Following the same logic, plant-eating animals make up a lot more of the biomass in an ecosystem than carnivorous animals, because each carnivore eats many **herbivores** over a lifetime. It is for this reason that nut-eating squirrels are commonly seen, but spotting a mountain lion or a killer whale can be the event of a lifetime. Yet there is one meat-eating animal that is not uncommon. Do you see one now? Look in the mirror (or at the next nonvegetarian you meet). This is why this chapter is called "The Most Successful Species?"—the question mark is a reminder that our success as a species carries momentous implications for all animal species, including us, and for the plants that nourish all.

RISING TO THE TOP OF THE FOOD WEB

How did our species get to be so successful? Remember the idea of carrying capacity discussed in Chapter 3. There, the pasture could only accommodate a limited number of grazing animals. It is that limitation, you will recall, that shapes the tragedy of the commons. Over the course of the past ten thousand years, humans have managed to evade that limitation as far as our own species is concerned. We seem to have *enlarged the carrying capacity* of environments to accommodate more humans. This came about through two major waves of change: the invention of **agriculture** several thousand years ago; and the Industrial Revolution, which began more than two hundred years ago. Some elements of these revolutionary transformations are likely to be unsustainable, as we see now in the challenge of global warming, driven by the burning of fossil fuels for industry and by the release of greenhouse gases from agriculture.

Although humans are thought to have emerged into our current genetic lineage several million years ago in eastern Africa, recorded human history extends back only about eight thousand years. For more than 99 percent of our time on Earth, humans have been a hunting and gathering species, similar in some ways to the troops of chimpanzees that still inhabit our common African homeland. Like several other mammal species, humans seem to have hunted effectively in groups, so that large or swift prey could be brought down by teams of people. Humans may have been more effective than other hunting species because we developed language and were able to coordinate our actions better and learn faster. It is likely, in short, that we became the most successful species long before history was invented.

From Africa, humans spread into other parts of the world, reaching Australia by about forty thousand years ago. Our ability to cross water in boats, to make clothing and build shelter so that we could survive cold and harsh environmental conditions, and to control fire—these and many other adaptations were important

to the diffusion of humanity across such a wide geographical range. In this way, too, we were a species capable of a rare kind of success, able to expand carrying capacity by living in habitats where we required technology such as heated shelters and warm clothing to survive. We were able to modify landscapes and to heat shelters through the controlled use of fire. In some places, such as Australia and parts of North America, hunting and gathering persisted until European colonization. But large farming economies existed in what would become the midwestern United States, as well as in the Andes and in Mexico, long before Europeans arrived.

CONTROLLING THE FOOD SUPPLY, CHANGING THE LAND

Agriculture brought the greatest proportional expansion of humans' carrying capacity. One anthropologist has called agriculture the "greatest technical achievement in the human record."[1] Carrying capacity is a function of technology, specifically food-production technology. This means that, as humans shifted to different food-production methods, they also changed the size of the human population that can be fed, so long as environmental conditions enabled food production to continue at a high level.

Enlarging the human carrying capacity has meant replacing ecosystems that were managed lightly or not at all with agricultural ecosystems controlled by people (see Box 6.1: Agricultural Ecosystems, page 132). How have people reshaped the carrying capacities of the landscapes they inhabit? The story began long before there was writing, so there are uncertainties and vigorous debates among archaeologists and anthropologists. One version is based on the work of noted scholar William McNeill, one of the first contemporary historians to develop ecological ideas in the portrayal of human history, and geographer Jared Diamond, particularly in his wide-ranging book, *Guns, Germs, and Steel*.[2]

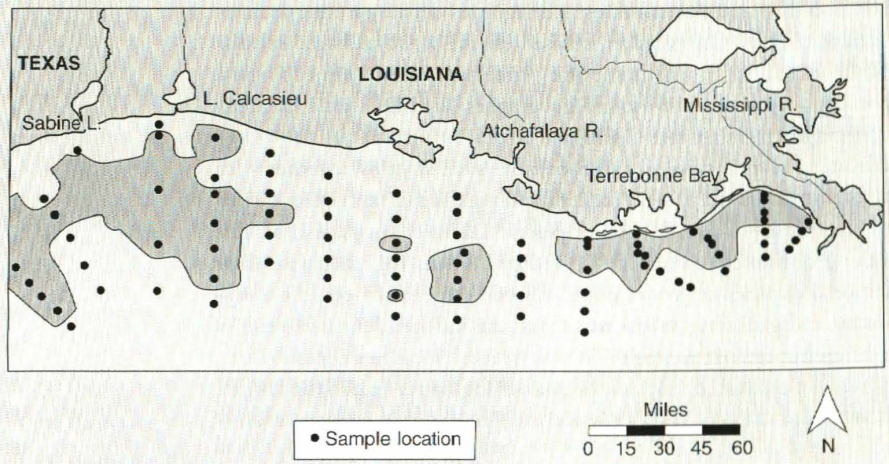
The domestication of grains, beans, and root crops such as yams, together with a suite of tamed animals that included chickens and pigs, seems to have occurred within a fairly brief time—but in far distant places (Table 6.1 on page 133). The differences in the groups of species domesticated by humans, together with their common nutritional capacity to feed a population far larger than could be supported by hunting and gathering, seems to suggest the independent invention of agriculture in different parts of the world. The most recent Ice Age ended not long before the first signs of cultivated crops in the archaeological record, so the climate changes that accompanied the retreat of the ice may be related to the invention of agriculture.

BOX 6.1

AGRICULTURAL ECOSYSTEMS

The practice of agriculture includes dramatically different human relationships with the land, as we can see in our own country. America was a developing country in the colonial period. The American Indians were already growing crops in coastal and southern New England when the English arrived in 1620. Indeed, the Indians were able to help feed the starving Puritans in that first winter. The Indians practiced a shifting agriculture, farming land for several years and then moving on as the nutrients in the soil were depleted. This style of agriculture was practiced together with hunting and gathering. In the tropics today, this method of making a living is sometimes called "slash and burn," a derogatory term that might lead one to overlook the fact that this has been, over wide areas and long periods, a sustainable means of gaining a livelihood.

Agricultural practices replace the natural ecosystem with one of human design. This usually means that the number of species of plants and animals in a cultivated landscape is far smaller than were found on that same land before humans took it over. The species that live on the farm are chosen for their value to people, rather than because they are able to survive against the pressures of natural selection. Chickens that can be carried off easily by hawks, lettuce that is relished by deer, fields of grain that cannot exist without protection by scarecrows—all of these are



Gulf of Mexico hypoxic zone, July 21–27, 2008.

species that are abundant because people nurture and protect them. The plants and animals of a farm are generally removed when they are young (think of lamb or spinach). Young organisms mostly grow rapidly, and replacing them with seedlings or newborns resets the biological clock each year, enabling people to gain more from their cultivated ecosystems.

The ecosystem of the farm is often precarious. Soil that is turned over each spring is carried off more easily by rain or wind than soil anchored by the roots of trees and brush. Erosion can be accelerated by poor practices such as plowing in patterns that do not slow the runoff of rainwater. In contemporary farming in many nations, fertilizer is added to the soil, and pesticides are used to kill off insects and other species that compete with people for farm produce. When fertilizers and pesticides are in turn carried off by rain into waterways, they pollute water and foster the growth of organisms that choke streams or lakes. The Mississippi River's waters carry nutrients and pesticides into a large zone in the Gulf of Mexico where the nutrients suffocate the marine life by lowering the oxygen level of the water. The resultant "dead zone" (the shaded area in the figure) is a desert—it is "hypoxic," as scientists say, meaning without life-sustaining oxygen. You can see by the state boundaries of Louisiana and Texas that the hypoxic zone in 2008 was quite large. In some years, the area of the dead zone is as large as New Jersey.

TABLE 6.1 DOMESTICATION OF PLANTS AND ANIMALS BY HUMANS

Area	Plants	Animals	Estimated date of domestication (years before present)
Southwest Asia (Near East)	Wheat, pea, olive	Sheep, goat	10,500
China	Rice, millet	Pig, silkworm	9,500
Mesoamerica	Corn, beans, squash	Turkey	5,500
Andes and Amazonia	Potato, manioc	Llama, guinea pig	5,500
Eastern North America	Sunflower, goosefoot	None	4,500

Source: Based on Jared Diamond, Guns, Germs, and Steel *(New York: Norton, 1997), 100.*

Agriculture brought about a very large expansion in the number of people who could be supported by a given land area. Most of the material in most plants, such as leaves, stems, and wood, cannot be digested by people. In a small number of plant species, however, we can consume significant parts—including seeds such as the grains on an ear of corn, flowers such as broccoli or artichoke, roots such as potatoes and the manioc that feeds many in Africa today—and thus these are the plants we have promoted and protected through agriculture. Humans have also managed to breed a small number of animal species successfully under domestic conditions, including turkeys, cattle, and guinea pigs. Domesticated plants and animals, cultivated intensively over a relatively small land area, enabled humans to obtain many times more food per acre than was possible through hunting and gathering. As shown in Table 6.1, the main food sources of today were being produced regularly long ago. As Jared Diamond has pointed out, "By Roman times, almost all of today's leading crops were being cultivated somewhere in the world."[3]

As Europeans colonized the New World from the sixteenth century onward, they often occupied lands where the native peoples had been living partly or wholly by hunting and gathering. In this way of life, fire is often employed as a management tool: undergrowth is burned so as to promote the sprouting of green shoots, which attract game animals so they can be hunted.

When the English arrived in New England, they learned to grow corn and vegetables from the Indians who lived along those shores. The English added grazing animals and replaced hunting and gathering with a sedentary way of life based on private ownership of land, as discussed in Chapter 3. This unleashed a set of forces that reshaped the landscape (Table 6.2). People did different things on the land: they plowed and grew crops over a wider area; they grew animals and used their manure to fertilize the land; they killed wolves that threatened their domestic animals; they divided the land into farms owned by individuals, and they built towns where there was little farming in densely settled areas, but crops could be brought to marketplaces along roads. All this replaced the forests of New England with the pastoral landscape portrayed by Thomas Cole in *The Oxbow* (see Chapter 2).

As the historian William Cronon documented in *Changes in the Land*, the new agricultural practices changed the landscape—but not sustainably.[4] The ideas and institutions brought by the English led to much more intensive use of the land. New methods of cultivation and domestication of animals produced more abundant food supplies, although the higher density of animals and crop plants also favored the spread of disease and pests. There were other, less visible costs as well. Because the English concept of property meant permanent cultivation of a given plot of land, soil was not allowed to recuperate and farming did not last as the sole support of its human population. Now, almost four centuries later, New England has returned to a lightly used, forested landscape. There are many more

TABLE 6.2 FORCES CHANGING THE LANDSCAPE OF NEW ENGLAND, 1620–1830, AS A HUNTING AND GATHERING ECONOMY WAS REPLACED BY INTENSIVE AGRICULTURE

Changes
• Domestication of grazing animals
• Plowing of cleared land
• Ownership of domesticated animals (instead of hunting wild animals)
• Killing of wolves (carnivore competitors)
• Fencing of land
• Separation of different land uses, especially pasture from nonpasture
• Building of roads to link farms to markets
Consequences
• Much higher levels of food and other materials used by humans (benefit)
• Higher densities of domesticated animals (benefit)
• Habitats favoring weeds, pests, and diseases, mostly introduced species (cost)
• Overgrazed lands (cost)
• Depleted soils (cost)

Source: William Cronon, Changes in the Land *(New York: Hill and Wang, 1983), chap. 7.*

people living there now, and they mostly import their food—as one can see by the brightly colored fruits and vegetables available in food markets there in late winter, when local fields are covered in snow.

SETTLEMENT, SOCIETY, COMPLEXITY

Agriculture brought more than larger food supplies. It stimulated a qualitative change in human society: **permanent settlements** and the rise of **specialized roles** in society. Consider the rain forests and coral reefs discussed in Chapter 5. Permanent, complex structures seem to foster high levels of biological diversity. Something similar appears in cultural development. Hunting and gathering is a nomadic way of life, as people follow seasonal abundances of plants ripening in different microhabitats and exploit the life cycles of migrating fish or birds or game. With cultivated plants and animals, however, year-round settlement becomes imperative in order to tend the crops as they grow, to store the surplus after the