Chapter 15

Sierra Nevada Ecoregion

By Christian G. Raumann and Christopher E. Soulard


Ecoregion Description

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

Figure 1. Map of Sierra Nevada Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this “Status and Trends of Land Change” study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Western United States ecoregions are listed in appendix 2. See appendix 3 for definitions of land-use/land-cover classifications.
The climate of the Sierra Nevada Ecoregion is primarily Mediterranean, characterized by cool, wet winters and long, dry summers. Most areas of elevation above 2,100 m have a Boreal climate, and the highest elevations, typically above 3,600 m, have an Alpine climate. Precipitation increases with elevation from west to east as storm systems moving from the west are subject to orographic uplift, causing rain and snowfall. Because most precipitation from storm systems falls on the western slope of the Sierra Nevada range, a strong rainshadow limits precipitation on the steep eastern slope. This climatic gradient plays a significant role in determining the type and distribution of ecological communities. In order to provide water resources for the growing populations in low-elevation areas of California and Nevada, numerous reservoirs on the western and eastern slopes of the Sierra Nevada range collect runoff from the winter snow pack.

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

Despite resource regulation, California’s growing urban population has greatly increased the demand for wood, water, hydroelectricity, and recreational opportunities from the Sierra Nevada Ecoregion. Timber harvesting surged in the 1950s and 1960s to meet the demand for year-round recreation (Sierra Nevada Ecosystem Project Science Team and Special Consultants, 1996). Major highways and ski resorts were constructed in the 1950s and 1960s to meet the demand for year-round recreation (Sierra Nevada Ecosystem Project Science Team and Special Consultants, 1996). Over the past several decades, the demand for natural resources within the Sierra Nevada Ecoregion has altered ecological communities in the region by changing land-use/land-cover patterns.

In terms of nonmechanical land-cover change components, frequent fires of low to moderate intensity are an integral driver of change within the region’s ecological communities. Fires create a cycle of disturbance and succession that floral and faunal communities have adapted to and often require to propagate and thrive (Skinner and Chang, 1996). By the late 20th century the regional fire regime had greatly changed, primarily as a result of logging during the settlement period of the 1950s and 1960s and effective fire suppression activities mandated by State and Federal policies since the 1920s. Consequently, fires were less frequent and more severe than before (Skinner and Chang, 1996). Forest density increased and contributed to higher tree mortality because of greater intertree competition, insect attack, disease, and storm damage (Oliver and others, 1996). These conditions led to an increased supply of fuel which, in turn, resulted in an increased fire hazard, including the likelihood of high-severity fire (Manley and others, 2000). A shift to a warmer and moister climate may also have contributed to this altered fire regime by reducing winter severity and providing a longer growing season (McKelvey and others, 1996).

**Contemporary Land-Cover Change (1973 to 2000)**

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

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

Results show that in 2000 the Sierra Nevada Ecoregion was dominated by forest (70.1 percent), with grassland/shrubland (20.4 percent), barren (2.7 percent), nonmechanically disturbed (2.4 percent), wetland (2.2 percent), and water (1.1 percent) making up almost all the remainder of land cover (table 3). Developed, mining, agriculture, ice/snow, and mechanically disturbed classes each made up less than one percent of the region (table 3). Land-use/land-cover classes
that underwent the greatest net change (that is, total area gained minus total area lost) in relation to their area in 1973 were forest (4.7 percent decrease), grassland/shrubland (6.0 percent increase), and nonmechanically disturbed (which accounted for 0.2 percent or less of the ecoregion’s area in each year between 1973 and 1992 but increased to 2.4 percent of the classified area in 2000). Although the developed and agriculture classes each made up less than 1 percent of the Sierra Nevada Ecoregion, the developed class underwent the greatest relative increase in area (16.6 percent), and agriculture underwent the greatest relative decrease in area (5.2 percent). However, it is important to note that considerable uncertainty is associated with estimates for very rare land-cover classes.

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

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

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

The land-use/land-cover change patterns measured in the Sierra Nevada Ecoregion between 1973 and 2000 are consistent with information in the literature. Much of the clearcutting and reservoir water-level change in the region has been driven by the demand for wood, water, hydroelectricity, and recreational opportunities associated with California’s growing urban population. As for fires, many of the severe contemporary fires in the Sierra Nevada Ecoregion are likely the result of a fuel buildup caused by fire suppression activities mandated by State and Federal policies since the 1920s.
Figure 6. September 2004 appearance of area (intermediate background slopes) undergoing regeneration following Manter Fire at southern end of Sierra Nevada Ecoregion in Sequoia National Forest, Tulare County, California. Manter Fire ignited on July 22, 2000, and burned about 300 km². Land-cover types shown are forest, grassland/shrubland, and wetland.

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

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

Figure 9. Courtright Reservoir in Sierra National Forest, Fresno County, California, in southern part of Sierra Nevada Ecoregion, showing lowered surface levels in late summer (September 2004). Land-cover types shown are forest, barren, and mechanically disturbed (latter is due to reservoir drawdown).
Table 1. Percentage of Sierra Nevada Ecoregion land cover that changed at least one time during study period (1973-2000) and associated statistical error.

[Most sample pixels remained unchanged (95.0 percent), whereas 5.0 percent changed at least once throughout study period]

<table>
<thead>
<tr>
<th>Number of changes</th>
<th>Percent of ecoregion</th>
<th>Margin of error (+− %)</th>
<th>Lower bound (%)</th>
<th>Upper bound (%)</th>
<th>Standard error (%)</th>
<th>Relative error (%)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>3.1</td>
<td>2.5</td>
<td>0.6</td>
<td>5.6</td>
<td>1.7</td>
<td>55.1</td>
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<td>2</td>
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<td>1.1</td>
<td>2.1</td>
<td>0.4</td>
<td>22.2</td>
</tr>
<tr>
<td>3</td>
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<td>0.3</td>
<td>0.0</td>
<td>0.5</td>
<td>0.2</td>
<td>77.6</td>
</tr>
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<td>4</td>
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<td>0.0</td>
<td>0.0</td>
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<td>90.3</td>
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</tbody>
</table>

Overall spatial change 5.0 2.5 2.4 7.5 1.7 34.9

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

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

<table>
<thead>
<tr>
<th>Period</th>
<th>Total change (% of ecoregion)</th>
<th>Margin of error (+− %)</th>
<th>Lower bound (%)</th>
<th>Upper bound (%)</th>
<th>Standard error (%)</th>
<th>Relative error (%)</th>
<th>Average rate (% per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimate of change, in percent stratum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1973–1980</td>
<td>0.9</td>
<td>0.5</td>
<td>0.4</td>
<td>1.3</td>
<td>0.3</td>
<td>36.0</td>
<td>0.1</td>
</tr>
<tr>
<td>1980–1986</td>
<td>0.7</td>
<td>0.4</td>
<td>0.4</td>
<td>1.1</td>
<td>0.2</td>
<td>33.2</td>
<td>0.1</td>
</tr>
<tr>
<td>1986–1992</td>
<td>1.6</td>
<td>0.5</td>
<td>1.1</td>
<td>2.1</td>
<td>0.4</td>
<td>21.6</td>
<td>0.3</td>
</tr>
<tr>
<td>1992–2000</td>
<td>3.9</td>
<td>2.5</td>
<td>1.3</td>
<td>6.4</td>
<td>1.7</td>
<td>44.3</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Estimate of change, in square kilometers

| 1973–1980    | 454                           | 241                     | 213             | 695             | 164               | 36.0               | 65                      |
| 1980–1986    | 400                           | 196                     | 205             | 596             | 133               | 33.2               | 67                      |
| 1986–1992    | 868                           | 276                     | 592             | 1,144           | 188               | 21.6               | 145                     |
| 1992–2000    | 2,059                         | 1,344                   | 715             | 3,404           | 913               | 44.3               | 257                     |
Table 3. Estimated area (and margin of error) of each land-cover class in Sierra Nevada Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

<table>
<thead>
<tr>
<th>Year</th>
<th>Water Developed</th>
<th>Mechanically disturbed</th>
<th>Mining</th>
<th>Barren</th>
<th>Forest</th>
<th>Grassland/Shrubland</th>
<th>Agriculture</th>
<th>Wetland</th>
<th>Non-mechanically disturbed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% +/-</td>
<td>% +/-</td>
<td>% +/-</td>
<td>% +/-</td>
<td>% +/-</td>
<td>% +/-</td>
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<td>% +/-</td>
<td>% +/-</td>
</tr>
<tr>
<td>1973</td>
<td>1.1</td>
<td>0.5</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>2.7</td>
<td>1.5</td>
</tr>
<tr>
<td>1980</td>
<td>1.1</td>
<td>0.5</td>
<td>0.2</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
<td>2.7</td>
<td>1.5</td>
</tr>
<tr>
<td>1986</td>
<td>1.1</td>
<td>0.5</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>2.7</td>
<td>1.5</td>
</tr>
<tr>
<td>1992</td>
<td>1.1</td>
<td>0.5</td>
<td>0.2</td>
<td>0.3</td>
<td>0.8</td>
<td>0.3</td>
<td>0.1</td>
<td>2.7</td>
<td>1.5</td>
</tr>
<tr>
<td>2000</td>
<td>1.1</td>
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<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.2</td>
<td>0.1</td>
<td>2.7</td>
<td>1.5</td>
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<tr>
<td>Net change</td>
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<td>0.0</td>
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<td>0.0</td>
<td>0.0</td>
<td>-3.5</td>
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<tr>
<td>Gross change</td>
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<td>0.0</td>
<td>0.0</td>
<td>1.9</td>
<td>0.7</td>
<td>0.0</td>
<td>4.5</td>
<td>2.3</td>
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</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Area, in percent stratum</th>
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<tbody>
<tr>
<td>1973</td>
<td>1.1 0.5 0.2 0.3 0.4 0.3 0.2 2.7 1.5 73.5 4.6 19.2 4.0 0.3 0.4 2.2 1.2 0.2 0.0</td>
</tr>
<tr>
<td>1980</td>
<td>1.1 0.5 0.2 0.3 0.1 0.1 0.2 2.7 1.5 73.2 4.6 19.7 3.9 0.3 0.4 2.2 1.2 0.2 0.0</td>
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<tr>
<td>1986</td>
<td>1.1 0.5 0.2 0.3 0.3 0.2 0.1 2.7 1.5 73.1 4.6 19.9 3.9 0.3 0.4 2.2 1.2 0.0 0.2</td>
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<tr>
<td>1992</td>
<td>1.1 0.5 0.2 0.3 0.8 0.3 0.1 2.7 1.5 72.5 4.5 19.8 3.9 0.3 0.4 2.2 1.2 0.2 0.3</td>
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<tr>
<td>2000</td>
<td>1.1 0.5 0.3 0.3 0.4 0.2 0.1 2.7 1.5 70.1 4.6 20.4 3.8 0.3 0.4 2.2 1.2 2.4 0.1</td>
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<tr>
<td>Net change</td>
<td>0.0 0.1 0.0 0.0 0.0 0.0 0.0 -3.5 2.3 1.1 0.6 0.0 0.0 0.0 0.0 2.3 0.1</td>
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<tr>
<td>Gross change</td>
<td>0.0 0.1 0.0 0.0 1.9 0.7 0.0 4.5 2.3 2.6 0.9 0.0 0.0 0.0 0.0 3.2 0.8</td>
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<table>
<thead>
<tr>
<th>Year</th>
<th>Area, in square kilometers</th>
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<tr>
<td>1973</td>
<td>612 288 127 134 191 144 73 100 1,446 799 39,274 2,477 10,259 2,143 160 223 1,176 666 84 109</td>
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<tr>
<td>1980</td>
<td>606 287 127 134 65 39 73 100 1,446 799 39,104 2,466 10,534 2,093 160 223 1,176 666 114 152</td>
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<td>1986</td>
<td>606 287 127 134 153 89 73 100 1,446 799 39,046 2,455 10,616 2,074 160 223 1,176 666 0 1</td>
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<tr>
<td>2000</td>
<td>586 287 148 150 215 106 73 100 1,446 799 37,427 2,477 10,872 2,043 152 212 1,176 666 1,307 1,345</td>
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<td>Net change</td>
<td>-26 30 21 23 23 129 0 0 0 0 -1,847 1,241 613 319 -8 12 0 0 1,223 1,354</td>
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<td>Gross change</td>
<td>26 30 21 23 1,016 368 0 0 0 0 2,412 1,249 1,367 468 8 12 3 3 1,690 1,362</td>
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Table 4. Principal land-cover conversions in Sierra Nevada Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

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

<table>
<thead>
<tr>
<th>Period</th>
<th>From class</th>
<th>To class</th>
<th>Area changed (km²)</th>
<th>Margin of error (+/− km²)</th>
<th>Standard error (km²)</th>
<th>Percent of ecoregion</th>
<th>Percent of all changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973–1980</td>
<td>Mechanically disturbed</td>
<td>Grassland/Shrubland</td>
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<td>144</td>
<td>98</td>
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<td>152</td>
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References Cited


