13 Use of Fire Regimes at the Ecoregion Scale

Fire-excluded ecosystems are prone to changes in composition and density and are susceptible to catastrophic fire and invasion by nonnative species. The cause of the problem in many areas includes more than a century of fire exclusion and suppression along with increased human development at the wildland-urban interface. Grazing and logging have also contributed to this problem.

To correct this problem, fire and land management must return ecosystems to a healthier, *sustainable* condition. One way to do this is to modify the current structure of ecosystems to mimic natural structures (cf., Bailey 2002).

13.1 Ecosystem Structure and Process

Ecosystem structure and process are related. For example, riparian forests evolved with flooding and fire-adapted forests evolved with fire. However, the frequency of flood or fire may vary place to place and year to year or even decade to decade; and the intensity may vary flood to flood or fire to fire. For ecosystems to sustain natural structures, they will need to experience the same kinds of processes in which they evolved (Allen et al. 2002; Savage 2003).

13.2 Range of Variation

Restoration works best if ecosystems are returned to within a "natural range of variation" (Landres et al. 1999). Ecosystems, for example, not only have variability through time because of climate change, but also across the landscape and the nation because of disturbance events, successional processes, and natural climatic variation as distinct from climate change. From forests to desert to steppe, the continent's ecosystems vary vastly. It is not possible to reconstruct how each system looked in the past. Instead, we can reset altered ecosystems back to within a range of natural variability. As Savage (2003) puts it, "If we can restore the natural processes, the natural structure should follow."

It seems reasonable that regions differing substantially in background climate should therefore have different fire regimes. In fact, fires burn with more or less regular rhythms. The simplest means to reveal a fire regime is to consider the distribution of water within an ecosystem. If they are too wet, they won't burn. The ecosystem's moisture changes with the daily and seasonal fluxes of the moisture of air masses as they move through the region. Long-term fire records around the Pacific Ocean trace nicely the pulses of the Pacific Decadal Oscillation. In this oscillation, the Pacific alternates from warm to cool phases and causes wet and dry periods on the adjacent North American continent. These

R.G. Bailey, *Ecoregions*, DOI 10.1007/978-1-4939-0524-9_13, © Springer Science+Media, LLC 2014

wet–dry rhythms set the ecological cadence for fire regimes.

13.3 Different Ecoregions, Different Fire Regimes

Different ecoregions produce different fire regimes (Bailey 2010). Several studies have looked at variation in fire regimes at the ecoregion scale. We will examine three of them.

13.3.1 Precolonial Fire Regimes (Vale)

Precolonial fire regimes for different vegetation types in North America have been determined by analyzing fire scars. In areas lacking trees, the development of vegetation after recent fires plus early journal accounts and diaries have been used to make inferences about fire regimes. Thomas Vale (1982) synthesized this information in his book, *Plants and People*.

Vale analyzed "natural" vegetation types based on ecoregions. He used two information sources to characterize fire regimes: he extracted relevant information from 45 published fire regime studies, and he assessed species-specific fire ecology for plants indicative of the areas mapped. He found that fire regimes varied by ecoregion (Fig. 13.1). In the northern coniferous forest and woodland (boreal forest), for example, infrequent large-magnitude fires carried the flames in the canopy of the vegetation, killing most of the forest. Such fires are called "crown fires" because they burn in the upper foliage or crown of the trees.

Other environments, such as the deciduous forests of the east, probably had infrequent crown or severe surface fires. These areas are typically cool or wet and consist of vegetation that inhibits the start or spread of fire.

In mountainous regions, fire frequency is related to elevation. The lower-elevation forests in the western United States had a regime of frequent, small-magnitude, surface fires. Here, the burning was restricted to the forest floor and most mature trees survived. Ponderosa pine forests are good examples of this kind of forest.

13.3.2 Fire Regime Types (The Nature Conservancy)

The Nature Conservancy (2004), working in cooperation with the World Wildlife Fund and the International Union for Conservation of Nature, has recently completed a global assessment of fire regime alteration on an ecoregional basis. The assessment identified three broad fire regime types (Fig. 13.2). The report reveals that, among globally important ecoregions for conservation, 84 % of the area is at risk from altered fire regimes. Almost half of priority conservation ecoregions can be classified as "fire-dependent" (shown in reddish brown).

In *fire-dependent systems*, fires are fundamental to sustaining native plants and animals. Many of the world's ecosystems—taiga forest, chaparral shrublands, savanna—have evolved with fires. What characterizes all of these ecosystems is resilience and recovery following exposure to fires. In the case of chaparral, fire does not kill most of the shrub layer; the shrubs sprout back from root crowns.

Among all the ecoregions, 36 % are *fire-sensitive*; and for this ecoregion group frequent, large and intense fires were, until recently, rare events. In these systems, plants lack the adaptations that would allow them to rapidly rebound from fire. These areas are typically cool or wet and consist of vegetation that inhibits the start or spread of fire. Examples include the tropical moist broadleaf forest and temperate rainforests.

Another 18 % of ecoregions are classified as *fire-independent ecosystems*. Here fires are largely absent because of a lack of vegetation or ignition sources, such as in Africa's Namibian Desert or in tundra ecosystems in the arctic.

According to The Nature Conservancy, fire regimes are degraded in more than 80 % of

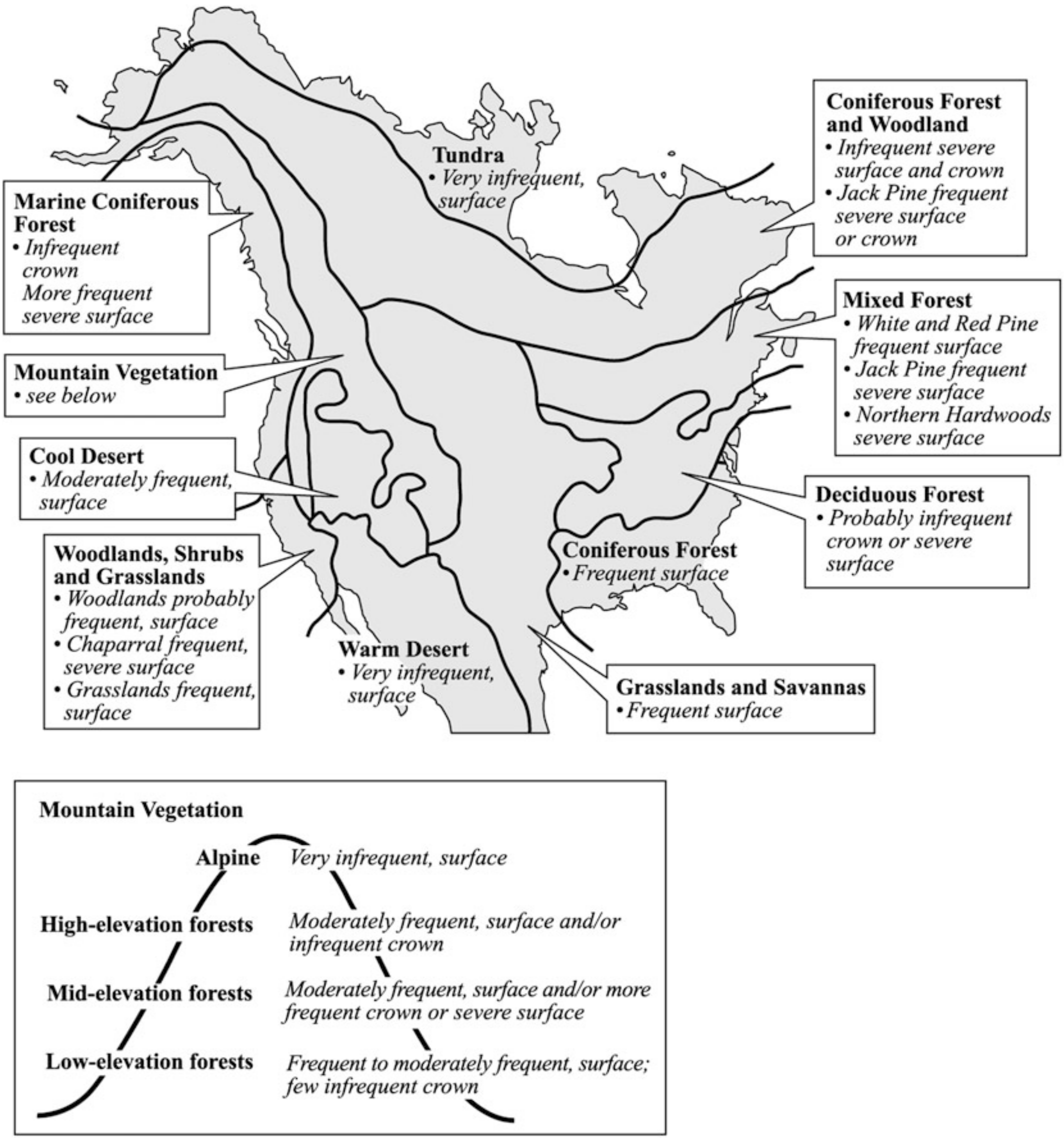

Fig. 13.1 Precolonial fire regimes of broad vegetation types (based on ecoregions) in North America. Only major divisions of the ecoregion map are shown. From Vale (1982); reprinted with permission of the Association of American Geographers

globally important ecoregions. The majority of North American forests and grasslands are adapted to fire of varying frequencies and intensities; but fire—ecologically misunderstood and therefore ecologically misinterpreted—has been suppressed so routinely for so long that some ecosystems are now likely to burn at catastrophic levels rather than at natural ecosystem-sustaining levels. Such fires favor post-fire invasion by fire-loving alien plants that once established inhibit regrowth of native vegetation, which makes recovery to the original natural ecosystem impossible. A good example is the nonnative cheatgrass that has invaded and continues to expand in sagebrush steppe in the western United States.

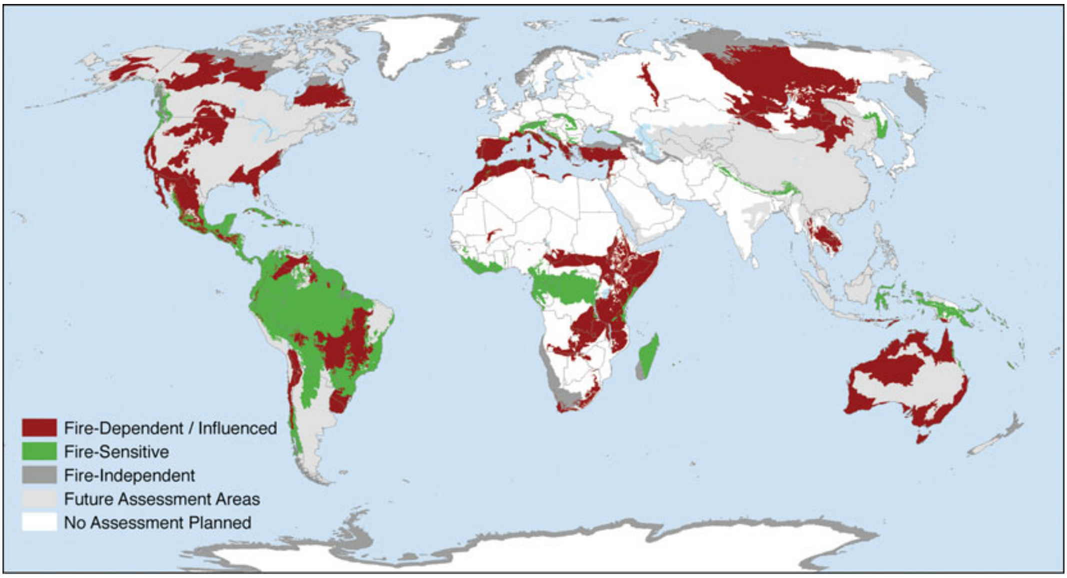

Fig. 13.2 Dominant fire regimes in priority ecoregions for biodiversity conservation. *Reddish brown* areas are fire dependent; *green* areas are fire sensitive; *gray* areas are fire independent. From The Nature Conservancy (2004)

13.3.3 Characterizing the US Wildfire Regimes (Malamud et al.)

The spread of wildfires and their severity patterns show distinct regional styles across the United States (Malamud et al. 2005). Using high-resolution Forest Service wildfire statistics, this study was based on 31 years (1970–2000) of wildfire data consisting of 88,916 fires all of which were at least 1 acre or larger and within the National Forest System. To allow spatial analysis with regard to the biophysical factors that drive wildfire regimes, the researchers classified the wildfire data into ecoregion divisions (areas of common climate, vegetation, and elevation). In each ecoregion, they asked: What is the frequency-area distribution of wildfires? The study compared area burned, number of fires, and the wildfire recurrence interval. These parameters were calculated at the ecoregion division level. The study created maps to display wildfire patterns and risk for the entire continental United States.

The authors found that the ratio of large to small wildfires decreases from east to west (Fig. 13.3a), meaning a relatively higher proportion of large fires occurs in the west compared to the east. This may be due to greater population density and increased forest fragmentation. Alternatively, the observed gradient may be due to natural drivers, with climate, vegetation, and topography producing conditions more conducive to large wildfires.

The fire recurrence interval differs markedly between ecoregions. For example, the **fire cycle** values ranged from 13 years for the Mediterranean Mountains Ecoregion to 203 years for the Warm Continental Ecoregion (Fig. 13.3b). Note the term “fire cycle” does not mean that a fire will occur “every” 13 years, or “every” 203 years. It is a probabilistic hazard dealing with possibilities rather than absolutes: a recurrence interval of 100 years would mean that in ANY year, we have a 1 in 100 chance of a fire of a given size.

13.3.4 Other Studies

In other studies, gradients similar to those observed by Malamud et al. (2005) have been described and related to climate and vegetation. Turner and Romme (1994) describe **wildfire occurrence gradients** as a function of elevation and latitude. They attribute these gradients to

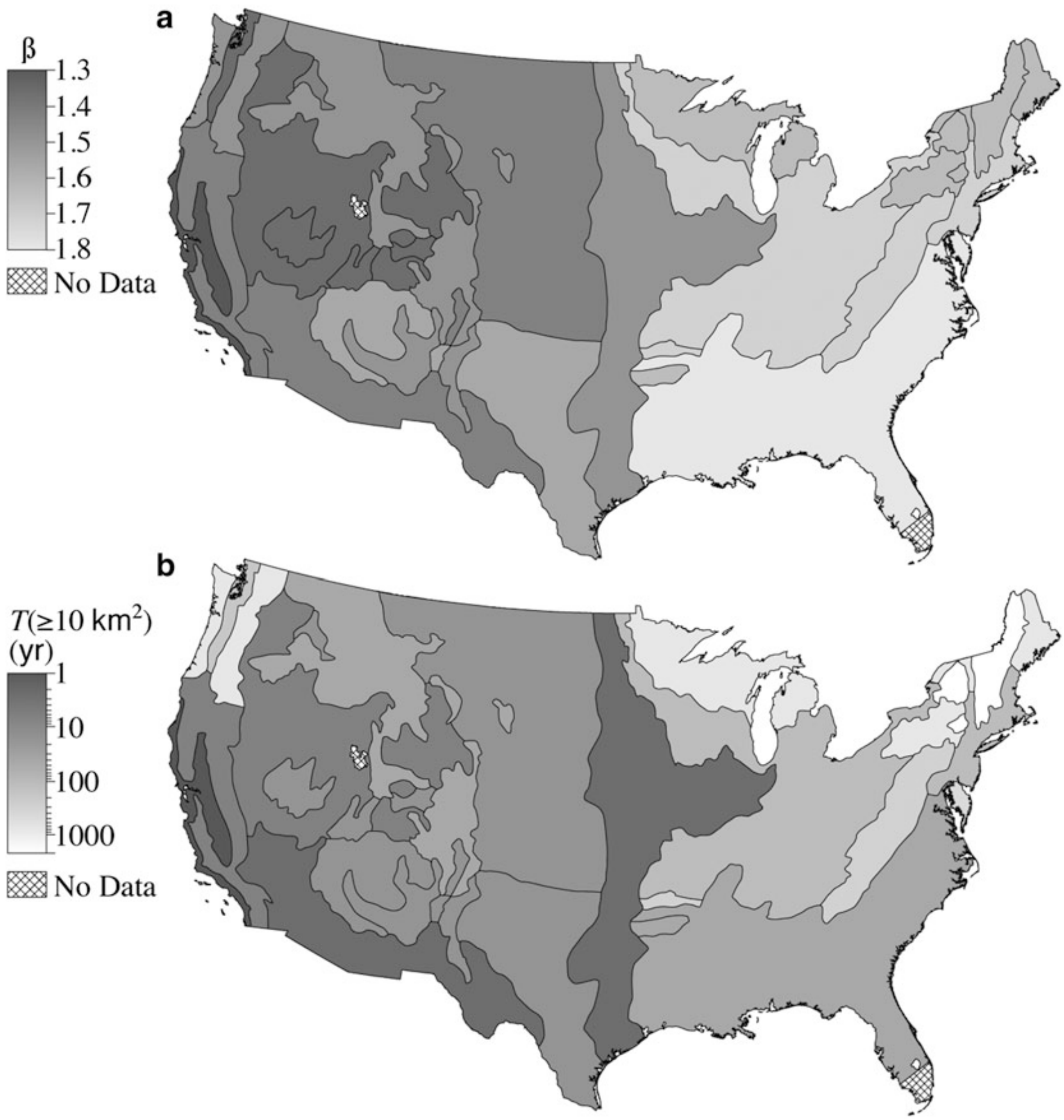

Fig. 13.3 Maps of wildfire patterns across the conterminous United States for 1970–2000 for US Forest Service wildfires classified by ecoregion division. (**a**) Ratio of large to small wildfires. The darker the color, the greater the number of large fires. (**b**) Fire recurrence interval. The legend goes from dark to light, representing "high" to "low" hazard. From Malamud et al. (2005)

broad climatic variation and note western and central regions tend to have frequent fires with forest stand structures dominated by younger trees, whereas the eastern region experiences longer inter-fire intervals and older stand structures. A statistical forecast methodology developed by Westerling et al. (2002) exploits these gradients to predict area burned in western U.S. wildfires by ecoregion a season in advance.

Littell et al. (2009) found that climate drivers of synchronous fire differ regionally. They identified four distinct geographic patterns of ecoregion provinces (ecoprovinces) across the West, and each ecoprovince had its own unique set of climate drivers that affect annual area burned by wildfire. For example, in northern mountain ecoprovinces dry, warm conditions during the seasons leading up to and including

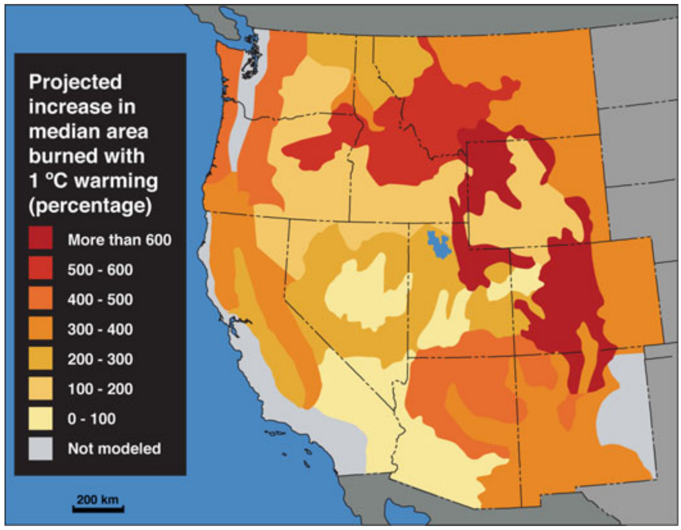

Fig. 13.4 Percentage of increase (relative from 1950 to 2003) in median area burned in western United States ecoprovinces for a 1 °C temperature increase. From Peterson and Littell (2012)

the fire season are associated with increased area burned suggesting that dry fuel condition was the key determinant of regionally synchronous fires. In contrast, in the southwestern dry ecoprovinces moist conditions the seasons prior to the fire season are more important than warmer temperatures or drought conditions in the year of the fire suggesting that fuel abundance determined large fire years.

Littell et al. (in Peterson and Littell 2012) also found that climate change will affect the area burned by ecoregion province in the western United States. They projected the statistical models of Littell et al. (2009) forward for a 1 °C temperature increase, calculated median area burned and probabilities that annual fire area would exceed the maximum annual area burned in the historical record (1950–2003). Fire area is projected to increase significantly in most ecoregion provinces (Fig. 13.4); probability of exceeding the historical maximum annual burn area varied greatly by ecoprovince. Spracklen et al. (2009) found that the forest area burned by wildfires in the western United States will increase, relative to present day, more than 50 % by 2050 as a result of climate change. The most severely affected areas will be the forests in the Pacific Northwest and Rocky Mountains ecoregion provinces, where the forest area destroyed by wildfire is predicted to increase 78 % and 178 %, respectively. Yue et al. (2013) estimate the changes in future wildfire activity and their impact on carbonaceous aerosols over the western United States during the mid-twenty-first century will vary by ecoregion, although the estimates varied depending on which of two different fire prediction approaches was used.

Not only does fire size vary by ecoregion, it varies by land management agency. In California's Sierra Nevada region, the size of high-severity fires and percentage of high-severity fire, regardless of forest type, is less in Yosemite National Park than on Forest Service lands (Miller et al. 2012). These changes in fire regime are largely attributed to both changing climate and land management practices, including suppression of fires and past timber harvesting, during the last century. The primary Forest Service response to wildfire is contain and extinguish, while the National Park Service is more likely to let fires burn so fuels do not build up.

For a synthesis of knowledge describing how climate change will affect fire regimes at the ecoregion scale, see Sommers et al. (2011).

13.4 Use of Fire Regime at the Ecoregion Scale

The results of these studies can be used to assess burn probabilities across the nation to identify

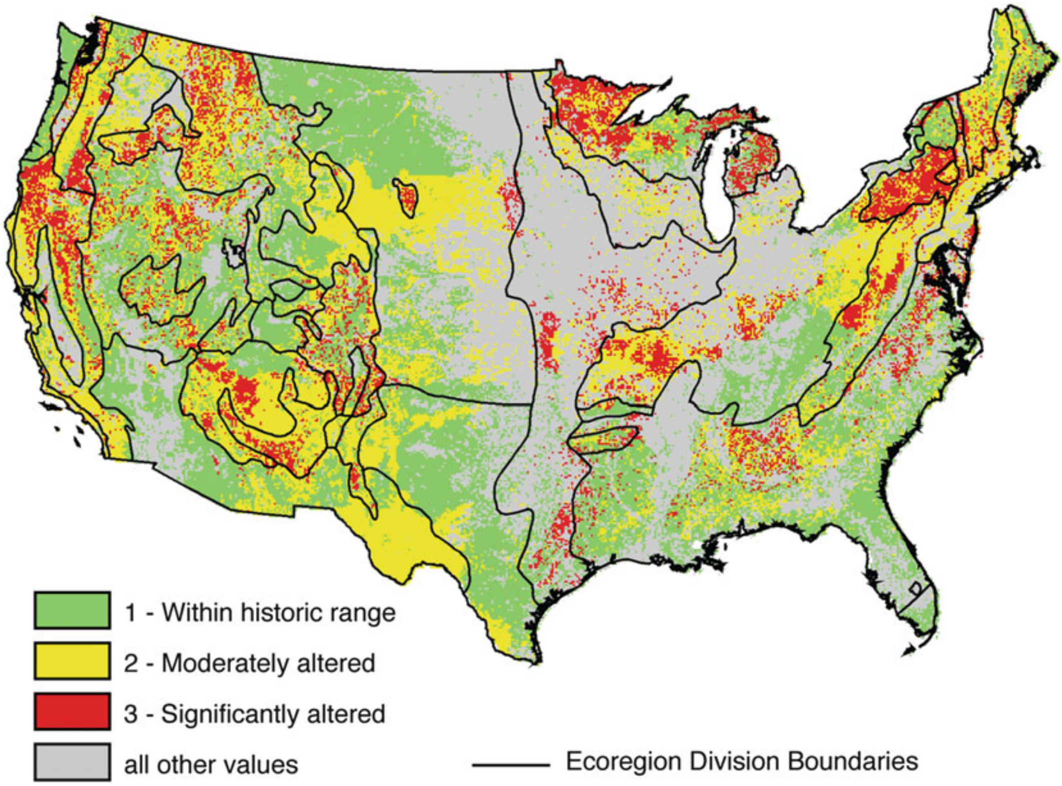

Fig. 13.5 Fire regime condition class (as mapped by Schmidt et al. 2002) with ecoregion division boundaries (*thick black lines*). *Green* areas (condition class 1) are largely intact and functioning; *yellow* areas (condition class 2) are moderately altered; *red* areas (condition class 3) are significantly altered; *gray* areas are nonvegetated, agricultural, or urban

areas with high risk. This helps government agencies better plan for wildfire hazards. They can also be used as a baseline from which to assess natural fire regimes, and these assessments can be used to abate the threat of fire exclusion and restore fire-adapted ecosystems. In fact, these baseline reference conditions are currently being developed as part of the LANDFIRE project (http://www.landfire.gov) by the US Forest Service (Missoula Fire Sciences Laboratory), the US Geological Survey (EROS Data Center), and The Nature Conservancy for all biophysical system across the United States. In addition, understanding fire regimes at the ecoregion scale can provide valuable insights important for designing fuel treatments by helping to determine high-hazard from low-hazard situations.

Finally, what can be done to reduce the risk of fire? Savage (2003) and Allen et al. (2002) suggest several principles to guide the implementation of ecologically justifiable restoration projects. Two of the most important ones are:

1. Restoration of natural fire regimes (e.g., in southwestern ponderosa pine forests reduce the widespread risk of crown fires by return to low-intensity surface fire).
2. Pay attention to *both* structure and process (e.g., thinning young trees to reduce the fuel load may not work unless low-intensity surface fires are also reintroduced).

Analysis of the literature to date strongly indicates that thinning or burning treatments, or both together, do have effects consistent with restoring low-severity fire behavior in western United States pine forests (Fule et al. 2012).

Recent data from the Forest Service reflect the scale of the challenge. Schmidt et al. (2002) mapped **fire regime condition class** (FRCC), which is an ecological metric used by federal agencies, The Nature Conservancy, and others to determine the degree to which the vegetation and fire regimes of a given area have changed compared to reference conditions. As shown on their map (Fig. 13.5), fire management has significantly changed the fuel levels of many forests, and concurrently, the frequency and intensity of fire. About 30 % of all ownerships (except those related to agriculture, barren, and urban land) are in high-risk categories (shown in yellow and red). In many ecoregions this percentage is much higher. For example, in the mountains of the southwest, as much as 83 % is moderately to severely altered.

13.5 Why Ecoregions Are Needed

The same forest type can occur in different ecoregion divisions. For example, ponderosa pine forest occurs in the northern Rocky Mountains and in the southwest. This does not imply that the climate, topography, soil, and fire regime are necessarily the same. In the southwest, the historical fire regime is of frequent, low-intensity, surface fires that tend to maintain open, multi-age forests. Farther north in the Rocky Mountains, cooler conditions mean moister forests in which fires burn less readily. This distinction is important because fire management strategies and restoration protocols are often applicable only to the *local* region in which they were developed. Therefore, management strategies planned to address the fire and fuel issue such as those documented in the interagency National Fire Plan should take into consideration ecoregional variation in fire regimes. This 10-year comprehensive strategy can be viewed online at: http://www.fireplan.gov.

13.6 Use of Ecosystem Patterns Within Ecoregions

Macroclimate accounts for the largest share of systematic environmental variation at the macroscale or ecoregion level. At the mesoscale, **physiography** (geology and landform) modifies the macroclimate and exerts the major control over ecosystem patterns and processes within climatic zones. With this in mind, Bailey et al. (1994) used physiographic factors to subdivide the ecoregion provinces of the United States into subregional areas, or *sections,* that have different landform characteristics. These differences are important because the character of the landform with different geology will vary in the climatic zone. In the same climatic zone, different geologies, such as granitic mountains or volcanic plateaus, will weather and erode differently forming different landform relief. Where this occurs, the spread of a disturbance like wildfire may differ among landforms. Swanson et al. (1990) hypothesized that in forested, steep-mountain landforms along the northwest coast of the United States where landform relief does not exceed several tree heights (e.g., Coast Ranges), disturbance agents such as fire and wind can readily move through the forest with little regard for topography. Landforms may have a greater effect on the spread of disturbance and mosaic structure where relief substantially exceeds tree height (e.g., Cascade Range). The classification and mapping of physiography as was done to delineate ecological subregions at the section level should provide an important means of discriminating broad areas with differing fire regimes within a particular ecoregion.

At finer scales, one finds considerable variation in fire regimes in response to local topography, vegetation, and microclimate (cf., Cleland et al. 2004). As we have seen, local ecosystems occur in predictable patterns within a particular ecoregion. Similar fire regimes occur on similar sites within an ecoregion. Knowledge about fire regimes on similar sites allows **ecological restoration** so as to incorporate the natural variability of fire regimes across the ecoregion.

13.7 Future Range of Variation

The range of variation concept is a useful starting point, *but* it is limited for a number of reasons. First, many systems have been fragmented because of human disturbance; because of this, fires will not carry the way they did historically.

Second, the introduction of nonnative species (e.g., cheatgrass) has made permanent changes in fire frequencies. Third, fire size and intensity of the past are clearly not acceptable in developed areas. And, fourth, system boundaries and fire regimes will change as the climate changes (cf., McKenzie et al. 1996; Rogers et al. 2011). Therefore, only where possible, we need to restore the natural range of variation. We must also determine our feasible alternatives for the "Future Range of Variation."

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