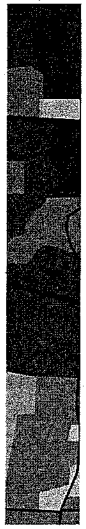

3

When Humans and Nature Collide

Imagine Exponentia, a booming city of the early twenty-first century. A hundred years ago, Exponentia was a town of barely 5,000 residents; today, it has more than 100,000, with most of that growth taking place in just the last half-century. A large proportion of the city's residents have high-tech jobs, and many of them appreciate the easy access that the city has historically had to beautiful natural areas. As a result of its recent growth, however, the town-become-city now extends well out into the neighboring farmlands, rangelands, and mountains and has become part of a larger metropolitan complex (see Figure 3-1). Exponentia is fictional, but cities like it can be found across North America; as you read the next few paragraphs, imagine your local version of Exponentia and fill in the relevant details.

Planners are familiar with many of the human challenges that accompany rapid growth, such as the need to fund additional roads, schools, public safety services, and water and sewer infrastructure. But how does urban growth affect native species and habitats? The most obvious effect of the city's expansion is the loss of native habitat. This is a zero-sum game with three players: natural habitats, agricultural lands, and urban land uses. As one land use expands—typically, human-inhabited areas—one or both of the others contract. Granted, these are not completely mutually exclusive categories; for example, lightly used rangelands and sparsely inhabited regions can serve as good habitat for some native species. But, by and large, every acre of the landscape can be assigned to one or

another of the categories, and the unmistakable trend—and one that shows no sign of changing—is that native habitat has been shrinking over time.

As the four diagrams of Exponentia shown in Figure 3-1 illustrate, human development is not likely to occur in all areas equally. Development proceeds rapidly on relatively flat sites with well-drained soils, since these make good building sites. Development is slower to reach remote, steep, or poorly drained lands, although homes may appear on hillsides and along ridgetops if local ordinances allow. So, in this hypothetical example, while only about half of the total area has been developed in the past fifty years, most of the flat lowlands have been lost, while the hillsides remain relatively untouched.

Consequences of Human Settlement

As human settlements spread and our activities expand, we affect native biodiversity in many ways. Urban and agricultural land uses destroy and fragment native habitats; our homes, machines, and industries pollute, degrade, and alter the land, air, and water; we harvest (and often overharvest) native species from their habitats; and we accidentally or intentionally introduce non-native species. For example, since European settlement of North America, nearly all of the continent's tallgrass prairie has been converted to agriculture. Most of the states and provinces originally containing tallgrass prairie have lost 98 percent or more of their prairie area.[1] Human impacts affect different regions in different ways, but the cumulative effect—multiplied across landscapes and regions—is to change the Earth in profound ways that are virtually irreversible on human time scales. The remainder of this chapter explores these impacts, laying out the major ecological challenges that this book will help readers address.

Habitat Destruction: Taking up Space

Habitat destruction occurs when native habitats are replaced by human land uses, such as housing, commercial developments, and farmland. When this happens, resident plants and animals perish. Any animals that do survive the conversion may seek refuge in adjacent areas, if suitable habitat exists, but these refugees may be unable to find adequate food, shelter, or territory if the habitat is already occupied and may perish as well. But not all examples of habitat destruction are alike in their consequences. The short-term ecological effect of habitat destruction depends greatly on its *thoroughness*, while the long-term impact depends also on the *permanence* of the changes.

The thoroughness of habitat destruction can be thought of as a continuum. At one end of the spectrum are places like lower Manhattan or large-scale monoculture farms, where native habitats have been completely obliterated. Small ves-

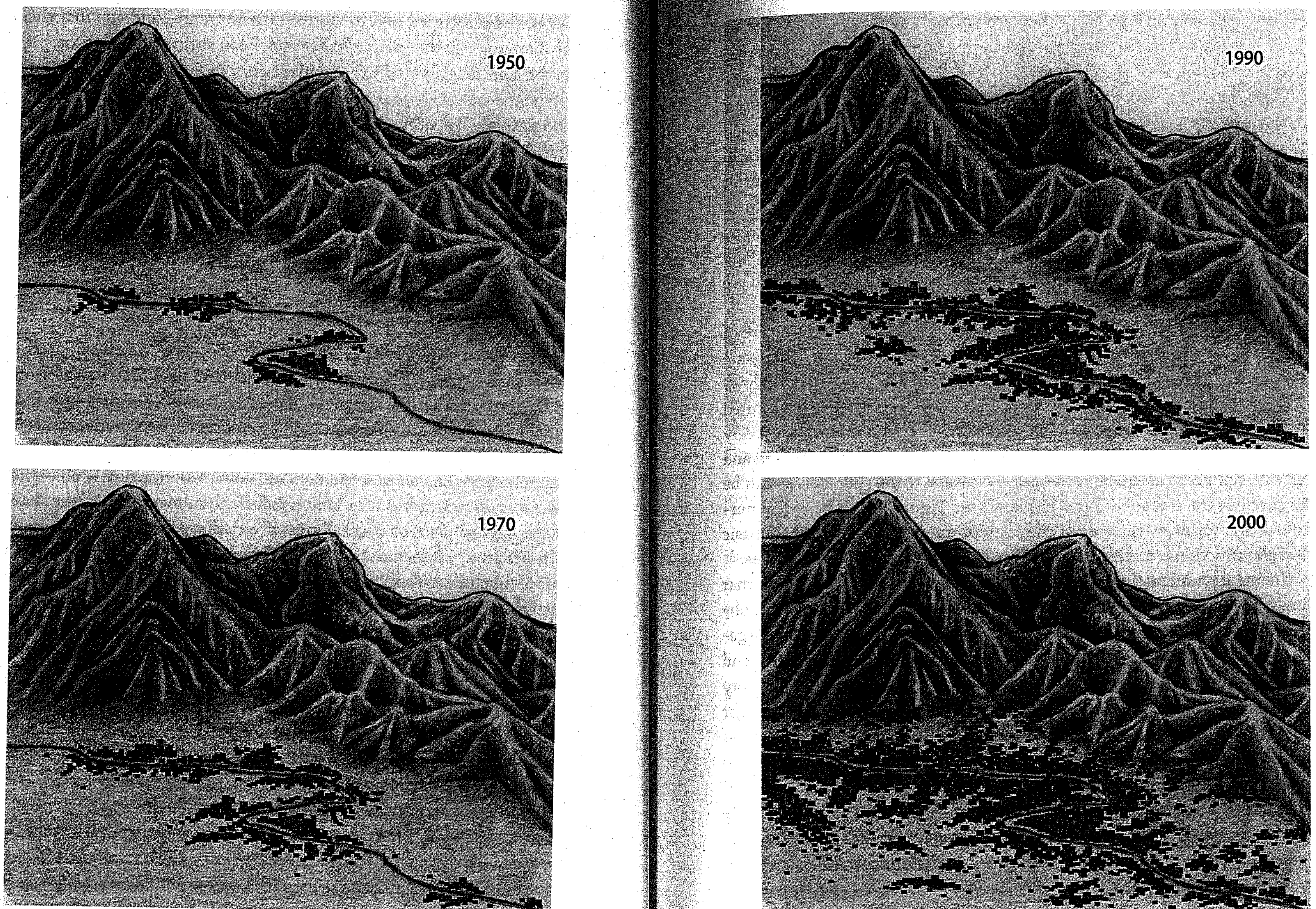

Figure 3-1. This time series of figures shows urban expansion for the hypothetical city of Exponentia from 1950 to 2000. As shown in this series, development tends to occur first on prime, flat, productive sites, moving later into more remote areas and those with environmental constraints.

tiges of open space may remain, but they are probably nothing like the native habitats of the area. At the other end of the spectrum are human land uses that retain large areas in their natural condition—for example, a campground situated within a native forest or a lightly cut woodlot. In the middle are suburbs, parks, golf courses, college campuses, and low-intensity agricultural areas such as pastures. The thoroughness of habitat destruction in these areas varies greatly depending not just on the number of buildings constructed or the amount of pavement laid but also on the amount and quality of native vegetation retained. Measures commonly used in planning and development such as "percent green space" are poor indicators of habitat retention because they fail to differentiate intact native habitats from turfgrass and other manicured vegetation, which are often a biological wasteland for native species.

The permanence of human land use changes depends both on the nature of the changes and on the ability of the ecosystem to recover from them. In some cases, the native habitats can regenerate naturally and relatively easily following human land use changes. For example, much of the northeastern United States is heavily forested today, even though most of this region was actively farmed 100 or 150 years ago. Dirt roads, croplands, pastures, wooden houses, and even old railroad beds can all be reclaimed by nature within decades, as can be seen throughout the forests of New England (see Figure 3-2). These regenerated forests are not exact replicas of the presettlement forests, but their basic structure and function are intact, as are most of their dominant plant species.

In other cases, humans have changed the land and its ecology so greatly that restoring it to its original condition may be virtually impossible. In metropolitan areas, where we have paved much of the landscape, the likelihood that large-scale regeneration will occur within several generations is becoming more and more remote. Farming can also alter the land on a near-permanent basis. In many arid regions of western North America, intensive irrigation with groundwater has led to soils becoming overly saline from the small amounts of salt that are naturally found in groundwater. A 1996 report from the U.S. Natural Resources Conservation Service found that at least 48 million acres (19 million ha) of cropland and pasture are currently affected by salinization, an area equivalent in size to the state of Nebraska. The report notes that "reclaiming saline soils economically is difficult, if not impossible. Salinized soil is lost to agricultural production, at least in the near term."[2]

We are certainly not suggesting that humans stop paving or irrigating altogether but, rather, that planners and designers strive to limit activities and changes that alter the land in severe and long-lasting ways. As the examples above illustrate, land use changes that significantly alter an ecosystem's physical substrate—soil—tend to be less reversible (or take longer to reverse) than

Figure 3-2. This house near Lords Hill in central Vermont was abandoned many years ago. As in so many places throughout eastern North America, the forest has grown up around the house, covering what was once farmland.

those that do not.[3] In addition, some ecosystems respond more severely than others to outside perturbations (such as human activity) and tend to return to their predisturbance condition more slowly once the perturbation ends. For example, ecosystems where plant growth and soil formation are slow—such as deserts, tundra, and alpine ecosystems—tend to take longer to regenerate after a disturbance. Finally, different biotic communities regenerate at different rates; the basic structure of a prairie ecosystem may coalesce within several years (assuming that the soils are in good shape), whereas an old-growth redwood forest might take a millennium to form.

Although conservationists sometimes speak of extinction as the only permanent change that humans can effect, other impacts can change the landscape for many generations. Planners, designers, and developers should be especially careful about creating changes in nature that will not be undone in our grandchildren's lifetimes.

Habitat Fragmentation: Being a Bad Neighbor

Habitat *fragmentation* occurs when urban and agricultural land uses divide native habitats into discontinuous patches. A close examination of Figures 3-1a through 3-1d shows that the native habitats around our hypothetical city, Exponentia, did not disappear in wide swathes all at once; instead, they were nibbled away incrementally and discontinuously as individual developments expanded outward. When formerly contiguous native landscapes become broken into isolated patches, several ecological problems can occur. In general, the smaller a habitat fragment, the smaller the populations of resident species it can support. Small populations are at much greater risk of extinction than large populations, and once a population is extirpated from an isolated patch of habitat, the site's isolation decreases the chance that it will be recolonized.

Fragmented landscapes also have a high proportion of *edge habitat*, where natural lands are influenced by adjacent urban or agricultural areas. These edge areas are unsuitable habitat for many native species because they tend to have a different microclimate and vegetation structure than *interior* areas as well as suffering detrimental impacts from adjacent human land uses, such as noise, dust, and agricultural chemicals. Also, the edge zone is often attractive to predators and thus is a dangerous place for many native species. In fragmented habitats, many open spaces that appear to contain native ecosystems may actually have limited habitat value because they have such a high proportion of edge. The process and effects of fragmentation are discussed in much more detail in Chapter 6.

Exotic Species: Bringing Unwelcome Friends

Since colonial days, North America has been overrun by *exotic species* (also known as *non-native species*) introduced by humans. The number of exotic species is especially high around ports and other coastal areas that were settled early by Europeans; in these areas, up to a third of the plant species can be exotics (see Figure 3-3). For example, according to the U.S. Geological Survey's *Status and Trends of the Nation's Biological Resources*, the small, cold state of Massachusetts has about as many exotic plant species as much larger and warmer California and Florida—probably because of the hundreds of years that Massachusetts ports have been receiving cargo and plants from around the world (Massachusetts has 1,019 exotic plant species, while California and Florida have 1,113 and 1,017, respectively).[4]

Most non-native species exist in relatively low numbers and do not cause major problems. However, some exotics spread rapidly, outcompeting native species and even altering whole ecosystems. These are known as *invasive species*. In his 1943 essay "What Is a Weed?" Aldo Leopold states that "good and bad are attributes of numbers, not of species."[5] While the definition of a weed is inherently subjective, most invasive species share certain traits that make them especially problematic for native ecosystems. According to Leslie Mehrhoff, curator of the University of Connecticut Herbarium, invasive species tend to have the following characteristics:

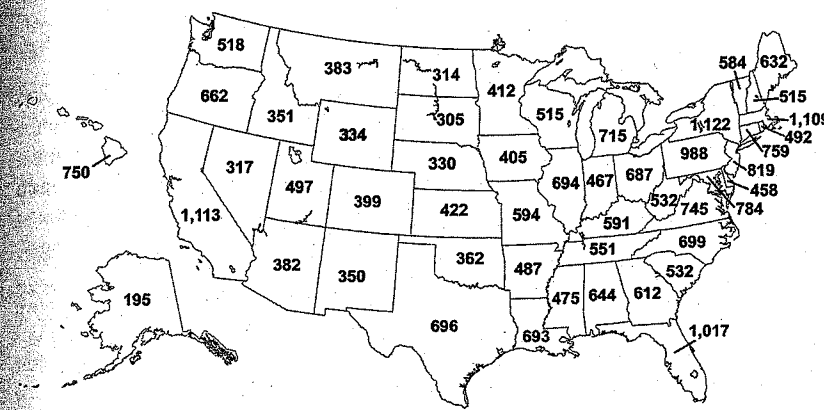

Figure 3-3. Every part of the United States has been invaded by hundreds of exotic plant species, and some states have over 1,000 exotic plant species. The numbers indicate how many exotic plant species are found in each state. (Redrawn from Michael J. Mac et al., *Status and Trends of the Nation's Biological Resources*, 2 vols. [Reston, VA: U.S. Department of the Interior, U.S. Geological Survey, 1998].)

1) Each plant produces large quantities of seeds or propagules;
2) The plants have very effective dispersal mechanisms;
3) The plants are readily established;
4) The plants grow rapidly;
5) The plants compete very effectively.[6]

Some exotic species can cause amazing amounts of ecological mischief, and a consensus is growing among biologists that exotic species are second only to habitat destruction as a threat to North America's native biota. Unlike housing developments and industrial parks, exotic species are often able to infiltrate and overwhelm native habitats before the general public becomes aware of the threat. Many exotic plant species have been imported intentionally, for use either in gardens or in erosion control and land reclamation projects—and some species, such as kudzu, have been imported for both purposes (see Box 3-1). Unfortunately, as international trade and travel increase, the problem of exotic species is likely to worsen. Although only a small proportion of the many exotic species that reach the shores of North America successfully establish populations, the flow of species is so great that every year brings new problems.

Habitat Degradation and Pollution: Fouling Our Nests

Like all living organisms, human beings create waste materials. We breathe out carbon dioxide and water vapor, and we excrete nitrogen compounds and undigested food. When few humans live in an area, our wastes are simply part of

Box 3-1
A Few Notorious Exotic Species

Kudzu (*Pueraria montana*), a native of eastern Asia, is a perennial vine of the legume family. The plant was first brought into the United States in 1876 for display as an ornamental vine at the Centennial Exposition in Philadelphia; in 1935, the U.S. Soil Conservation Service pressed this hardy vine into service to halt erosion on farmland and along roadsides, paying farmers to plant it. Eleven years later, kudzu covered some 3 million acres across the South, an area the size of Connecticut. In 1970, the U.S. Department of Agriculture listed the plant as a common weed, and today more than 7 million acres in twenty-five states are infested with it.[1]

While kudzu, with its blanketing, choking appearance, is impossible to miss, other invasive exotic species, such as garlic mustard (*Alliaria petiolata*), can sneak into an area virtually unnoticed. Some invasive species continue to be welcomed by the general public even long after biologists become aware of how damaging they can be for native species. For example, purple loosestrife (*Lythrum salicaria*) is widely planted as an ornamental even though it can escape cultivation and take over wetland areas with impressive and dismaying speed. Fifty percent or more of the native plant biomass in a wetland area can be replaced by loosestrife, which crowds out rare and endangered native species and disrupts the life cycles of many animals that depend on native plants. In some cases, entire wetlands can be covered by purple loosestrife.[2]

Saltcedar trees (several species in the genus *Tamarix*) not only replace native wetland plants in the arid West but actually change the physical habitat. Their deep roots appear able to draw more water out of the soil than the native species they replace, and they concentrate salts from the water in their leaves. Since they are deciduous, when they lose their leaves, the high salt content leaches into the surface soil, creating conditions that are inimical to many native plants. Finally, saltcedar grows in riparian zones and wetlands, disrupting these fragile and ecologically critical habitats.[3]

Animals, too, can run amok when introduced to favorable habitats. Gypsy moths (*Lymantria dispar*) were introduced to the Boston area in about 1869 to establish a silk moth industry on this continent (the project failed entirely). When the moths escaped from the backyard of Ettiene Leopold Trouvelot, the French painter and amateur entomologist who imported them, they began ravaging the neighborhood. Early attempts to control the spread of the species using scalding water and burning kerosene proved fruitless. In 1981, gypsy moth caterpillars defoliated 12 million acres throughout the northeastern United States, and their range keeps spreading.[4]

NOTES

1. R. Westbrooks, *Invasive Plants, Changing the Landscape of America: Fact Book* (Washington, DC: Federal Interagency Committee for the Management of Noxious and Exotic Weeds, 1998), http://www.denix.osd.mil/denix/Public/ES-Programs/Conservation/Invasive/intro.html.
2. Westbrooks, *Invasive Plants*.
3. National Park Service, "Saltcedar," http://www.nps.gov/plants/alien/fact/tama1.htm (accessed July 25, 2003); The Nature Conservancy, "Element Stewardship Abstract for Tamarix," http://tncweeds.ucdavis.edu/esadocs/documnts/tamaram.pdf (accessed July 25, 2003).
4. U.S. Forest Service, http://www.fsl.wvu.edu/gmoth/ (accessed April 14, 2000; Web page no longer available); National Agricultural Pest Information System (NAPIS), "Gypsy Moth Fact Sheet," http://www.ceris.purdue.edu/napis/pests/egm/facts.txt (accessed June 29, 2001).

normal ecosystem functioning, as are the wastes of other large animals. But when we aggregate into cities and concentrate large volumes of waste, or when we create and apply novel chemical pesticides or spread huge amounts of fertilizer on our crops and lawns—then we cause problems.

The effects of pollution on biodiversity are sometimes readily apparent. For example, Lake Erie and Boston Harbor both experienced radical ecosystem changes and the loss of native species because of pollution from sewage and industrial waste, although both have subsequently recovered significantly after the pollutant sources were addressed. But pollution also affects ecosystems in more subtle ways, including by:

- altering the chemical balance of ecosystems in ways that favor invasive exotic species or affect the competitive balance between native species
- weakening organisms so that they are more susceptible to natural threats
- eliminating certain pollution-sensitive species, often leading to cascading effects on other species
- reducing the structural diversity (i.e., the number of suitable subhabitats) within ecosystems.[7]

Overharvesting of Natural Populations: Being Gluttons at Nature's Table

Much of nature's economy is based on the "harvesting" of one species by another. Except for plants, which harvest their own energy from sunlight, most of the species on Earth get their energy by feeding either on living organisms (as herbivores and carnivores do) or on dead organisms or biological waste products (as decomposers and detritivores, such as bacteria, fungi, and some insects, do). In fact, much of evolution consists of adaptations by species to become either more efficient in their harvesting of other species or better at escaping being harvested.

When a few thousand humans fish in a river the size of the Columbia or search for nuts and berries in a forest the size of Delaware, we function like one of several large-bodied, effective predators and herbivores in the ecosystem. However, when we employ advanced technology, even the nineteenth century's relatively simple technology of trains, telegraphs, nets, and traps, we become something quite different: we can cause the extinction of what was possibly the most numerous bird species ever to live on the planet, the passenger pigeon (*Ectopistes migratorius*). With today's technology—fishing boats equipped with sonar, global positioning systems, and highly effective nets; or chainsaws and logging trucks—we can come close to wiping out species in any ocean or forest.

Global Climate Change: Changing the Rules of the Game

Even in areas where careful land management practices have kept floods and erosion at bay, planetwide events may cause problems. The Earth's climate appears to be warming significantly, almost certainly due to the increase in greenhouse gases that humans have released into the atmosphere since the start of the Industrial Revolution. Greenhouse gases, such as carbon dioxide (CO_2) and methane (CH_4), are generated by various human and natural processes, especially by the burning of forests and fossil fuels. In North America, electricity generation, transportation, and industrial production (in that order) account for most greenhouse gas emissions.[8]

While climate scientists are not yet certain what effects global climate change will have at any given site, they are developing a strong consensus about the overall pattern of effects. One of the more profound anticipated consequences is the rise of sea levels, which would inundate low-lying coastal areas. Sea level rise will result from three trends: the melting of the Antarctic ice cap as the global climate warms (thus adding more water to the oceans), the expansion of the water in the oceans as the temperature rises, and the creation of large icebergs that drop from the Antarctic ice cap into the ocean. If especially large icebergs calve off into the ocean, they will cause an immediate rise in sea level, just as the water level rises when a person gets into a bathtub. This is not mere speculation. In March 2000, the largest iceberg seen in four decades split off from the Ross Ice Shelf in western Antarctica. The berg was almost the size of Connecticut and measured 185 miles by 23 miles.[9]

Climate scientists predict that, if atmospheric CO_2 levels continue to rise as they have over the past 150 years, most of the United States will experience a 3°F to 10°F (2°C to 5.5°C) temperature rise by the year 2100—in contrast to the 1°F rise that occurred during the twentieth century.[10] The warming effects in northern regions such as Canada and Alaska are expected to be even greater.[11] But the predicted results of global climate change go far beyond a simple warming. Many regions will experience significant drying as warmer temperatures cause more water to evaporate from the land. As a result of the extra moisture in the air, some areas will see increased rains—especially an increase in the very heavy rains that cause flooding.[12] The distribution of ecosystem types is also expected to change significantly as a result of the changes in temperature and moisture regimes. Although strong consensus exists among climate scientists that significant changes will take place, different computer models yield different predictions about the exact changes that will occur and how these will affect different parts of North America.

The rapidly changing climate will cause problems for many species as the climatic zones to which they are adapted either disappear or shift more quickly than the species can move. Although some species that reproduce and disperse rapidly will be able to expand or move their ranges as the climate changes, few tree species will be able to migrate quickly enough to keep pace with rapid climate changes. Some habitats, such as the highland forests of the Sky Islands in the San Pedro watershed, could disappear entirely if the climate becomes too warm; their current inhabitants might then go extinct if there is no cooler place to which they can migrate. In addition, some ecologists are concerned that native species will not be able to move their ranges because human land uses will block their way. Such obstacles may render many nature reserves unsuitable for the species that they were intended to protect. For example, in North America, large east-west expanses of agricultural or urban land may impede the migration of forest species that would otherwise be able to expand their ranges northward to adapt to a warming climate.

Land use professionals should expect the effects of climate change to hit home during the twenty-first century. Planners and other local government officials may face new challenges related to mitigating damage from storms, flooding (especially in coastal areas), and other natural hazards; maintaining viable public water supplies as local conditions become drier; and keeping residents safe from wildfire in drier climates.[13] In regions where large parts of the economy depend on the weather, climate change may be a serious economic threat; for example, warmer temperatures in northern New England may threaten the ski industry as well as possibly undermine fall tourism and spring maple syrup production.[14] To protect ourselves from a warmer climate and more extreme weather events, we may spend more on cooling, insurance, and public safety.

For most or all of the problems posed by global climate change, technological solutions will be available—but at what cost? Does it make sense to create an environment that is increasingly hostile to human survival and then spend money to find clever ways to engineer around these self-inflicted problems? An increasing number of world leaders think not and have already taken steps to slow the rate of increase of greenhouse gas emissions into the atmosphere, with the goal of eventually stopping and then reversing the increase altogether. But even if we take immediate action to reduce greenhouse gas emissions, a lag of several decades or even centuries will occur before some of the effects of the reduction of greenhouse gases are felt. During this time, warming will continue along with the increase in severe weather patterns, and some climatic changes may be effectively irreversible.[15] Efforts to reduce greenhouse gas emissions have begun to take root at the local level throughout North America. Numerous state, provincial, and municipal governments across the continent have drafted climate change action plans that include such steps as making buildings more energy efficient, encouraging modes of transportation that are less reliant on fossil fuels, and even planting trees to remove CO_2 from the atmosphere. Another way of reducing greenhouse gas emissions—high taxes on gasoline—has proven very effective in Europe, where the average fuel efficiency of vehicles is much higher than in North America.[16]

Powerful Effects of Local Human Activity

As we will discuss in Chapter 4, natural habitats are in a constant state of flux: new plant material grows and soils are formed until a disturbance such as a large fire or storm comes along to destroy much of the living and dead plant matter (biomass) or to wash away soils. Over time, however, the total plant biomass in most regions remains roughly constant, and the same can be said for the total amount of soil. In contrast, humans in many areas create a constant, ongoing loss of plant matter from the ecosystem by cutting forests and keeping them from regrowing or by using natural landscapes as pastureland, allowing cattle, goats, and sheep to graze in a way that prevents the plant cover from regenerating. The loss of forest, shrub, or prairie cover from an area is in itself not unnatural, as all regions experience some type of disturbance or another. What is unnatural—and so difficult for nature to recover from—is the unending pressure that humans sometimes apply. As a survey of some of the earliest sites of agriculture and civilization reveals, such pressures can have effects that last for millennia.

In the 1920s and 1930s, spurred by the catastrophic soil erosion of the Dust Bowl era, Walter Clay Lowdermilk of the U.S. Soil Conservation Service conducted field studies of several cradles of civilization to see how early farmers had managed their soils.[17] He discovered that a number of the areas that are today deserts, such as portions of Israel, Egypt, Lebanon, Iraq, and China, suffered from severe soil erosion after several centuries of agriculture and animal husbandry. He found a few places in each of these currently desert regions that had been protected from overfarming and overgrazing, such as the sites of ancient temples and monasteries. These sites held soils that were still able to support native vegetation much as it was thousands of years ago.

In China, Lowdermilk found that deforestation along the upper reaches of the Yellow River had led to a massive accumulation of silt in the river's course and a concomitant rise in the river's level. This rise required the building of huge dikes to keep the river within its banks, but in 1852, the river burst through its restraints and killed millions who lived within its floodplains, all as a result of excess forest cutting upstream. Elsewhere in his travels, Lowdermilk discovered regions where soils on steep slopes had been carefully conserved for centuries or longer—in some cases, by farmers annually carrying baskets of soil on their backs from the lower portions of hillside fields to the upper, more erosion prone reaches. Similar patterns have held in recent years; deforestation and other land use changes in upstream areas have increased the severity of flooding downstream, as occurred along the Mississippi River in 1993 and in the Nicaraguan lowlands during Hurricane Mitch in 1998.[18]

Perhaps more remarkably, human land use patterns can change local and regional climate over short time scales, sometimes in profound ways that affect the viability of native ecosystems and local economies. Many of these effects are linked to agriculture, which can change temperature and moisture conditions by removing native vegetation or irrigating dry land. On the high plains of northeastern Colorado, for example, the conversion of grasslands to irrigated and dry agricultural fields appears to have led to cooler, wetter conditions both in the farmed areas and in distant mountain regions.[19] In southern Florida, extensive draining of natural wetlands to plant vegetable, sugar, and citrus crops may have led to an increased frequency and severity of winter freezes, one of which (in 1997) resulted in losses of more than $300 million and the displacement of 100,000 migrant farm workers.[20] This unintended consequence of agricultural cultivation is ironic considering that farmers moved into southern Florida in the first place to avoid damaging winter freezes. Cities can also essentially generate their own weather systems, as their dark paved surfaces and rooftops absorb solar energy and create *urban heat islands*. Compared to nearby rural areas, cities were found to be 1°F to 6°F (0.6°C to 3°C) warmer and have 5 to 15 percent less sunshine, 6 percent less relative humidity, 20 to 30 percent lower wind speeds, and 5 to 15 percent more precipitation (including thunderstorms driven by local heat convection).[21]

As long as human beings actively counteract their impacts on the landscape, we may be able to prevent broad-scale degradation for a time, but as the floods of China, Nicaragua, and the United States, and the deserts of the Middle East, reveal, it may be impossible to avoid a reckoning. The effects of humans on the landscape have been recognized for millennia, as Plato, writing in 360 B.C., lamented: "There are remaining only the bones of the wasted body . . . all the richer and softer parts of the soil having fallen away, and the mere skeleton of the land being left . . . now losing the water which flows off the bare earth into the sea. . . . There may be observed sacred memorials in places where fountains once existed."[22]