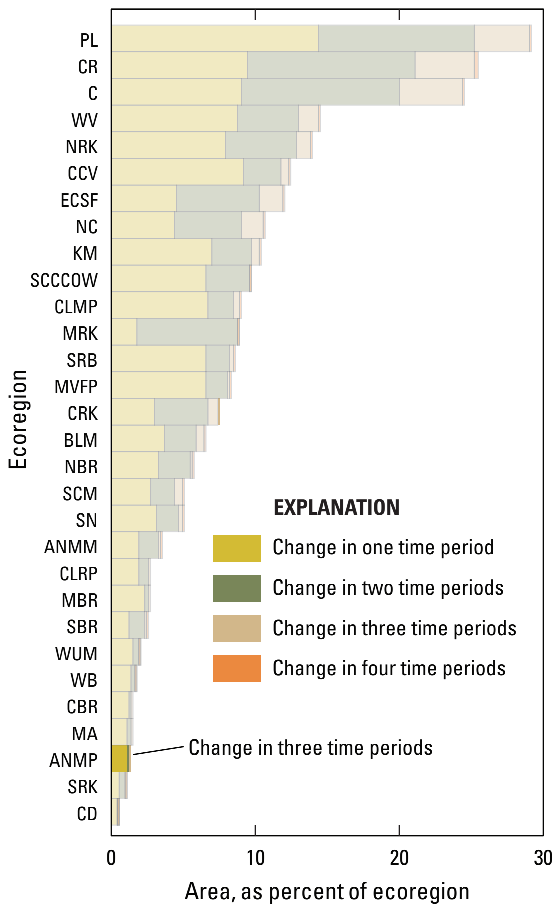


Figure 2. Overall spatial change in Arizona/New Mexico Plateau Ecoregion (ANMP; darker bars) compared with that of all 30 Western United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level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

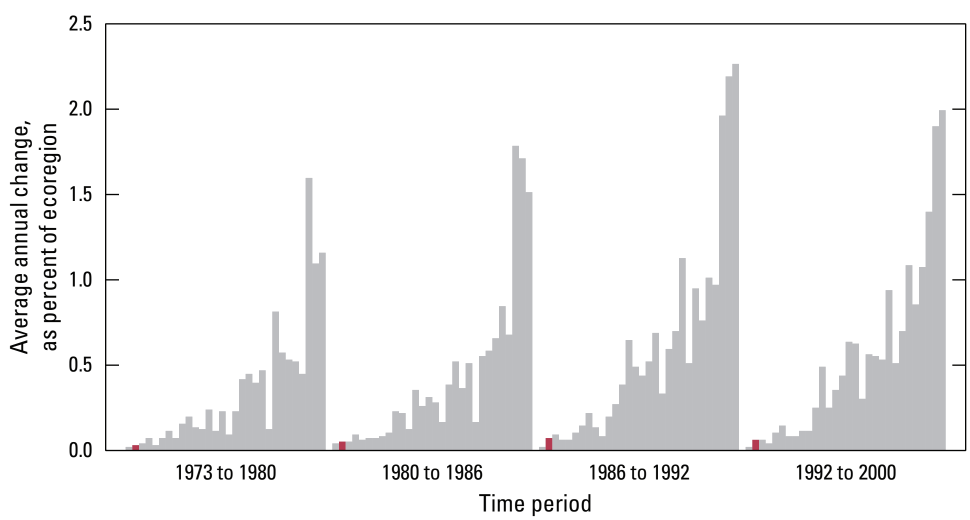
19 percent (table 3). The barren class accounted for 1.7 percent of the land cover, and the water, developed, mining, agriculture, wetland, and nonmechanically disturbed classes collectively made up the remaining land cover.

The developed and grassland/shrubland classes had the greatest net change during the study period. Grassland/shrubland declined by 0.5 percent (810 km^2), from 78.0 to 77.6 percent of the ecoregion. The developed class increased by 144 percent during the study period but remained only 0.7 percent of the ecoregion in 2000. The remaining classes experienced minimal net change (table 3).

Examination of net-change values alone can mask land-cover dynamics that occur within a given study period. Figure 4 illustrates the fluctuations that occurred in land-cover classes between time periods. Changes in grassland/shrubland occurred at variable rates over the study period; a slight increase occurred between 1986 and 1992, and the greatest decrease occurred between 1992 and 2000. The developed class increased the most between 1980 and 1986 but consistently gained over the entire study period. Mobility in active sand dunes was mapped during the study period, and it is conceivable the intense drought that began in this area in 1996 allowed for more sand deposition and active transport than in previous years, possibly explaining the 80 km^2 growth of the barren class over the study period. Research by U.S. Geological Survey scientists confirmed that drought conditions on the Navajo Nation Reservation have accelerated destabilization and mobility of sand dunes, owing to the detrimental effect on stabilizing vegetation (Redsteer and Block, 2004).

The most common land-cover conversions between 1973 and 2000 involved the grassland/shrubland, agriculture, and developed classes (table 4). Grassland/shrubland to developed (533 km^2) was the primary conversion between 1973 and 2000, followed by agriculture reverting to grassland/shrubland (470 km^2). Fire caused the next most common conversion of grassland/shrubland to nonmechanically disturbed, which occurred between 1992 and 2000 (393 km^2). Agriculture 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 Arizona/New Mexico Plateau Ecoregion are represented by red bars in each time period.



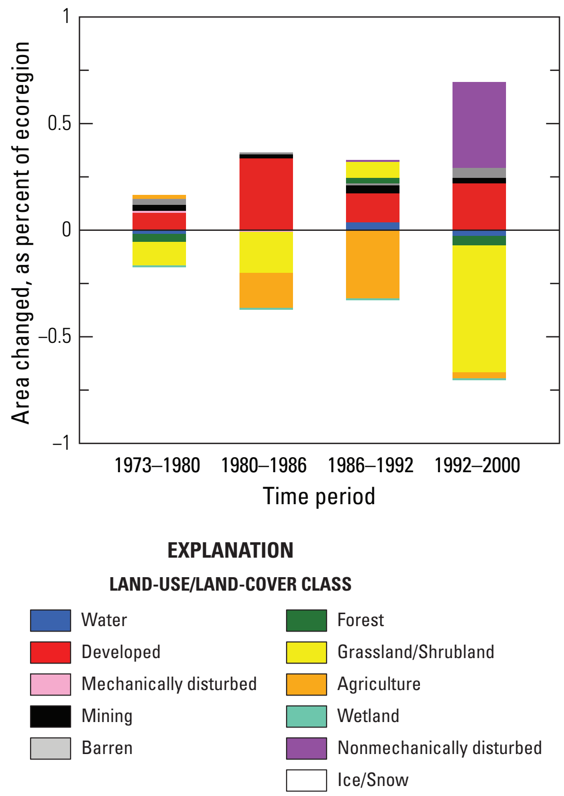


Figure 4. Normalized average net change in Arizona/New Mexico Plateau Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix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

developed was the fourth most common land-cover conversion. The overall net loss in agriculture (to grassland/shrubland and developed) was 30.8 percent of the area occupied by agriculture in 1973. However, although fieldwork confirmed the presence of many of the conversions listed in table 4, the margins of error in the table demonstrate the high degree of uncertainty derived from this study's interpretations.

The Arizona/New Mexico Plateau Ecoregion experienced little change in major land-cover classes between 1973 and 2000. Except for the Albuquerque metropolitan area, the ecoregion is sparsely populated, consisting mainly of large expanses of grassland/shrubland devoted to grazing (fig. 5). In an ecoregion where 78 percent of the land cover is grassland/shrubland, most land-cover change would be expected to occur in that dominant class. Change in grassland/shrubland class was distributed throughout the ecoregion, occurring in 26 out of 32 study blocks.

Change in the agriculture class occurred mainly in study blocks located along the San Juan River or in or near the Estancia basin region of central New Mexico. The largest observed area of former agricultural lands had evidence of abandoned canals leading from the nearby river. Statistics for the ecoregion's largest agricultural area, the San Luis Valley, indicated a small decrease (1.5 percent) in acreage devoted to farming between 1987 and 2002 (U.S. Department of Agriculture, 1992, 2002).

The Albuquerque metropolitan area is the location of most of the growth of developed land in the ecoregion. In 2000, Albuquerque's population was 448,607 (U.S. Census Bureau, 2001b), having grown from 243,751 in 1970 (U.S. Census Bureau, 1973). This 84 percent growth rate is substantial; moreover, the entire Albuquerque metropolitan area grew 125.7 percent within this same time frame (U.S. Census Bureau, 1973, 2001b). This population growth is reflected in the continually increasing acreage devoted to urban development. A 1997 U.S. Geological Survey study that mapped urban land use from aerial photographs noted that the Albuquerque metropolitan area had grown from 49,746 to 84,889 acres between 1973 and 1991, a 71 percent increase in area (Braun and others, 1998). Growth of the Albuquerque metropolitan area is expected to continue, with population projected to hit one million by 2021 or before (Siemers, 2007).

Coal mining in the Navajo Nation and the prolific amount of coal-bed methane available in the San Juan Basin will remain important and have many potential impacts on the Arizona/New Mexico Plateau Ecoregion. The area occupied by mining more than doubled during the study period (although the area remained as roughly 0.1 percent of ecoregion area). This small reported area might be attributable to the fact that no areas of coal mining were captured in our study blocks, as well as the fact that the footprint of new oil or gas wells mapped in study blocks within the San Juan Basin was minimal. Increased mining activity in the future may cause more land-cover change in the ecoregion, especially in the San Juan Basin.

The small land-cover changes that did occur during the study period were mainly due to increased urbanization, at the expense of natural grassland/shrubland and agricultural lands, as well as agricultural abandonment. It is important to keep in mind, however, that these land-cover changes were minor, and they represent a small percentage of the overall land cover of the ecoregion.

Figure 5. Rangeland southwest of Albuquerque, New Mexico.

Table 1. Percentage of Arizona/New Mexico Plateau Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (98.8 percent), whereas 1.2 percent changed at least once throughout study period. Two dashes (--) indicate that, because zero pixels changed four times during study period, relative error is not calculable]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	1.1	0.6	0.5	1.8	0.4	38.9
2	0.1	0.0	0.0	0.1	0.0	34.3
3	0.0	0.0	0.0	0.0	0.0	39.2
4	0.0	0.0	0.0	0.0	0.0	--
Overall spatial change	1.2	0.7	0.6	1.9	0.5	36.9

Table 2. Raw estimates of change in Arizona/New Mexico Plateau 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	40.2	0.0
1980–1986	0.3	0.3	0.0	0.5	0.2	66.4	0.0
1986–1992	0.4	0.3	0.1	0.7	0.2	44.6	0.1
1992–2000	0.5	0.3	0.1	0.8	0.2	49.2	0.1
Estimate of change, in square kilometers							
1973–1980	422	250	171	672	170	40.2	60
1980–1986	513	503	10	1,016	341	66.4	85
1986–1992	789	520	269	1,308	352	44.6	131
1992–2000	891	647	245	1,538	438	49.2	111

Table 3. Estimated area (and margin of error) of each land-cover class in Arizona/New Mexico Plateau 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	0.0	0.3	0.2	0.0	0.0	0.1	0.0	1.7	1.6	18.8	6.1	78.0	6.0	0.8	0.8	0.3	0.3	0.0	0.0
1980	0.1	0.0	0.3	0.3	0.0	0.0	0.1	0.1	1.7	1.6	18.8	6.1	78.0	6.0	0.8	0.7	0.3	0.3	0.0	0.0
1986	0.1	0.0	0.5	0.4	0.0	0.0	0.1	0.1	1.7	1.6	18.8	6.1	77.9	6.0	0.7	0.6	0.3	0.3	0.0	0.0
1992	0.1	0.1	0.6	0.5	0.0	0.0	0.1	0.1	1.7	1.6	18.8	6.1	77.9	6.0	0.6	0.6	0.2	0.3	0.0	0.0
2000	0.1	0.0	0.7	0.6	0.0	0.0	0.1	0.1	1.7	1.6	18.8	6.1	77.6	5.9	0.5	0.6	0.2	0.3	0.2	0.3
Net change	0.0	0.0	0.4	0.5	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	−0.4	0.5	−0.2	0.3	0.0	0.0	0.2	0.3
Gross change	0.1	0.0	0.4	0.5	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.9	0.5	0.3	0.3	0.0	0.0	0.2	0.3
Area, in square kilometers																				
1973	111	83	524	463	0	0	102	93	3,289	2,999	36,322	11,852	150,513	11,487	1,523	1,447	486	529	0	0
1980	99	82	606	518	8	9	129	120	3,313	2,998	36,283	11,843	150,403	11,487	1,543	1,423	485	529	0	0
1986	104	85	934	856	3	5	147	122	3,318	2,998	36,282	11,842	150,212	11,506	1,385	1,231	484	526	0	0
1992	138	106	1,067	964	8	7	180	135	3,330	2,998	36,305	11,838	150,281	11,536	1,073	1,151	481	521	6	9
2000	116	79	1,277	1,187	3	4	212	155	3,369	2,996	36,265	11,833	149,703	11,471	1,053	1,130	475	514	396	580
Net change	5	40	753	900	3	4	110	76	80	76	−57	68	−810	981	−470	517	−10	16	396	580
Gross change	168	96	753	900	27	20	110	76	102	86	178	148	1685	967	590	512	13	16	409	580

Table 4. Principal land-cover conversions in Arizona/New Mexico Plateau 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	104	101	68	0.1	24.7
	Agriculture	Grassland/Shrubland	62	66	45	0.0	14.7
	Grassland/Shrubland	Developed	59	73	50	0.0	14.0
	Forest	Grassland/Shrubland	38	53	36	0.0	9.0
	Grassland/Shrubland	Barren	31	33	22	0.0	7.4
	Other	Other	127	n/a	n/a	0.1	30.1
		Totals	422			0.2	100.0
1980–1986	Grassland/Shrubland	Developed	172	214	145	0.1	33.6
	Agriculture	Developed	151	221	150	0.1	29.5
	Agriculture	Grassland/Shrubland	49	55	37	0.0	9.5
	Grassland/Shrubland	Agriculture	40	39	27	0.0	7.8
	Grassland/Shrubland	Water	22	12	8	0.0	4.2
	Other	Other	79	n/a	n/a	0.0	15.4
		Totals	513			0.3	100.0
1986–1992	Agriculture	Grassland/Shrubland	327	445	302	0.2	41.4
	Grassland/Shrubland	Developed	113	116	79	0.1	14.4
	Grassland/Shrubland	Forest	96	133	90	0.0	12.2
	Forest	Grassland/Shrubland	61	83	56	0.0	7.8
	Grassland/Shrubland	Water	55	60	41	0.0	7.0
	Other	Other	137	n/a	n/a	0.1	17.3
		Totals	789			0.4	100.0
1992–2000	Grassland/Shrubland	Nonmechanically disturbed	393	575	390	0.2	44.1
	Grassland/Shrubland	Developed	188	212	143	0.1	21.1
	Forest	Grassland/Shrubland	53	77	52	0.0	6.0
	Grassland/Shrubland	Barren	42	43	29	0.0	4.8
	Agriculture	Grassland/Shrubland	32	35	24	0.0	3.6
	Other	Other	182	n/a	n/a	0.1	20.4
		Totals	891			0.5	100.0
1973–2000 (overall)	Grassland/Shrubland	Developed	533	598	405	0.3	20.4
	Agriculture	Grassland/Shrubland	470	467	316	0.2	18.0
	Grassland/Shrubland	Nonmechanically disturbed	393	575	390	0.2	15.0
	Agriculture	Developed	201	293	198	0.1	7.7
	Grassland/Shrubland	Agriculture	197	151	102	0.1	7.5
	Other	Other	821	n/a	n/a	0.4	31.4
		Totals	2,615			1.4	100.0

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