CHAPTER **13**

The Humanized Environment

Lou Linwei/Alamy Stock Photo

FIGURE 13.1 **Shanghai, China.** This residence hall at Shanghai University is typical for Chinese students. Chinese universities have different living conditions for Chinese and international students. Chinese students generally live in older halls with with limited access to electricity and in more crowded conditions, with 4 to 8 per room. International students studying in China typically live in newer halls with 2 people per room.

"That's the hall where I lived, and over there is the facility where I showered," the Chinese student explained as she toured me around her home campus (**Fig. 13.1**). I paused before asking a question. She had studied in the United States the year before and taken my geography course, so she was used to my questions. I wanted to know about access to hot water. "Can you tell me about the shower facility?" I asked.

"Oh yes. We can shower in our dorms, but it's cold water and the lights turn off at 11 P.M." She then explained that they can access hot water in the shower facilities on certain hours and days of the week.

Earlier that day, I had been thinking how remarkable the Shanghai subway system is. The underground tunnels and trains are gleamingly clean, and the route map is expanding each year. China's economy is growing quickly, and the central government has invested more than $60 billion in the Shanghai subway system alone since it began construction in 1993. The seven longest subway systems in the world are in cities in China, and all have been built since the 1980s.

But while China is building a world-class infrastructure system, it is still struggling with the same water and electricity shortages that much of the world is facing. Dutch scientists estimate that 4 billion people worldwide already experience a water shortage at least 1 month a year (Mekonnen and Hoekstra 2016). Growth in population and wealth are driving global consumption and increasing the human impact on the environment, but not without consequences.

CHAPTER OUTLINE

13.1 Explain what natural hazards are and how natural hazards can become natural disasters.

- Tectonic Hazards and Disasters
- Hydrological Hazards and Disasters
- Meteorological and Climatological Hazards and Disasters

13.2 Identify the ways that humans impact Earth through land use, water use, and resource extraction.

- Land Use
- Water Use
- Resource Extraction

13. 3 Explain how climate change is impacting human-environment interactions.

- Hurricanes
- Water Scarcity

13. 4 Explain How Human Consumption Is Changing the Scale of Human Impact and Challenging Sustainability.

- Global Patterns of Consumption
- Sustainability
- Waste Disposal

13.1 Explain What Natural Hazards Are and How Natural Hazards Can Become Natural Disasters.

Earth is dynamic and ever changing. The lithosphere, or crust and upper mantle, is broken into tectonic plates that are constantly in motion. The water that covers more than 70 percent of Earth moves through oceans, rivers, and lakes into soil and plants, and is treated and used by humans. Changing winds and weather systems are shaped by the uneven heating of Earth and its atmosphere. The constant motion of these three processes—tectonic, hydrological, and meteorological or climatological—creates **natural hazards**, naturally occurring physical phenomena that produce change.

How much damage a natural hazard causes depends on its proximity to people and property. If a volcano erupts on an island with no people and no property, it is a natural hazard, but not a natural disaster. When a volcano erupts on an island that is populated with people and property, it becomes a **natural disaster**, a naturally occurring physical phenomenon that causes damage and loss of life. Kilauea is the largest of several active volcanoes on the Big Island of Hawai'i. It has erupted continuously since 1983, but in April 2018, the eruption was large enough to collapse the crater, transform the landscape, and destroy 700 homes (Andrews 2018). Previous eruptions of Kilauea were natural hazards, but the lava flow in 2018 created a natural disaster. A fissure that appeared in May sent lava flowing into the Leilani Estates subdivision (**Fig. 13.2**). Hawai'i Volcanoes National Park remained closed until near the end of September 2018, which amplified the economic cost of the natural disaster. The closed park and active eruptions meant fewer tourists and less revenue for the people in the area.

USGS/Alamy Stock Photo

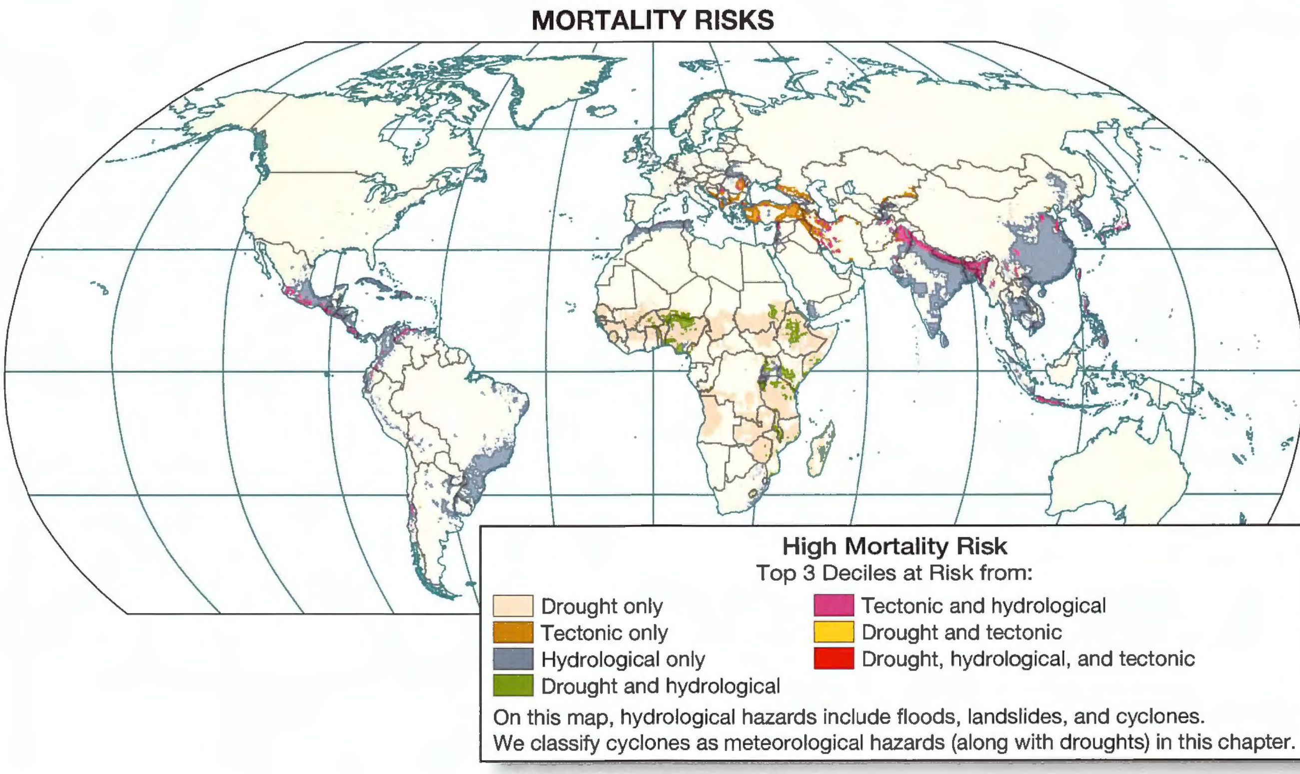
FIGURE 13.2 Big Island, Hawai'i. A pyroclastic lava flow from the Kilauea volcanic eruption moves toward a subdivision along Hookapu Street in the Leilani Estates subdivision. The eruption destroyed homes and forced evacuations on the Big Island.

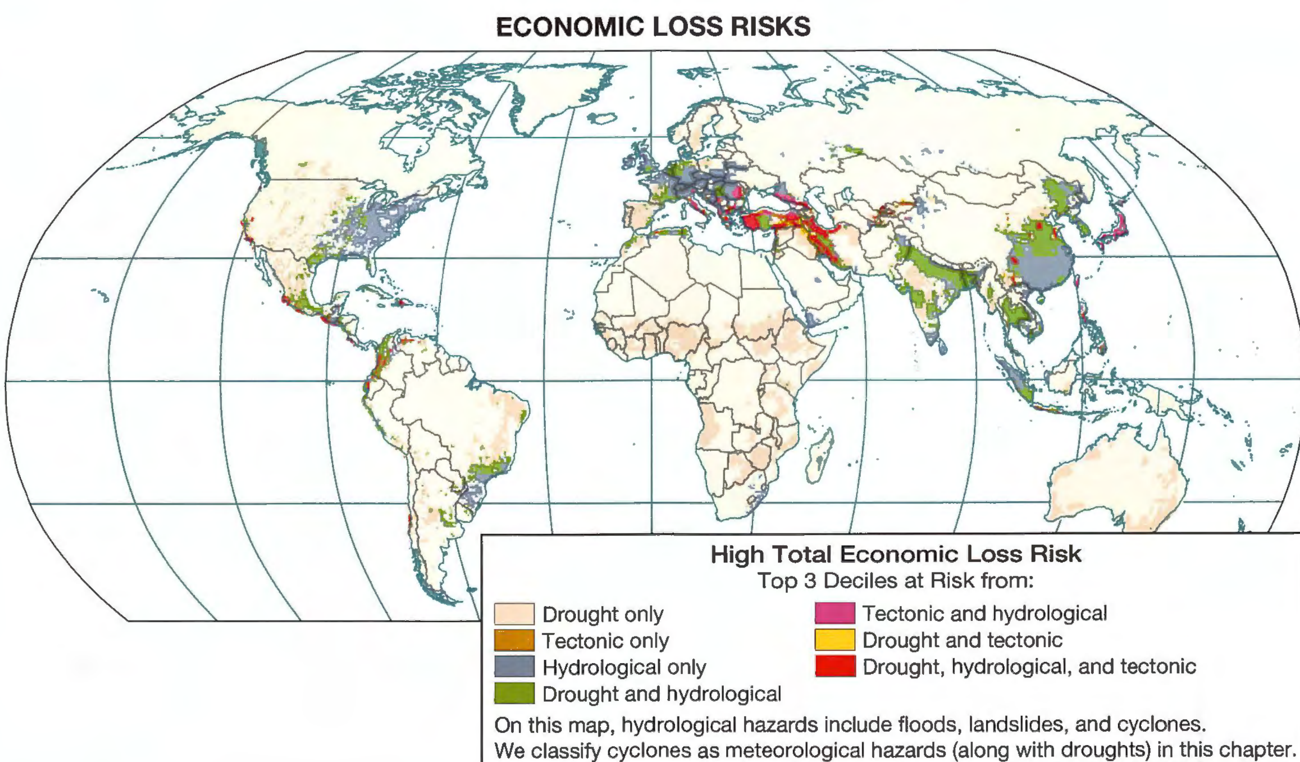
A natural disaster map highlights the places in the world most susceptible to natural disasters, whether caused by tectonic activity (earthquakes, volcanoes, and tsunamis), hydrological hazards (floods or landslides), or meteorological and climatological hazards (cyclones and droughts) (**Fig. 13.3**). Comparing the map of mortality risk with the map of total economic loss risk shows that when a natural disaster hits an area with higher incomes, the area is likely to be hit financially, whereas an area with lower incomes is likely to be hit by both financial loss and the loss of lives. For example, when a devastating earthquake hit the Kobe region in Japan in 1995, it caused enormous property damage, but fewer than 6500 people died. When an earthquake of a similar magnitude struck Haiti in 2010, well over 100,000 people lost their lives.

Tectonic Hazards and Disasters

Earth's **lithosphere** (crust and upper mantle) is broken into approximately 15 major plates and several minor plates (**Fig. 13.4**). These plates are in constant motion, with most movement happening where plates meet, along plate boundaries. Tectonic plates **diverge** (spread apart), **converge** (come together), or **transform** (slide past one another). Where plates are diverging, as at the Mid-Atlantic Ridge, magma moves to the surface from the upper mantle, creating new crust and volcanic activity in a process called **seafloor spreading**. The newest oceanic crust in the Atlantic is found just adjacent to either side of the Mid-Atlantic Ridge. The age of the ocean floor increases as you move out to the east and west, in parallel bands from the ridge. The oldest oceanic crust in the Atlantic is found close to the North American and Eurasian plates (**Fig. 13.5**).

While new crust is formed where plates diverge, old crust is pushed down into the upper mantle and recycled in what are called **subduction zones**, areas where an oceanic and a continental plate converge or meet. The oceanic plates, which are denser, subduct underneath the less-dense continental plates (**Fig. 13.6**). The Pacific plate, an enormous oceanic plate surrounded by several continental plates, forms subduction zones where it converges with continental plates. When the edge of an oceanic plate subducts under a continental plate, it melts under the heat and pressure of subduction and becomes magma. Magma can then rise to the surface and create





Courtesy of: Center for Hazards and Risk Research at Columbia University and the World Bank, "Natural Disaster Hotspots—A Global Risk Analysis," March 29, 2005.

FIGURE 13.3 **Mortality and Economic Risks in Natural Disaster Hot Spots.** The top map shows the potential mortality risks and the bottom map shows economic risks if major natural disasters occur in natural disaster hot spots.

a **volcanic arc**, a chain of volcanoes that parallels the subduction zone. **Trenches** are long, narrow, deep features that mark the place where an oceanic plate is subducting under a continental plate.

The tectonically active region of volcanoes and earthquakes on plate boundaries around the Pacific is called the **Ring of Fire** (**Fig. 13.7**). The map of this area shows volcanic arcs (e.g., the Aleutian Islands in Alaska and the islands

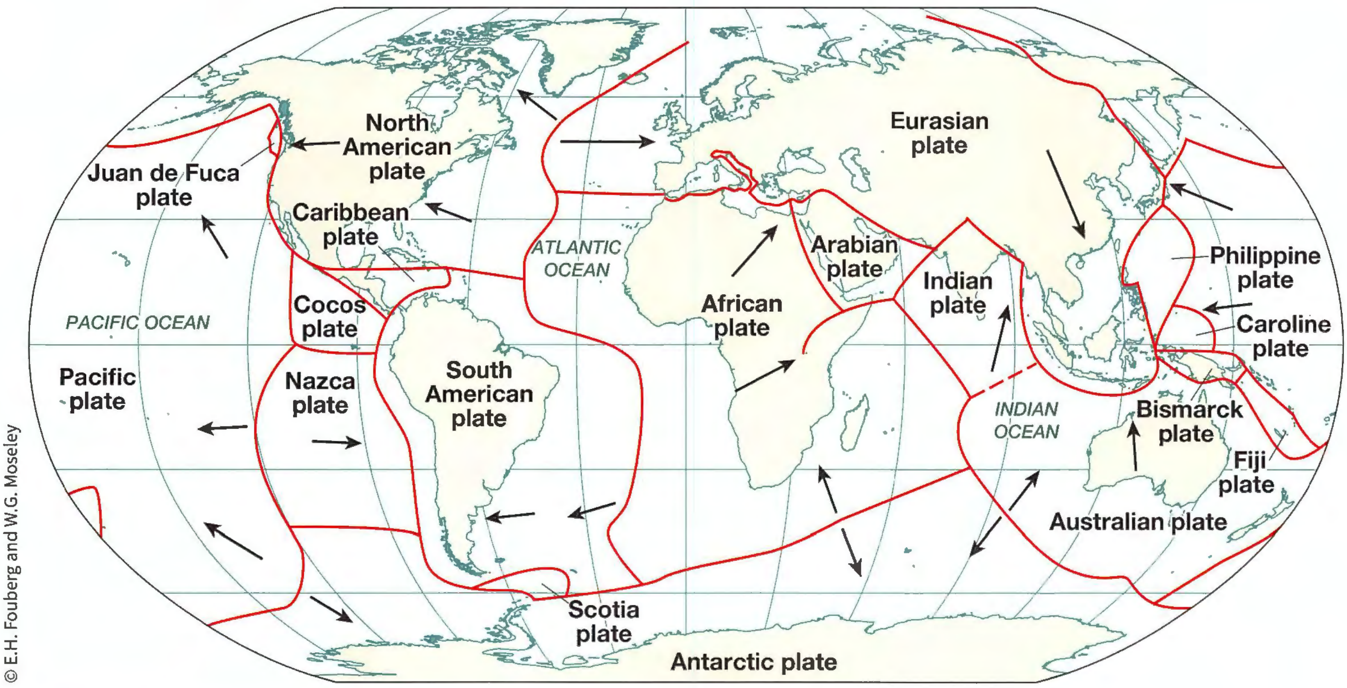


FIGURE 13.4 **Tectonic Plates.** Earth's lithosphere (crust and upper mantle) is broken into approximately 15 major plates, composed of either oceanic or continental crust, and several minor plates.

of Japan) on the continental side of the plate boundaries. Trenches form along plate boundaries in subduction zones. Eruptions on the volcanic arcs and movement of the plates along the plate boundaries are natural hazards.

Tsunamis **Tsunamis** are seismic sea waves that result from underwater earthquakes or volcanoes. Not all underwater earthquakes create tsunamis. The size of a tsunami depends on the location of the earthquake or volcano, the magnitude

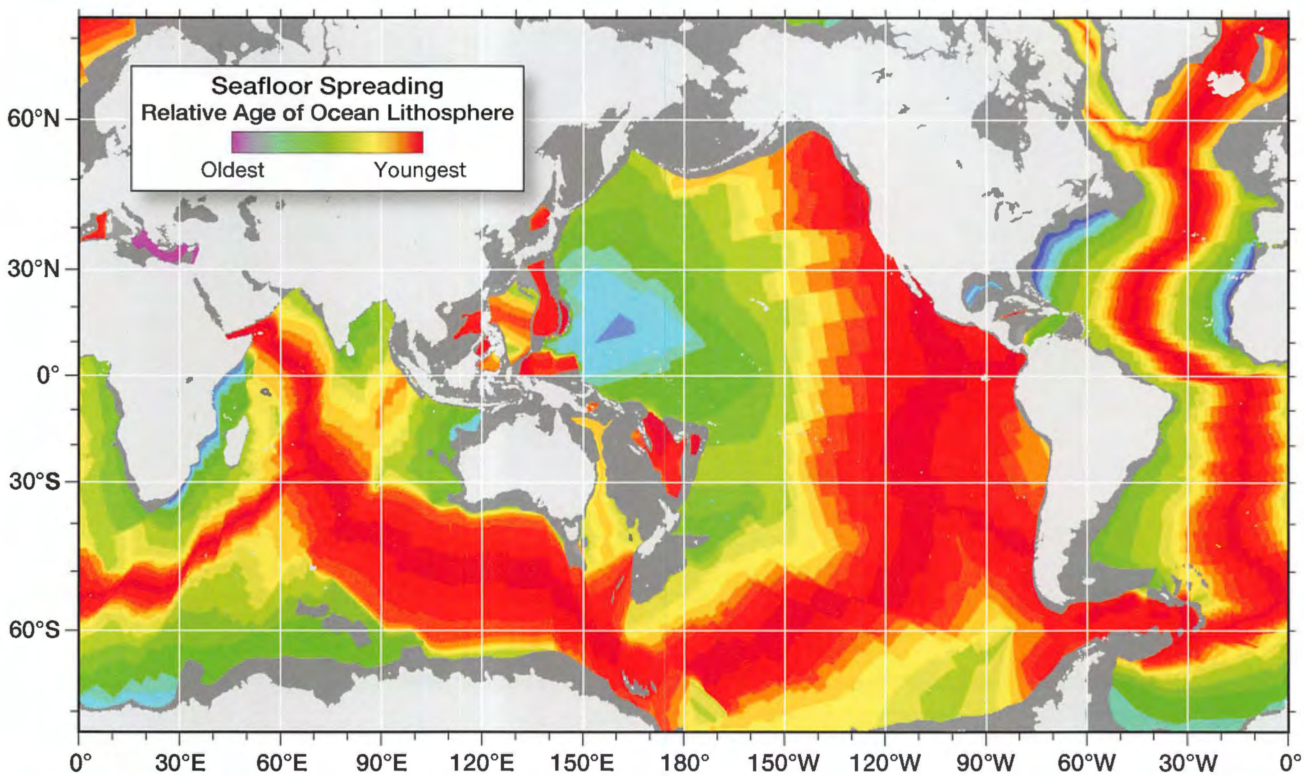


FIGURE 13.5 **Seafloor Spreading.** The seafloor in the middle of the Atlantic Ocean is spreading along a divergent plate boundary. Where plates are spreading, molten rock is rising and cooling along both sides of the Mid-Atlantic Ridge.

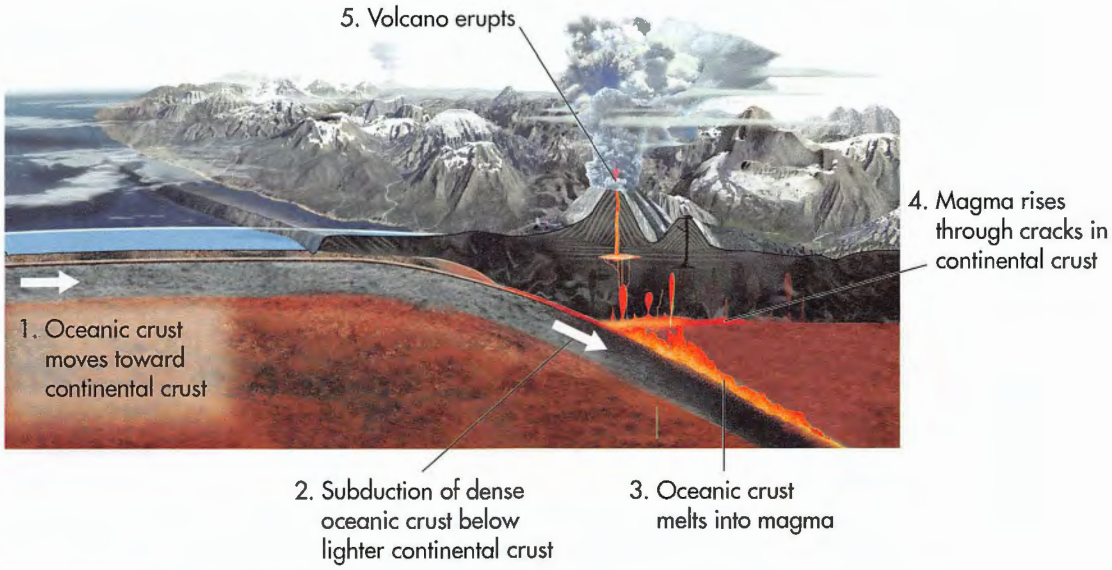


FIGURE 13.6 Subduction Zone. A subduction zone forms where a denser oceanic plate descends under less dense continental plate.

of the tectonic activity, and its proximity to inhabited areas. Large displacements along a subduction zone can generate massive tsunamis.

In a tsunami, the movement of crust sets the ocean water in motion, creating huge waves. If you were on a cruise ship in the middle of the ocean, nothing catastrophic would mark the passing of a tsunami. Your ship would be lifted and lowered, but it would not overturn. On shore, however, a tsunami wave can be catastrophic. As the tsunami moves to shore, the amount of space beneath it, the distance between the ocean surface and the ocean floor, shallows (**Fig. 13.8**), and the energy in the moving water rises, creating a wall of waves that crash onshore and destroys people and property.

Whether a tsunami, earthquake, or volcano becomes a natural disaster depends on the magnitude of the tectonic events, the proximity of the events to people and property, and the preparedness of the region impacted. The 2004 Indian Ocean tsunami began with a violent earthquake measuring more than 9.1 on the (10-point) Richter scale that happened in a subduction zone off the west coast of the island of Sumatra, Indonesia. The tsunami waves hit Sumatra and Phuket, Thailand, on the east and Sri Lanka on the west. The coasts of

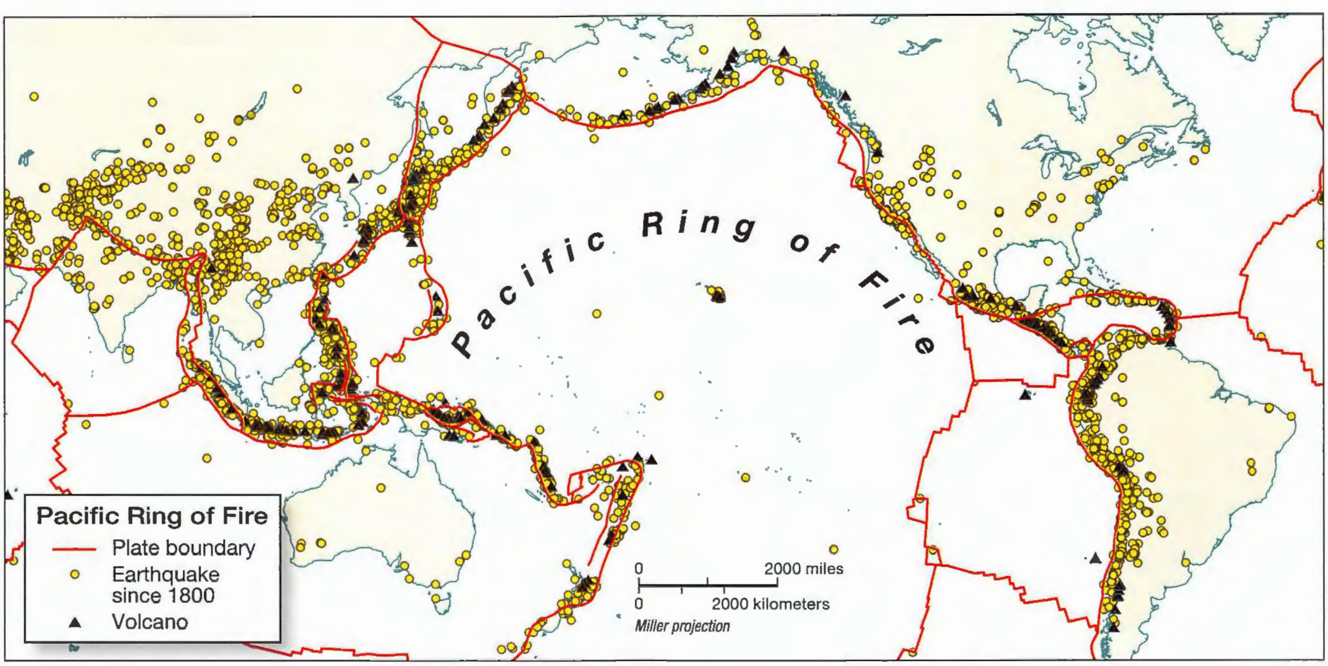


FIGURE 13.7 Pacific Ring of Fire. Active volcanoes and earthquakes surround the Pacific plate and are found primarily along subduction zones where oceanic plate is subducting under continental plate.

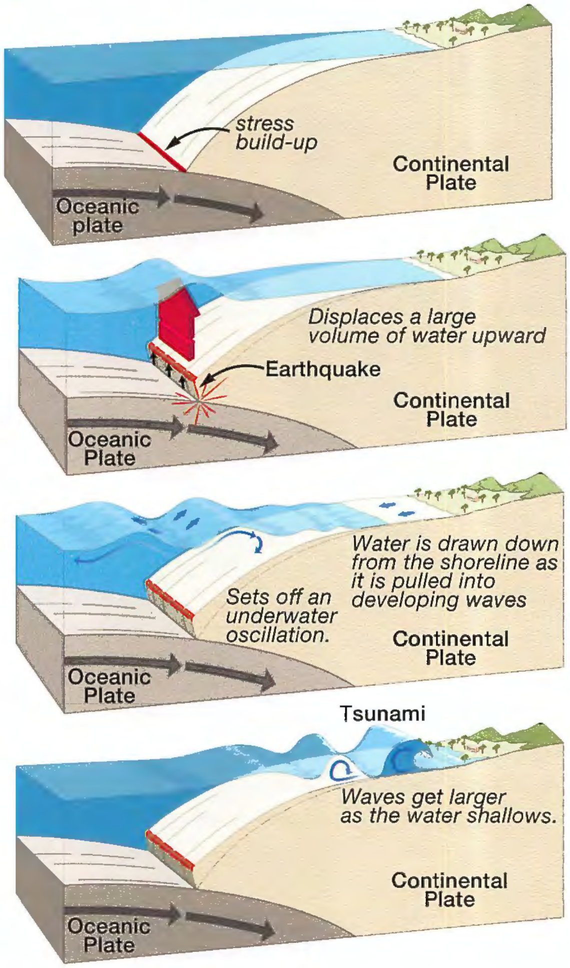


FIGURE 13.8 **Tsunami.** Earthquakes and volcanoes that occur underwater generate seismic sea waves called tsunamis. Water is displaced, which sets off an oscillation. Seismic waves form and get larger as the ocean shallows.


Robert Gilhooly/Alamy Stock Photo

FIGURE 13.9 **Ishinomaki, Japan.** The 3/11 tsunami leveled large parts of Ishinomaki, Japan, as seen in this photograph. Few houses stand in an area that was heavily populated before the tsunami.

Sumatra and Phuket are densely populated, and the beaches attract many tourists. With no warning that the earthquake had occurred and a tsunami was coming, more than 230,000 people died when the tsunami waves hit.

On March 11, 2011, an earthquake registering 9.0 on the Richter scale occurred along a subduction zone off the east coast of Japan. The earthquake generated tsunami waves that reached heights up to 128 feet (39 m) when they hit the coast (**Fig. 13.9**). Japan has a tsunami warning system, but the subduction zone is so close to the coast of Japan that the people in Sendai (in northern Japan) only had about 8 to 10 minutes of warning. What came to be known as the 3/11 tsunami killed more than 15,000 people. The tsunami leveled property, destroying about 120,000 buildings and partially destroying hundreds of thousands more. More than 150,000 Japanese lost their homes. The World Bank estimated the total economic impact of the 3/11 tsunami at $235 billion.

Both the 2004 Indian Ocean tsunami and the 3/11 tsunami in Japan were natural hazards that created natural disasters. Both tsunamis hit densely populated coasts. With no warning system, the Indian Ocean tsunami killed more than 230,000 people. With a warning system that gave people 8 to 10 minutes to move to higher ground and farther inland, the 3/11 tsunami killed more than 15,000 people. The Indian Ocean tsunami caused approximately $10 billion in damages, and the 3/11 tsunami caused $235 billion in damages. Japan, a higher income country, was more susceptible to monetary damage from the tsunami, and Indonesia, a lower income country, was more susceptible to loss of life.

Hydrological Hazards and Disasters

More than 70 percent of Earth is covered by water that cycles through soil, plants, humans, animals, freshwater lakes and rivers, oceans, and the atmosphere. The amount of water on Earth has not changed, but its distribution has changed over long periods of geologic history. During periods of **glaciation**, more water is in the form of ice in glaciers at higher latitudes and elevations. During warming periods, more of Earth's water is in liquid form in oceans, rivers, and lakes.

About 97.5 percent of Earth's water is saltwater and the rest is freshwater. In the current era, almost 69 percent of freshwater is in glaciers and ice caps, another 30.1 percent is in groundwater, and about 1.2 percent is surface or other freshwater found in rivers, lakes, and reservoirs. Of the small portion of freshwater that is surface water, 69 percent is ground ice and permafrost, 20.9 percent is in lakes, 3.8 percent is soil moisture, 3 percent is in the atmosphere, and the rest is in living things, rivers, swamps, and marshes. The entire Earth has 332,500,000 cubic miles (1,386,000,000 cubic km) of water, and of that, only 22,339 cubic miles (93,113 cubic km) is in rivers and lakes. These numbers mean that only 0.006 percent of all water on Earth is in the rivers and lakes


Robert Timoney/Alamy Stock Photo

FIGURE 13.10 **Bristol, United Kingdom.** Flash flooding in Bristol filled lower-elevation roads with enough floodwater that they looked like rivers. Impervious surfaces in cities, like roads that may also be at lower elevations, often flood after large rainfalls.

that provide freshwater for human and animal consumption and serve as a source of irrigation for crops.

It is difficult to believe that such a small portion of all the water on Earth is in rivers and lakes when flooding of these rivers and lakes can create large-scale damage to people and property. However, when they meander from side to side, rivers carve **floodplains**, flat areas adjacent to river channels that are designed to flood. At flood stage, river water flows over its banks and into the floodplain, depositing sediment as it slows down. After the river recedes to its channels and water evaporates off the floodplain, this nutrient-rich sediment is left behind. Farmers around the world are drawn to floodplains to grow crops in these nutrient-rich soils, and people concentrate cities and settlements near freshwater sources, whether rivers or lakes. Because of this concentration of people, property, and cropland, flooding often creates natural disasters.


AP Images/Nati Harnik

FIGURE 13.11 **Bellevue, Nebraska.** The Missouri River flooded and low spots in fields around the region also flooded when heavy rains in March fell on frozen ground. This photo was taken in May, two months after the rains.

Flash Floods

A **flash flood** happens when excessive rain or meltwater from snow overflows rivers, fills dry riverbeds, and causes a rapid rise in water levels. People try to prevent such floods by building dams and levees to control the flow of rivers and to keep river water in stream channels and off floodplains. But they also build **impervious surfaces**, including concrete and asphalt surfaces and buildings, that prevent rain dumped by large storms from percolating into soil and down into groundwater. When large rainstorms land on impervious surfaces that either purposefully or inadvertently direct floodwaters, flash flooding can result (**Fig. 13.10**).

In spring 2019, Nebraska, Iowa, and parts of South Dakota and Minnesota experienced widespread flooding when inches of rain fell on melting snow that was underlain by frozen ground (**Fig. 13.11**). The cold, snowy winter meant that soil was still frozen

-/AFP/Getty Images

FIGURE 13.12 **Kerala, India.** Volunteers and rescue personnel evacuate locals in a boat in a residential area after heavy monsoon rains flooded villages.

when rain started falling in March. The rainwater was warm enough to help speed the snowmelt, and all the water from rain and snowmelt flowed quickly over frozen ground. "The flat, frozen land, unable to soak in much of the water, spread it fast and furious, the way liquid would spread across a tiled floor. And the runoff quickly filled many rivers and streams to overflowing" (Hassan 2019). Rivers quickly breached dams and levees.

Floodwater stood on croplands for months, creating a natural disaster for farmers and residents of floodplains. In Nebraska, the cause was a snowy winter followed by rainfall amounts that were higher in March than in previous years. With climate change, "a warmer atmosphere can hold more water," which increases the likelihood of high rainfall, snowfall, and snowmelt (Hassan 2018). The devastating floods in the U.S. Midwest in 2019 created $1.3 billion in damages in Nebraska alone, which included "$449 million in damages to roads, levees and other infrastructure; $440 million in crop losses; and $400 million in cattle losses" (Schwartz 2019).

Meteorological and Climatological Hazards and Disasters

Meteorological hazards are created by the uneven heating of the Earth and Earth's atmosphere. This uneven heating generates winds that rebalance energy in the atmosphere, moving heat from the hotter equatorial area to the colder poles. The water vapor that is in the atmosphere is not evenly distributed spatially or seasonally. Because warm air can hold more water vapor than cold air, places near the equator that receive constant heating from the sun and have higher temperatures can evaporate more, hold more moisture, and produce more condensation and precipitation. Evaporation of ocean water adds more moisture to the atmosphere. When both the ocean and the air above the ocean are warmer, the resulting high evaporation rates fuel storms, including hurricanes. That is why hurricanes happen at tropical latitudes where oceans are warmer, and from August to October when ocean temperatures and evaporation rates are highest.

Monsoons

The uneven heating of Earth also creates high- and low-pressure systems and seasonal precipitation in climate regions. A **monsoon** is a prevailing wind coming from one direction for a long period of time. The monsoon climate region, which is located on either side of the equator in coastal areas, has a wet monsoon and a dry monsoon. During the wet monsoon, the prevailing wind flows from a high-pressure system over the ocean to a low-pressure system over land, pulling warm, moist air from the ocean onto the land. During the dry monsoon, the prevailing wind flows from a high-pressure system over land to a low-pressure system over the ocean, pulling cool, dry air across the land.

Monsoons are regularly occurring climate phenomena that do not generally pose a natural hazard or create natural disasters. Instead, the rains are welcomed each summer because they regenerate rivers and flood the fields where rice is grown. However, increasing temperatures in the oceans are creating more intense wet monsoons in India. A recent study of the Indian monsoon found that "extreme wet and dry spells within the monsoon period have increased since 1980" (Ogburn 2014). Such changing monsoon intensities impact people, property, and agriculture in India. In 2018, the southern state of Kerala experienced the "worst monsoon flooding in a century, with more than one million people displaced, and more than 400 reported deaths" (Taylor 2018). The intense monsoon rains caused flooding and landslides that displaced approximately 800,000 people (**Fig. 13.12**). When the monsoon, which is a climatological event that is predictable and desirable, becomes unreliable and unpredictable, it can become a natural hazard or even a natural disaster.

TC Thinking Geographically

Tourism is a major focus of **development** efforts in lower income tropical countries with beautiful coastlines, like Indonesia. Explain how developing tourism on coastlines impacts the vulnerability of countries to natural hazards and natural disasters.

13.2 Identify the Ways That Humans Impact Earth Through Land Use, Water Use, and Resource Extraction.

Early societies had relatively small populations, and their impacts on the physical environment were limited in both duration and intensity. With the development of agriculture and settlement in agricultural villages, people increasingly altered the physical environment, but the effects of these early activities were still limited in scale. Even the beginning of urbanization and the development of cities, which concentrated large numbers of people in certain places, had relatively limited global effects. However, the current era includes large-scale industrialization, intensification of agriculture, the growth of megacities, massive consumption and waste generation, and global trade. For the first time in history, the combined impacts of humanity's destructive and exploitative actions are producing environmental changes at a global scale.

The natural environment is being modified and stressed by human activity in many obvious and some less-obvious ways. Some environmental stress is more obvious because it takes place around human habitats, such as that caused by cutting forests and emitting pollutants into the atmosphere. Less-obvious environmental stress takes place away from dense concentrations of humans, including that caused by mining mountaintops, burying toxic wastes that contaminate groundwater supplies, and dumping vast amounts of garbage into waterways and the world's oceans. Humans have terraced mountains to grow rice, built miles of aqueducts and qanats to move water, and dammed enormous rivers to make places livable for larger numbers of people.

Over the last 500 years, both the rate and the scale at which people modify Earth have increased dramatically. Particularly during the last half-century, every place on Earth has been transformed, either directly or indirectly, by people. The twentieth-century surge in the size of the human population, combined with a rapid escalation in consumption, magnifies humanity's impact on Earth in unprecedented ways. Earth is predicted to reach 9.9 billion people by 2050. Because people across the world do not consume or pollute in the same ways, we cannot make a simple chart showing that each additional person born on Earth results in a certain amount of consumption or generates a specific amount of pollution or waste. Nonetheless, a greater number of people on Earth coupled with current levels of human consumption necessarily translates into greater environmental change (**Fig. 13.13**).

Recognizing the rapid growth of human population and the incredible role humans play in shaping Earth's environment, scientists report that we have entered a new geologic epoch, the **Anthropocene**. The Anthropocene is the current geologic time period when humans are the dominant influence on climate and environment. *Anthropo* means "human" and *cene* is a term used by geologists to denote time periods in Earth's history.

Land Use

As the number of people on Earth increases, so too does the strain on land. People clear forests and burn grasses to plant crops. People flatten mountains to build transportation systems and mine resources. Cities grow at remarkable rates and sprawl into productive farmland. **Land use** refers to the ways people use land resources for specific purposes. For example, agriculture is a land use. **Land cover** refers to what is on the ground, such as grasses, trees, or pavement (Coffey 2013). What people choose to do with the land—land use—changes over time, and these choices impact land cover. If we choose to deforest a swath of land to grow crops, we change the *land use* from forest to agriculture. At the same time, our choice impacts the *land cover*, switching it from forest to row crops.

Geographers map land cover using both remote sensing and GIS (geographic information systems). Mapping land use requires millions of data points and a classification system to organize the data. A global land use map based on land use data and population density gives us an idea of how people extract productivity from land (**Fig. 13.14**).

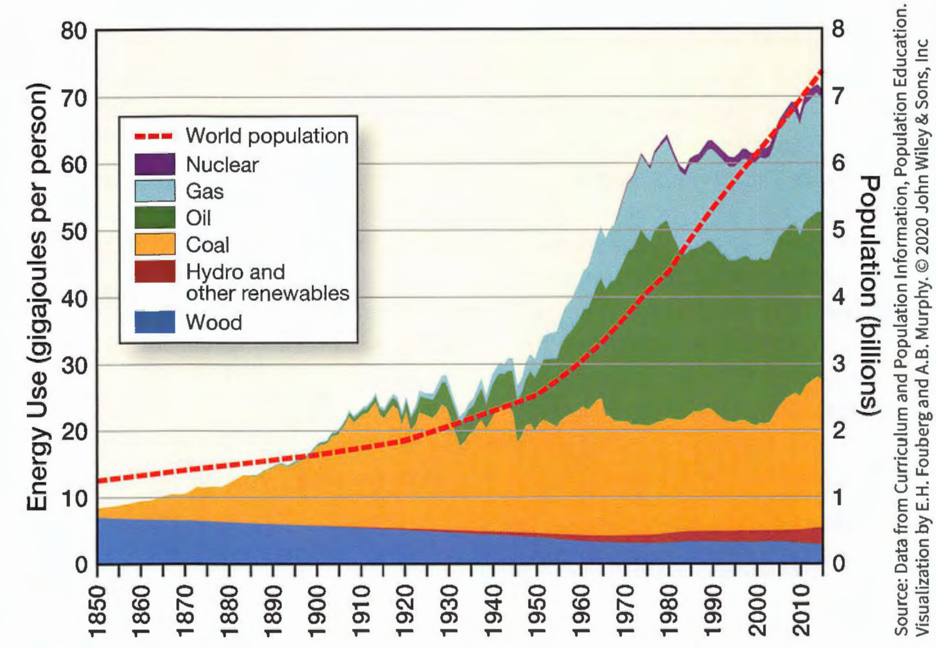
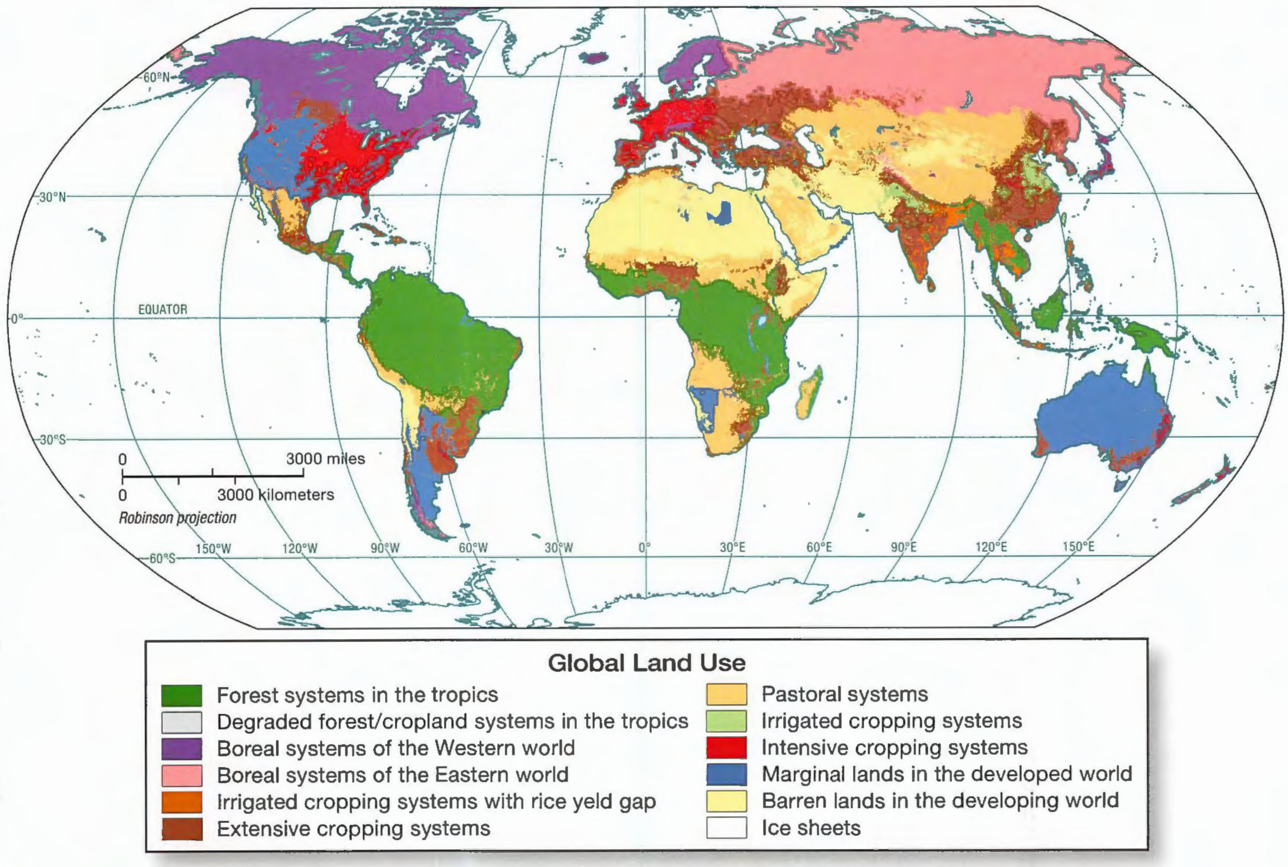


FIGURE 13.13 Human Population and Energy Consumption since 1850. As the number of people on Earth has quickly risen, energy consumption has grown markedly. Energy sources have also diversified.



Global map provides new insights into land use", November 5, 2013.

FIGURE 13.14 Global Land Use. A group of European scientists created this map of 12 land system archetypes (LSAs) based on intensity of land use, environmental and climate conditions, and socio-economic factors. Regardless of the factors going into global land use maps, land use varies by latitude and elevation and correlates strongly with climates.

Instead of simply mapping land cover, such as crops, a land use map shows differences in farming methods, including areas of extensive agriculture and intensive agriculture. **Extensive agriculture** uses little fertilizer, pesticides, and machinery to farm the land, while **intensive agriculture** uses significant capital investments, including in fertilizer, pesticides, and machinery, relative to the amount of land farmed. The yield, or amount of crop grown per acre, is typically less with extensive agriculture than with intensive, but extensive agriculture may have less impact on waterways because of less runoff from fertilizers and pesticides. However, farmers who practice intensive agriculture have little interest in wasting fertilizers and pesticides because each has a cost. A great deal of research and technology goes into helping farmers in intensive agriculture decide when and where to spray pesticides or apply fertilizer, and what seeds to plant in different conditions.

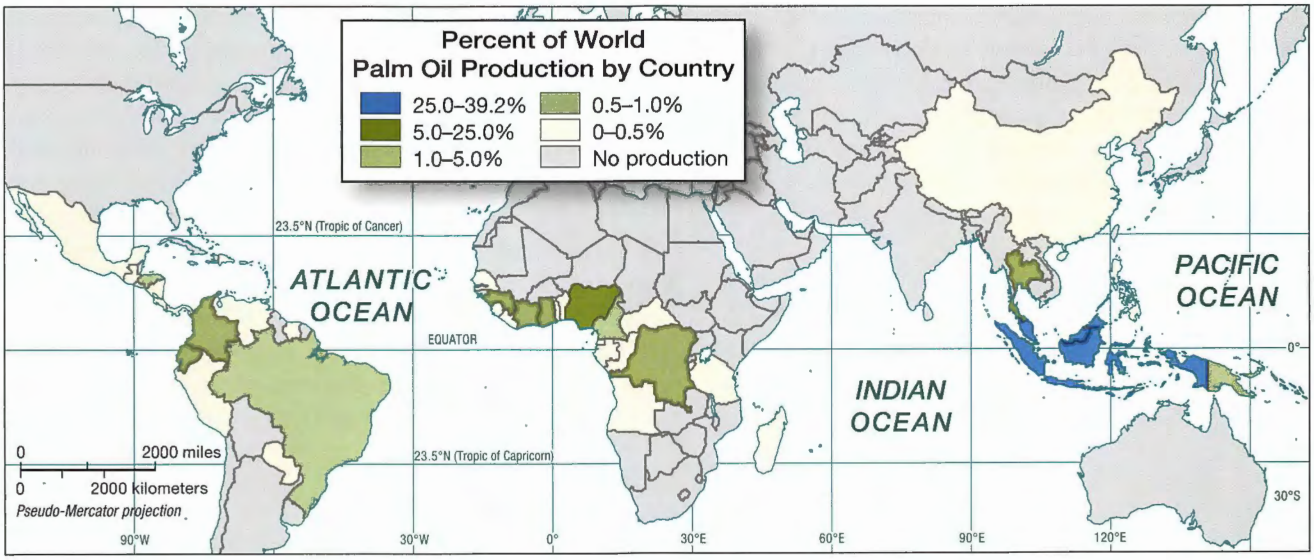
Deforestation and Palm Oil Plantations

A land use map also differentiates forest systems. High-latitude, boreal forests in the Western world are differentiated from those in the Eastern world. Forest systems in the tropics are differentiated from degraded forests in the tropics.

Forests play a critical role in the oxygen cycle. Through photosynthesis, plants take in carbon dioxide from the air, water, and sunlight, and produce oxygen, which humans need to breathe. The destruction of vast tracts of forest, typically caused by clearing forestland for agriculture or livestock use, is called **deforestation**. Deforestation impacts the carbon cycle because it removes a major sink of carbon dioxide from Earth. In addition, burning trees to clear a forest releases massive amounts of carbon dioxide into the atmosphere. Between 2000 and 2013, 10 percent of all anthropogenic (human-caused) greenhouse gases released into Earth's atmosphere came from tropical deforestation (Vijay et al. 2016). Indonesia had so much deforestation in 2015 that it outpaced the United States as the biggest emitter of greenhouse gases that year.

A major motivator for deforestation in Indonesia is the production of palm oil, which is now the most widely used vegetable oil in the world. Around 50 percent of the products in a grocery store, from snack food to shampoo, include palm oil. Palm oil is also used as a biofuel in the United States and the European Union. When the United States and Europe passed laws mandating the increased use of biofuels in the early 2000s, cropland needed to be expanded, and it has been at the expense of forests:

> Lawmakers never anticipated that their well-intentioned plan—to help the climate by helping American farmers—might instead transform Indonesia and present one of the greatest threats to the planet's tropical rain forests. But as Indonesian palm oil began to flood Western markets, that is exactly what began to happen. (Lustgarten 2018)



Vijay V, Pimm SL, Jenkins CN, Smith SJ (2016) The Impacts of Oil Palm on Recent Deforestation and Biodiversity Loss. PLoS ONE 11(7): e0159668. https://doi.org/10.1371/journal.pone.0159668.

FIGURE 13.15 Palm Oil Production. Palm oil is produced in the tropics, along the equator (between the Tropic of Cancer and the Tropic of Capricorn), with highest production levels in Indonesia and Malaysia.

Agricultural production had already spread to nearly all marginal land, including semiarid lands in the western United States. To create a bigger supply of vegetable oils to meet the demand for biofuels the law created, the United States had to look toward imports. In this way, a policy intended to decrease dependence on foreign oil and the burning of fossil fuels contributed more greenhouse gases to the atmosphere than all of Europe did in 2015. Because forests have carbon trapped in the trees and soils, clearing and burning "the existing forests to make way for oil-palm cultivation had a perverse effect: It released more carbon. A lot more carbon" (Lustgarten 2018).

Palm oil production is having the biggest impact on Indonesia and Malaysia (**Fig. 13.15**). The two countries produce 90 percent of all palm oil, and they are also home to 90 percent of the world's orangutans. Biodiversity is directly impacted by crop production. When you clear a complex rainforest ecosystem and plant rows of palm oil trees, habitat is directly lost. The ecosystem of a palm oil plantation is nothing remotely like the ecosystem of a naturally occurring rainforest (**Fig. 13.16**). The population of orangutans on the island of Borneo (which is shared by Indonesia and Malaysia) has declined by 50 percent since 1999 (Gibbens 2017).

The demand for palm oil continues to climb because it can be used in so many products and because its yield is much higher per acre than that of soybean oil or coconut oil. The massive deforestation effort across the tropical zone to rachet up production of palm oil is directly impacting indigenous people and small landholders. More than 700 conflicts between large palm oil corporations and indigenous people or small landholders have been reported in Indonesia alone. The Indonesian government has generally fallen on the side of the palm oil producers, though under international pressure, it recently passed legislation placing a moratorium on oil palm permits.

Water Use

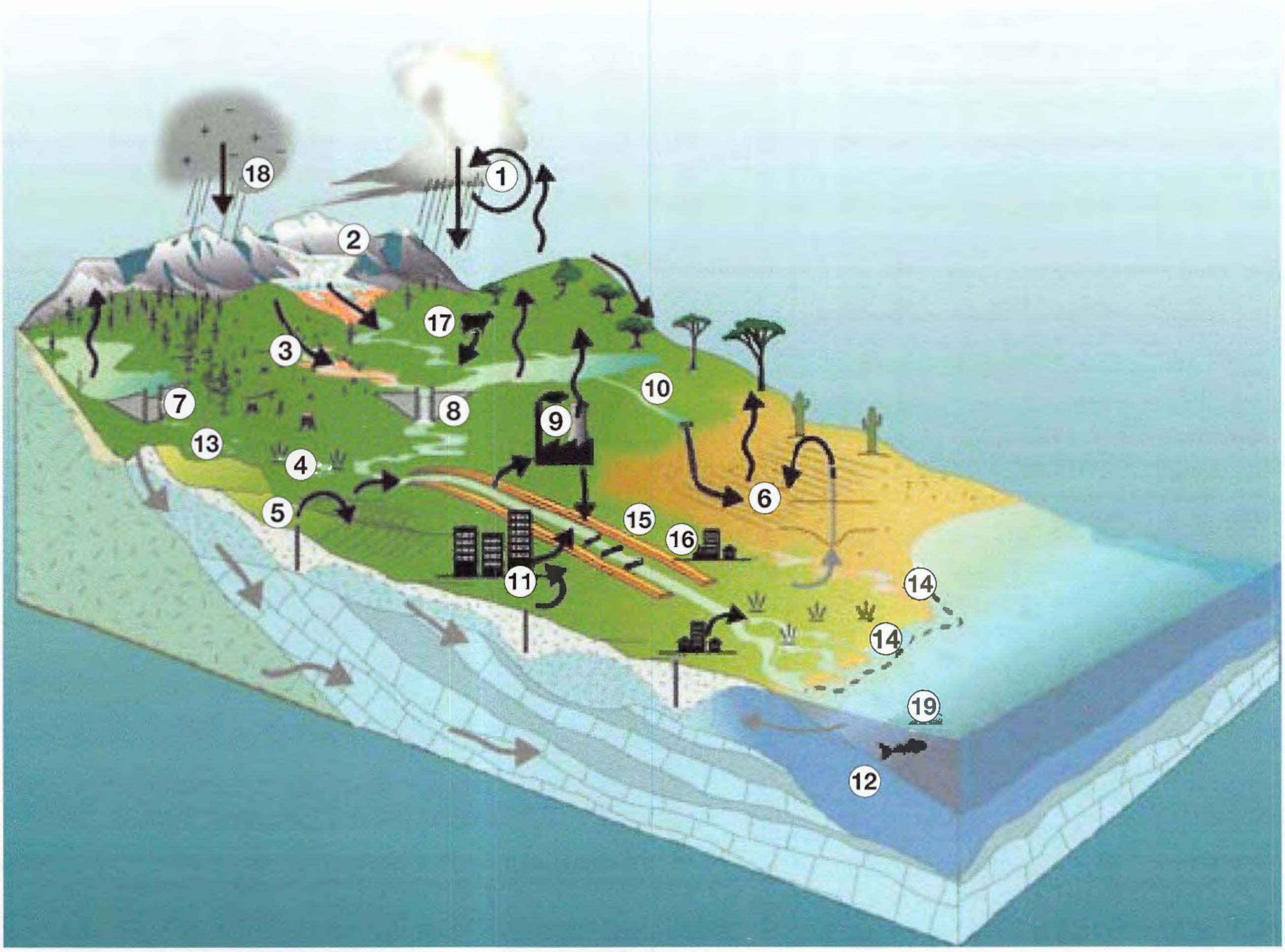
Resources that are replenished even as they are being used are **renewable resources**, and resources that are present in finite quantities are **nonrenewable resources**. Water, essential to life, is a renewable resource. The volume of precipitation in the world is enormous; spread out evenly, it would

Rich Carey/Shutterstock.com

FIGURE 13.16 Malaysia. The border is sharp between a palm oil plantation at the bottom of the photo and tropical rainforest at the top of the photo. Rainforests have great biodiversity that is threatened by turning forest land into palm oil plantations.

cover Earth's land area with about 33 inches (83 cm) of water each year. But the available supply of freshwater is not distributed evenly across the globe. Figure 1.22 shows the world distribution of precipitation, with the largest totals recorded along the equator and in the tropics. While the amount of water on Earth is plentiful, the global supply of freshwater is anything but plentiful. Chronic water shortages afflict rural and urban areas.

We learn to think of water as a constant whose distribution is sustained through the **hydrologic cycle**, in which water from oceans, lakes, soil, rivers, and vegetation evaporates, condenses, and then falls as precipitation on land. Precipitation infiltrates and recharges groundwater or runs off into lakes, rivers, and oceans. However, physical geographer Jamie Linton questions the utility of any model of the water cycle that does not consider the role of humans and culture, suggesting that by "representing water as a constant, cyclical flow, the hydrologic cycle establishes a norm that is at odds with the hydrological reality of much of the world" (Linton 2008). For example, the hydrologic cycle does not consider the norms of water in arid regions of the world, and it also assumes that water cycles in a predictable, linear fashion. But the amount of water cycling through the Earth is not a constant. For instance, changes in land cover affect how much water is in the cycle. The **global water system** better accounts for human water use and the built environment (**Fig. 13.17**).



Source: Adapted from American Geophysical Union.

1. Hydrological cycle accelerated
2. Mountain snow and ice lost
3. Tree removal increases runoff, reduces transpiration, affects water table and landscape salinity
4. Wetlands dried up or drained
5,6. Ground- and surface water used for irrigated agriculture
7,8. Dams alter flow and reservoirs increase evaporation
9. Industrial water coolers release water vapor
10. Water transfers between basins
11. Urban, mining, and construction areas alter water flows and quality
12. Coastal saltwater intrudes inland
13. Impoundments reduce flows
14. Siltation, erosion, and nutrient flows change coastlines and affect water quality
15. Levees and locks modify flows and channels
16. Settlements alter floodplain landscapes
17. Grazing affects runoff and water quality
18. Industry causes acid rain
19. Coastal waters polluted and species lost

FIGURE 13.17 The Global Water System. Unlike the traditional diagram of the hydrologic cycle (water cycle), the human imprint is reflected in this diagram of the global water system.

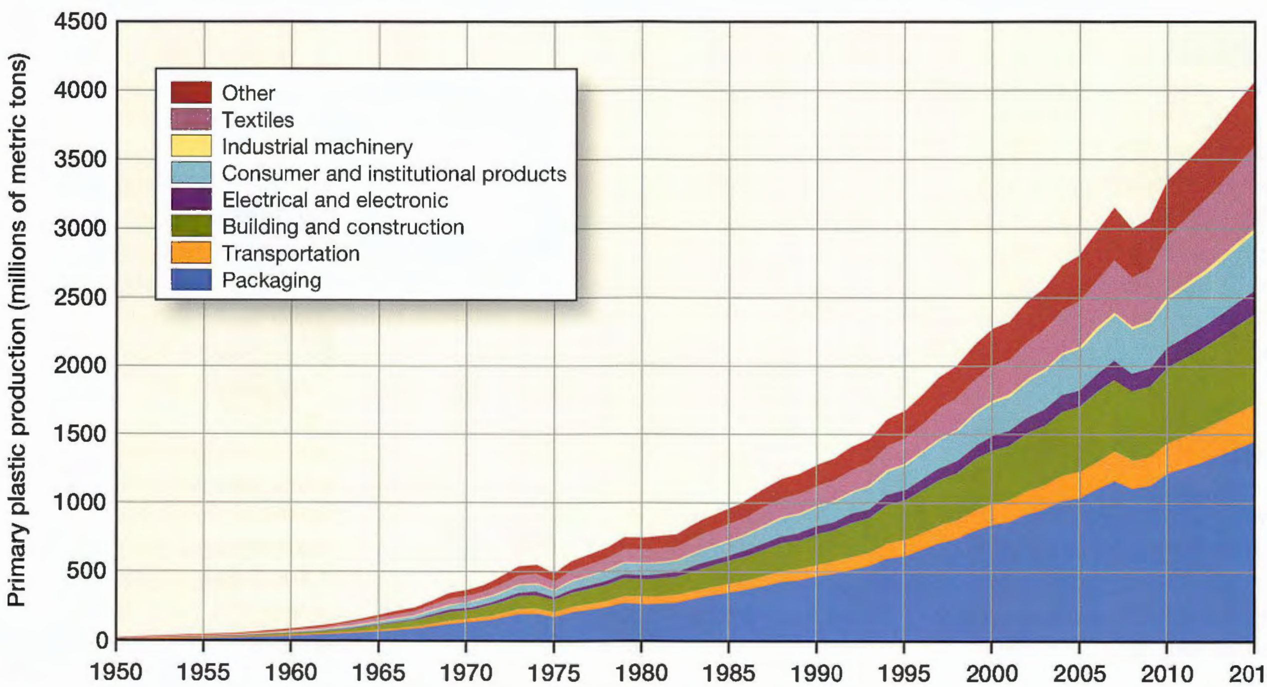
A Plastic Ocean Earth is often called the Blue Planet because more than 70 percent of its surface is covered by water and views from space are dominated by blue hues and swirls of white clouds. Oceans are essential to life. First, they produce oxygen through photosynthesis of phytoplankton and other plants. Oxygen is essential to human, animal, and plant survival. Oceans also absorb enormous quantities of carbon dioxide (CO_2). Ocean currents redistribute energy from the tropics to the polar regions. Oceans also provide resources, including fish stocks, and are homes for fish farms. Oil companies extract billions of barrels of oil from the continental shelf under oceans.

With oceans covering 70 percent of Earth, it would seem that Earth's 7.6 billion people would not impact the entire ocean, but we do. About 10 percent of the plastic used by humans ends up in the ocean each year, and the amount is compounding quickly as the amount of plastic waste ratchets up each year (**Fig. 13.18**). Of the 8.3 billion metric tons of plastic that has been produced, 6.3 billion metric tons has been discarded as waste. Plastic recycling bins are everywhere, but little plastic is recycled. Only 9 percent of the 6.3 billion metric tons of waste is recycled. Another 12 percent is incinerated, and 79 percent is "accumulated in landfills or the natural environment" (Geyer et al. 2017).

Human use of plastic and fascination with it are relatively recent. The first plastics were made in the 1920s and were used primarily in the military. After World War II, less expensive, synthetic plastics were created and the use of plastics exploded. The diffusion of the automobile, the growth of suburbs, and growing numbers of people in the workforce after World War II all helped create demand for convenience. Plastics are used in household appliances like toasters and goods like hairbrushes, but their most widespread use is in packaging. Think of the number of premade meals in your grocery store, whether in the freezer section or the hot food case at the deli. Each one is encased in plastic. Now imagine the number of grocery stores in the world (one estimate is 40,000 grocery stores in the United States alone) and you start to realize how ubiquitous single-use plastic packaging is.

Human use of plastic impacts the environment from the point of production. Plastics are synthetic polymers made up of monomers, which are carbon-based compounds derived from oil. Chemists can create a broad range of plastics in the lab, and large-scale production of goods is made simple because plastics are easily shaped into everything from a toy car to a toilet bowl brush to a computer keyboard. The moldability of plastics is what makes them so attractive for producing consumer goods and packaging.

Plastics do not easily decay. Once created, used, and disposed of, plastics break down slowly over time but do not biodegrade. Plastics are either directly disposed of in the ocean or find their way there from beaches, through waterways that empty into the ocean, through improper disposal or incineration, or through natural hazards like tsunamis that demolish the built environment and carry waste into the ocean (**Fig. 13.19**). In the ocean, sunlight and waves break plastics down into millions of smaller pieces called **microplastics** that not only float on the surface but also are carried to depths by marine invertebrates (Parker 2017). The presence of microplastics is directly impacting marine life and humans. The smallest animals in the food chain, foraging fish like anchovies, eat plastic in the ocean. Larger fish eat the smaller fish, and humans ingest the toxicity of the plastic when they consume the larger fish.



Data from Geyer R, Jambeck JR, Law KL. Production, use, and fate of all plastics ever made. Sci Adv. 2017;3(7):e1700782. Published 2017 Jul 19. doi:10.1126/sciadv.1700782. Visualization by E.H. Fouberg and A.B. Murphy. © 2020 John Wiley & Sons, Inc.

FIGURE 13.18 **Plastic Production Since 1950.** The growth in the amount of plastic produced for packaging has ramped up at a faster rate than other uses.

Rich Carey/Shutterstock.com

FIGURE 13.19 **Semporna, Malaysia.** Much of the plastic we produce ends up in oceans and washes onto beaches, following currents and wave patterns.

Ocean waves deposit microplastics and even larger pieces of plastic on beaches, and ocean currents circling around high-pressure systems gather plastic dumped into the ocean into huge gyres. The **Great Pacific Garbage Patch** is the biggest of the garbage gyres and forms around the high-pressure cell in the northern Pacific Ocean. More plastic swirls through this gyre than through others because plastic is produced, consumed, and dumped at alarming rates around the North Pacific, which is flanked by Asia on the west and North America on the east. As the high-pressure cell moves, the gyre of plastic moves with it. Scientists can reach the Great Pacific Garbage Patch, but removing the plastics would have more consequences for the ocean. Right now, the only way to remove the microplastics is by using fine-mesh nets, which would also skim the ocean phytoplankton, the base of the ocean's food chain and source for atmospheric oxygen.

Resource Extraction

Since the Industrial Revolution began in the late 1700s, humans have increasingly turned to technology to solve problems, improve productivity, protect against disease, and create new products. But technologies come at a cost. Resource extraction, including drilling for oil and natural gas, mining for elements, and logging, have fundamentally changed economic, political, and environmental systems. The products humans have created and the multitude of ways we have innovated to produce and ship goods are truly remarkable. However, there are by products, including hazardous toxins, pollution, and health problems, that we are only now beginning to recognize.

Human ingenuity has enabled both population and life expectancies to grow but has also led to degradation of the oceans (oil and gas exploitation and spills, pollution dumping, and massive overfishing), land surfaces (open-pit and mountaintop mining, dams, and irrigation projects), the biosphere (deforestation, vegetation loss), and the atmosphere (air pollution).

As the first parts of the planet to industrialize, western Europe and North America long led the world in industrial-related pollution. Now attention is turning to China, which rapidly industrialized in the late 1900s and early 2000s. China is extending industrial production through its One Belt, One Road and Maritime Silk Road initiatives to around 100 countries worldwide (see Chapter 8 and Chapter 10).

Hydrocarbons Oil is a nonrenewable resource. It is not a question of whether the world's oil supply will run out but when. Because discoveries of new reserves continue to be made, and because the extraction of hydrocarbons is becoming ever more efficient, it is difficult to predict exactly how much longer oil will remain a viable energy source. Many suggest that the current level of oil consumption can be sustained for up to 100 years, although you can find as many arguments for much shorter or much longer time frames. Despite the range of calculations, most scientists believe that by the middle of

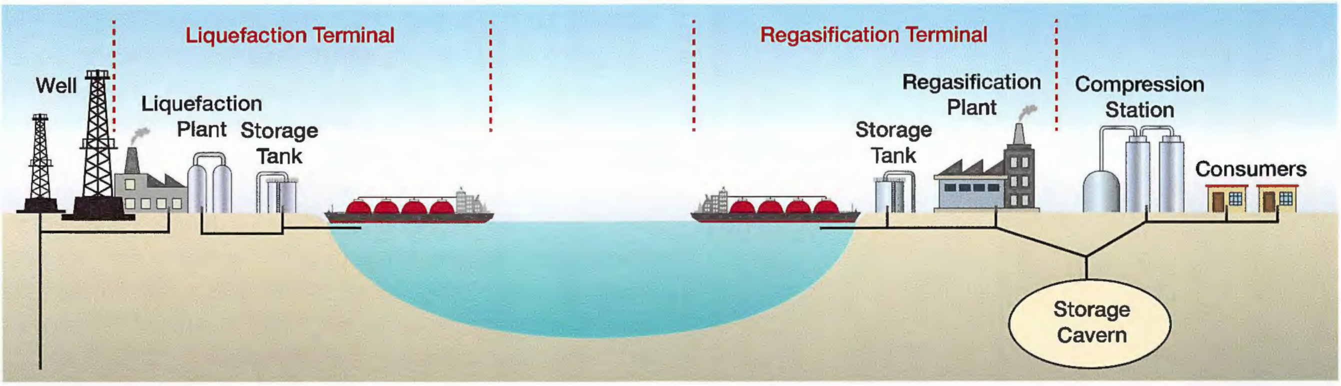


FIGURE 13.20 Liquification and Regasification of Natural Gas. Transporting liquid is easier than transporting gas. Scientists created a method to liquefy natural gas at its source location, ship it long distances, and regasify it at its destination.

this century, alternative sources will have to play a much more significant role than they do now.

The widespread technological change that has happened since the beginning of the Industrial Revolution has been built on burning **hydrocarbons**: organic compounds made of hydrogen and carbon. Because hydrocarbons can be burned when in the presence of oxygen, they can be used as fuel. The Industrial Revolution was built on burning coal to power steam engines. We still use coal as a fuel, especially in power plants. And you see the ubiquitous use of oil in gas pumps across the country.

In recent decades, natural gas has emerged as an increasingly common alternative to oil. Natural gas can be extracted from the oil refinement process. Major subsurface reservoirs of natural gas also exist, and we use fracking and other methods to extract natural gas from the subsoil. Like oil, natural gas is a hydrocarbon that releases carbon dioxide when it is burned, but it burns somewhat more cleanly than oil.

Despite its advantages, natural gas is difficult to store and transport. To address this problem, scientists have figured out how to condense natural gas at a very low temperature to create liquefied natural gas (LNG). The process is expensive, and LNG is highly flammable, but demand for LNG is increasing. The largest exporters of LNG are Qatar, Australia, Indonesia, and the United States. As part of a nation-wide fuel switching program, China has rapidly increased its demand for LNG. Most of China's power is created through burning dirty coal (power plants that do not using air scrubbers), and to reduce air pollution, the government has instituted a fuel-switching plan to cleaner-burning natural gas. A great deal of engineering is needed to liquify and then regasify natural gas (**Fig. 13.20**).

Natural gas deposits are not always easy to reach. Hydraulic fracturing, or fracking, is one method used to reach these deposits in shale (**Fig. 13.21**). Hydraulic fracturing requires injecting a high-pressure fluid—water mixed with sand and a proprietary blend of chemicals—into deep shale rock formations to create small fissures and release natural gas. The gas is captured and transported via pipeline to compression stations or liquification terminals.

Hydraulic fracturing comes at a potentially high environmental cost. First, it uses a lot of water. In addition, the chemicals added to the water may contaminate groundwater. Residents who live near fracking operations have reported unclean or even flammable water coming out of their faucets. Second, fracking can also create seismic activity. Some earthquakes are too small to be easily detectable, but scientists do not know what the long-term consequences may be. Finally, removing oil and gas from shale also emits greenhouse gases, especially methane.

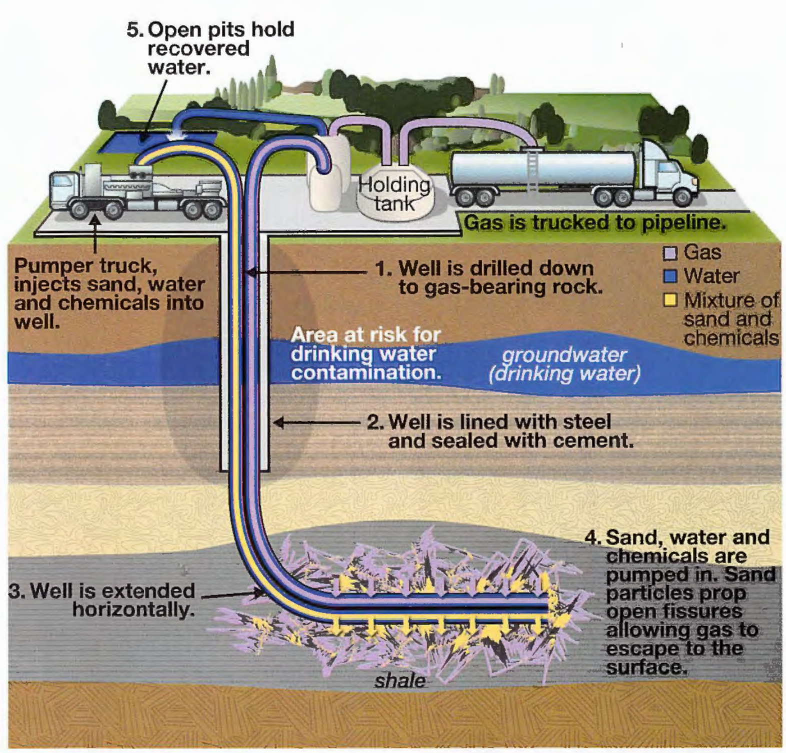


FIGURE 13.21 How Hydraulic Fracturing (Fracking) Works. First, deep wells are drilled and then chemicals and water are pumped into the wells to force natural gas out of shale and toward the surface.

FIGURE 13.22 **Lake Benton, Minnesota.** The wind park near Lake Benton, Minnesota, was developed beginning in 1994 and now includes more than 600 wind turbines.

Rare Earth Elements One advantage of alternative energies is that their production creates fewer emissions of carbon dioxide and other greenhouse gases. However, the production of alternative energy still requires resources and infrastructure. A single wind turbine (**Fig. 13.22**) is made of fiberglass, weighs hundreds of metric tons, stands 90 meters (196 ft) high, and "fundamentally relies on roughly 300 kilograms of soft, silvery metal known as neodymium," a rare earth element (Biello 2010, 16). Neodymium is used for the powerful magnets in a wind turbine that generate electricity. It is one of 17 elements on the periodic table that are considered rare earth elements.

Rare earth elements are in demand because they are used not only in wind turbines, but also in alternative energy cars, computers, screens, compact fluorescent light bulbs, cell phones, MRI scanners, and advanced weapons systems (Biello 2010). They are found in rock, and 97 percent of the rare earth elements mined today come from China. Mining is only the first step in their exploitation, because making them usable requires separating elements that are bound together in rock. Once the rocks are mined, Chinese companies intensively boil them in acid to separate the neodymium from other rare earth elements, repeating the process "thousands of times because the elements are so chemically similar" (Biello 2010, 17).

The chemical processing of rare earth elements uses electricity and water—leaving behind chemicals and residuals, including thorium (a radioactive metal) and salt. The environmental consequences of rare earth element mining have historically been costly enough that production stopped at the one mine in the United States in 2002, in part because of the cost of complying with environmental laws.

Looser environmental laws and lower labor costs have increased the production of rare earth elements in China during the last decade (**Fig. 13.23**). In Inner Mongolia, China,

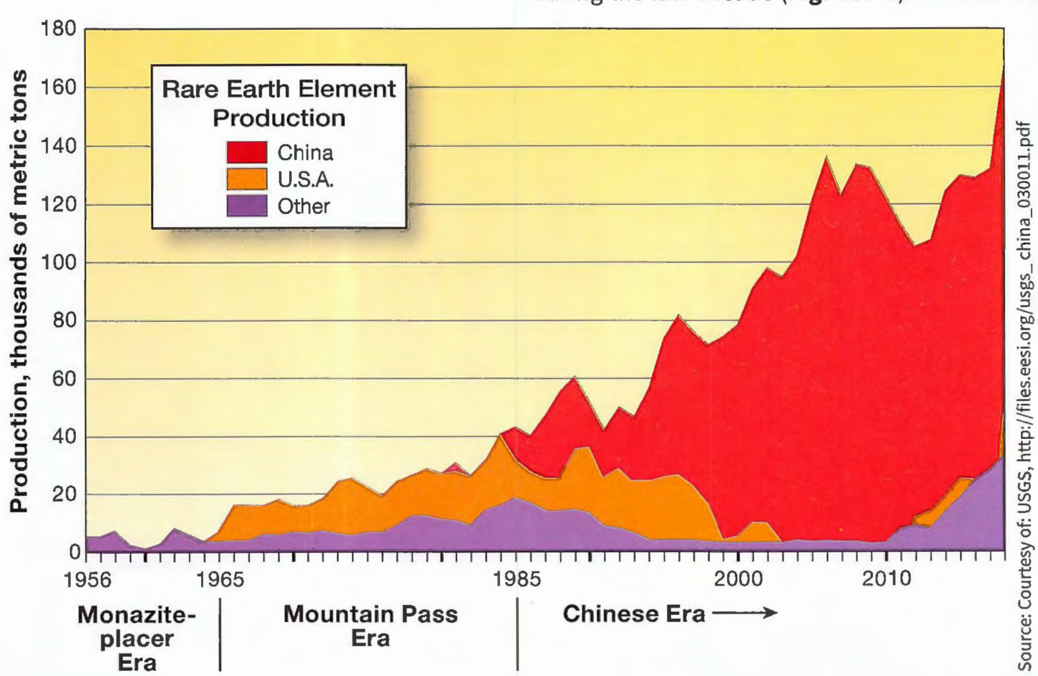


FIGURE 13.23 **Rare Earth Element Production Since 1956.** Rare earth elements are produced primarily in China because of the environmental impacts of extraction and refinement. Technological devices like cell phones are increasingly recycled to extract and reuse the rare earth elements in them.

DigitalGlobe/ScapeWare3d/Getty Images

FIGURE 13.24 **Inner Mongolia, China.** Satellite imagery of the Bayan Obo mine shows two large open-pit, circular mines near the center top of the image. The leaf-shaped features to the right and left of the mines are tailings (ground rocks) piles.

the extraction of rare earth elements at the Bayan Obo mine alone accounts for 40 percent of the world's supply. China closed off access to the mine to all outsiders, but the mine's enormous pits and waste ponds can still be viewed from space and are even visible using Google Earth (**Fig.13.24**).

China will likely remain the leading producer of rare earth elements in the near term. However, recycling rare earth elements from discarded devices and new mining efforts in the United States, Australia, and Vietnam will likely improve the availability of rare earth elements from sources outside of China in years to come.

TC Thinking Geographically

Coal fuels most power plants in Ohio. Look at this website to understand where most coal is produced in the United States: https://www.eia.gov/energyexplained/coal/where-our-coal-comes-from.php. Think through how coal is transported to Ohio's power plants. If Ohio changed its fuel source to renewable energy (wind, solar), how would that create new **development** opportunities, including technologies, businesses, and employment opportunities in and around Ohio? How would it impact the coal-producing states?

13.3 Explain How Climate Change Is Impacting Human–Environment Interactions.

The sun emits shortwave radiation that travels over 94 million miles through the atmosphere to reach Earth's surface. Earth absorbs the shortwave radiation and then emits longwave radiation, creating **sensible heat,** the temperature we feel around us. This process of absorption and emission happens every place on Earth that receives the sun's energy.

This description is not the complete picture, though. The atmosphere is a layer of gases surrounding Earth. The shortwave energy from the sun travels through the atmosphere to reach the surface, and the longwave radiation from Earth travels through the atmosphere as it rises. Naturally occurring greenhouse gases cluster at the top of the troposphere (about 8 to 11 miles above Earth's surface). These **greenhouse gases** absorb some longwave energy emitted from Earth and act like a "lid," reradiating it back to the surface. This naturally occurring greenhouse effect keeps Earth about 59°F (15°C) warmer than it would be without greenhouse gases (**Fig. 13.25**).

The basic premise of climate change science is that humans are burning hydrocarbons, which releases greenhouse gases that intensify the greenhouse effect. Since the Industrial Revolution, the amount of greenhouse gases in the atmosphere has increased at an alarming rate. Automobiles, steel mills, power plants, oil and natural gas refineries, and chemical plants account for much of this increase. An overwhelming majority of climate scientists have concluded that the increase in greenhouse gases from anthropogenic (human) sources is causing the Earth to retain more energy. Energy is the driver of climate, ocean currents, winds, and storms. Adding more energy into Earth's atmosphere has consequences, and like other global processes, those consequences are uneven and often unintended.

The average temperature of Earth has risen 1.1°F (0.6°C) since 1980. In the same time frame, the amount of carbon dioxide in the atmosphere has risen from 336 to 441 parts per million (**Fig. 13.26**). Because the average temperature of Earth is increasing, climate change is sometimes called global warming, but *climate change* is a more accurate term because it's not as simple as a cozy blanket warming us up "just a bit." The temperature alone is not the story; the added energy in Earth's atmosphere is what matters. Energy fuels Earth processes, and entire systems are changing.

Sea-level rise is one aspect of climate change. Low-lying islands in the Indian Ocean and the South Pacific are already experiencing this effect. Tuvalu is an average of 6.5 feet (2m) above sea level (**Fig. 13.27**), and current predictions mean that the Pacific Ocean will inundate Tuvalu by 2050. Change has already reached the island. Rainfall is less predictable, saltwater is flowing into coastal freshwater supplies, and storms are intensifying. Media reports often call Tuvaluans "climate change refugees." Locals reject the term *refugees*, however, because it suggests they are passive victims (Farbotko). Tuvaluans are actively choosing migration to cope with the impact of climate change (see Chapter 3).

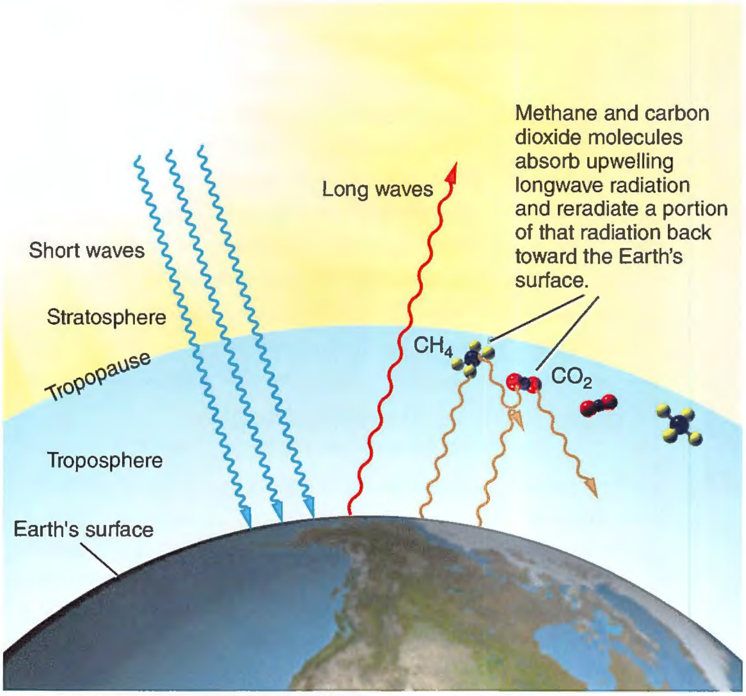
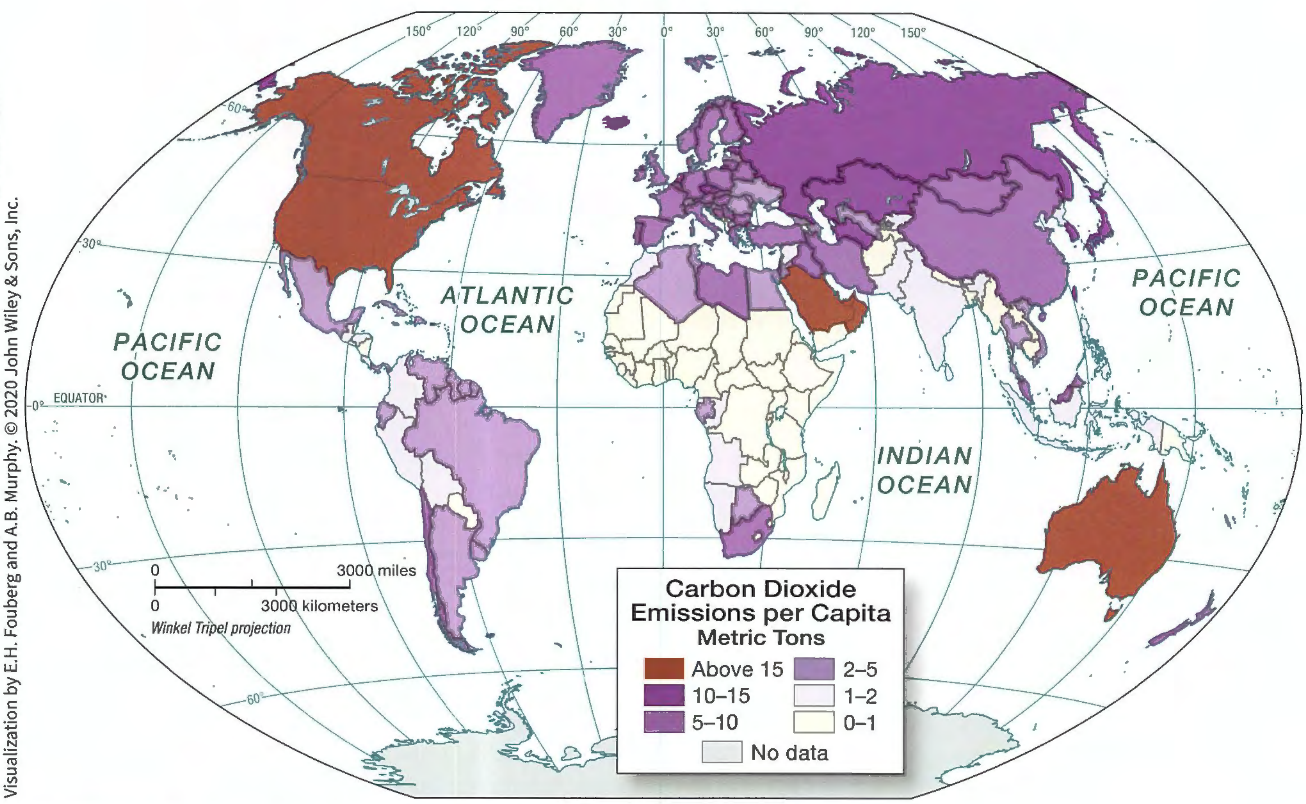


FIGURE 13.25 Greenhouse Effect. Incoming solar radiation (insolation) is relatively short wave. Earth absorbs the energy and emits energy at longer wavelengths. The long wave energy moves up through the troposphere and hits greenhouse gases, where some of the energy is absorbed, some makes it through to the stratosphere, and some is reradiated to Earth. The energy reradiated to Earth creates a warming effect called the greenhouse effect.

Hurricanes

With higher temperatures and more energy in the atmosphere, the rates of evaporation—through which liquid water turns to water vapor—increase. Energy must be added in the form of latent heat to transform liquid water to water vapor. In a storm, this water vapor is condensed into liquid water, and in the process of condensation, latent heat is released. Because energy fuels evaporation and is released through condensation, higher temperatures and warmer oceans mean that more energy goes into storms, whether hurricanes or midlatitude cyclones.

Today greater energy is fueling more intense hurricanes. For example, Hurricane Harvey dumped 60 inches of rain on Houston, Texas, in fall 2017 (**Fig. 13.28**). Scientists found that "the amount of energy Harvey pulled from the ocean in the form of rising water vapor" was equal to the "the amount of energy it dropped over land in the form of rain." In other words, the energy that went into evaporation was released through condensation. And because climate change led to warmer oceans and warmer air, the amount of energy in the hurricane system increased. Scientists estimate that "climate change caused Harvey's rainfall to be 15 to 38 percent greater than it would have been otherwise" (Fischeti 2018).



Data from: United Nations Development Programme, Human Development Report, 2007/2008.
Visualization by E.H. Fouberg and A.B. Murphy. © 2020 John Wiley & Sons, Inc.

FIGURE 13.26 Carbon Dioxide Emissions per Capita. China's total carbon dioxide emissions exceed those of the United States. However, in per capita emissions of carbon dioxide, mapped here, the United States, Canada, Saudi Arabia, and Australia are among the highest.

FIGURE 13.27 **Tuvalu.** The country of Tuvalu has an average elevation of 6.5 feet and the highest elevation is 15 feet above sea level. Much of the Pacific island country is barely above sea level.

Water Scarcity

One-fifth of the world's population lives in regions confronting **water scarcity**, the lack of enough water to meet demand. Remarkably, geographers have found that countries facing growing water concerns tend toward cooperation instead of political violence. Cooperation usually takes the form of transboundary or multilateral treaties governing the use and protection of water resources. Between 1948 and 1999, countries entered into more than 150 agreements over water. From the Mekong to the Ganges to the Indus to the Niger, treaties have helped to promote the equitable management of river waters.

Geographers Shira Yoffe, Aaron T. Wolf, and Mark Giordano created the *Basins at Risk* project to monitor changes in river flows and cooperation levels between countries. The researchers integrated socioeconomic, political, and physical variables into a geographic information system (GIS). Tying the data to specific countries and river basins, they tested how well the data predicted historical disputes and cooperation between countries over international river basins (2001). Their research found that no single indicator, including per capita GDP, population density, dependence on water for agriculture, or government type, predicted conflict over water. Between 1948 and 1999, cooperation over water "far outweighed overall conflict over water and violent conflict in particular" (2001, 72). Their findings dispelled many statements coming from academics in international relations and environmental security research that arid places fight more over water than nonarid places. Yoffe, Wolf, and Giordano found that "arid regions were not . . . substantially less cooperative than other climate zones" (2001, 89). Their map of current conflicts, protests over water, and indicators of conflict by river basin reveals no clear connection between arid climate regions and water conflict (**Fig. 13.29**).

However, not all agreements over water will be able to handle the extremes of drought and flooding that are more likely with climate change. It takes cooperation to reach a water treaty or agreement, and cooperation needs to continue over monitoring and enforcement. Water stress is rising in basins where the extremes of drought and flooding from climate change are challenging the agreements.

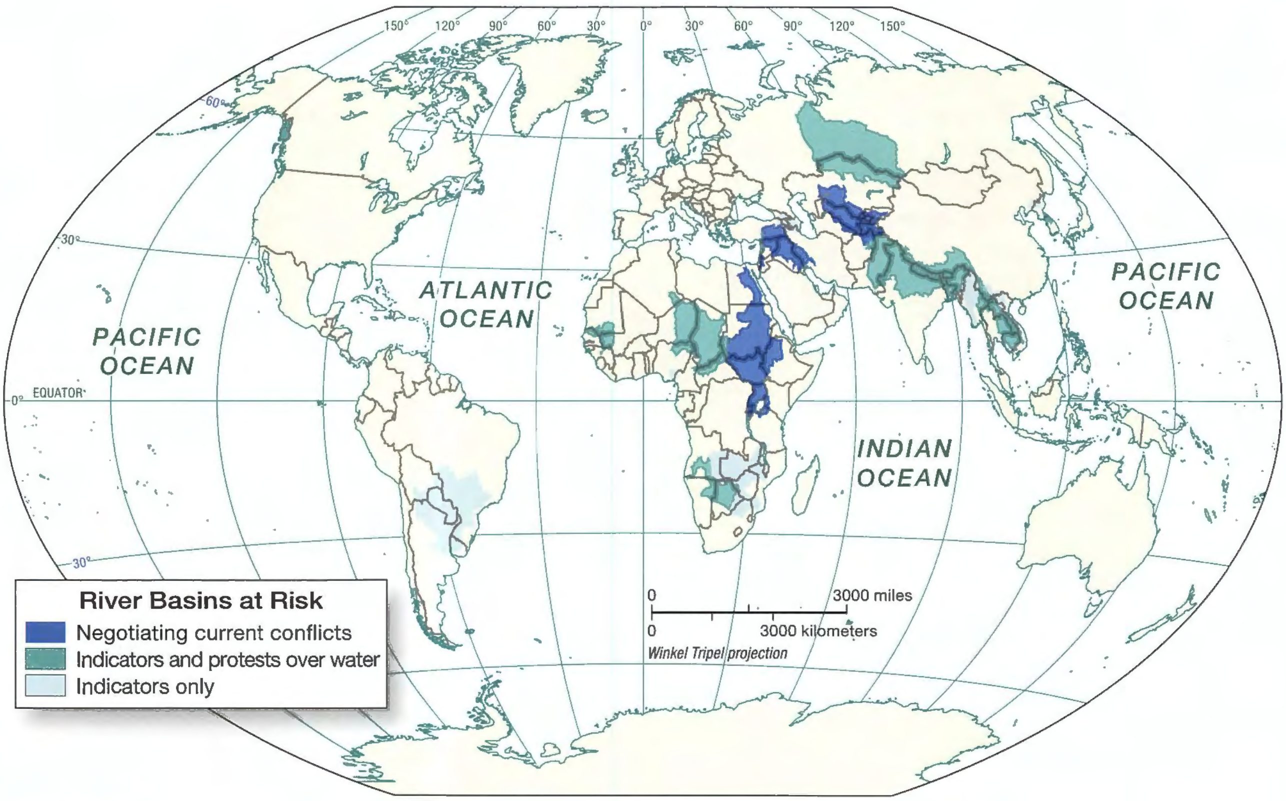
People cope with water stress by moving. People may migrate to another place, or those with livestock may move herds to more dependable freshwater sources. Migration and movement spurred by growing extremes in water variability are occurring both across country borders and within countries. A 2018 World Bank study predicts that a growing number of people will move within their country in response to water stress, either flooding or drought. Specifically, the World Bank predicts 143 million internal migrants by 2050. This will be in addition to a growing number of migrants crossing borders.

Human-Induced Water Scarcity in the Aral Sea

In addition to being caused by extreme fluctuations caused by climate change, water scarcity can be created by humans. As human populations have expanded, people have increasingly settled in arid regions. One of the great ecological disasters of the twentieth century occurred in Kazakhstan and Uzbekistan, whose common boundary runs through the Aral Sea. Streams that feed this large body of water were diverted to irrigate the surrounding desert, mainly for commercial cotton production.

Both Kazakhstan and Uzbekistan were part of the Soviet Union (USSR) when it controlled much of Eurasia between

FIGURE 13.28 **Houston, Texas.** Hurricane Harvey caused record flooding in Houston in 2017.

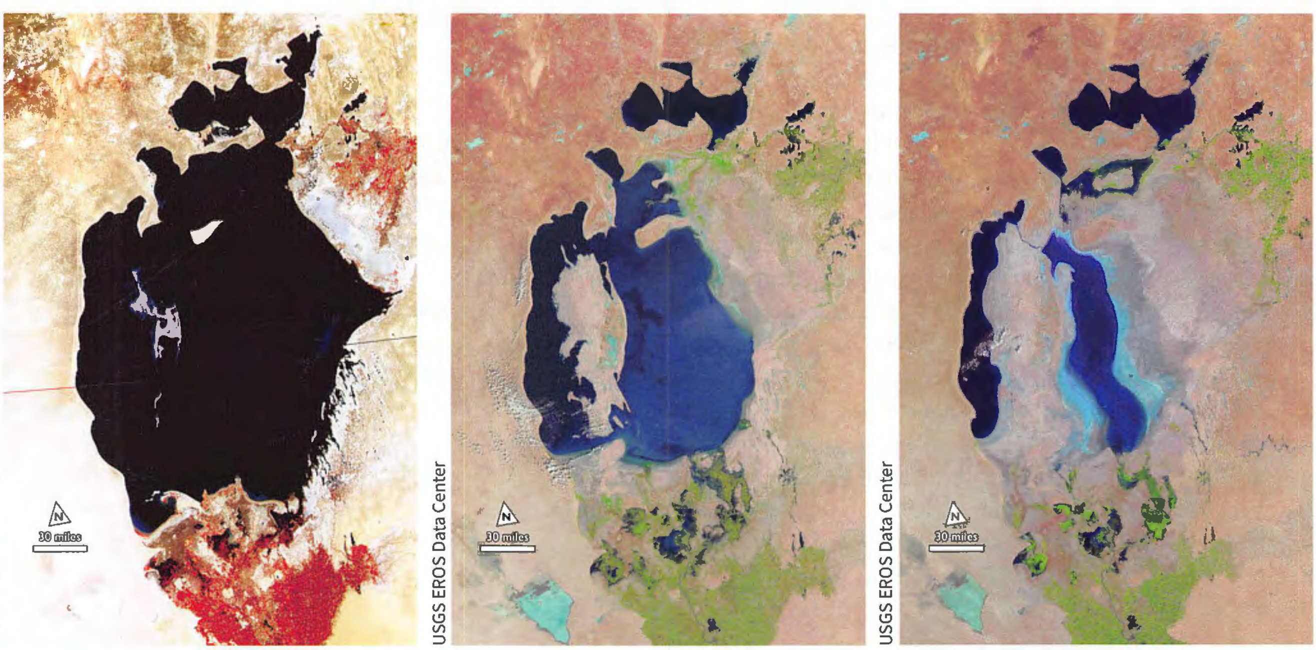


Source: Based on Yoffe, S., Wolf, Aaron T. and Giordano, M., "Chapter 4 Conflict and Cooperation over International Freshwater Resources: Indicators and Findings of the Basins at Risk Project", Oregon State University.

FIGURE 13.29 River Basins at Risk. Geographers at Oregon State University created a database of conflicts and protests in and around river basins globally. Through their research, they found water scarcity did not correlate with protests and conflicts over river use.

1924 and 1991. Under the Soviet policy of centralized planning, the countries were required to produce a certain amount of cotton each year. Cotton is a water-intensive crop. To produce it in an arid climate, farmers diverted water from the two rivers that fed the Aral Sea. Over a short time, between the 1960s and the 1990s, the Aral Sea lost more than three-quarters of its total surface area (**Fig. 13.30**).

In 2001, the Kazakhstan government, with a loan from the World Bank, began work to restore the lake. A dam was completed in 2005, and leaky irrigation canals have been fixed.



USGS EROS Data Center

USGS EROS Data Center

USGS EROS Data Center

FIGURE 13.30 The Aral Sea. The Aral Sea on the border of Kazakhstan and Uzbekistan has shrunk significantly. The image on the left is from 1977, and the one in the middle is from 1998. The image on the right from 2010 reflects a loss of three-quarters of its surface area and more than 90 percent of its volume.

As a result, the northern end of the lake is capturing more water from the Syr Darya River and the fishing industry has rebounded slightly. The southern part of the Aral Sea is not rebounding as well as the northern. The independent Uzbekistan government continues to set cotton production quotas for farmers and imposes a system of forced "volunteer" labor, pulling people out of their regular work and into cotton fields to help harvest by hand each year. In both countries, overuse of the land has created salty, parched soils. Because of overuse, pesticides have leached into the groundwater and created an additional environmental impact in the region.

TC Thinking Geographically

Study the map of flooding caused by Hurricane Harvey in Houston in 2017: https://www.air-worldwide.com/Models/Tropical-Cyclone/Hurricane-Harvey-s-Lasting-Legacy--Flood/. Describe the **pattern** of flooding, paying particular attention to rivers, streams, and coastlines. Then determine how impervious surfaces in Houston impacted flooding both during Hurricane Harvey and in flooding events that have happened since.

13.4 Explain How Human Consumption Is Changing the Scale of Human Impact and Challenging Sustainability.

We can map the forces of globalization, from container ships to instant global communication to the movement of electronic money. We can see which places are most connected and which are most remote. What we cannot see are cause and effect. In a globalized world, every policy and every action has unintended consequences. A decision made in one place has outcomes halfway around the world. Think for a minute about the example of the secondhand clothing trade discussed in Chapter 10. You donate a shirt in your hometown, and it gets bundled into bales with hundreds of other pieces of clothing, stuffed into containers, and shipped to Africa. The intention is to help someone who needs clothing. The unintended consequence is supporting an entire industry of secondhand clothing, using fossil fuels to propel a container ship across the Atlantic, and undermining the textile industry in Africa, whether in Senegal or Zambia.

Living in a world where we cannot see or even imagine the outcomes of our actions makes it perhaps easier to ignore them. But one problem we need to be aware of is **human consumption**, which is increasing rapidly with growing populations and rising levels of income, and which has both intended and unintended consequences. You purchase a gift for a friend on an Etsy store to support a creative person's small business. Eventually, that gift reaches the end of its life cycle and your friend disposes of it. At that point, the gift could end up anywhere in the world as part of the global system of waste disposal. The scale of human consumption today and the consumption predicted for 30 years from now creates a range of problems that need to be addressed. Being conscious of this problem, whether as consumers or producers of goods, is a first step.

Global Patterns of Consumption

Humans rely on Earth's resources for survival. At the most basic level, we consume water, oxygen, and organic and mineral materials. Over time we have developed increasingly complex ways of using resources to intensify agricultural and industrial production. Our **pattern** of consumption has shifted from all of our needs coming from a small, concentrated area, to our needs being imported from dozens of countries, some of which are halfway around the world. To examine patterns, geographers look at how things are distributed and then analyze whether they are clustered, dispersed, or follow some other pattern. Ancient hunter-gatherers subsisted, on average, on the resources found within an area of about 26 square kilometers (10 sq mi) (Simmons 1996). Today, we consume resources at a level and rate that far exceed basic subsistence needs.

Nongovernmental organizations such as the Global Footprint Network and the World Wildlife Fund create scales to measure the amount of resources needed to support individuals and countries today. The **ecological footprint** is the impact a person or country has on the environment. It is measured by how much land is required to sustain the person's or country's use of natural resources and to dispose of the waste produced. The current average ecological footprint of a person today is 6.8 global hectares, which is "four times the resources and wastes that our planet can regenerate and absorb into the atmosphere" (Global Footprint Network 2018). The two most populated countries, China and India, have high total footprints, coming in at first and third, respectively. The ecological footprints of the United States (second), Russia (fourth), and Brazil (fifth) are quite high for countries with much smaller populations than China and India.

Most of us living in the global economic core draw on resources from places scattered all over the world. The **pattern** of our consumption is widespread. In any room in a house, goods are imported from all parts of the world. The countries with the highest per capita ecological imprint are small or arid countries that typically import foodstuffs and even water, making their imprint larger (**Fig. 13.31**). In rank order, the top five countries in terms of per capita ecological footprint are Qatar, Luxembourg, United Arab Emirates, Bahrain, and Kuwait. The United States and Canada rank seventh and eighth behind Trinidad and Tobago.

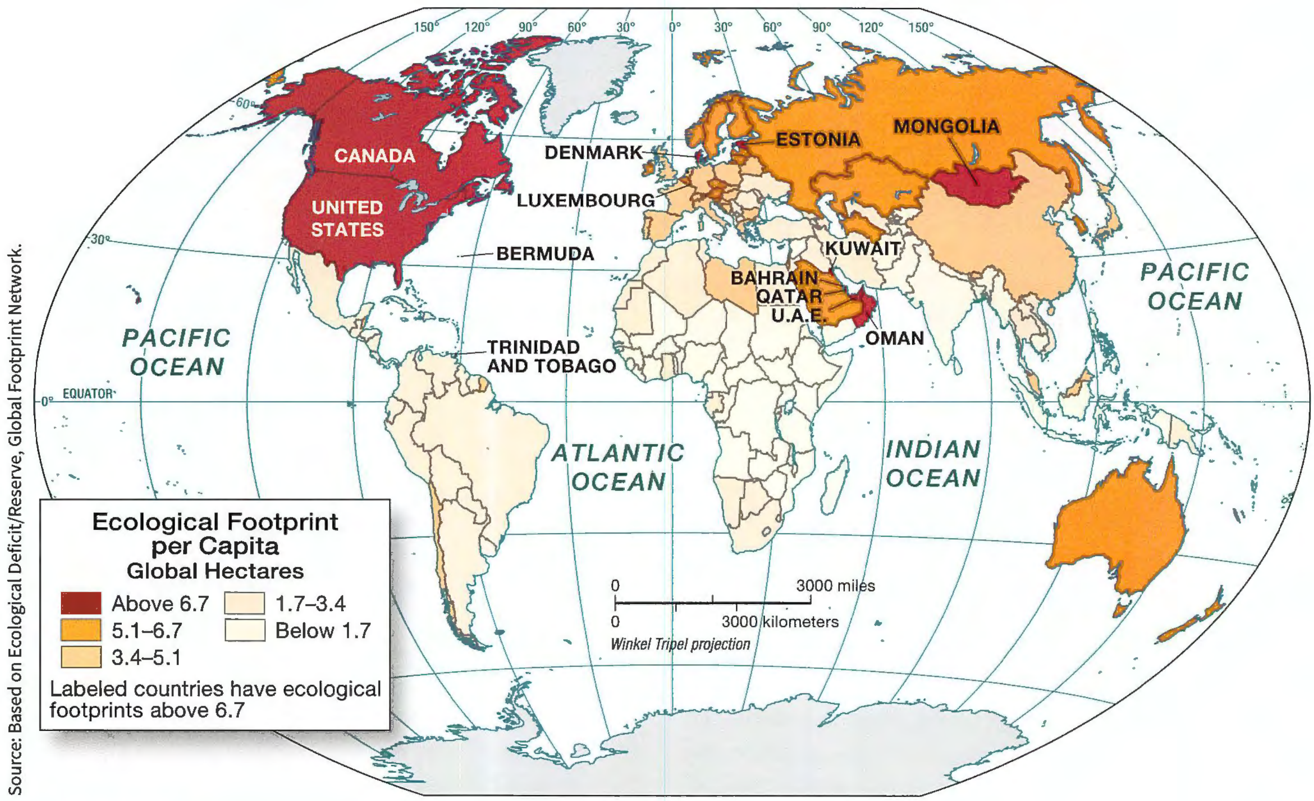


FIGURE 13.31 Ecological Footprint per Capita. Countries with the highest ecological footprint per capita (those that are labeled on the map) are dispersed across the world. Both small and large countries can have high ecological footprints per capita.

Countries with higher incomes account for a relatively small proportion of the world population (Chapter 2), but they make far greater demands on Earth's resources (per capita) than do their counterparts in lower income countries. It has been estimated that a baby born in the United States during the first decade of the twenty-first century, at current rates, consumes about 250 times as much energy over a lifetime as a baby born in Bangladesh over the same lifetime. In food, housing and its components, metals, paper (and thus trees), and many other materials, the consumption of individuals in affluent countries far exceeds that of people in countries with lower incomes.

Impervious Surfaces The ecological footprint helps us think geographically about human impacts on the natural world. People living in the global economic periphery tend to affect their immediate environment, putting pressure on soil, natural vegetation, and water supplies, and polluting the local air with the smoke from fires. The environmental impact of the global economic core is much greater. Consumers in the core have access to a vast array of goods with few limits on what they can get and when they can get it. They purchase fruits that ripen at a time different from the local growing season by importing them from across the world. When purchasing goods online, consumers may not know how far products will travel before they reach them. The demand for low-cost meat for hamburgers in the United States has led to deforestation in Central and South America to make way for pastures and cattle herds. In the process, water demand has increased in such areas (**Table 13.1**). This example shows just one of the many ways in which the American (and Canadian, European, Japanese, and Australian) consumer has an impact on distant environments.

TABLE 13.1 Estimated Liters of Water Required to Produce 1 Kilogram of Food

Estimated Liters of Water Required to Produce 1 Kilogram of Food

Food	Liters
Chocolate	17,196
Beef	15,415
Chicken meat	4,325
Rice	2,497
Bread	1,608
Potatoes	287

Determining environmental impact when people consume widely distributed resources that are produced halfway around the world is difficult. Mapping mines, factories, forests, and farms may help calculate where resources are produced, but it does not tell us where they are consumed. However, geographic tools can help create global measurements of human consumption using remotely sensed data. Geographer Paul Sutton and a

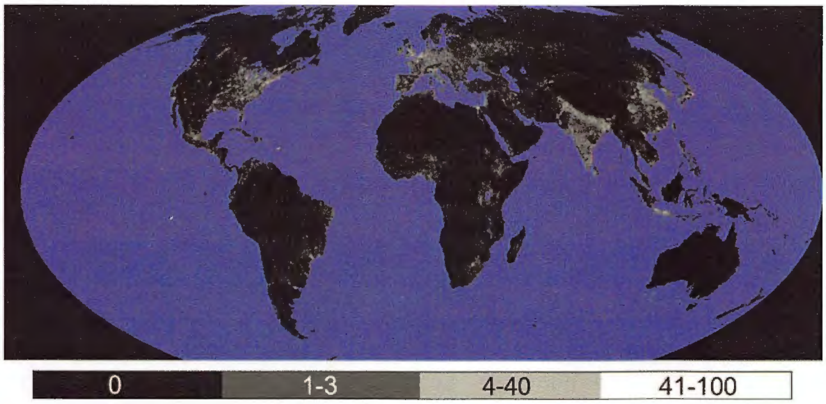


FIGURE 13.32 **Global Impervious Surfaces.** Using satellite data and other data layers, scientists measured the amount of impervious surfaces globally. The lighter the color on the map, the more impervious surfaces.

Source: Paul C. Sutton, Sharolyn J. Anderson, Christopher D. Elvidge, Benjamin T. Tuttle and Tilottama Ghosh, "Paving the planet: impervious surface as proxy measure of the human ecological footprint", Progress in Physical Geography 2009; 33; 510. DOI: 10.1177/0309133309346649

team of researchers mapped locations of human consumption by measuring impervious surfaces using remote sensing and GIS. They stated that the impervious surfaces people construct for "shelter, transportation, and commerce" are "one of the primary anthropogenic modifications of the environment" (Sutton et al. 2009, 513). Using statistical analysis, several layers of data from satellite images, and population data, the researchers derived estimates of impervious surfaces for the entire world. They created a measurement of constructed area per person that can be used as a proxy measure for resource consumption (**Fig. 13.32**).

Growing Consumption in China

The growing wealth over the last two decades in the semiperiphery, especially in the world's most populated countries—China and India—has significantly increased the overall global consumption of consumer goods. As recently as the 1980s, China's GDP was smaller than Spain's. Over the past few decades, however, the Chinese economy has surged forward. In 2010 China surpassed Japan to become the world's second largest economy, and in 2013, it became the world's second biggest consumer country.

Overall consumer spending in the United States still significantly outpaces that in China, but China is gaining ground, and because of the size of its population, it surpasses the United States as a consumer in some areas. In 2010 China became the world's biggest consumer of energy, and it has led the world in the consumption of coal for many years. China has also emerged as one of the world's leading consumers of a wide variety of raw materials, from logs to iron ore to grains.

As global consumption of consumer goods increases, the market for luxury goods has similarly expanded. Luxury handbags by European designers (Louis Vuitton, Hermes, Gucci, and Chanel) have become a status symbol in China. Chinese nationals purchase 32 percent of luxury handbags globally (**Fig. 13.33**), and Chinese tourists often purchase goods in Japan, South Korea, Hong Kong, Thailand, or the United States.

Author Field Note — Consuming Luxury Goods in Bangkok, Thailand

"I led a group of college students and my family through Cambodia and Thailand over 12 days. We had taken in everything from the killing fields of the Cambodian genocide to the temples of Angkor Wat, to a local Buddhist festival with thousands of worshipers in Chiang Mai. Our last night in Bangkok fell on my son's birthday, and I asked him what he wanted to do that night. He looked at me and said 'Cheeseburger. Cheeseburger with ranch.' The Midwesterner in him was craving ranch dressing, which he normally uses to dip his fries, burgers, and chicken, as well as on salad. I realized to find not only a burger but ranch that would meet his standards, we were going to need to go to the Hard Rock Cafe in Bangkok. We jumped in a cab to the district of the city with luxury malls, including the Paragon and the Gaysorn. After a meal that passed his test, even though the ranch was only a 2 on his 10-point scale, we walked through the malls. From Supreme to Louis Vuitton to Commes des Garçon to Gucci, every brand he had ever seen posted by a social medial influencer filled the floors of the mall. He kept looking at me, asking, 'Are these knock-offs?' They were not. The luxury stores are clustered in Bangkok to serve tourists, lately especially Chinese tourists. Chinese are over 10 million of the 28 million tourists in Thailand. The number of Chinese tourists has taken off since 2014, and everyone from luxury stores to stalls in the city's night market rely on their consumption."

– E. H. Fouberg

SubstanceTproductions/Shutterstock.com

FIGURE 13.33 **Bangkok, Thailand.** Chinese tourists queue in line to shop for luxury handbags at a Louis Vuitton store in the Gaysorn Village mall, which is down the street from another luxury mall, the Paragon.

Japan and Hong Kong have the greatest market share of luxury handbag sales in the region. In Hong Kong, a local moneylender even allows women to hand over their designer bags as collateral to receive loans of up to 80 percent of the bag's value.

To meet the growing demand for natural resources, China has greatly expanded its overseas investments. From Africa to South America to other parts of Asia, Chinese firms are increasingly in evidence—extracting resources and shipping them back home. As a result, China's role in consumption-related environmental change now rivals that of the United States and the European Union. China's new international economic clout also carries with it predictable social consequences. In some places, Chinese investment is seen as a boost to the local economy and is welcomed. But there is growing concern that China is acting as a neocolonial power, altering environmental and social systems while returning relatively little to the local economy.

Sustainability

The idea of sustainability is often dated to the United Nations World Commission on Environment and Development. The commission issued its findings in the 1987 Brundtland Report, which was named after the Norwegian prime minister, Gro Harlem Brundtland, who chaired the group. The commission asked the central question of how humanity can improve the condition of developing countries without degrading the environment when Earth has limited resources (Kuhlman and Farrington 2010). The Brundtland Report answered the question by defining the concept of **sustainable development** as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Since the Brundtland Report, sustainable development has become the goal of thousands of programs enacted by both governments and nongovernmental organizations. Policymakers often look at three pillars or goals: social, economic, and environmental. Not all scholars support the idea of three pillars, but they are useful to think about because economic development may be at the expense of social or environmental development. The hope is that considering all three pillars will make work toward development more comprehensive and sustainable.

Planning for sustainability in development, industry, agriculture, or any other realm is difficult because it requires policymakers to think about long-term goals while ensuring short-term welfare. We tend to worry more about the immediate problem than the long term. To help gauge what is possible within a certain realm, policymakers have turned to the concept of **carrying capacity**, a measure of how much can be produced on a certain amount of land without causing environmental degradation. This concept ties into the original concept of sustainability better than it does the modern concept of sustainable development. Sustainability was originally applied to the use of renewable resources, and forestry provided the first application: One should not harvest more trees than there are new-growth trees. In this case, sustainable practice could be easily measured.

Carrying capacity is also often perceived as measurable because the term was first used to describe how much cargo a ship could hold. Over time, policymakers and scholars began using it as a measure of how much productivity land could handle. However, ecologists have largely dismissed the concept because land is not the same everywhere, species vary, conditions are in flux, and technology changes. Because it is intuitively logical, however, carrying capacity may still be a meaningful way to talk about sustainable development. It pushes humans to think about how much of something Earth can handle and perhaps plan for longer-term preservation of resources instead of immediate consumption.

Political Ecology Creating sustainable development at the local scale requires fieldwork because assumptions about human behavior and development at the global scale may not be true at local and regional scales. Starting in the 1960s and 1970s, geographers began using scale to study human–environment interaction. The field of **political ecology** approaches the study of human–environment interactions in the context of political, economic, and historical conditions operating at different scales, and its practitioners are interested in how political, economic, social, and ecological circumstances shape environmental issues like sustainable agriculture in a specific place.

Political ecologists work to understand whether the global assumptions we have about environmental issues play out at the local scale and how people in a local place negotiate experiences and understandings at different scales to make environmental decisions. For example, development experts assumed that globally, the poorest farmers do the least to conserve soil and therefore cause more soil degradation than wealthier farmers. Political ecologists such as geographer William Moseley dispelled this myth through fieldwork (**Fig. 13.34**).

Moseley studied the conservation behaviors of farmers in southern Mali. Through extensive fieldwork, interviews, and soil surveys, he found that poorer farmers in southern Mali were more likely to use organic materials to preserve topsoil, whereas wealthier farmers were more likely to use inorganic fertilizers and pesticides. Thus the poorest farmers caused the least soil degradation. The explanation for this outcome lies in the policies and power relationships at play in southern Mali. The government agricultural extension service in Mali singled out the wealthiest households for cotton farming, which "helped these households become even wealthier in the short term" (Moseley). Wealthier farmers who could afford inorganic fertilizers increased their usage when they faced an increasingly competitive global cotton market.

The work of political ecologists is important in solving environmental problems because the factors involved in a human-environment interaction vary by scale. Solving a global problem like climate change may require millions of individual accomplishments at local, national, and regional scales. To do so, we must question our assumptions and use fieldwork to understand the decisions people make in their environments.

Guest Field Note Approaching Agriculture Through Political Ecology in Try, Mali

William Moseley
Macalester College

In this photo, a young man brings home the cotton harvest in the village of Try in southern Mali. Prior to my graduate studies in geography, I spent a number of years as an international development worker concerned with tropical agriculture—both on the ground in Africa and as a policy wonk in Washington, D.C. I drew at least two important lessons from these experiences. First, well-intentioned work at the grassroots level would always be limited if it were not supported by broader-scale policies and economics. Second, the people making the policies were often out of touch with the real impacts their decisions were having in the field. As such, geography, and the subfield of political ecology, were appealing to me because of its explicit attention to processes operating at multiple scales, its tradition of fieldwork, and its longstanding attention to human-environment interactions. I employed a political ecology approach during fieldwork for my dissertation in 1999–2000. Here, I sought to test the notion that poor farmers are more likely to degrade soils than their wealthier counterparts (a concept widely proclaimed in the development policy literature of the 1990s). Not only did I interview rich and poor farmers about their management practices, but I tested their soils and questioned policymakers at the provincial, national, and international levels. My findings (and those of others) have led to a questioning of the poverty-environmental degradation paradigm.

FIGURE 13.34 **Try, Mali.**

Biodiversity The expanding ecological footprint of humans is resulting in a decline in biodiversity. Maintaining biodiversity is often a goal in sustainable development. Combining the words *biological* and *diversity*, **biodiversity** is the variety of plants and animals on Earth or in a specific area. Human encroachment on species habitat through logging, agriculture, and expansion of urban areas is dramatically increasing the natural rate of species extinction. Knowing the exact rate of species extinction is difficult because we do not know how many species Earth has. Scientists have recorded 1.9 million animal species, including everything from large mammals to small insects, and 450,000 plant species. Using recorded rates of disappearance for known species, scientists estimate that humans have caused species extinction rates 1000 times higher than in prehuman times (Dell'Amore 2014).

Because of the rapid expansion of smartphones, organizations can tap into citizen scientists and use crowdsourcing to record data and map locations. With millions of citizen scientists taking photos and uploading them with the geolocation of their phones to an app such as iNaturalist, we are gaining more data on the number and diversity of species and their range. Whether a species is threatened with extinction depends on the range of the species, its scarcity, and its geographic concentration. If a species with a small range, a high degree of scarcity, and a small geographic concentration has its habitat threatened, extinction can follow. Because most species have small ranges, human-created changes like draining a wetland, killing off coral, or damming a river in one place can affect a species. Conservationists work to preserve species by preserving species habitat. Using geographic data collected on apps, through drone images, and from satellite data, conservationists can better manage species habitat.

Waste Disposal

If anything has grown faster than population itself, it is the waste that households, communities, and industries generate. The level of socioeconomic well-being and solid waste production have a strong, positive correlation (**Fig. 13.35**). Globally, we generated 2.01 billion tons of municipal solid waste in 2016, according to a World Bank report. That same report predicted a global production of 3.4 billion tons annually by 2050. The United States is one of the largest producers of solid waste, debris, and garbage discarded by people, industries, mines, and agriculture. It produces about 4.87 pounds (2.21 kg) of solid waste per person per day, which adds up to more than 284 million tons (258 million metric tons) per year. The kind of waste varies by region. More than half of the waste produced in countries classified as low to middle income is organic, made up of food and green waste. Countries classified as higher income produce much more nonorganic waste, especially plastics from packaging.

After production, waste is collected and disposed. Collection happens in cities and towns, where waste is either

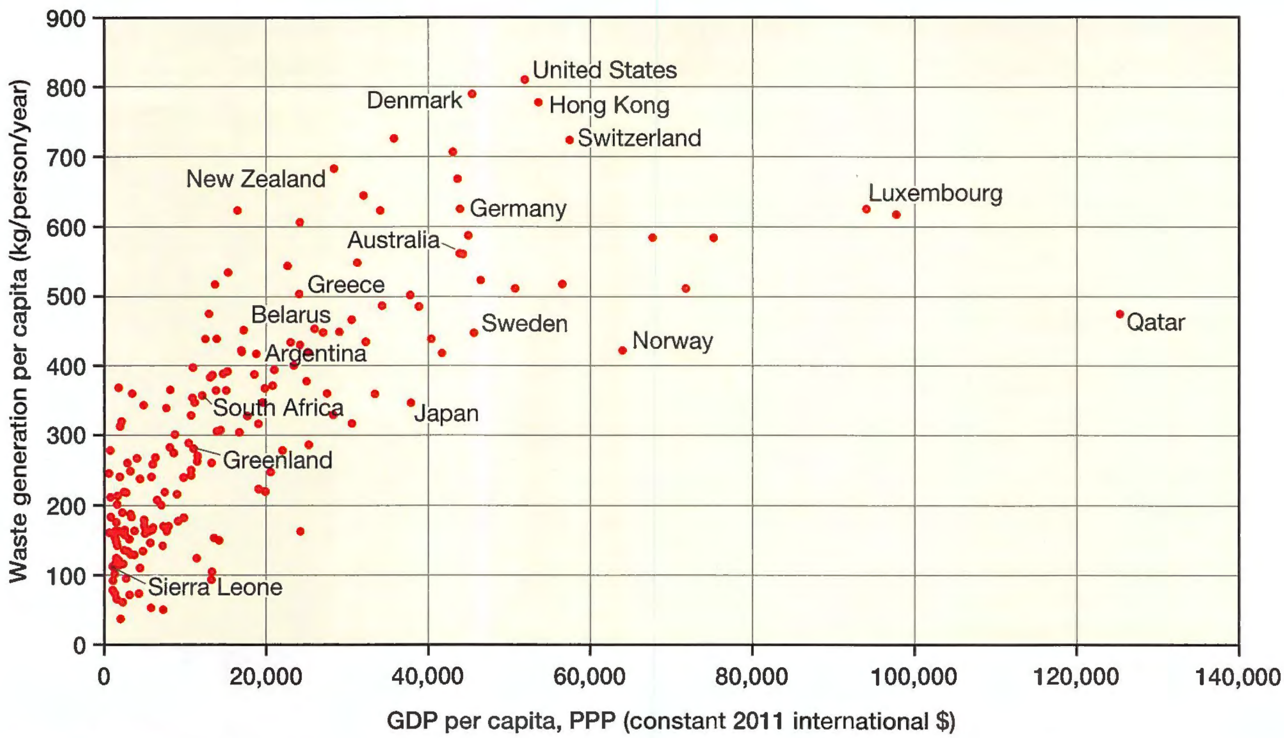


FIGURE 13.35 GDP and Solid Waste. Countries with higher gross domestic products (GDPs) generally produce larger amounts of solid waste, creating a positive correlation between GDP and solid waste.

collected door to door or dropped off at a central location. Waste collection rates are close to 100 percent in countries with higher incomes. In countries considered middle income, waste collection rates are 51 percent, and in countries classified as lower income, waste collection rates are only 39 percent (World Bank 2018). Across all country income levels, waste disposal rates are higher in cities than in rural areas.

Cities are expected to solve their own waste disposal, but disposal has become global. The growing volume of waste must be put somewhere, but space near cities is expensive and difficult to find. In lower income countries, over 90 percent of waste is deposited in open dumps, which are often located near housing in major cities. Decomposition sends methane gas into the air, rain and waste liquids carry contaminants into the groundwater below, and fires pollute the surrounding atmosphere. Breathing the gas and being constantly exposed to bacteria deteriorate the health of people who live on or near garbage dumps. In addition, dumps that receive trash beyond their capacity can create landslides that can cover homes and kill residents. In 2017, 113 people died in Addis Ababa, Ethiopia, from a landslide at a garbage dump, and in the same year, 19 died from a similar landslide in Colombo, Sri Lanka (**Fig. 13.36**).

In countries that can afford it, waste is placed in sanitary landfills. The city digs a hole, sets a floor of materials to treat seeping liquids, and then mixes layers of soil over compacted layers of waste. The number of suitable sites for sanitary landfills is decreasing, and it is increasingly difficult to design new sites. About a dozen states in the United States, mostly on the east coast, have reached capacity in their sanitary landfills. States truck or send garbage by rail to distant landfills, which is expensive and can be dangerous. If the transported waste is hazardous, a truck or train accident can have disastrous consequences.

Exporting Waste Globally, wealthier countries such as the United States, those in the European Union, and Japan export solid waste, including hazardous waste and industrial waste, to East Asia, Central and South America, the Middle East, and Africa. Accepting waste for disposal generates income, but it comes at a cost if the country does not have the capacity to treat and dispose of the waste properly. In the late 1980s, exporting waste to countries with lower incomes created controversy. Countries negotiated the Basel Convention in 1989, a treaty designed to regulate global waste export. The treaty does not prohibit exportation of hazardous waste, but it regulates the export of hazardous waste from countries with higher incomes to countries with lower incomes. The convention also sets goals to regulate the toxicity of waste close to the site of waste production. One hundred eighty-seven countries have ratified the Basel convention. The United States is the only country that has not signed it.

Until 2018, China imported more than 50 percent of the world's waste. As part of a program to reduce air pollution in China, the government officially banned the import of 24 types of waste, including plastic, in 2018 (**Fig. 13.37**). The plastic waste that Europe, the United States, and Canada sent to China was often slated for recycling but would end up being burned

Sanka Gayashan/Shutterstock.com

FIGURE 13.36 **Colombo, Sri Lanka.** Sri Lanka has both sanitary landfills and garbage dumps, and there is a world of difference between them. Sanitary landfills are dug and fully lined to keep dangerous waste from contaminating the water table and soil. On the other hand, garbage dumps like the Meethotamulla garbage dump in the background of this photo are unstable and toxic. This dump caught fire, collapsed, destroyed more than 140 houses, and killed 19 people in 2017.

or dumped. One scientist explained that the wealthier countries exported "their mixed toxic plastic wastes to developing Asian countries claiming it would be recycled in the receiving country. Instead, much of this contaminated mixed waste cannot be recycled and is instead dumped or burned, or finds its way into the ocean" (DM 2019).

In response to China's waste ban, countries who are signatories to the Basel Convention met and created a legally binding framework to reduce plastic waste. Germany immediately banned plastic bags and joined a new international waste alliance called Prevent, which included 30 countries working with major industries that use plastics in packaging, including Nestlé and Coca Cola, and major universities (DM 2019). The aims are to prevent the production of waste and to reduce waste as much as possible.

China's plastic waste ban had immediate impacts on where European plastic waste is sent (**Fig. 13.38**). China announced the ban in 2017 and began it in 2018. Europe responded by reducing plastic exports to China and increasing exports to Vietnam, Malaysia, and Turkey. While no longer importing plastic waste, China is still creating revenue from the plastic waste trade. Instead of importing the plastic into China, Chinese have built facilities across Southeast Asia, especially in Vietnam and Malaysia, where they process plastic waste. Chinese-owned plastic waste facilities are popping up across Southeast Asia, and the toxicity from burning plastic is now polluting the atmosphere above Southeast Asia instead of above China.

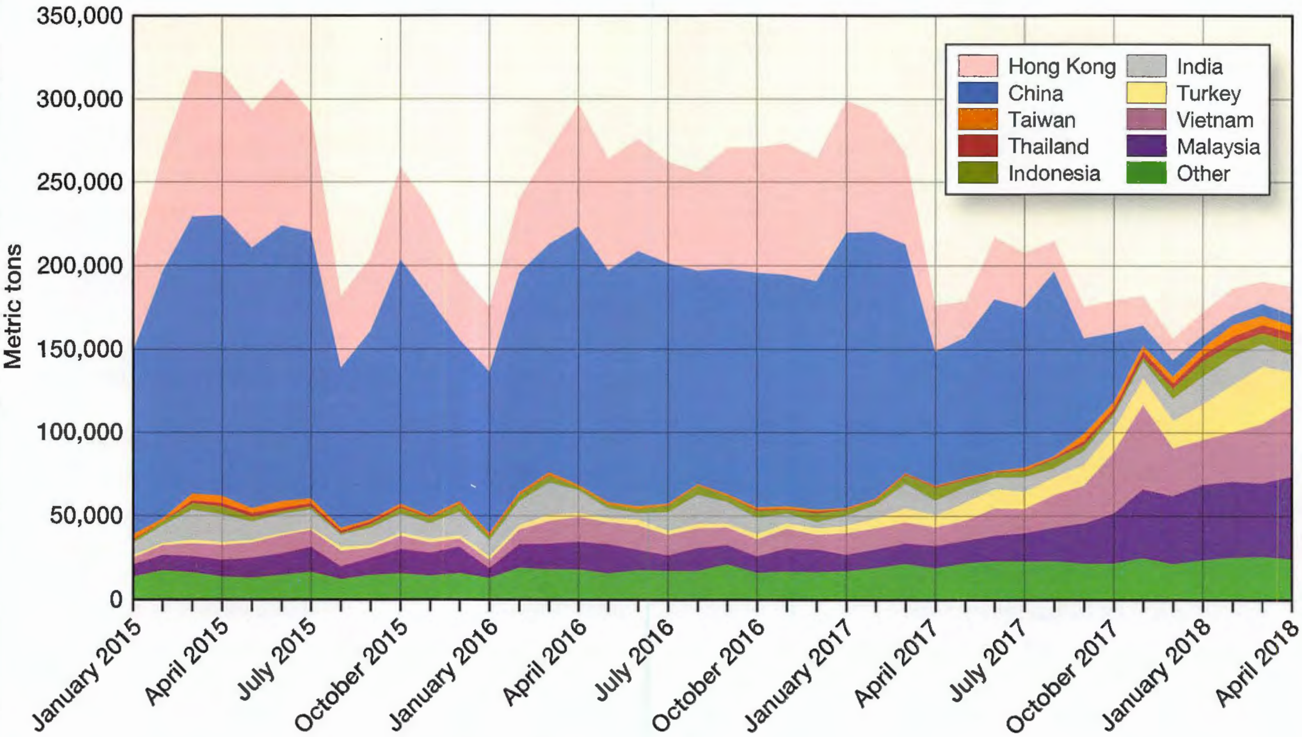
Waste Disposal on Everest

Humans are impacting even the most remote places on Earth. By the 1920s, the Himalayas included several of the last mountains that humans had not ascended. Over 30 years, 10 parties of mountaineers attempted to reach and scale Mt. Everest at 29,029 feet (8848m). The first people to scale Mt. Everest were Tenzing Norgay and Edmund Hillary, who were part of a British-led expedition in 1953. Norgay was the most experienced Himalayan mountaineer in the British-led group and was part of a Swiss team that in 1952 had reached 28,210 feet (8598m). Norgay took part in six other expeditions of Everest before the successful climb to the summit. Hillary was a New Zealand explorer and beekeeper who had attempted three Himalayan expeditions in the two years leading up to the successful scaling of Everest.

Norgay had lived his life at higher elevations. He was born in Tibet and then migrated to Nepal and married a Sherpa

Jim Xu/Getty Images News/Getty Images

FIGURE 13.37 **Guiyu, China.** Before 2018, China imported plastic trash from around the world and burned it along with other globally imported garbage at sites like this one.



Source: Adapted from "Recycling - secondarymaterial price indicator", Eurostat COMEXT, July 2018.

FIGURE 13.38 **Export of Plastic Waste for Recycling from the European Union.** Until China banned importation of plastic waste, European Union (EU) countries primarily exported plastic waste to China and Hong Kong for recycling. Since the ban went into effect in 2018, the EU sends more plastic waste to Vietnam and Malaysia.

woman. Sherpas are an ethnic group who live in Nepal at a high elevation near Everest Base Camp 1. Since the first parties attempted to reach the summit, Sherpas have fueled the climbing economy on Everest. They meet climbers at base camp and do high-altitude work to carry oxygen tanks and camping and hiking materials up Mt. Everest. A "river of money" is flowing through Sherpa communities as more and more people attempt the summit or trek to Base Camp 1. Nepal's Department of Tourism records show that as of 2019, 5891 people have reached the summit of Everest, and the pace is quickening (**Fig. 13.39**). Nepal's records show that 563 people reached the summit in 2018; 302 of the 563 were Nepali workers, including Sherpas, who had permits to work as high-altitude guides.

Human impact on Everest is increasing as the number of people with the means to hire Sherpas, pay deposits, invest in travel insurance, and buy high-tech climbing and hiking equipment is growing. In addition to those climbing the summit or attempting to do so, many more are trekking in Nepal. Tourism agencies advertise six-day treks to

AP Images/Rizza Alee

FIGURE 13.39 **Mt. Everest.** The number of climbers attempting to ascend the summit of Mt. Everest is growing quickly. On this day in May 2019, a line of climbers waited to ascend. Overcrowding makes climbing Everest dangerous for climbers and Sherpas.

Everest Base Camp 1 at 5364 meters, and while hundreds are making that trek, no report gives the exact number. But the trekkers create waste, both solid and fecal. Solid waste includes plastic, wrappers, cans, glass, paper, gear, and equipment. Parties attempting to reach the summit of Everest pay a $4000 deposit on waste removal. About half the parties get their deposit back, which happens if each member carries 18 pounds (8 kilos) of waste down the mountain. The government of Nepal hires porters to ascend to each basecamp and carry trash off the mountain.

Human waste is another matter. Fecal material is collected in bags and barrels and carried to central locations in Sherpa villages. The Nepali government pays climbers to carry waste from base camps and off the mountain (**Fig. 13.40**). The fecal material is either dumped into pits or thrown into ravines. When monsoon rains fall in the summer and water flows through the ravines, human waste is carried downstream. The waste is significantly impacting water quality for locals. Two mountaineers are developing a biogas solution that would use microorganisms to digest waste, leaving behind fertilizer and methane gas that could be captured and used for fuel.

NAMGYAL SHERPA/AFP/Getty Images

FIGURE 13.40 **Everest Base Camp, Nepal.** Nepalese climbers pose after collecting garbage from the Everest clean-up expedition. 20 Nepali climbers collected 4,000 pounds (1,800 kg) of garbage in a risky expedition to clean up Everest.

TC Thinking Geographically

Why is Mt. Everest getting so crowded? Think about **globalization** and how climbing Mt. Everest has changed from a feat of human exploration to an expression of human **identity**. What has made this shift possible and how can you see the shift in the **cultural landscape** of Mt. Everest?

Summary

13.1 Explain What Natural Hazards Are and How Natural Hazards Can Become Natural Disasters.

1. Natural hazards and natural disasters are both naturally occurring physical phenomena that create change. The difference between them is whether they cause loss of life and destruction of property. If a natural hazard, like a volcano erupting, happens close to a populated area, killing people and damaging infrastructure and houses, it is a natural disaster. Natural hazards are created by Earth processes, including movement of lithospheric plates (tectonic change), movement of water (hydrological change), and weather or climate (meteorological or climatological change).
2. Earth's lithosphere, or upper mantle and crust, is divided into more than 15 plates. Tectonic natural hazards most often happen along boundaries between plates. Plates can diverge (spread apart), converge (come together), or transform (slip past each other). When two plates of different densities converge, they form a subduction zone. The oceanic plate is denser and goes under the continental plate at the converging plate boundary. Subduction zones create massive earthquakes under the ocean, which generate destructive seismic sea waves called tsunamis. How much damage a natural disaster like a tsunami causes in terms of human lives and property damage depends on the country and whether it has a tsunami warning system. The Indian Ocean tsunami in 2004 killed 230,000 people and did more than $10 billion in damage to coasts of Indonesia and Thailand. The 3/11 tsunami in Japan in 2011 killed 15,000 people and did an estimated $235 billion in damages.
3. A flash flood happens when excessive rain or meltwater from snow overflows rivers, fills dry riverbeds, and causes a rapid rise in water levels in a short time. Flash floods are increasingly common because climate change has warmed oceans, which makes evaporation rates higher. Flash floods often happen in cities near infrastructure and buildings because impervious surfaces do not absorb rainwater, creating conditions for flooding if the storm drainage system is not well built or cannot handle the quantity and frequency of rainwater.
4. Monsoons are predictable patterns of winds coming from a certain direction for an extended period. Monsoon rains are welcome because they flood rice fields and regenerate rivers. However, climate change is making monsoon rains less predictable and more extreme. A monsoon is a climatological norm and not a natural hazard, but it can become a natural disaster if extremes bring widespread flooding or drought.

13.2 Identify the Ways That Humans Impact Earth Through Land Use, Water Use, and Resource Extraction.

1. Recognizing the rapid growth of human population and the incredible role humans play in shaping Earth's environment, scientists report we have entered a new geologic epoch, the Anthropocene. As the number of people on Earth continues to rise to a predicted 9.9 billion by 2050, people create greater strain on land by clearing forests, building infrastructure, mining minerals, growing crops, raising livestock, and creating sprawling cities at accelerated rates. Geographers differentiate between land use, which is how people use the land, and land cover, which is what is physically on the land.
2. Palm oil is an inexpensive oil derived from oil palm trees. It is used in everything from snack foods to shampoo and is found in an estimated 50 percent of items in a grocery store. Tropical forests are being deforested at greater rates and land is cleared through burning to plant oil palm plantations. Indonesia and Malaysia produce about 90 percent of the world's palm oil. Deforestation of tropical forests removes a carbon dioxide sink, releases more carbon dioxide into the air, and creates conflict between large palm oil companies and indigenous and small landholders.
3. Over the last century, humans invented and began using plastic in millions of goods and products. Once created, used, and disposed of, plastics break down slowly over time but do not biodegrade. They are either directly disposed of in the ocean or find their way there from beaches, through waterways that empty into the ocean, through improper disposal or incineration, or through natural hazards like tsunamis that demolish the built environment and carry waste into the ocean. Plastics have entered the food chain, which is dangerous for sea life and humans.
4. Since the Industrial Revolution, humans have relied on hydrocarbons as a source of fuel. Coal first powered steam engines in factories, trains, and ships. The advent of the automobile created demand for oil. Indoor heating and cooling systems create demand for energy, and power plants are often fueled by coal. Natural gas burns cleaner than oil, and demand for natural gas is increasing. Extracting natural gas through fracking has consequences, including pollution of groundwater from the chemicals pumped into the ground to release and extract the natural gas.

13.3 Explain How Climate Change Is Impacting Human–Environment Interactions.

1. The greenhouse effect is a naturally occurring process in Earth's atmosphere. The sun emits shortwave radiation, which Earth absorbs. Earth emits longwave radiation that creates sensible heat (the heat we feel in temperature). Some of the longwave radiation from Earth travels toward the top of the troposphere (the lowest layer of Earth's atmosphere). Greenhouse gases at the top of the troposphere absorb some of the longwave radiation from Earth and counter-radiate it back to Earth's surface. This naturally occurring process keeps Earth at a livable temperature for humans. The basic premise of climate change science is that humans are burning hydrocarbons, which release excess greenhouse gases that intensify the greenhouse effect and trap more energy in Earth's atmosphere than would be trapped naturally. These human-created greenhouse gases are a major concern of climate change scientists.
2. With higher temperatures and more energy in the atmosphere, evaporation rates increase. Through evaporation, liquid water turns to water vapor. Energy must be added in the form of latent heat to transform liquid water to water vapor. In a storm, water vapor is condensed into liquid water, and in the process of condensation, latent heat is released. Because energy fuels evaporation and is released through condensation, higher temperatures and warmer oceans mean that more energy goes into storms, whether hurricanes or midlatitude cyclones.
3. Geographers use GIS to help understand and solve environmental problems, including water scarcity. They have studied conflict between countries within river basins and have found that water stress does not generally compound conflict. Instead, under water stress, countries are more likely to agree to solutions for equitable water use.

13.4 Explain How Human Consumption Is Changing the Scale of Human Impact and Challenging Sustainability.

1. Human consumption is increasing rapidly with growing populations and rising levels of income. At the most basic level, we consume water, oxygen, and organic and mineral materials. Over time we have developed increasingly complex ways of using resources in pursuit of intensified agricultural and industrial production. Consequently, many societies now consume resources at a level and rate that far exceed basic subsistence needs. The ecological footprint is the impact a person or country has on the environment. It is measured by how much land is required to sustain a person's or country's use of natural resources and to dispose of the waste produced.
2. The Brundtland Report defined the concept of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainable development is often considered according to three pillars: social, economic, and environmental.
3. Socioeconomic well-being and solid waste production have a strong, positive correlation. Rising middle and upper classes globally and especially in the two most populated countries in the world, China and India, are creating higher levels of consumption globally. Greater consumption means greater waste production. The United States, Canada, and Europe used to export waste to China. In 2018, China stopped the import of 24 kinds of waste, including plastic. In response, 187 countries, not including the United States, met to extend the Basel Convention, creating a legally binding framework to reduce plastic waste. Chinese businesses continue to profit off waste production and are building plastic waste disposal sites in Southeast Asia, especially in Malaysia and Vietnam. Europe shifted export of plastic waste from China to Malaysia, Vietnam, and Turkey after China instituted its ban.

Self-Test

13.1 Explain what natural hazards are and how natural hazards can become natural disasters.

1. Natural disasters cause:

a. damage to property and permanent changes in landscape.

b. permanent changes in landscape and loss of human life.

c. damage to property and loss of human life.

d. loss of human and animal life.

2. When a natural disaster hits an area with higher incomes, damages will likely be:

a. higher in terms of property loss than loss of lives.

b. higher in terms of loss of lives than property loss.

c. higher in terms of landscape changes than loss of lives.

d. higher in terms of loss of lives than landscape changes.

3. The Mid-Atlantic Ridge is a good example of a ______ plate boundary.

a. converging **c.** transforming

b. subduction **d.** diverging

4. When you study a map of the Ring of Fire and look at the plate boundaries around the Pacific plate, you can tell that many of the plate boundaries (especially near Alaska and Japan) are ______ because of the presence of ______.

a. transforming / earthquakes

b. subducting / trenches

c. diverging / volcanoes

d. converging / mountains

13.2 Identify the ways that humans impact Earth through land use, water use, and resource extraction.

5. The current geologic era is often called the ______ because of the rate of human impact on the environment.

a. Amorphous **c.** Pleistocene

b. Manmade **d.** Anthropocene

6. If you look at a map of land cover, you can tell if an area is agricultural or forest. If you look at land use, you can tell differences in:

a. farming methods, such as intensive versus extensive.

b. how long the land has been used for agriculture.

c. the amount and frequency of pesticide use.

d. the presence or absence of irrigation systems.

7. Growing demand for palm oil, which is now used in about 50 percent of products in grocery stores, has led to tropical deforestation, especially in Malaysia and Indonesia. Tropical deforestation is problematic for all of the following reasons except:

a. tropical forests are a major sink (user) of carbon dioxide from the atmosphere.

b. burning trees to clear a tropical forest releases carbon dioxide into the atmosphere.

c. clearing tropical forests creates conflict between large palm oil companies and indigenous and small landholders.

d. clearing tropical forests creates conflicts between countries that compete for large palm oil company investments.

8. True or False: Once created, used, and disposed of, plastics break down slowly over time but do not biodegrade.

13.3 Explain how climate change is impacting human–environment interactions.

9. The greenhouse effect is naturally occurring and creates an atmosphere that is ______ than/as Earth's atmosphere would be without it.

a. warmer **b.** colder **c.** about the same

10. With climate change, the atmosphere has higher rates of evaporation because:

a. warm air can hold more water vapor than cold air.

b. cold air can hold more water vapor than warm air.

c. warm air has a higher specific heat capacity than cold air.

d. cold air has a higher specific heat capacity than warm air.

11. Geographers who study international conflict over river basins have found that water scarcity generally:

a. leads to higher conflict between countries in a river basin.

b. leads to higher cooperation between countries in a river basin.

c. is caused by anthropogenic overuse of water.

d. is caused by climate change.

12. The Aral Sea in Central Asia dried up significantly in a relatively short time primarily because:

a. climate change created drought.

b. farmers diverted water to grow cotton.

c. Uzbekistan built a dam that diverted water from reaching the sea.

d. Kazakhstan added salt to the Aral Sea to build fish farms.

13.4 Explain how human consumption is changing the scale of human impact and challenging sustainability.

13. The countries with the overall highest ecological footprint are China, the United States, and India. When measuring ecological footprint per capita, the top five countries in terms of impact are primarily:

a. wealthy. **b.** poor. **c.** arid. **d.** humid.

14. Using remote sensing and GIS, a team of geographers found that impervious surfaces are a good proxy (substitute) measurement of:

a. resource extraction.

b. resource consumption.

c. lower precipitation from climate change.

d. higher precipitation from climate change.

15. Since the 1980s, China has been the primary importer of waste generated by the United States, Canada, and Europe. In 2018, China banned importation of 24 types of waste, including plastic. Starting in 2018, Europe shifted exportation of plastic waste to ______, where Chinese businesses set up plastic disposal sites.

a. Australia and New Zealand **c.** Kenya and Uganda

b. Chile and Argentina **d.** Malaysia and Vietnam