Applications of Ecoregional Patterns

12

This method of understanding processes and resultant patterns provides important design inspiration for sampling networks and managed landscapes that are **sustainable**, as well as their relevance to ecosystem management and research. These applications are reviewed here; see the author's *Ecoregion-Based Design for Sustainability* (Bailey 2002) and *Research Applications of Ecosystem Patterns* (Bailey 2009a) for details, as well as Dranstad et al. (1996), Knight and Reiners (2000), Thayer (2003), van der Ryn and Cowan (1996), and Woodward (2000). A new geography text of the United States and Canada by Chris Mayda (2012) explores sustainability within the framework of ecological regions

12.1 Design for Sustainability

As outlined in the previous chapter, ecosystems recur in predictable patterns within an ecoregion thereby reflecting processes that create these patterns. Ecoregion-based analysis strives to identify and explain geographic patterns in ecosystems in terms of formative process. **Ecoregional design** is based on the assumption that the factors which shape these patterns can be used to guide planning and design of landscapes, resulting in human-built environments which are designed differently to best fit each ecoregion's unique characteristics. By working with nature's design, designers and planners can create landscapes that function sustainably like natural ecosystems.

Several steps lead toward implementing this approach.

12.1.1 Understand Ecosystem Pattern in Terms of Process

Rather than occurring randomly, local ecosystem units occur in repetitive spatial patterns within an area called an "ecoregion." These patterns reflect a formative process. For example, rocky reservoirs support pines within grasslands of the semiarid Great Plains of the central United States (Woodward 2000). The relationship between pattern and process will vary by region.

12.1.2 Use Pattern to Design Sustainable Landscapes

The natural patterns and processes of a particular region provide essential keys to the sustainability of ecosystems, and can inspire designs for landscapes that sustain themselves. To be sustainable, a designed landscape should imitate the natural ecosystem patterns of the surrounding ecoregion in which they are embedded. As we saw before, trees signify rocky reservoirs of available water on the arid Great Plains. Planting these same trees on fine-grained plain soils, with only atmospheric precipitation to sustain them would kill the trees. By working with nature's

R.G. Bailey, *Ecoregions*, DOI 10.1007/978-1-4939-0524-9_12, © Springer Science+Media, LLC 2014

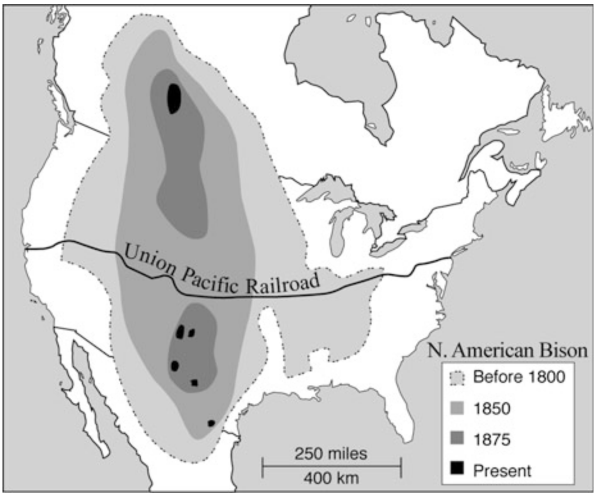


Fig. 12.1 Distribution of bison in North America from 1800 to 1975. After Ziswiler (1967), p. 2

design, one can create landscapes that function sustainably like natural ecosystems. Ecoregional design is the act of understanding the patterns of a region in terms of the processes that shape them and then applying that understanding to design and planning.

In addition:

- **Observe how a region functions and try to maintain functional integrity** The tropical rainforest, for instance, provides so much oxygen that it can be considered as a lung of the biosphere. So we should not use it only for massive lumbering, but instead, take advantage of its other resources, such as medicines, many not yet discovered. Changing the natural patterns by adding subdivisions, roads, or other elements changes the ecological functions. For example, animals change their routes, water flows are changed in direction and intensity, erosion commences, and so on. One of the earliest and best known examples of this is when the Union Pacific Railroad broke the large and intact habitat of the American bison into two patches separated by a corridor (Fig. 12.1) in 1869.
- **Maintain diversity by leaving connections and corridors** Fundamentally, most natural systems are diverse; therefore, good ecological design will maintain that diversity. Local ecosystems interact with each other to some variable degree and in so doing establish some interdependence; therefore, ecosystem diversity depends on leaving some connections and corridors undisturbed. These principles are being put to use in the proposed Northern Rockies Ecosystem Protection Act (H.R. 2638). The act provides a holistic form of ecosystem protection that explicitly connects several of America's most beautiful wildernesses (Fig. 12.2) and is based on the principle that biodiversity thrives in interrelated ecosystems.
- **Honor wide-scale ecological processes** Good ecological design that is sustainable depends on honoring such natural ecological processes as hydrologic cycles, animal movement patterns, and **fire regimes**, among others. Identifying fire regimes will assist in fire planning. In the past, forest fires occurred at different magnitudes and frequencies in different climate-vegetation regions (Vale 1982) (Fig. 13.1), such as discussed in this book. In fire-driven ecosystems, suppressing fires or delaying fires indefinitely does not confer a sort of victory; they only assure more difficult fire battles in the future.
- **Match development and use to landscape pattern** By doing so, we allow ecological patterns to work for us. We can use natural drainage instead of storm drains, wetlands

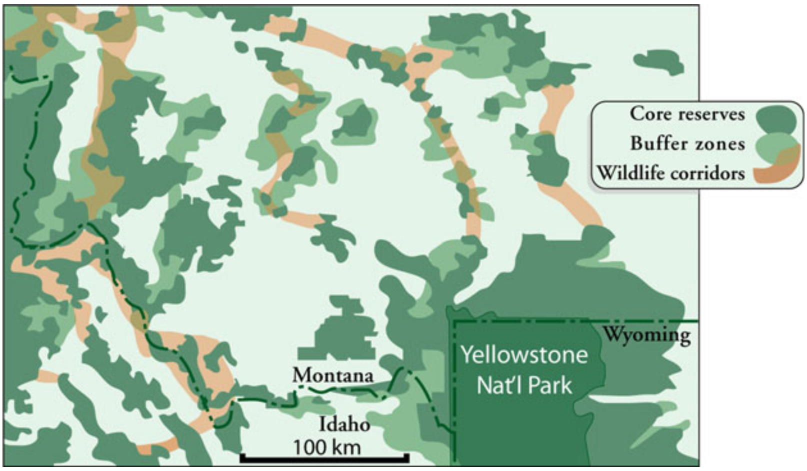


Fig. 12.2 System of core reserves, buffer zones, and wildlife corridors proposed by the Northern Rockies Ecosystem Protection Act. Redrawn from Van der Ryn and Cowan (1996)

instead of sewage treatment plants, and indigenous materials rather than imported ones. Instead of channeling storm runoff into concrete drains and then to a sewage system, undeveloped drainage swales can be used to mimic nature and help provide sponges for flood protection (Barnett and Browning 1995).

- **Match development and use to the limits of the region** The solution to developing an ecological design grows from integrating design within the limits of place. For example, in the Lake Tahoe region of California-Nevada, USA (Bailey 1974), I conducted a land capability analysis using ecoregional design concepts to create land development controls that would take into account environmental limitations (e.g., soil erodibility) and ecological impacts (e.g., lake sedimentation). These controls limit land coverage (Table 12.1).
- **Design sites by considering their relationships with their neighbors** In a problem related to the Lake Tahoe site, I was to distinguish capability at both a local level and within the context of a larger area or region. My solution was to evaluate capability in two ways: on inherent features and limitations of the area; and on the geomorphic features which surround this area. This type of rating excluded small pockets of high capability lands, such as rolling uplands, when surrounded by highly fragile, erosive, or unstable lands.

Table 12.1 Land coverage allowances[a], Lake Tahoe Regional Planning Agency[b]

Capability district	Land coverage allowed (%)
1	1
2	1
3	5
4	20
5	25
6	30
7	35

[a] The Land Capability Map identifies the capacities of the lands in the region to withstand disturbance without risk of substantial harmful consequences occurring. These disturbances are expressed in this ordinance in terms of land coverage. Specific permitted amounts of land coverage are established for each capability district. *Source: Ordinance #12, Lake Tahoe Regional Planning Agency, p. 9*

[b] From Schneider et al. (1978)

12.2 Significance to Ecosystem Management

While relevant for the design of sustainable landscapes, the concept presented above has a strong application for managing productive land uses and their environmental impacts. Understanding ecoregional patterns plays a critical role in management activities such as livestock

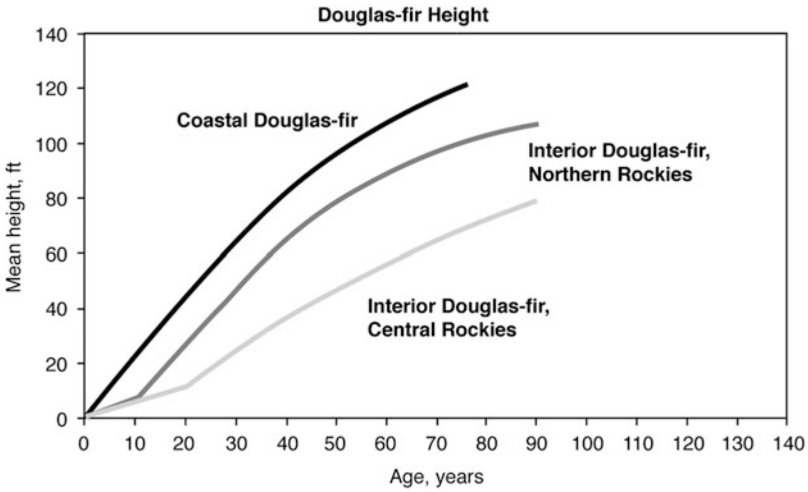


Fig. 12.3 Height-age ratio of Douglas-fir varies in different climate-defined ecoregions

grazing, timber harvest, water diversion, and many others. An obvious application in livestock grazing is determining how much livestock for how long to maintain grazable vegetation indefinitely. Indifference to ecosystem management can lead to overgrazing that permanently diminishes an ecosystem's ability to produce grazable forage and thereby losing that ecosystem's ability to support livestock.

12.2.1 Local Systems Within Context

This perspective of seeing context can be applied in assessing the connection between action at one scale and effect at another. For example, logging on upper slopes of an ecological unit may affect downstream riparian and meadow habitats.

With the ecosystem approach, the interaction between sites can be understood because processes emerge that are not evident at the site level. An example is a snow-forest landscape that includes dark conifers that cause snow to melt faster than either a wholly snow-covered or a wholly forested basin. Landscapes function differently as a whole than would have been predicted by analysis of the individual elements (cf. Marston 2006).

The need for seeing context is also important because ecosystem characteristics have no particular regional alliance. Because of compensating factors, for example, the same forest type can occur in markedly different ecoregions: ponderosa pine forests occur in the Northern Rockies and the southwest United States. This distribution does not imply that the climate, topography, soils, and fire regime are the same. These forests will have different productivity and response to management. For these reasons, there is a need to recognize regional differences. Cowardin et al. (1979) recommended the classification of Bailey (1976) to fill the need for regionalization for their classification of wetlands and deepwater habitats of the United States. Forest health monitoring (FHM) of the interior part of the western U.S. was conducted using an ecoregion approach to group inventory plots that have similar characteristics (Rogers et al. 2001). For the annual forest health assessments of the country, Conkling et al. (2005 et seq.) use Bailey's revised ecoregions (Cleland et al. 2007) as assessment units for analysis.

12.2.2 Spatial Transferability of Models

Predictive models differ between larger systems. The same type of forest growing in different ecoregions will occur in a different position in the landscape and have different productivity. For example, Fig. 12.3 shows that the height-age ratio of Douglas-fir varies in different climatically defined ecoregions. The ecoregion determines which ratio to apply to predict forest yield. This is important, because if a planner selects the wrong ratio, yield predictions and the forest plans upon which they are based will

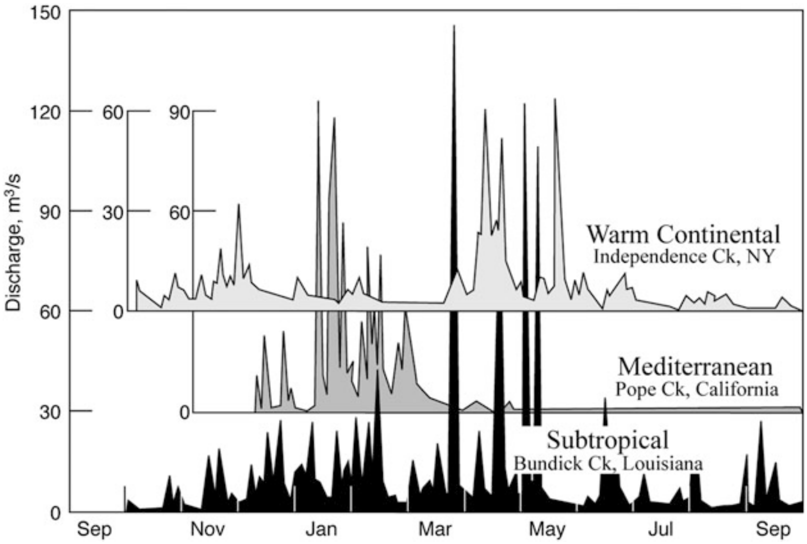


Fig. 12.4 Hydrographs for three small rivers in different climate regions. Adapted from Muller and Oberlander (1978), p. 166; reproduced with permission

be wrong. The ecoregion map is helpful in identifying the geographic extent over which results from site-specific studies (such as **growth and yield models**) can be reliably extended. Thus the map identifies areas for the spatial transferability of models.

In Canada, studies have found that the height-diameter models of white spruce were different among different ecoregions (Huang et al. 2000). Incorrectly applying a height-diameter model fitted from one ecoregion to different ecoregions resulted in overestimation between 1 and 29 %, or underestimation between 2 and 22 %.

Another example makes an even more compelling case. Each of five regional **Forest Inventory & Analysis** (FIA) programs has developed its own set of volume models, and the models have been calibrated for regions defined by political boundaries corresponding to groups of states rather than ecological boundaries. These regional models sometimes bear little resemblance to each other. The same tree shifted a mile in various directions to move from southwest Ohio (previous Northeastern FIA) to southeast Indiana (previous North Central FIA) to northern Kentucky (Southern FIA) could have quite different model-based estimates of volume. Growth estimates are likely improved if growth models are calibrated by ecoregions rather than states or FIA regions (Lessard et al. 2000; McNab and Keyser 2011).

Models relating **lichen** community composition in a given ecoregion to major environmental factors, such as climate and air quality, have been developed from plot data collected by FIA (Will-Wolf and Neitlich 2010; Jovan 2008).

12.2.3 Links Between Terrestrial and Aquatic Systems

Because ecoregions are based on climate and because precipitation has a climatic pattern, the streams draining any specific ecoregion have similar hydrographs (Beckinsale 1971, Fig. 12.4). This makes it possible to estimate the hydrologic productivity and streamflow characteristics of ungaged streams within the same region.

Streams depend on the terrestrial system in which they are embedded. They therefore have many characteristics in common, including biota. Delineating areas with similar climatic characteristics makes it possible to identify areas within watersheds with similar aquatic environments. A good example is the distribution of the northern hog sucker in the Ozark Uplands of Missouri, USA, which covers several watersheds (Fig. 12.5). This species of fish is widespread but not uniformly distributed throughout the Mississippi River basin. In

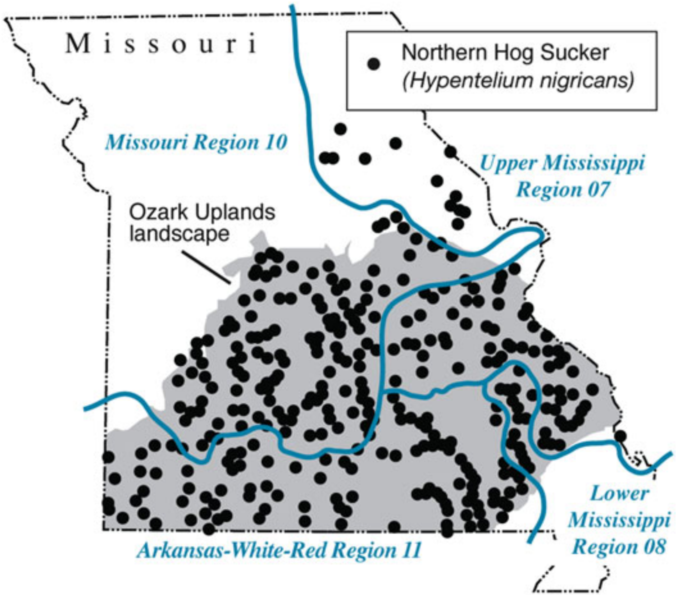


Fig. 12.5 Distribution of the northern hog sucker in relation to the Ozark Upland landscape and hydrologic units in Missouri. Fish data from Pflieger (1971); hydrologic unit boundaries from U.S. Geological Survey (1979)

Missouri, it is found almost exclusively in the Ozark Uplands ecoregion.

12.2.4 Design of Sampling Networks

Considered collectively, the conceptual material presented to this point positions ecoregion users to design efficient sampling networks. Ecoregion maps delimit large areas of similar climate where similar ecosystems occur on similar sites. As we have seen, local ecosystems occur in predictable patterns within a particular region. Sampling representative types allow a planner, designer, or manager to extend data to analogous (unsampled) sites within the region with a high degree of reliability (Bailey 1991; Robertson and Wilson 1985), thereby reducing sampling and monitoring costs. A sampling network design should capture the local ecosystem patterns and variation in those patterns within regions exhibit variation in landform and soil characteristics (see Chap. 11). Identification of sites based on ecoregional classification could be used to **impute** their characteristics from sampled FIA sites, for example, using *k*-Nearest Neighbors or similar techniques (McRoberts et al. 2002).

Another example comes from the Rocky Mountains, a temperate steppe mountains ecoregion. This ecoregion, like all ecoregions, is a climatic region within which specific **plant successions** occur upon specific landform positions. The most likely successional series growing on a site within an ecoregion can be

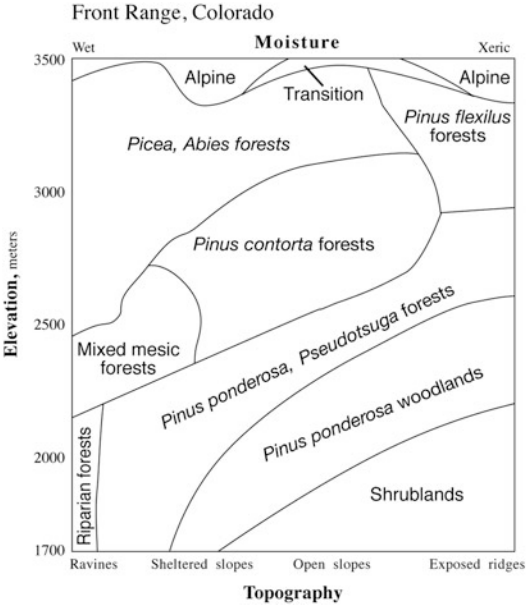
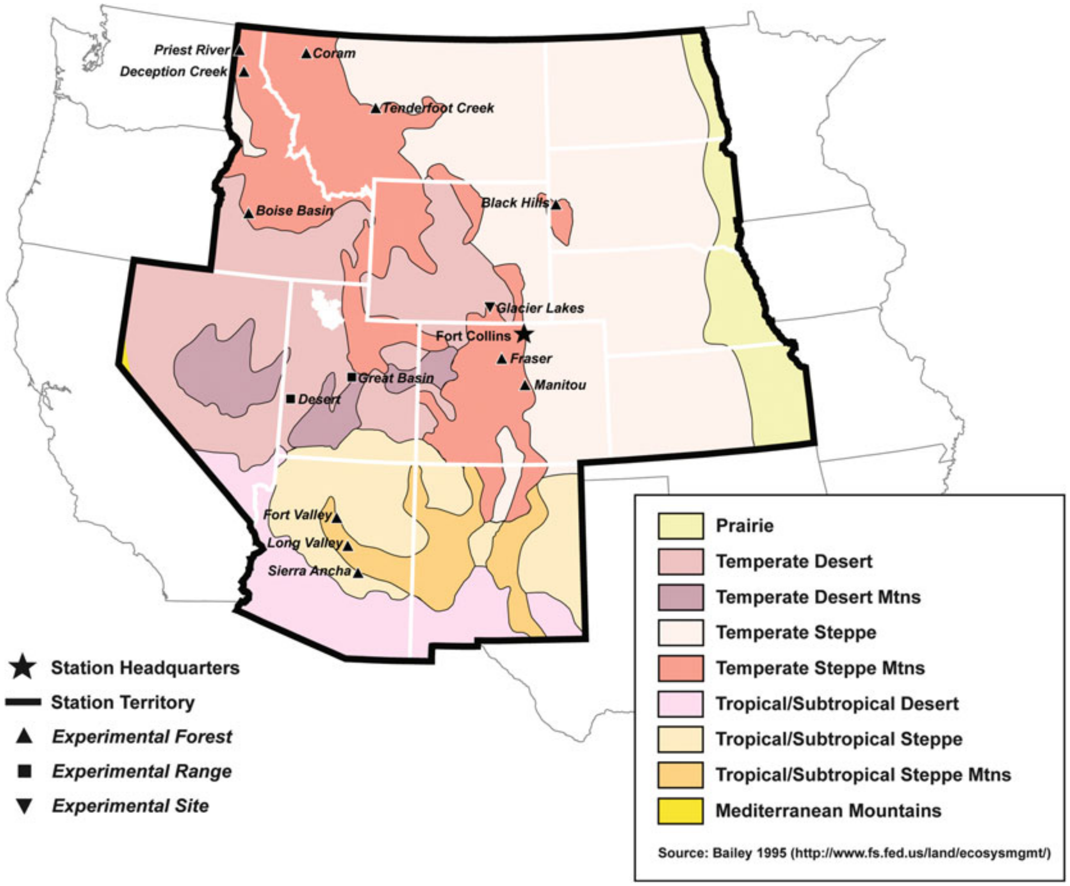


Fig. 12.6 Relationships between elevation-topography and climax plant communities, Front Range, CO. *Source*: Peet (1981) in Bailey (2009b)



Source: Bailey 1995 (http://www.fs.fed.us/land/ecosysmgmt/)

Fig. 12.7 Approximate boundaries of ecoregion divisions map (level 2 of the ecoregion hierarchy) of the U.S. Forest Service's Rocky Mountain Research Station and locations of experimental forests and ranges

predicted from landform information if the vegetation-landform relationships are known in a particular ecoregion. For example, Douglas-fir forests occur on moist, mid-elevation sites within the Front Range of Colorado. Fig. 12.6 shows the relationships between elevation-topography and climax plant communities. Understanding these relationships, vertically and horizontally, within ecoregion delineations allows the transfer of knowledge from research sites (or inventory plot) to like sites within the same ecoregion. In fact, O'Brien (1996) and Rudis (1998) found that surveys involving comprehensive sampling efforts will more accurately characterize unmonitored sites (plots) when samples are stratified according to ecologically similar areas such as ecoregions. Unfortunately, we often do not understand the spatial relationships between the FIA plots and the landform-vegetation types within a particular ecoregion. If these were developed, we could likely produce better small-area estimates of vegetation conditions.

12.2.5 Transfer Information

Ecoregion maps show areas that are hypothesized to be analogous with respect to ecological conditions. Testing and validation of ecoregion delineations seem to bear this out (Olson et al. 1982; Inkley and Anderson 1982; Bailey 1984; McNab and Lloyd 2009). This makes it possible to transfer knowledge gained from one part of a continent to another. Figure 12.7 shows a map of ecoregions overlaid with experimental forests and ranges of the

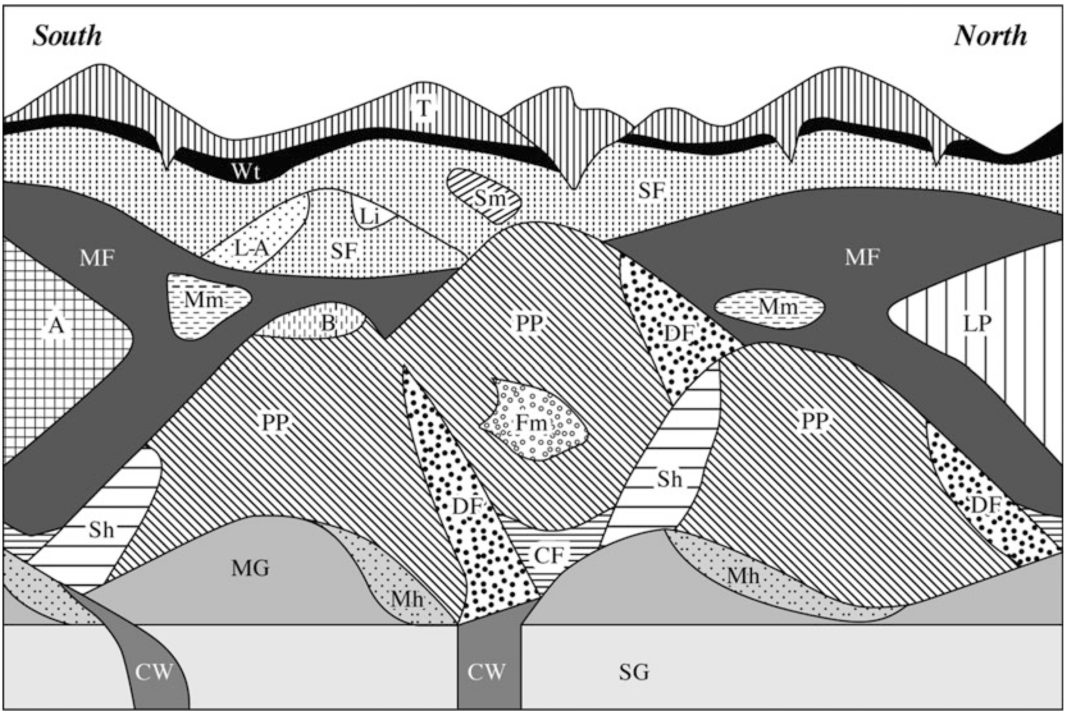


Fig. 12.8 Diagrammatic distribution of vegetation types in the mountains of the Front Range in Boulder County, CO. From Gregg (1964)

USDA Forest Service's Rocky Mountain Research Station. It shows how the ecoregion map identified forests/ranges that fall into groups with *similar ecology*. We say similar ecology because an ecoregion is a climatic region within which specific plant successions occur upon specific landform positions. The most probable vegetation growing on a site within an ecoregion can be predicted from landform information if one knows the vegetation–landform relationships in various ecoregions. (Refer to Douglas-fir example in preceding subsection.) Figure 12.8 shows the relationship between elevation-topography and climax plant communities. These relationships provide a blueprint for site analysis and management of native vegetation. Understanding the plant community gradients with respect to elevation and topography also provides a basis for separating climax from successional stands. For example, lodgepole pine forest occurring in the Douglas-fir forest zone in the Rockies may be successional following fire.

12.2.6 Determining Suitable Locations for Seed Transfer

Seed transfer zones are geographic areas within which plant materials can be moved freely with little disruption of genetic patterns or loss of local adaptation. Ecoregions have been suggested as potential seed transfer zones (Miller et al. 2011; Jones 2005) because they encompass areas with similar elevation and climate. Elevation and climate gradients appear to contribute significantly to geographic patterns of genetic variation and adaptation in many plants including trees (Post et al. 2003), shrubs, forbs, and grasses (Casler 2012).[1] One proposed refinement to the use of ecoregions as areas of plant movement has been to combine them with plant hardiness zones (Cathey 1990; revised Agricultural

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[1] Hancock et al. (2010) found that ecoregions contribute to geographic patterns of genetic variation and adaptation of humans.

Research Service 2012) to map **plant adaptation regions** (Vogel et al. 2005). In a comparison of five region-scale ecological classification schemes, Steiner and Greene (1996) concluded that the author's ecoregion scheme was the best descriptor for regional classification of **germplasm** because of its hierarchical arrangement; the number of distinctive classes based on soils, landform, and natural vegetation; and its availability in a geographic information system format.

Ecoregions can also be used to design research. For example, Dey et al. (2009) reported that when treatment plots are located so as to account for regional differences, the results can be used to improve a manager's ability to predict oak regeneration successes and failures following given **silvicultural practices**.

12.2.7 Understanding Landscape Fragmentation

Historically, a high level of landscape heterogeneity was caused by natural disturbance and environmental gradients. Now, however, many forest landscapes appear to have been fragmented due to management activities such as timber harvesting and road construction. To understand the severity of this fragmentation, the nature and causes of the spatial patterns that would have existed in the absence of such activities should be considered. This provides insight into forest conditions that can be attained and perpetuated.

12.2.8 Choosing Planting Strategies for Landscaping and Restoration

Understanding the patterns of sites also can inspire design for urban and suburban landscapes that are in harmony with the region they are embedded within. For example, desert plants thrive on the arid south side of houses in the southwestern United States. The north side is moist and humid and can support larger, denser plants.

Furthermore, like streams, cities do not exist independently of what surrounds them. Ramage et al. (2012) found that urban trees were consistently related to the surrounding biome (ecoregions). Classifying metropolitan areas by ecoregion forms a baseline for selecting native plants for landscaping or to restore natural conditions as well as transferring information among similar cities (Sanders and Rowntree 1983). A source of native plant information can be found in *Description of the Ecoregions of the United States* (Bailey 1995). This information is an important guide to knowing which plants will thrive in a particular ecoregion.

Gardens can be seen as extensions of the surrounding landscape and responsive to the various regions of the country. Designing urban and suburban landscapes that mimic the native vegetation by using regionally appropriate plants is the safest course to ensure landscape sustainability. By using an ecoregional pollinator guide, one can learn what native plants can be found in one's ecoregion and what pollinators they attract. These guides are published online by the Pollinator Partnership at http://www.pollinator.org/guides.htm

12.2.9 Environmental Risk Assessment

Ecological risks associated with human activity will vary depending upon the activity and where it takes place. The plants and animals of different regions respond differently to the same environmental stress. For example, Pidgeon et al. (2007) found the effect of housing development on bird species richness across the USA varied by ecoregions. Many ecoregional differences in hydrologic responses to human-modified land cover were reported by Poff et al. (2006). In the late 1970s, the ecoregion concept was used to stratify the United States into seven hydrologic regions in order to better predict the effects of silvicultural activities on **non-point source pollution** (Troendle and Leaf 1980) and later to predict the hydrologic effects of forest disturbance, including fuel reduction treatments (Troendle et al. 2010).

Hazards occur extensively in certain regions—landslides in southern California—creating a regional problem (Radbruch-Hall et al.

1982). By knowing the geographic factors that cause slides within a region, one can identify and then either avoid hazardous landslide areas or apply mitigation measures.

Likewise, certain terrestrial ecoregions have desertification risk, as their prevailing climate is arid, semi-arid, or dry subhumid, which represent 38 % of the terrestrial surface. Nunez et al. (2010) developed a method to make possible the inclusion of the desertification impact derived from human activity (agriculture, industry, mining, etc.) in land-use studies.

12.2.10 Learn from Successful Ecological Designs and Predict Establishment of Invasive Species

Ecoregion maps identify region-scale ecosystems throughout the world. For example, temperate continental ecoregions are always located in the interior of continents and on the leeward, or eastern, sides; therefore, the northeastern U.S. is ecologically similar to northern China, Korea, and Japan (Fig. 1.4, p. 3). This makes it possible to learn from successful ecological designs in similar ecoregions as well as to predict what new harmful organisms could successfully establish and spread if they were to arrive. It should be noted that not all parts of similar ecoregions are equally susceptible to the future expansion of invasive species, especially in mountain ecoregions that are broken into complex patterns of disturbance and habitats (Parks et al. 2005).

On a related note, the ecoregion concept could be useful for the safe importation of invertebrate biological control agents (Cock et al. 2006). Movement of insect species between countries in the same ecoregion is clearly less risky than moving species between disjointed similar ecoregions.

12.2.11 Maintain and Restore Biodiversity

Rather than occurring randomly, species distributions are sorted in relation to environment (Fig. 12.9). This means that similar environments tend to support similar groups of plants and animals in the absence of human disturbance (cf. Rodriguez et al. 2006).

Ecoregional analysis capitalizes on this by identifying climatic and landform factors likely to influence the distribution of species. This analysis uses these factors to define a landscape classification that groups together sites that have similar environmental character. Such a classification can then be used to indicate sites likely to have similar potential ecosystem character with similar groups of species and similar biological interactions and processes.

One of the major advantages of this approach, as opposed to directly mapping land cover, for example, is its ability to predict the potential character of sites where natural ecosystems have been profoundly modified (e.g., by land clearance or fire) or replaced by introduced plants and animals (e.g., pests and weeds).

Ecoregions have been ranked with respect to expected changes in biodiversity for the year 2100 due to climate change (Sala et al. 2000). Mediterranean climate and grassland ecosystems likely will experience the greatest proportional change in biodiversity. Northern temperate ecosystems are estimated to experience the least biodiversity change because major land-use change has already occurred.

12.2.12 Facilitate Conservation Planning

The scientific community has taken an interest in the importance of scale. Recognizing the need to move beyond traditional nature preserves to protect biodiversity, scientists have begun broadening their perspective. One of the most powerful ideas to emerge for directing conservation efforts is that of ecological regions, or ecoregions. With similar climate, geology, and landforms, ecoregions support distinctive grouping of plants and animals. Transcending unnatural political boundaries, these ecoregions provide powerful conservation planning tools.

The concept of ecoregions has been adopted by dozens of organizations in the United States and around the world as a way of thinking about

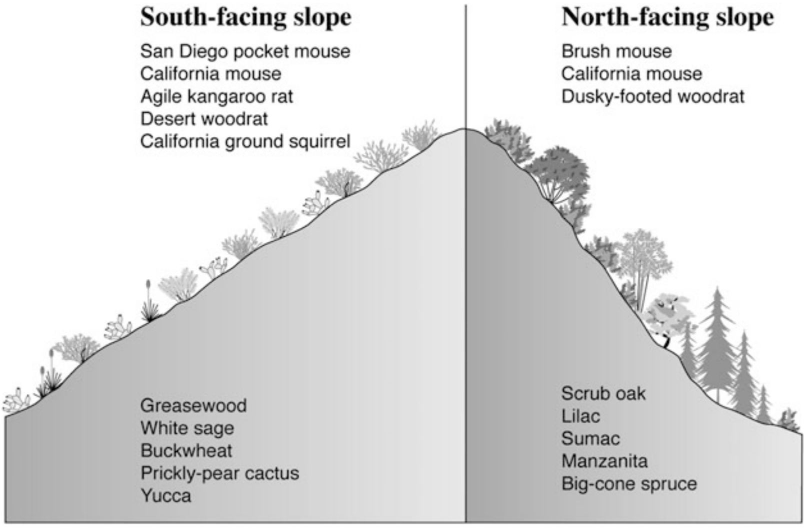

Fig. 12.9 Mammal and plant communities on south-facing and north-facing slopes in lower San Antonio Canyon, San Gabriel Mountains, California. From Vaughan et al. (2000). *Mammalogy*, 4E. © Brooks/Cole, a part of Cengage Learning, Inc. Reproduced with permission. www.cengage.com/permissions

structuring global and continent-scale conservation efforts. For example, The Nature Conservancy has shifted the focus from conservation of single species and small sites to conservation planning on an ecoregional basis (Stein et al. 2000; Valutis and Mullen 2000). The Nature Conservancy modified Bailey's classification to identify 63 ecoregions across the United States. Organizations such as the National Wildlife Federation[2] and the U.S. Fish and Wildlife Service (cf. Corace et al. 2012) have found that ecoregions (*sensu* Bailey) define useful geographical units for conservation. Likewise the Department of Interior has initiated a national network of 22 Landscape Conservation Cooperatives (LLCs) that are based on bird conservation areas, which are loosely based on ecoregions. The World Wildlife Fund has developed an ecoregion classification system to assess the status of the world's wildlife and conserve the most biologically valuable ecoregions (Olson and Dinerstein 1998). It builds on Omernik (1987) and other analyses to provide a global-level view of ecoregions and to highlight those ecoregions worldwide that are particularly significant and should be priorities for conservation action. The U.S. Forest Service uses the Bailey ecoregion classification (Bailey 1995) to evaluate the adequacy of ecosystem representation within the National Wilderness Preservation System (Loomis and Echohawk 1999; Cordell 2012). Jepson et al. (2011) provide a critique of the various approaches to ecoregion-style conservation planning.

12.3 Significance to Research

It is important to link the ecosystem hierarchy with the research hierarchy. In so doing, research structures and ecosystem hierarchies correlate such that research information, mapping levels, and research studies work well together. Comparison of research structures and ecosystem levels can identify gaps in the research network.

At the ecoregional scale, existing research locations can be compared with ecoregion maps to identify underrepresented regions or gaps in the network (Fig. 12.10). For example, experimental forests or ranges administered by the Forest Service occur in only 26 of 52 ecoregion provinces (Lugo et al. 2006). Several ecoregions have no research facilities while others have more than one. The greatest number (14) falls within the Laurentian mixed forest ecoregion of the Lake States and Northeast. A more comprehensive analysis could include other types of

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[2] See the National Wildlife Federation's website "Ecoregions" at https://www.nwf.org/Wildlife/Wildlife-Conservation/Ecoregions.aspx.

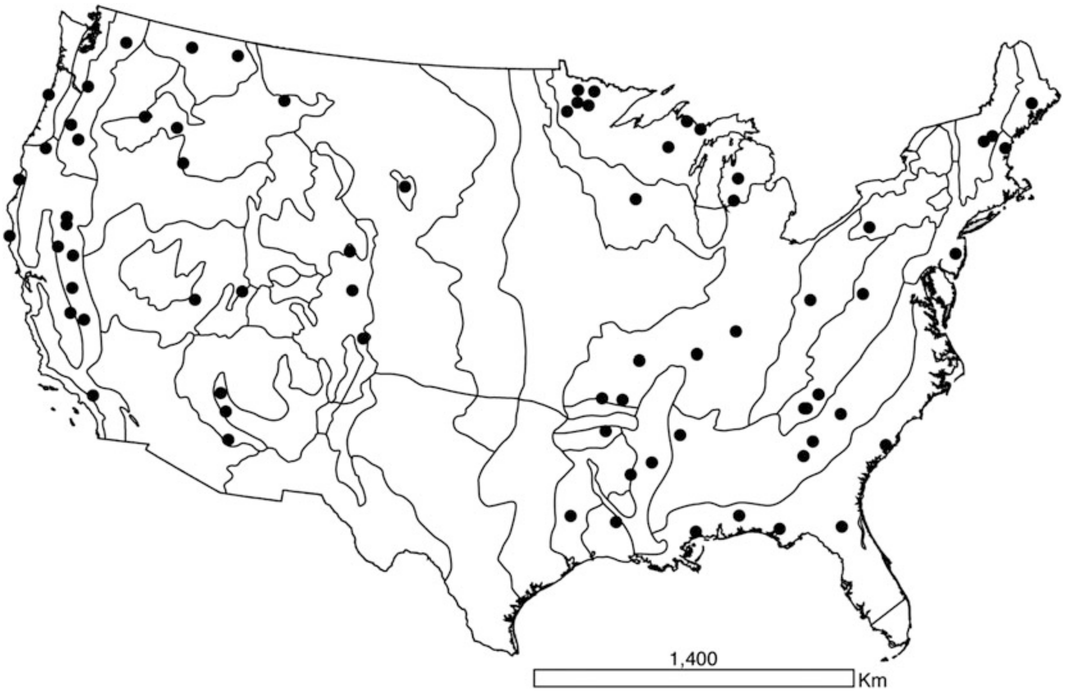

Fig. 12.10 Approximate boundaries of ecoregion provinces (level 3 of the ecoregion hierarchy) within the conterminous United States and locations of experimental forests and ranges administrated by the U.S. Forest Service. *Source*: Alga Ramos, Forest Service, International Institute of Tropical Forestry, San Juan, Puerto Rico

similar research sites, such as Long-Term Ecological Research (LTER) sites, Long-Term Agro-Ecosystem Research (LTAR) sites, Research Natural Areas, National Ecological Observatory Network (NEON) sites, and the like. This analysis could reveal gaps in coverage both across and within ecoregions.[3]

12.3.1 Restructuring Research Programs

The many useful applications of the study of ecosystem patterns suggest new scientific directions for research and points the way for restructuring research programs. To address critical ecological issues, it is essential to move from the traditional single-scale management and research on plots and stands to mosaics of ecosystems (landscapes and ecoregions) and from streams and lakes to integrated terrestrial-aquatic systems (i.e., geographical ecosystems). FIA thematic maps (e.g., biomass, forest types, etc.) could assist with this.

12.3.2 Some Research Questions

These studies reveal useful applications of ecosystem patterns. There still remain many relevant research questions associated with these patterns, including: What are the natural ecosystem patterns in a particular ecoregion? What are the effects of climatic variation on ecoregional patterns and boundaries? And, what are the relationships between vegetation and landform in different ecoregions? While some workers have suggested that GIS analysis can assist in answering these

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[3] Along similar lines, the U.S. Army has developed a ecoregion-based map to identify environments across the globe that are analogous to Army installations where training and testing of soldiers and equipment take place (Doe et al. 2000). Comparing this map with the locations of current installations allows Army planners to assess the ability of the Army to conduct pre-deployment activities in similar environments, which is critical to mission success.

questions, that approach should be used with caution because it will help identify pattern but cannot generate an understanding of the processes that create these patterns (Bailey 1988).

12.3.3 Natural Ecosystem Patterns

Historically, a high level of landscape heterogeneity was caused by natural disturbance and environmental gradients. Now, however, many forest landscapes appear to have been fragmented due to management activities such as timber harvesting and road construction. To understand the severity of this fragmentation, the nature and causes of the spatial patterns that would have existed in the absence of such activities should be considered. This analysis provides insight into forest conditions that can be attained and perpetuated (Knight and Reiners 2000).

12.3.4 Effects of Climatic Variation

Current climate exerts a very strong effect on ecosystem patterns, and climate change may cause shifts in those patterns (Neilson 1995, see Chap. 10). Anthropogenic and climatic change could yield ecoregions that are much different, or less useful, after many years. Therefore, temporal variability is an important research issue. While several researchers are doing work on the effect of climate change on tree species distribution (cf. Iverson and Prasad 2001), others are working on the impact of climatic change on the geography of ecoregions. For example, Jerry Rehfeldt of the Rocky Mountain Research Station (personal communication) has predicted the potential distribution of the American (Mojave-Sonoran) Desert ecoregion under the future climate scenario produced by the IS92a scenario of the Global Climate Model,[4] with about 21 °C warming and 50 % increase in precipitation. He has produced maps that show a greatly expanding desert under this scenario. Despite the percentage increase in precipitation, the amount of rainfall fails to keep pace with the increase in temperature, so the climate becomes more arid.

There are limits to the number of sites that can be established for monitoring changes in the global environment. Obviously, sites should be representative. Stations also should be located where they can detect change. The boundaries between climate-controlled ecoregions are suitable for this purpose. FIA has roughly 160,000 forested sample sites. This criterion could identify a subset of these sites which could be more intensively sampled to provide the needed monitoring information.

12.3.5 Relationships Between Vegetation and Landform

The relationships between vegetation and landform position change from ecoregion to ecoregion, reflecting the effect of the macroclimate. Vegetation strongly influences where animals live—some more so than others—and such factors as soil moisture and topoclimates determine which plants live where; hence site-specific vegetation character. Trees make a simple example: they change their positions in different regions (Table 12.2). Any such changes invoke related changes such as in the vigor of other tree species, ecosystem productivity, and so on. Knowledge of these differences is important for extending results of research and management experience and for designing sampling networks. These relationships have been extensively studied in some regions (cf. Odom and McNab 2000) but, unfortunately, not in others. Where sufficient studies have been done, these relationships might be modeled and mapped to improve understanding of these ecosystems.

All of the applications discussed in this chapter involve expanding our perspective to see the patterns that exist within a region. These patterns, interpreted in terms of process, can be very useful to land managers and scientists. In the next chapter, we discuss fire regimes of different ecosystems at the scale of ecoregion, and

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[4] This is one of the emissions scenarios developed in 1992 under the sponsorship of the Intergovernmental Panel on Climate Change. IS92a has been widely adopted as a standard scenario for use in impact assessments.

Table 12.2 Relationships between vegetation and landform in various ecoregions in Ontario, Canada

	Topoclimate		
Ecoregion	Hotter	Normal	Colder
1	P		
2	P		P
3	P		P
4	A	P	P
5	A		A,P
6	C		A,P
7			C,A

From Burger (1976)

P *Picea glauca* (white spruce), A *Acer saccharum* (sugar maple), C *Carya ovata* (shagbark hickory)

go on to explore how understanding fire regimes at this scale can abate the threat of fire exclusion and restore fire-adapted ecosystems.

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