Chapter 1

Introduction

What is geography?

In the news, immigrants risk their lives to reach safety and opportunity in new lands, whereas some citizens in destination countries worry about losses of jobs and their cultures. In parts of the world, parents struggle to feed multiple children, whereas in other places, employers struggle to fill positions as populations shrink. The decline of manufacturing employment in the developed economies of Europe and North America has devastated many towns and left myriad workers unemployed or with wages well below their previous salaries. At the same time, a burgeoning working class has developed in much of Asia as farmers leave the fields and take up jobs in urban factories. Struggles for political power depend on how voting districts are drawn, while citizens hotly debate the influence of religion in public life and the benefits and challenges of linguistic and ethnic diversity. These topics and more are the subject of human geography. But what makes geography distinct from other disciplines that also study these issues?

Students often associate geography with identifying countries, cities, rivers, mountains, and other features on a map. Although the ability to find features such as these on a map is useful to geographers, it is not the focus of geography. Geography exists as a distinct academic discipline because of its focus on physical space, and for this reason, it is considered a spatial science. When geographers use the words *space* and *spatial*, it is in the context of geometric space, not outer space. It is concerned with the three-dimensional location of features on the surface of the earth. To put it simply, the key questions that geographers ask are, Where are things located, and why are they there?

These questions give geographers a unique understanding of how the world is organized and how human and physical features interact to create unique places and regions. They look at the spatial patterns, or distributions, of everything from plant species to unemployment. Geographers further study the spatial relationship between different phenomena, such as how political attitudes and religious beliefs overlap in certain places. The concepts of origin, diffusion, and spatial interaction are also important elements of geography. The world religions of Christianity, Judaism, and Islam originated in the Holy Land of the Middle East and then diffused across the globe, transforming societies as they spread to new locations. Finally, geography looks at human-environmental interaction, or how humans influence and change the environment, as well as how the environment shapes humans in terms of where you live, what you eat, and more. Understanding spatial distributions and the processes that drive them helps you understand the world in which you live. This knowledge allows you to make predictions and decisions about how to address a range of pressing social and environmental issues. Each of these concepts is discussed in detail later in this chapter.

Geographic inquiry is thus wide-ranging and focuses on big issues, with the goal of understanding the causes and potential solutions to economic development and employment, food production, urban congestion, population explosions and busts, religious and ethnic conflict, climate change, plant and animal extinctions, and other contemporary challenges (figure 1.1).

ArcGIS® Online mapping service

Considering that the guiding principle of geography is understanding where things are located and why they are there, maps are an essential tool. Although people have used maps for millennia, in recent decades maps have evolved from being static and drawn on physical media to being dynamic and digital. This book examines a range of geographic issues, drawing heavily on the power of ArcGIS Online, Esri's digital mapping service at www.arcgis.com.

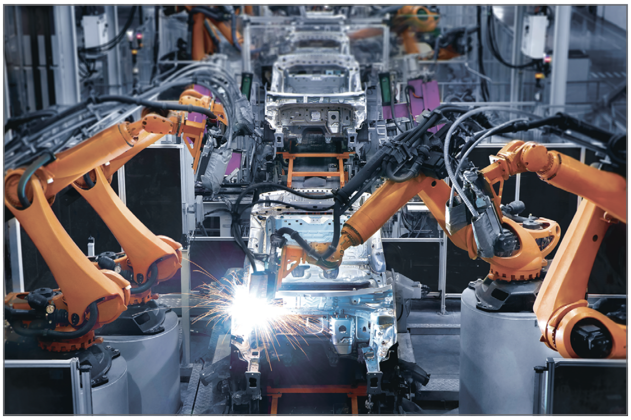


Figure 1.1. Automobile assembly line. The spatial pattern of economic development, such as where industry locates, is one issue explored by geographers. The automobile industry has endured dramatic shifts in recent decades as manufacturing has moved away from Detroit, Michigan, to factories in the southern United States, Asia, and Latin America. These shifts, as well as technological change such as the increased use of robotics, impact the quantity and types of employment. Photo by Xieyuliang. Stock photo ID: 587205803, Shutterstock.

ArcGIS Online is a powerful cloud-based system that allows you to explore and analyze thousands of geographic datasets. Traditional data, in the form of text and spreadsheets, becomes immensely more useful by adding a spatial component through maps.

For instance, by mapping a conventional list of customers' addresses, you can not only visualize where customers live but also identify neighborhoods in which few or no customers reside. Analytic tools can enhance an understanding of customers by mapping statistically significant hot spots, in which clusters of customers live, and cold spots, in which few customers live. By detecting these patterns, you can analyze underlying social, economic, and environmental characteristics of the hot spots and cold spots. You can add data to the map, which may indicate that the cold spot is due to concentration of a distinct immigrant group. Based on this geographic information, you can develop a site-specific marketing campaign to appeal to this group.

In this book, most maps are produced with data from ArcGIS Online. This allows students and instructors to observe maps in a static, printed format and explore them in detail in ArcGIS Online. In addition, each chapter provides supplementary ArcGIS Online exercises, in which you will explore geographic datasets with sophisticated analytic tools.

Considering that this book is built around ArcGIS Online, before moving on to more detail on the discipline of geography, it is important to first understand how maps function and how new digital technologies are reshaping the way geographers study the world.

Geographic tools and data

Geospatial technology

The traditional tools that geographers have used throughout history have dramatically transformed with the development of geospatial technologies. These digital technologies developed in recent decades and allow geographers to collect data about the earth and run sophisticated analyses. With the Global Positioning System (GPS), remote sensing, and GIS, vast quantities of data about human and natural features can be collected with great precision and analyzed with sophisticated techniques. Most people are not even aware that these geospatial technologies have become an integral part of our lives. Your smartphone can track your location with GPS, and Google Maps provides vast quantities of satellite imagery and geographic data on roads, businesses, parks, public buildings, and more. Based on this information, you can determine where you are, and then calculate the fastest route from your location to a coffee shop or find not just any local coffee shop but one with a high customer rating.

GPS identifies the location of a receiver unit (such as your smartphone) on the surface of the earth. Created by the US Department of Defense to aid in precision targeting and navigation, the system relies on three components: a receiver unit, a constellation of satellites, and ground-based tracking stations (figure 1.2). A system of 24 satellites circles the globe, and the precise location of each satellite is tracked by ground stations. GPS receivers communicate with satellites by sending and receiving radio waves. The time it takes for radio waves to travel between the receiver and a satellite is used to calculate the distance between them. With a minimum of three satellites, a 2D location (latitude and longitude) on the earth's surface is determined. With at least four satellites, a 3D location (latitude, longitude, and altitude) is determined. Based on this system, a GPS receiver works only when it has a clear line of sight to satellites and thus is of limited use indoors. However, many smartphones use technology that compensates for this limitation by using Wi-Fi and cell tower connections with known latitude and longitude coordinates to determine location.

The most common use of GPS is for navigation. You use GPS technology every time you use Google Maps on your phone to identify where you are and where you need to go. GPS also assists navigation for aircraft, ships, and ground vehicles. But GPS receivers are also powerful tools used for field data collection. Many GPS units allow for the collection of data as points, lines, and areas. An urban arborist can collect point data on trees, noting not only each tree's location but also information on the species, height, health, and more.

Figure 1.2. GPS consists of a receiver unit, ground control stations, and a constellation of satellites. Ground control stations track the precise location of satellites. Location is determined by measuring the time it takes radio signals to travel between a receiver unit and satellites with known locations. Image by Art Alex. Stock vector ID: 532342483, Shutterstock.

A surveyor can collect line data on property boundaries and roadways, with associated information on owners, condition, material, and so on. A biogeographer can collect data on areas of illegal logging, noting where the logging has occurred as well as the time and type of tree that is being stolen.

Another important geospatial tool is remote sensing. Remote sensing consists of images of the earth's surface, typically taken from satellites or aircraft (figure 1.3). Passive remote sensing instruments mounted on these platforms read reflections of the sun's radiation or heat emitted from the earth's surface. Different types of features, such as asphalt, cement, water, soils, rocks, and vegetation types, all reflect radiation differently, thus giving features a unique spectral signature. Active remote sensing instruments emit energy, such as with a laser or microwaves, which bounces off features, showing their location and shape.

One of the most common uses of remotely sensed imagery is for basemaps, as used in digital maps such as ArcGIS Online. However, imagery goes well beyond simple basemaps. By analyzing the spectral signature of features, you can classify areas such as those in a thematic map of land use or land cover that shows urban areas, forests, different crop types, and more (figure 1.4). Remote sensing is also used for economic research by looking, for example, at the number of cars in retail parking lots and viewing tanker railcars at oil refineries. In environmental monitoring, it is used to track oil spills and determine the health of forests. Local governments use remote sensing to study urban growth and transportation needs. International aid and human rights organizations use it to help evaluate the condition of refugee settlements or identify areas with mass graves from war crimes. In public health, remote sensing helps evaluate areas of mosquito infestation.

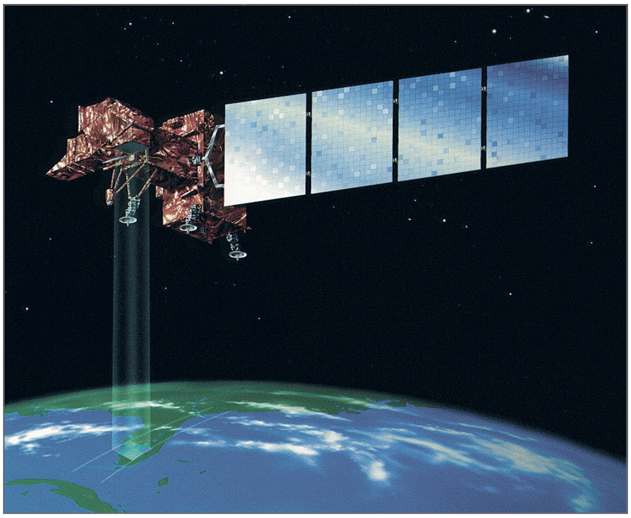


Figure 1.3. The Landsat 7 satellite, operated by the US Geological Survey. Satellites and aircraft are common sources of remote sensing imagery. Image by NASA.

Figure 1.4. Satellite remote sensing imagery. Remote sensing data can be used for economic analysis by counting cars in commercial areas, as indicated in a mall in Riverside, California, *top*. False-color infrared images, which indicate vegetation in red, are used to identify land uses and monitor the health of vegetation, as indicated around Des Moines, Iowa, *bottom*. Explore the chapter 1 web maps at links .esri.com/HG_01. Data sources: World Imagery basemap, Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS user community. Infrared vegetation. USA NAIP Imagery: False Color. Esri; data sources: Esri, USDA Farm Service Agency.

As these examples indicate, remote sensing data is used in numerous professional and technical fields.

GIS is a powerful tool for creating, storing, and analyzing geographic data. GIS combines spatial data (in other words, the location of things) with attribute data (in other words, characteristics of things), bringing the power of maps and spreadsheets together. GIS data is stored and viewed as layers, in which each layer represents a specific theme (figure 1.5). For instance, a municipal GIS database can have a layer of city trees with their location as well as attribute information for tree species, health, and height. Another layer can have sewer systems with attribute information for diameter and age. Another layer can have parcels with attributes for ownership, land-use zoning, and type of structure.

GIS is a powerful tool for studying spatial distributions and spatial relationships. By looking at a layer of mosquito habitat and comparing it with a layer of recent urban growth, public health officials can analyze and predict how many malaria infections are likely to occur. With a layer of household income, a layer of ethnicity, and a layer of population density, a company can find the best location to sell a product targeting an ethnic group. For environmental analysis, a layer of roads and a layer of tree species can be used to predict where logging is likely to occur.

Because of the numerous uses of geospatial technologies, many employment opportunities exist for people with these skills. Private companies, such as insurers, market researchers, and environmental consultants, need people who can collect data and map it with geospatial technologies. Government agencies, such as those in urban and community development, environmental protection, public health, public works, and economic development, need people with these skills, as well. Nonprofit organizations that provide social services, protect the environment, and improve health and economies locally and internationally also hire people with backgrounds in geospatial technology.

Figure 1.5. A GIS consists of layers of data, which can include land use, roads, parcels, buildings, vegetation, topography, and more. Image by Naschy. Stock vector ID: 526267657, Shutterstock.

Data sources

Geographic data can be produced in a variety of ways. Private companies produce many types of data, as do governments and researchers at universities and think tanks.

Private companies often collect customer data, such as home addresses and purchasing history. With this data, they can produce maps showing the types of products and services people buy in different parts of cities. A detailed picture of population can be mapped by adding census data collected by governments, which is based on household surveys and can include the number of people, race and ethnicity, income, education, and other variables. Phone interviews and mail surveys can also be used to collect data and map people's attitudes and opinions on public issues.

Geospatial technologies, such as GPS and airborne remote sensing, are also important sources of data. As mentioned previously, GPS units are used in the field to collect data on any number of things, such as the location of potholes in streets, graffiti locations, buildings in rural villages, well sites, vegetation clusters, and bird nests. Remote sensing technology uses satellites and aircraft to collect data on larger areas.

With this technology, data on crop types and health, urban growth, deforestation, illegal construction, and more can be collected.

Geographers use field analysis of the cultural landscape. By going into the field and making observations of the cultural landscape, from how people move and interact in parts of the city to types of buildings and land uses in different locations to people's perceptions of neighborhoods, geographers collect and map a range of data.

Data quality and metadata

With numerous sources of geographic data, users must be careful when evaluating data quality. Many times, a GIS user will find interesting data that appears useful for a work project or class paper. However, without investigating the quality and source of the data, the user may end up with inaccurate or misleading analysis results.

The most common types of data quality issues include spatial, temporal, and attribute accuracy; completeness; and data source reliability.

Spatial accuracy

Are features in the correct location, and what degree of precision do they have? For instance, is a hospital mapped at the correct street address, or did it get placed at a similar address in the wrong city? Is a property boundary mapped at a survey level of precision down to centimeters, or is it mapped at a coarser scale, such as meters? If you are building a perimeter wall around a property, a dataset mapped with an accuracy of meters will not suffice.

Temporal accuracy

When was the data created? A map showing voting patterns by county can clarify attitudes toward social issues. However, map users need to know whether the data is current or whether it was created too long ago to be useful.

Attribute accuracy

Are the values in attribute fields correct? For instance, does a map of average income by zip code have the correct values? Poorly built databases may have errors, or the numbers presented may have wide margins of error that must be accounted for when interpreting patterns.

Completeness

Are all features included, or are some missing? For instance, when mapping home burglaries, is data available for all parts of the city? If not, there may be a false impression that no burglaries occur in one area, whereas in reality, the absence of burglaries may be due to missing data.

Data source

The origin of the data can indicate level of quality. For instance, a dataset made by the US Census Bureau should be based on high data quality standards. A dataset made by an unknown blogger or for a class project may not be as reliable.

Data quality and other important information are part of a spatial dataset's metadata. Metadata is information about a dataset. It can include data quality, as discussed, as well as information on data collection methods, who produced the data, projection and coordinate systems, and more. When evaluating spatial data, you should review the metadata.

Map basics

To work well with geospatial technologies, it is important to understand maps and the ways in which data is presented with them. Different map types are available for conveying different varieties of data, whereas map scale can influence levels of detail and the types of spatial processes observed. Map projections can influence the user's perceptions of size, shape, and direction when reading maps, and various coordinate systems are used to describe where features are located. Count and rate data are often misunderstood by novice map users, whereas classification schemes can have a significant impact on how people interpret data. Each of these issues is discussed in detail in this section.

Map types

Maps can be classified into two broad categories: reference maps and thematic maps. Reference maps have a range of general information on them. For instance, US Geological Survey (USGS) topographic maps have information on natural and cultural features, such as elevation, roads, public buildings, water features, and political boundaries. Many online maps, such as Google Maps, also have general reference information on roads, businesses, public institutions, entertainment, and more. When you create a map in ArcGIS Online, you are presented with a topographic reference map as a basemap (figure 1.6).

Thematic maps, in contrast, focus on a single topic, or theme. This type of map may show population density, average income, dominant language, soil type, annual precipitation, or any number of other physical

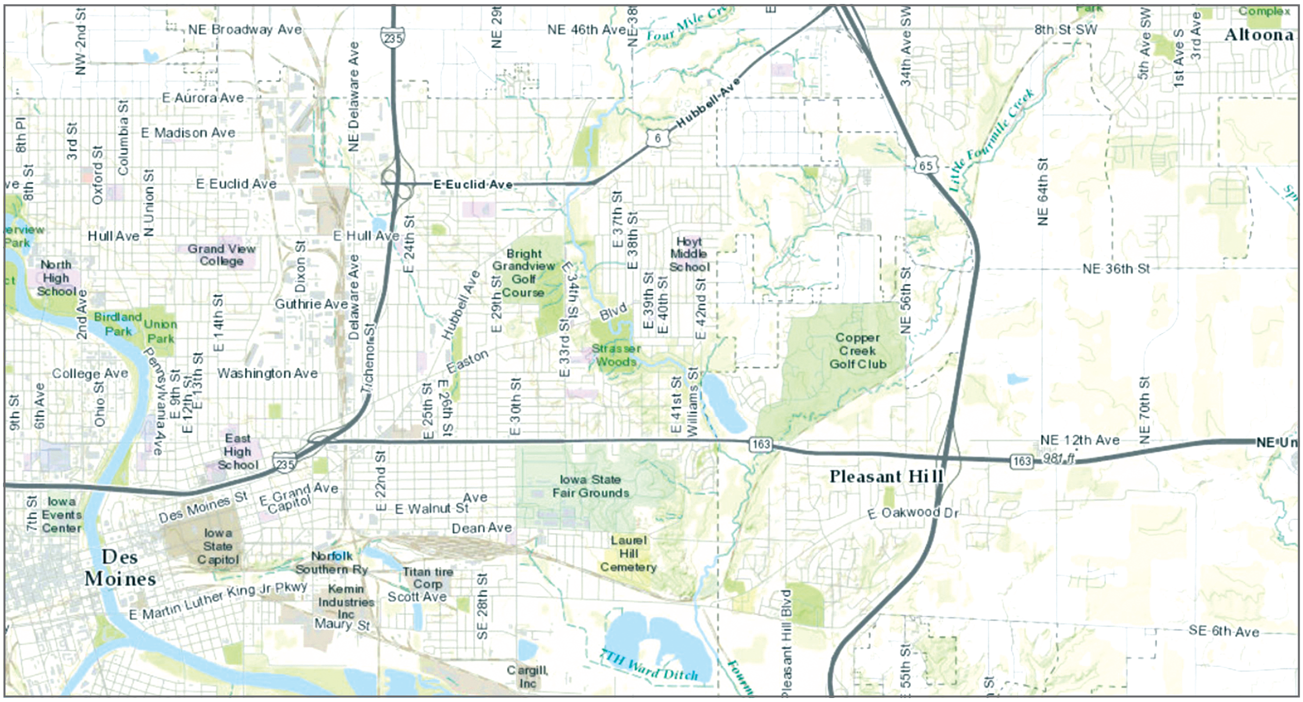


Figure 1.6. Reference map. The topographic basemap in ArcGIS Online includes general information, such as schools, roads, golf courses, cemeteries, and parks. Data sources: World Topo Map. HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS user community.

or cultural features. When you add layers to ArcGIS Online (excluding basemaps), such as ArcGIS Living Atlas of the World layers, you are adding thematic maps. Thematic maps can be represented in several ways, including choropleth maps, graduated-circle maps, isoline maps, dot density maps, flow line maps, and cartograms.

A common type of thematic map is the choropleth map. Choropleth maps use shades or colors to represent values of a variable within an area, such as census tracts, cities, counties, or states (figure 1.7).

Like choropleth maps, graduated-circle maps also represent values of a variable within an area. However, instead of using shades or colors to distinguish values, circles of different sizes are used. A large circle represents a high value, whereas smaller circles represent lower values (refer to figure 1.7).

Isoline maps consist of lines that connect points of the same value. Typically, isoline maps are used to map continuous surfaces, where data values change often over the earth's surface, such as values for temperature or elevation (figure 1.8).

Dot density maps use dots to represent a specified value within a geographic feature (refer to figure 1.8). If the population of a county is 10,000 people, a dot density map in which one dot equals 1,000 people would have 10 dots randomly placed within the county borders.

Flow line maps use lines of varying thickness to show the direction and quantity of spatial interaction between places. Thicker lines represent larger quantities, whereas thinner lines represent smaller quantities. These maps are often used to represent trade and migration flows between countries (figure 1.9).

Cartogram maps distort the area of features based on the value of a variable. A cartogram of population will show places with more people as larger and places with fewer people as smaller. In figure 1.9, state populations are indicated for three time periods. The size of each state varies according to its population size. Note how western states, such as California, change in size in each period.

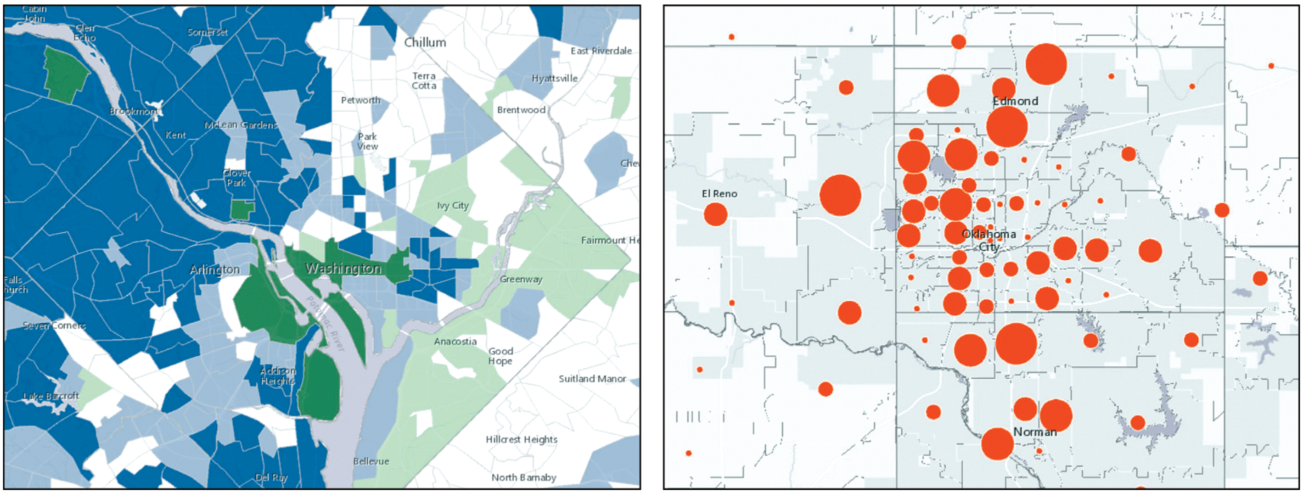


Figure 1.7. Thematic maps: choropleth and graduated circle. Choropleth maps use colors or shades within areal features to represent data. Graduated-circle maps use circles of different sizes to represent data. In the choropleth map, *left*, of median income in Washington, DC, dark blue is higher income and dark green is lower income. In the graduated-circle map, *right*, of people who purchased athletic shoes in the past 12 months in Oklahoma City, Oklahoma, larger circles represent more purchases. Explore the chapter 1 web maps at links.esri.com/HG_01. Maps by author. Data sources: 2016 USA Median Household Income, Esri, US Census Bureau. 2016 USA Adults That Exercise Regularly, Esri and GfK US, LLC, the GfK MRI division.

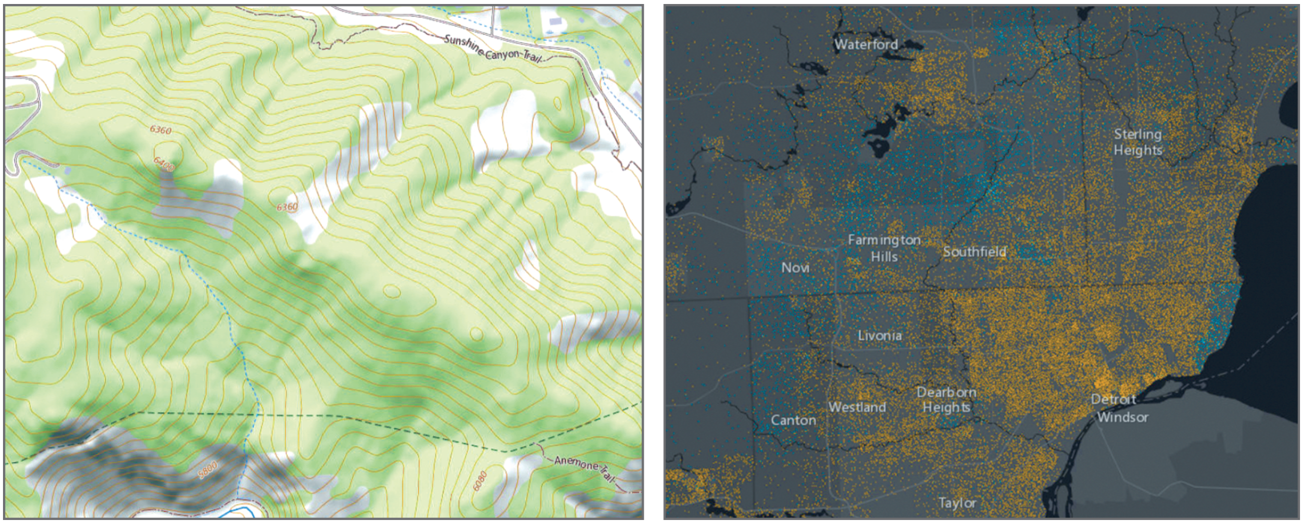


Figure 1.8. Thematic maps: isoline and dot density. Elevation contours on a topographic map are a type of isoline. Dot density maps use dots to represent values, such as number of households. In the isoline map, *left*, of topographic contours in Boulder, Colorado, each isoline represents 40 feet of elevation. In the dot density map, *right*, of income extremes around Detroit, Michigan, each dot represents 20 households, divided into those earning more than $200,000 per year and those earning less than $25,000 per year. Explore the chapter 1 web maps at links.esri.com/HG_01. Data sources: USGS National Map by Esri—USGS The National Map: National Boundaries Dataset, National Elevation Dataset, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; US Census Bureau—TIGER/Line; HERE Road Data. Income Extremes by Lisa Berry—Esri.

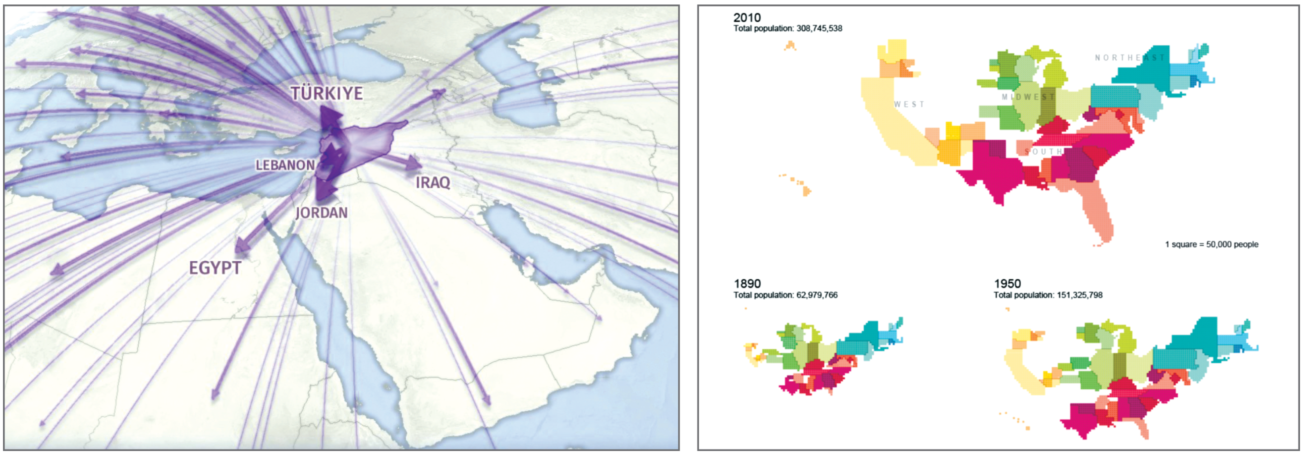


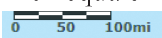
Figure 1.9. Thematic maps: flow line and cartograms. Flow line maps, *left*, use arrows of different widths to represent direction and quantities. The flow line map shows Syrian refugee flows in 2014. Cartograms, *right*, distort the area of feature based on their value. Image sources: The Uprooted by Esri Story Maps Team; data sources: UNHCR, Airbus Defense and Space. Cartograms of State Populations in 1890, 1950, and 2010 by US Census Bureau; data sources: Census 2010 tables.

Map scale

Scale is another issue to be aware of when creating and interpreting maps. Real estate companies often produce maps with no scale or with distorted scales to make desirable places seem closer. For instance, a real estate map may include the location of a new housing development, with lines showing freeways, beaches, and parks, giving the impression that they are all nearby. However, with no given scale, these places are often drawn to appear much closer than they really are.

Properly produced maps include a clearly defined map scale that indicates the ratio of map distance to real-world distance. The scale allows map readers to measure the size of features and the distance between them. Map scale is represented verbally, graphically, or as a ratio or fraction, as such:

Verbal scale: 1 inch equals 1 mile.

Graphic scale: 

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Ratio scale: 1:24,000.

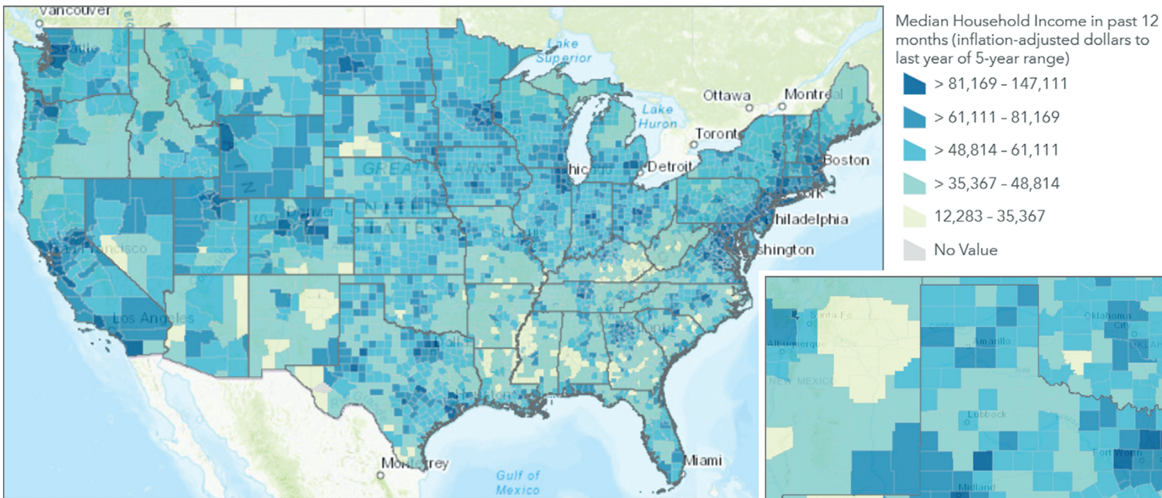
Fraction scale: 1/24,000.

In the case of ratio and fraction scales, the units remain the same on both sides of the scale. Using the examples noted, 1 inch on the map represents 24,000 inches in the real world.

Maps are often described as being large scale or small scale (figure 1.10). A large-scale map refers to a larger fraction or ratio, so features appear larger, whereas a small-scale map refers to a smaller fraction or ratio, so features appear smaller. For instance, 1:24,000 is a larger ratio than 1:100,000, so it is a larger-scale map.

Large-scale maps are more focused, or zoomed in, on a specific area. They cover a smaller area and include more detail because the features are larger. A city map is a larger-scale map than a country map and thus shows more features at the city scale. Small-scale maps are zoomed out and cover a larger area with less detail. A country map is a smaller-scale map than a city or neighborhood map.

To remember the difference between large- and small-scale maps, either think in terms of ratios or



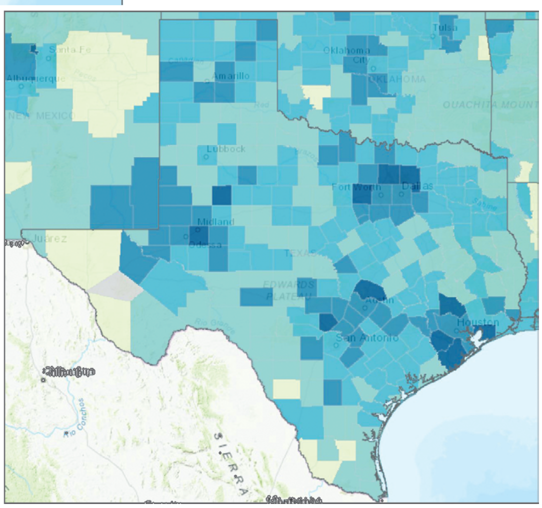


Figure 1.10. Small-scale and large-scale maps. Large-scale maps are more zoomed in than small-scale maps. Small-scale maps have smaller ratio scales and features are smaller. *Left*, US states appear smaller. *Right*, large-scale map where features are larger. Explore the chapter 1 web maps at links.esri.com/HG_01. Maps by author. Data sources: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS.

fractions, or use this trick: your neighborhood looks larger on a large-scale map (because it is more zoomed in), whereas your neighborhood looks smaller on a small-scale map (because it is more zoomed out).

Although map scale is important for measuring size and distance and determining the level of detail indicated, it is also important to understand scale in terms of how it affects the spatial patterns observed by geographers.

This effect is often referred to as the modifiable areal unit problem (MAUP). The unit of measurement used for analysis, be it countries, states, counties, cities, or some other area, can strongly influence the patterns observed on the map. For instance, at a state scale, the "red state/blue state" divide in US presidential elections indicates states such as Texas as solidly red (Republican Party). But by changing the scale of analysis, new spatial patterns emerge. At a county scale, large urban areas within Texas appear as blue (Democratic Party) patches (figure 1.11). So, although a state level of analysis is useful in understanding the Electoral College for presidential elections, a county-scale analysis is more useful for understanding US House of Representatives and local election results.

There is no single proper scale of analysis for all geographic questions. Rather, the proper scale depends on the question being asked. If the US government has funds available to help states tackle high unemployment, analyzing unemployment rates at a state level makes sense. On the other hand, if a city government wants to identify neighborhoods with high unemployment rates, the proper scale of analysis would be urban neighborhoods.

Geographers are interested in spatial patterns at a range of scales, always keeping in mind how patterns and processes interact between global and local levels. These interactions have become more essential to understand because of globalization, the process whereby places become increasingly interconnected through communication networks, transportation technology, and political policies.

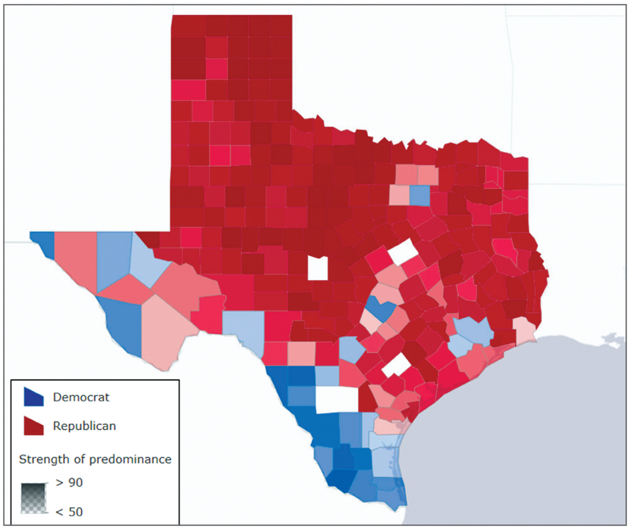


Figure 1.11. Scale of analysis and the modifiable areal unit problem. The areal unit used in a map heavily influences observed spatial patterns. Data aggregated at a state scale illuminates different patterns from those revealed by data aggregated at a county scale. Texas is heavily red (Republican Party) when mapped at the state level. It has voted Republican in all presidential elections since 1980. But by changing the areal unit to counties, areas of blue (Democratic Party) are revealed. Maps by author. Data sources: State level–Federal Election Commission. Texas counties–Texas Office of the Secretary of State.

For instance, global patterns of manufacturing output and employment show dramatic shifts from developed countries to developing countries, especially China and other Asian nations. This shift has had a profound impact on development patterns at a global scale, most obviously with the economic, political, and military rise of China. However, these global processes also play out at a more local scale. The shutdown of automobile factories in Detroit, Michigan, has had a devastating impact on that city.

Numerous impacts, such as massive population decline, abandonment of entire neighborhoods, increases in crime, and municipal fiscal crises, have played out locally in Detroit, all because of global shifts in manufacturing production. At the same time, local-scale impacts in China have transformed many cities, with greater wealth and opportunity combined with air, water, and soil pollution.

Thus, when deciding the proper scale for creating a map, you should first have a clear idea as to what processes—from global to local—you want to address.

Map projections

Map projections are necessary to transform a 3D spherical globe into a 2D flat map (figure 1.12). Imagine peeling an orange and making the peel flat: it is an impossible task without tearing and compressing the peel. The same problem arises when going from a spherical world to a flat map.

Map projections cannot preserve all spatial elements of a map: area, shape, distance, and direction. Map projections that preserve area are known as equal-area projections. These projections show the correct area, such as the square miles of countries and states, but shape, distance, and direction are incorrect. Projections that preserve shape are known as conformal projections. With these projections, the shape of features, such as country or state boundaries, is correct, but area, direction, and distance measurements are distorted.

The Mollweide projection is a good example of an equal-area projection (figure 1.13). Area is preserved, so, for example, the square miles within each country are accurate. However, shape, distance, and direction are distorted.

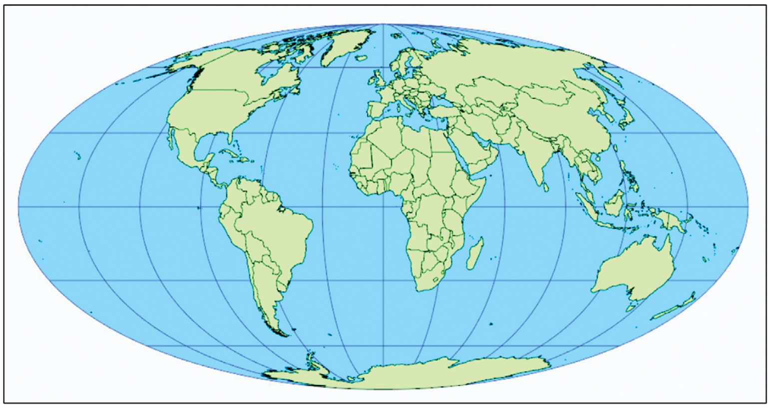
A popular map projection that illustrates the tradeoff between area and shape is the Mercator projection (also figure 1.13). This projection is conformal, so shape is preserved, but area is dramatically distorted toward the poles. For example, Greenland seems to be the same size as the entire continent of Africa, although it is about 14 times smaller. ArcGIS Online uses the Web Mercator projection, which is a slightly modified version of the traditional Mercator projection.

Coordinate systems

Considering that the major focus of geography is on where things are located, geographers use various types

3D ArcGIS Scene 2D ArcGIS Map

Figure 1.12. Map projection. When you transform a spherical representation of the earth (ArcGIS scene, left) to a flat representation (ArcGIS map, right), distortions are unavoidable. Distortions can occur in area, shape, distance, and direction. Images by Esri.



Mollweide Projection

Mercator Projection

Figure 1.13. Equal area and conformal map projections. These examples represent an equal-area projection and a conformal projection. The Mollweide projection, *above*, is equal area. The area of each country is correct, but shape is distorted. The Mercator projection, *right*, is conformal. Shape is preserved but area is distorted. Maps by EsriedtmCF.

of coordinate systems that facilitate identification of places on the surface of the earth.

The latitude and longitude system is the most well-known GIS. It allows all locations on the surface of the earth to be identified by measuring angles north and south of the equator and east and west of the prime meridian (figure 1.14).

Latitude is measured from 0 degrees along the equator to 90 degrees north at the North Pole and 90 degrees south at the South Pole. Longitude is measured from 0 degrees at the prime meridian, a line that connects the North and South Poles, to 180 degrees west and 180 degrees east. The International Date Line, which demarcates the change from one calendar day to the next, is located approximately along the 180-degree meridian.

Whereas the equator, which splits the earth into the Northern and Southern Hemispheres, is a natural location for starting latitude measurements, there is no natural place to begin longitude measurements. Different prime meridians have been used over time, but by the late 1800s, largely because of Great Britain's maritime dominance in the 19th century, most maps began using the prime meridian at Greenwich, England.

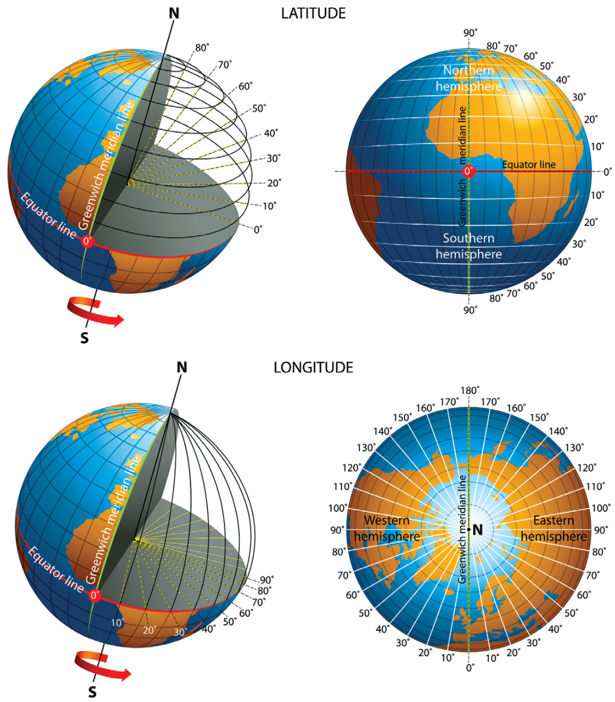


Figure 1.14. Latitude and longitude. This image illustrates latitude lines running from the equator to the North and South Poles and longitude lines running from zero degrees at the Greenwich prime meridian to 180 degrees. Image by NoPainNoGain. Stock vector ID: 326090990. Shutterstock.

Latitude and longitude coordinates can be written in decimal or degrees/minutes/seconds formats (figure 1.15). For example, the White House, located between the 38th and 39th northern parallels and between the 77th and 78th western meridians, is written as follows:

Decimal degrees: N 38.8977°, W 77.0366°
Degrees/minutes/seconds: N 38° 53′ 49.5456″,
W 77° 2′ 11.562″

Another commonly used method for describing the location of a place is with street addresses, whereby each address refers to a specific building in a specific place. The location of the White House, as a street address, is 1600 Pennsylvania Avenue NW, Washington, DC 20500.

One unusual and innovative coordinate system has been developed by what3words, a designer of geocode systems. With this coordinate system, the entire world is divided into 3 × 3 m grids, each of which is assigned three words. Thus, every place on the earth's surface can be identified with just three words within three meters of accuracy. This system has some advantages compared with traditional coordinate systems. First, many places do not have an official street address, which severely restricts the usefulness of a street address system in identifying locations. Second, although latitude and longitude describe specific locations, they are too long and complicated for most people to remember. In contrast, it is easy to remember three words. With this system, the location of the White House is described as "sulk.held.raves," which are the words assigned to the 3 × 3 grid at the middle of the White House. With the what3words app, businesses and governments can deliver goods and services to precise locations, from the proper building entrance on a large corporate campus to a remote home in rural Kenya. In 2016, the postal service of Mongolia, where few streets have official names, began using this system nationwide.

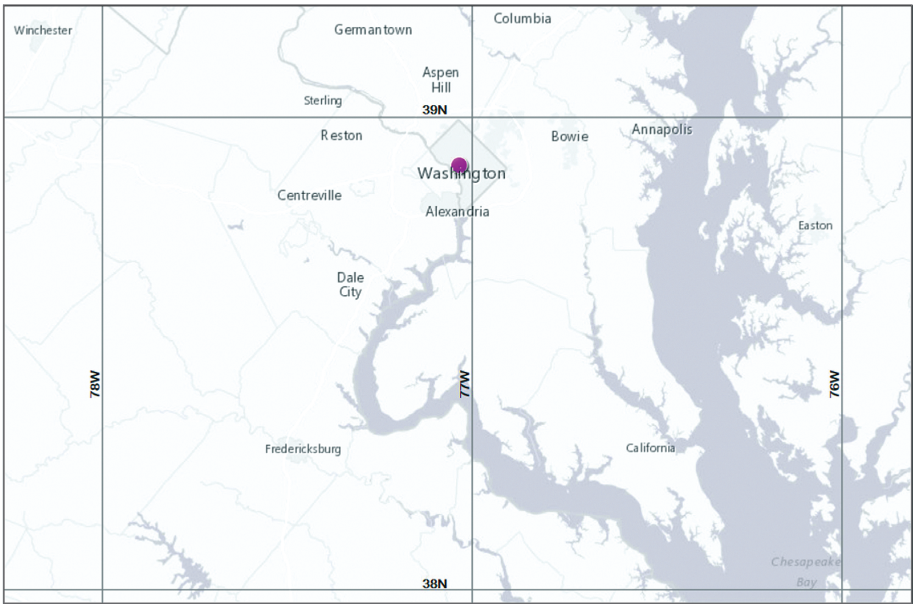


Figure 1.15. This map shows the location of the White House in relation to 1-degree latitude and longitude grid lines. Map by author. Data sources: Esri, HERE, Garmin, NGA, USGS, NPS.

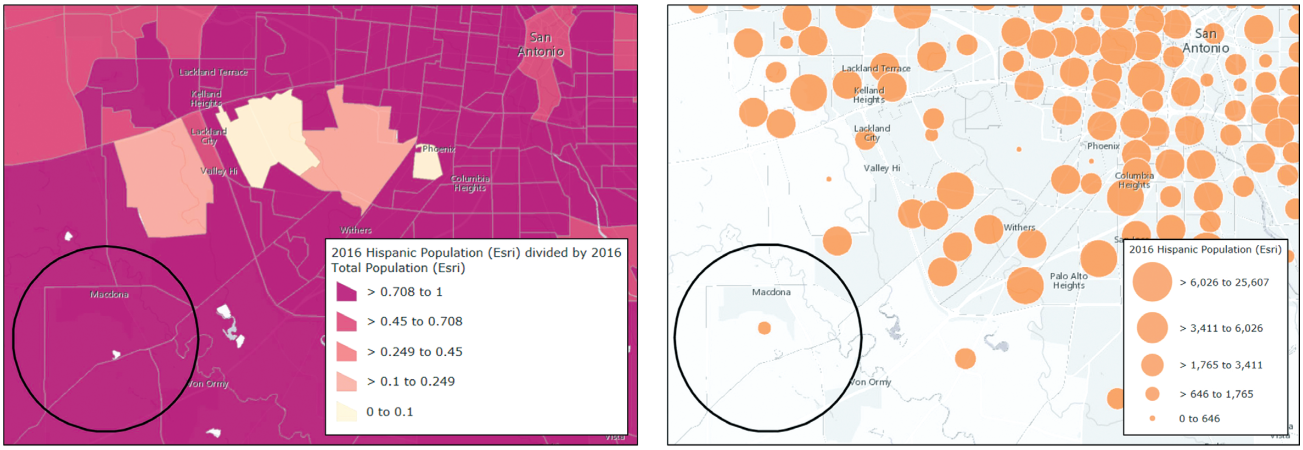
Many other types of coordinate systems are used throughout the world. When you take additional classes on geography and GIS, you will be able to delve more deeply into them.

Counts vs. rates

Another issue to keep in mind when creating and reading maps is the difference between counts and rates. As the name implies, counts are a count of the number of features in an area. A population count map depicts the number of people in an area, such as a city, whereas a terrorist activity count map provides the number of terrorist incidents, such as those within a country.

Rates compare one variable with another. In geography, it is common to calculate rates on the basis of population or area. A wheat production map can show the amount of wheat within a county divided by the area in square miles of the county, resulting in wheat production per square mile. Likewise, the number of people with influenza within a state can be divided by the total population of the state, giving the influenza rate per 100,000 people.

Understanding the difference between counts and rates is essential. If a political party targets the Hispanic community and is looking for a good location for a get-out-the-vote campaign, a map showing counts and a map showing rates can lead to very different location decisions (figure 1.16). For instance, census tracts may have a high proportion of Hispanic people (in other words, a high rate). This high rate may seem to indicate a good location for the campaign. However, although 90 percent of the population may be Hispanic, when mapping counts, it may turn out that there are only 100 people in the census tract. The small number of people may make the census tract a poor location for building voter participation.



Rate map | Count map

Figure 1.16. Counts vs. rates. When you create and interpret maps, different impressions result based on whether you classify data by rates or by counts. Is Macdona, Texas, a significant Hispanic neighborhood? The answer varies depending on whether Hispanic rates are mapped or whether Hispanic counts are mapped. In the rate map, *left*, the black circle includes an area with a high proportion of Hispanics. In the count map, *right*, the black circle includes an area with a low number of Hispanics. Explore the chapter 1 web maps at links.esri.com/HG_01. Maps by author. Data sources: 2016 USA Diversity Index. Esri, US Census Bureau.

Map classification

The classification scheme used with a map can have a major impact on the way it is interpreted. With a choropleth map, data is divided into categories, and each category is given a color or shade. The number of categories and the cutoff points for each category can dramatically alter the look of a map (figure 1.17). In the following example, a map using equal-interval classification would show incomes of $200,500 in the top category. However, the quantile classification scheme would include all households earning $92,674 or more. The map looks different depending solely on the chosen classification scheme (figure 1.18). The quantile scheme gives the impression that wide swaths of the Seattle region are upper income, whereas the equal-interval scheme makes the prevalence of upper-income areas look more limited.

Note that changing the map classification scheme does not involve changing the data. The data remains the same. All that changes are the cutoff points for each color category. Cartographers can thus easily manipulate the perception that a map gives without falsifying data in any way.

The geographic perspective

As discussed at the beginning of this chapter, geography is a discipline that, at its core, asks where things are located and why they are there. Broadly speaking, geography can be considered from a spatial perspective and an ecological perspective. The spatial perspective examines spatial distributions and processes, whereas the ecological perspective offers a holistic view that incorporates both human actions and environmental opportunities and constraints. This section dives deeper into the fundamental concepts that constitute the geographic perspective.

Space

Location and distance are key components of geographic inquiry and can be viewed in both absolute and relative terms.

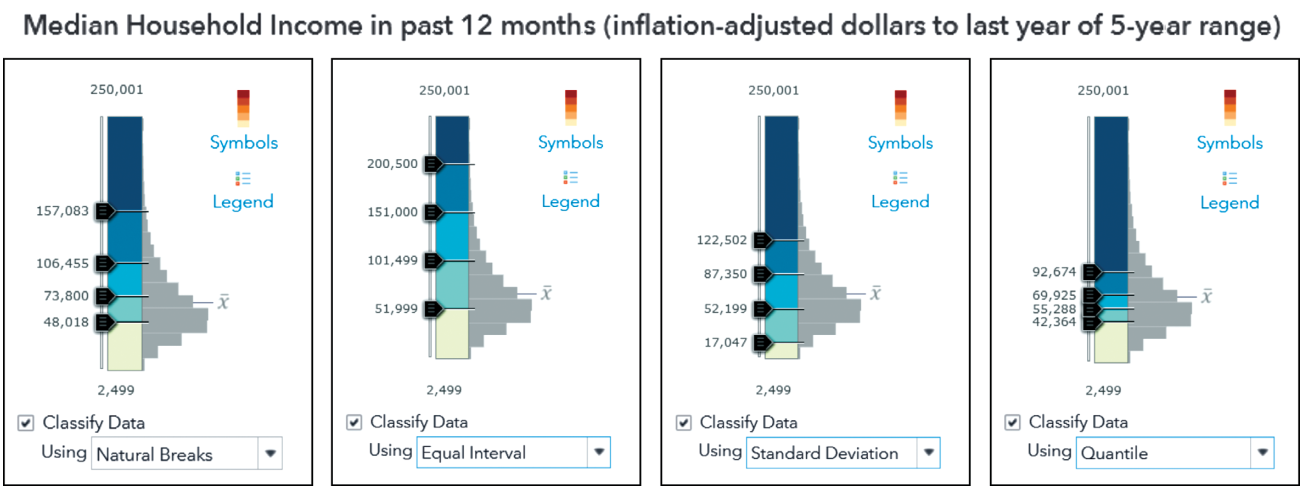


Figure 1.17. Classification schemes. Different classification schemes, *from left*, using Median Household Income layer: natural breaks, data is divided into categories based on natural groups within the data; equal interval, data is divided so that each category has the same range of values; standard deviation, data is divided into categories by standard deviations above and below the mean; and quantile, data is divided so that groups contain an equal number of values. Note how the category cutoff points can change dramatically depending on the classification scheme. Image by author. Data source: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS.

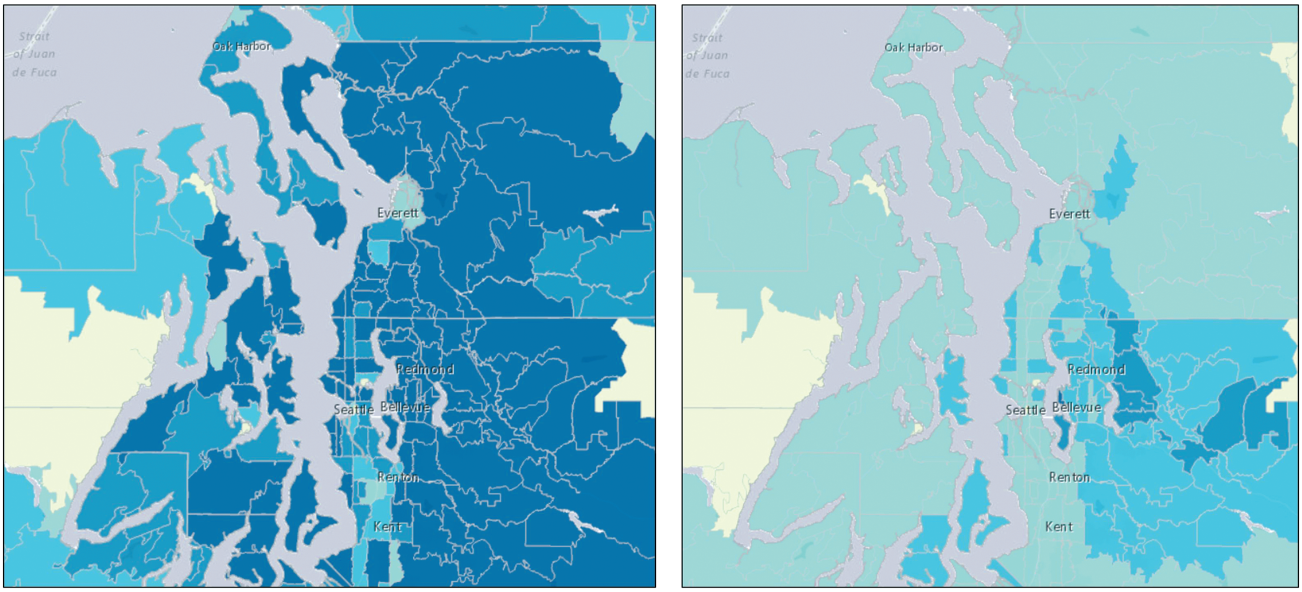
Absolute location describes a fixed point on the surface of the earth. The latitude and longitude coordinate systems, as well as street address systems, refer to absolute location.

Relative location is another way of describing where things are and is generally more significant for much geographic research. Relative location describes where a feature is in relation to another feature. For example, the location of a house can be described as *1 mile from* the freeway, *close to* shopping, *far from* the beach, or *adjacent* to a park. Each of these terms describes where the house is located relative to other important landscape features.

By understanding the relative location of features, geographers can analyze how spatial relationships explain events. For instance, by knowing the relative location of countries in the Middle East and Europe, it is possible to understand migration flows out of war-torn Syria. Syrians will flee to nearby countries, such as Türkiye, Lebanon, and Jordan, as well as to rich countries that are not too far away, such as Germany and Sweden. Many fewer migrants would be expected to go farther to Canada or the United States, both of which have a relative distance far from the Middle East.

As another example, relative location is useful in explaining real estate prices. Two identical houses, one adjacent to a golf course and one close to an industrial park, will have vastly different values, precisely because of their location relative to different land uses.

Closely related to location is the concept of distance. As with location, distance can be measured in absolute and relative terms. Absolute distance can be measured in traditional units, such as miles and feet or kilometers and meters. Relative distance looks at distance in terms of a surrogate value, such as cost or difficulty.



Quantile | Equal Interval

Figure 1.18. Classification schemes: quantile vs. equal interval. The quantile classification scheme, *left*, gives the impression that most of the city is affluent, whereas equal interval, *right*, shows affluent areas are more limited. Explore the chapter 1 web maps at links.esri.com/HG_01. Maps by author. Data sources: 2016 USA Median Household Income by Esri; Esri, US Census Bureau.

Absolute distance is commonly measured by geographers in two ways (figure 1.19). Euclidean distance measures the distance between two points in a straight line. When people use the vernacular "as the crow flies," they are referring to Euclidean distance. Drawing a straight line from your house to school would give you the Euclidean distance. However, in people's daily lives, they rarely travel in straight lines. For this reason, Manhattan distance, also called network distance, is also used in geographic analysis. Manhattan distance (named after the rectangular layout of Manhattan streets in New York City, New York) is the distance between two places along a grid. When you travel from home to school, you probably don't go there in a straight line. Most likely, you follow a street grid, which results in a longer total distance traveled.

Distance can also be measured in relative terms as cost distance. This can include cost in time or in difficulty of travel. For instance, cost distance can be calculated by measuring Euclidean or Manhattan distance and then weighting the distance value to account for the difficulty of travel. When walking from your house to the grocery store, you may have two options. Option one may be a flat route of 0.75 miles, whereas option two may be only 0.5 miles but it includes a steep hill. Because of the hill, you may add a cost value (either consciously or unconsciously) to give that distance a greater weight. If you decide that walking over the hill is twice as difficult as walking on the flat route, you can multiply the hill route by two (0.5 miles × 2 = 1.0 mile). Based on this calculation of cost distance, you would decide to take the flat 0.75-mile route.

Cost distance can also be measured in terms of time. People often say that they live "20 minutes" from school rather than saying they live eight miles from school. Geographers use cost distance when calculating drive times. Different types of roads have different speed limits or are made of different materials. A vehicle traveling for 20 minutes will go much farther on a state highway than on a narrow dirt road. For this reason, different road types can be weighted differently for calculating travel time. Also, traffic conditions can vary by time of day, resulting in a cost distance that varies not only over space but also over time.

Spatial patterns

Features on the earth's surface arrange themselves in spatial patterns. Analyzing these patterns allows geographers to elucidate not only how human and physical features are arranged but also the processes behind their formation.

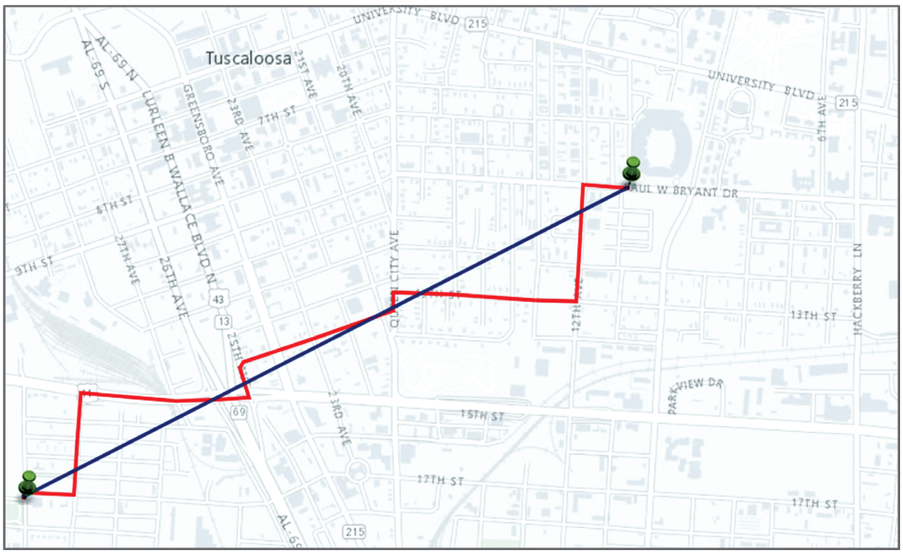


Figure 1.19. Measuring absolute distance. Euclidean distance in blue (1.48 miles) follows a straight path between two points. Manhattan or network distance in red (1.93 miles) follows the street grid. The red line can also be measured as cost distance in terms of time. The cost in time will vary on the basis of traffic conditions, so that at midnight it may be 8.5 minutes, whereas at 5:30 p.m. it may be 12 minutes. Map by author. Data sources: City of Tuscaloosa, Esri, HERE, Garmin, INCREMENT P, NGA, USGS.

A commonly used description of spatial patterns is density. Density is the number of features per unit area, as in the number of people per square mile or number of trees per square kilometer. Density is useful for illustrating spatial patterns that would not be indicated using raw numbers alone. For example, the population of California is about 39 million people, whereas the population of Singapore is only 5.5 million. With no additional information, you may get the impression that California is more crowded than Singapore. But when information on area is added, that impression quickly changes. California consists of 163,696 square miles, whereas Singapore is made up of just 278 square miles. So, Singapore has a much higher population density than California (figure 1.20).

Spatial patterns can also be viewed in terms of clustering, randomness, and dispersion (figure 1.21). As the name implies, clustered features are found grouped near each other. Clusters are often identified using hot spot analysis or a heat map (figure 1.22). Randomly distributed features have no distinguishable spatial pattern. Dispersed features are separated from one another and may even repel one another, as in competing facilities. They are not clustered and are even farther from one another than if the distribution were random.

Analyzing these types of spatial patterns has many applications. For example, if home burglaries are clustered in a specific neighborhood, police can increase patrols in that area, whereas detectives and community groups can focus on what the underlying causes of the crime cluster are. It may turn out that an active burglar lives nearby, or youth from a local high school may be committing crimes after school. If home burglaries are not clustered but have a more random pattern, other causes may be at play, such as burglaries being crimes of opportunity, in which criminals take advantage of homes with open windows.

Figure 1.20. Population density: Singapore. Singapore has one of the highest population densities in the world, with 5.5 million people living in just 278 square miles. Photo by joyfull. Stock photo ID: 138766448. Shutterstock.

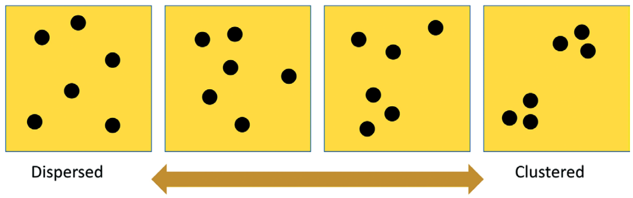


Figure 1.21. Spatial patterns can be seen as dispersed, random, or clustered. Image by author.

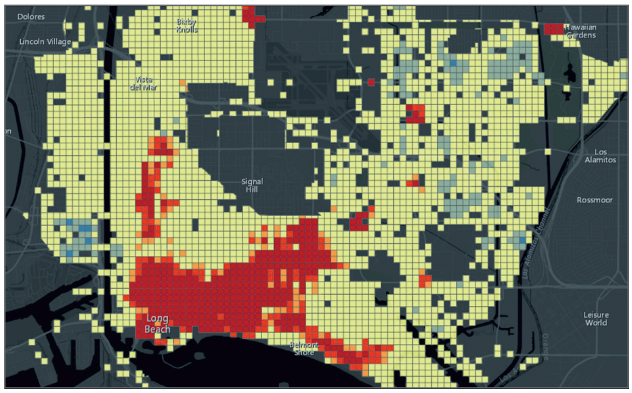


Figure 1.22. Mapping clusters as hot spots for residential burglary clusters in Long Beach, California. ArcGIS hot spot analysis indicates statistically significant hot spots and cold spots. Red represents hot spots with more burglaries, whereas blue represents cold spots with fewer burglaries. Hot spot analysis can uncover clusters of crime, different demographic groups, disease, natural hazard events, and more. Map by author. Data source: Long Beach Police Department.

Diseases often cluster, as well. If cancer rates cluster in a neighborhood, health researchers may search for environmental causes of the disease, such as a nearby toxic waste site. If cancer cases are randomly distributed around a city, environmental factors are less likely to be the cause.

Dispersed features can include shopping malls or chain restaurants in an urban region. Mall owners may intentionally maintain a distance from competing malls to avoid competition, whereas owners of a restaurant chain may space their stores so that they do not cannibalize sales from one another.

Spatial patterns can also be analyzed by measuring the center of features. With a map of consumer purchasing behavior, a business may want to find a new store location that lies at the center of its specific market segment. Likewise, geographers can study shifts in population by mapping the center of US population over time.

Spatial relationships

Mapping the spatial relationships of two or more features can offer insight into why particular patterns exist. Whereas spatial distributions describe how features are clustered or dispersed, spatial relationships depict where features are in relation to other types of features. For instance, geographers study the distance between different types of features or whether different feature types overlap (figure 1.23). If there is a disease cluster, geographers can examine the distance between the cluster and factories that emit toxic effluent. If the cluster is nearby, the effluent may be the cause of the disease. They can also study whether the disease cluster overlaps with the residences of workers in a specific type of occupation. It may turn out that the cluster is not due to nearby toxic effluent but rather that many residents in the disease cluster work in a mine that uses toxic chemicals.

Statistical tools are often used to study spatial relationships. With spatial correlation, it is possible to analyze the strength and direction of spatial relationships (figure 1.24) and whether they are positive, negative, or unrelated. In a positive relationship, both variables change in the same direction, as they do when places with high unemployment also have high rates of alcohol consumption. In a negative relationship, an increase in one variable leads to a decrease in another, as occurs when areas with high unemployment have lower traffic fatalities because of people driving less. When there is no pattern of increase or decrease between two variables, they are unrelated, as occurs when places with high unemployment have no correlation with the number of earthquakes.

With quantitative analysis, the phrase "correlation does not imply causation" is commonly used to describe the case in which variables can be correlated but one variable does not cause the other to change. To build on an earlier example, a cancer cluster may

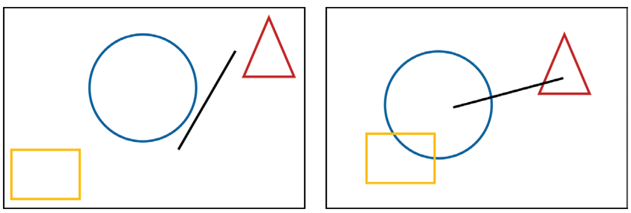


Figure 1.23. Spatial relationships. Geographers study the spatial relationship between features, such as, *left*, how far apart they are or, *right*, whether they overlap. Image by author.

Figure 1.24. Spatial correlation. Variables in the same place can be plotted to note whether they have positive, negative, or no relationship. Image by author.

be located near a toxic effluent site, leading some people to infer that cancer risk increases because of proximity to the site. But a third variable may not be considered. Even though the cancer cluster correlates with distance to toxic effluent, the cancer may be due to where residents of the cluster work. Many residents of the cluster may work in a mine that uses toxic chemicals, and exposure to those chemicals is causing the disease. Cancer may have a strong correlation with proximity to toxic effluent, but the proximity is not the cause.

It is therefore important to consider multiple explanations when looking at correlations and to use previous research and theory when determining which variables to include in an analysis. When mapping heart disease by county and determining which factors contribute to it, current scientific research says that variables such as smoking, diet, and physical inactivity are contributing factors. Rates of smoking, rates of high cholesterol from poor diet, and average hours of exercise per capita can be mapped on top of a heart disease map. With spatial statistical analysis, the strength of each variable can be analyzed in relation to rates of heart disease. It may become clear that some counties have high rates of heart disease primarily because of high rates of smoking, whereas others may have high rates because of a lack of physical activity.

Places and regions

Many people are drawn to geography because they love to explore and learn about the great diversity of the world. From quaint towns along the coast of Italy to the busy markets of Casablanca, and from the scenic valley of Yosemite National Park to the steppes of Kenya, the world offers a vast range of interesting landscapes to experience. To better study and understand the unique characteristics of the world's landscapes—the locations and spatial patterns of human and physical features—geographers use the concepts of place and region.

Places

Places are locations with a set of physical and/or human features that make them unique from other locations. Because of their uniqueness, they typically have names that can be found on general reference maps. For example, Yellowstone National Park is distinguished by natural geysers; wolves and other wildlife; and a complex tourism infrastructure of lodging, restaurants, roads, and hiking trails. Manhattan is distinguished by dense, high-rise buildings; an economy focused on areas such as finance, law, and advertising; and landmarks such as Central Park and Times Square. Venice Beach in Los Angeles is a place with eccentric boardwalk vendors and entertainers.

The unique combination of features within a place, when experienced by people, create what is known as a sense of place. Sense of place comes from an emotional reaction that forms as humans interact with places. Some places have a strong sense of place, evoking either a positive or a negative reaction in people. For many, a place such as Paris has a strong, positive sense of place. History, architecture, street layout, cafés, pedestrian activity, and parks combine to create a unique sense of place that people are strongly attached to. Because of this, demand for housing is strong and tourism is a flourishing industry there. In contrast, a neighborhood in a big city that is trash strewn, largely abandoned, and littered with remnants of drug use may have a strong negative sense of place that repels people.

Placelessness is the antithesis of sense of place. Some places lack uniqueness, offering homogeneous landscapes that differ little from other places. Many urban areas in North American cities consist of wide arterial streets lined by fast-food restaurants and gas stations. The architecture and design of these places remain basically the same, whether it is in Los

Angeles, Miami, Atlanta, or Phoenix. Some argue that cookie-cutter suburban residential development is also placeless. By this argument, these developments consist of large swaths of homogeneous suburban homes that lack design tied to local history or culture (figure 1.25).

When geographers talk about places, they typically focus on the wide range of characteristics that compose the place—the people, the built environment, the natural environment—and the ways in which these characteristics form either a strong sense of place or a bland placelessness.

People perceive and navigate through places, and develop a sense of place, through mental maps, which are the way humans organize places in their minds. Most people can draw a map of their city, country, or the world, but they can add more detail and precision in areas that they move through on a regular basis or are exposed to through the media. You probably have a detailed mental map of your neighborhood, which includes the location of local businesses, parks, the homes of people you like to visit (and those whom you do not), places that are pleasant to travel through, and places that are dangerous or unpleasant.

Mental maps influence how we move through our cities and neighborhoods, as people tend to follow familiar routes and avoid unfamiliar ones. People also move on the basis of perceived characteristics of areas in their mental maps, staying clear of areas considered dangerous or staying in areas viewed as aesthetically pleasing.

Beyond our own neighborhoods and cities, we still form mental maps. Most Americans can draw a rough map of the United States as well as a partial map of the world with some countries and continents. Through the study of geography, our mental map becomes more detailed. Well-developed mental maps allow us to better understand our world and the events that take place in it. Knowing that Iraq's neighbors include countries such as Syria, Türkiye, Iran, and Saudi Arabia makes it easier to understand the complex ethnic, religious, and political factors affecting that country: Islamic State fighters centered in Syria, ethnic Kurds that straddle Türkiye and northern Iraq seeking autonomy, and sectarian rivals from Saudi Arabia and Iran that clash in Iraq.

Figure 1.25. Placelessness. Homogeneous landscapes with few distinguishing characteristics are often considered placeless. Such places seem the same in any location, with no visible ties to local culture and history. Many people view bland streetscapes and cookie-cutter suburbs as placeless, from housing tracts in Phoenix, Arizona, *left*, to peripheral roadways in Moscow, Russia, *right*. World Imagery basemap by Esri; data sources: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS user community. Streetscape photo by Yuriy Stankevich. Royalty-free stock photo ID: 589563587. Shutterstock.

Regions

Regions are locations with unifying characteristics that distinguish them from other locations. Unlike places, which are viewed in a more holistic way and are more often found on general reference maps (Paris, Yellowstone National Park, Manhattan, Venice Beach), regions are distinguished by a limited number of human and/or physical characteristics.

Regions are a useful way of categorizing the world for purposes of geographic research. Just as biologists categorize the living world into species and historians categorize time into eras, geographers categorize space into regions. By creating categories, biologists can compare wolves with dogs, historians can compare the Middle Ages with the Renaissance, and geographers can compare North America and Latin America.

There are three types of regions: formal, functional, and perceptual.

Formal regions can be identified by mapping one or more human or physical features. The Corn Belt in the United States can be identified by mapping acreage devoted to corn production, whereas Tornado Alley can be found by mapping tornado frequency (figure 1.26). The Bible Belt can be mapped by the number of people who state they attend church on a regular basis. A common cultural trait, such as language or religion, can be used to distinguish North America from Latin America.

Functional regions are delineated by a central place, or node, and a surrounding hinterland that interacts with the node. For example, regional shopping malls and other businesses collect customer address data that they map and use to determine their functional sales region, or market area. A functional metropolitan region can be identified by mapping commuting patterns of workers and consumers who travel to a city (figure 1.27). The advantage of mapping functional regions is that it avoids the use of artificial city, county, or state boundaries when determining the region surrounding a central place.

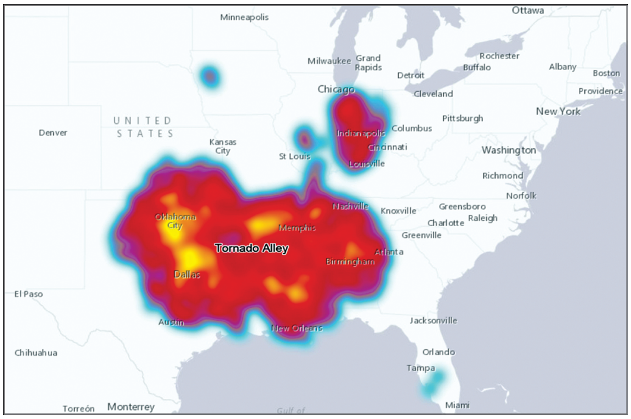


Figure 1.26. Formal regions: Tornado Alley. Formal regions are identified by mapping one or more variables. Tornado Alley is a commonly used term to describe the US region heavily impacted by tornadoes. However, there is no official definition of the region's precise boundaries. One way of identifying Tornado Alley as a formal region is by mapping clusters of supercell tornadoes. Explore the chapter 1 web maps at links.esri.com/HG_01. Map by author. Data source: National Weather Service, Storm Prediction Center, June 2009. United States Tornado Touchdown Points 1950–2008. Reston, VA: National Atlas of the United States.

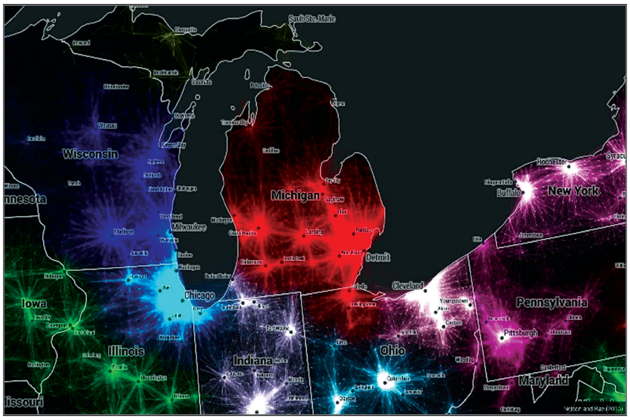


Figure 1.27. Functional regions: commuter megaregions of the United States. This map shows commuter flows between census tracts based on the 2006–2010 US census, American Community Survey. Metropolitan areas can be considered functional regions that consist of a central urban core and surrounding commuter neighborhoods. Functional regions often reflect more realistic areas for studying cities than official city and county boundaries in that they consider spatial interaction with surrounding areas. Map by Rae, Alasdair; Garrett.G.D.Nelson@dartmouth.edu (2016): United States Commutes and Megaregions data for GIS. Figshare. https://doi.org/10.15131/shef.data.4110156.v4.

Perceptual regions, also called vernacular regions, are based on subjective criteria of individuals. Everyone knows that the South and Southern California exist in the United States, but where exactly are they? One way of identifying this type of region is by having people draw boundaries on a map. With a large enough sample, a consensus as to where the boundaries lie will become clear.

Perceptual regions evolve over time. For example, the Middle East gained its name as a perceptual region from the European perspective. The Near East, Middle East, and Far East were historically identified by their locations relative to Europe. Perceptions of the boundaries of these regions have changed over time, but the Near East tended to be countries along the eastern Mediterranean Sea (those "near" Europe), the Middle East was around the Persian Gulf, and the Far East included Asian countries that face the Pacific Ocean (those "far" from Europe). Perceptions of these regions differ somewhat today, but again, having a sample of people draw the Middle East on a map would lead to a consensus on its boundaries.

It is important to keep in mind that the boundaries between all types of regions are typically fuzzy. Just as there is no specific day that divides the Middle Ages from the Renaissance, there is rarely a fixed line that separates one region from another.

Origin, spatial interaction, and spatial diffusion

Places, regions, and the spatial patterns of human features do not lie in isolation. Rather, patterns of human activity evolve through the movement and interaction of people and cultures from different locations. This movement and interaction help explain why unique spatial patterns, places, and regions form.

Origin

Many spatial phenomena can be viewed in terms of origin and diffusion. The origin is a starting point, a location where something begins. It is often referred to as a culture hearth. A disease outbreak, a new musical style, a new technology, or a new idea will begin in a specific part of the world. Although its origin point is still debated, the deadly flu pandemic of 1918 originated in one of several possible locations: Kansas in the United States, China, or France. From its origin point, it then diffused throughout the world, killing around 50 million people. Likewise, COVID-19 began in Wuhan, China, before diffusing into a worldwide pandemic. Hip-hop originated in the Bronx, New York, in the 1970s before becoming a global phenomenon. The major monotheistic religions of Judaism, Christianity, and Islam originated in the Middle East before spreading around the world.

Origin points must have the right conditions for a new phenomenon to form, and these conditions are typically related to human actions. For example, new disease outbreaks are more likely to occur in places with poor sanitation and weak health-care systems than in places where sanitation and health care are adequate. The leading theory in 2022 was that COVID-19 originated in a densely packed market in Wuhan, China, that sold live animals in poor welfare and hygienic conditions. Under these conditions, the COVID-19 virus probably jumped from an animal to its first human host.

Origin points for new social and technological innovations are likely to form in societies that are open to new ideas and that already have the technological prerequisites for the innovation. For instance, some countries foment new ideas through the protection of free speech, whereas other countries stifle innovation through heavy censorship and limits on open debate. In addition to having an open society, innovations cannot materialize unless technological prerequisites are in place. The Wright brothers' airplane could not have been built without technical knowledge of structures and materials, motors, and basic physics.

Thus, it is important to remember that the origin of new phenomena comes from the combination of multiple influences. This combination is typically the result of spatial interaction, the movement of ideas and things between places, and spatial diffusion, the spreading of an idea or thing across space over time.

Spatial interaction

Spatial interaction takes place when two or more areas are linked by a network. Transportation and communications linkages tie places together and allow for people, ideas, and things to move between them. The more spatial interaction one place has with other places, the more it will be exposed to new ideas and technologies. A place with airports and seaports, road networks, and government policies that facilitate the movement of goods and people will tend to be more innovative and be the origin point for new ideas and technologies. The same holds true for communications network connections. Places that are linked by telephone and internet connections allow for the quick movement of information, which fosters creativity and the formation of new ideas (figure 1.28). Thus, spatial interaction results from connectivity and accessibility. Transportation and communications networks connect locations, allowing people, ideas, and things to have access to different places.

Spatial interaction is strongly influenced by distance. This influence is described by cartographer Waldo R. Tobler's first law of geography, which states that "everything is related to everything else, but near things are more related than distant things." The same concept can be described as distance decay, whereby there is more interaction between places that are close together than between places that are far apart (figure 1.29).

For instance, Mexican cities along the US border will be more like US cities, whereas Mexican cities in southern Mexico are less similar. Northern cities have more signage in English, people use more Spanglish terms, and the latest consumer goods from the United States are more prevalent than in southern Mexican cities. This is because of greater spatial interaction—good

Figure 1.28. Internet café in Indonesia. People access the internet with cell phones and laptop computers at a café in Indonesia. Communications networks are an essential component of spatial interaction. When places are connected in this way, ideas and innovation spread. Photo by Lano Lan. Stock photo ID: 344025836. Shutterstock.

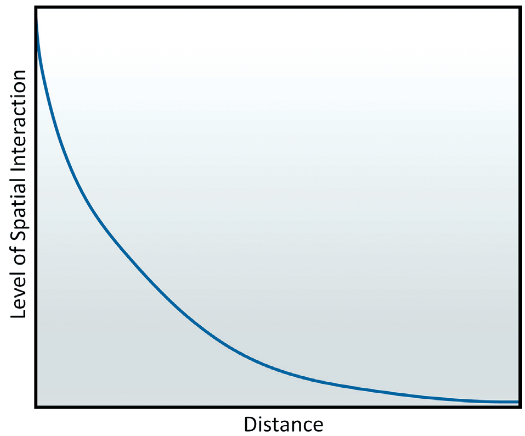


Figure 1.29. Distance decay. In line with Tobler's first law of geography, in which "everything is related to everything else, but near things are more related than distant things," the farther that places are from one another, the less interaction there is between them. Image by author.

connectivity and accessibility through roads and border crossings as well as TV and radio signals. This is also because of a greater diffusion of US culture and goods, especially through relocation and contagious diffusion, discussed in the next section. As one moves south from the US border, the influence of the English language and of US products and culture becomes less pronounced.

The same can be demonstrated with Mexican influence in US cities along the southern border, where the Spanish language and Mexican food, music, and other cultural features are more prevalent. Moving north, Mexican cultural influence declines as distance increases from the border.

Geographers also study spatial interaction in terms of core and periphery. Core areas include concentrations of things, such as political power, economic activity, specific cultural characteristics, or population density. The periphery includes surrounding areas that have spatial interaction with the core. Often, the core may have an advantageous position relative to the periphery. For instance, a political core makes laws that govern the periphery under its control, whereas an economic core creates wealth by using labor and natural resources from its periphery. At a global scale, core and periphery have been used to describe how wealthy countries (the core) exploit poor countries (the periphery) by extracting natural resources.

Core and periphery can also be considered in terms of regions, whereby the core of a region constitutes a heavy concentration of regional characteristics, whereas the periphery is the area where the characteristics gradually diminish. For instance, Louisiana may be considered part of the core of the South, but Texas can be considered part of the periphery, as southern music, food, and dialects gradually fade as one moves west across Texas.

With advances in communications and transportation technologies, some geographers refer to space-time compression. This is the idea that the world is "shrinking" as relative distance declines with changes in technology. New ideas now travel instantly to different places through communications technology, and people and goods move rapidly by car, ship, and airplane. As places become "closer" together, change brought about through spatial interaction happens more quickly. Global pop music stars now influence youth fashion around the world at the same time rather than just in smaller local or regional markets. Similarly, the 2008 financial crisis that began with banks in the United States quickly impacted the global economy. Whereas music, fashion, and economic crises were once local phenomena or spread slowly, they now impact people around the world in a short period of time.

Spatial diffusion

Spatial diffusion is another way that characteristics spread to new locations. From an origin point, an idea or thing can diffuse to new places, where it can then combine with other ideas or things and form something new.

Spatial diffusion can be broken down into two broad categories: relocation diffusion and expansion diffusion.

Relocation diffusion occurs when people move to a new location and take their ideas and possessions with them. With relocation diffusion, the number of people using an idea or possession does not change, but the place where they are used changes. When Spaniards first migrated to the Americas, they brought their religious ideas and weapons with them. Thus, through relocation diffusion, Christianity and European military technology spread to the New World. This diffusion process occurred even before the Indigenous people of the Americas began practicing Christianity and using steel weapons.

Likewise, Latin American culture has diffused to many parts of North America as Latino immigrants relocate north (figure 1.30). Latin American languages, food, music, and other cultural elements can now be

Figure 1.30. Ecuadorian restaurant in New York. Latino immigrants bring their culture with them through the process of relocation diffusion. Photo by Lee Snider Photo Images. Stock photo ID: 426459184. Shutterstock.

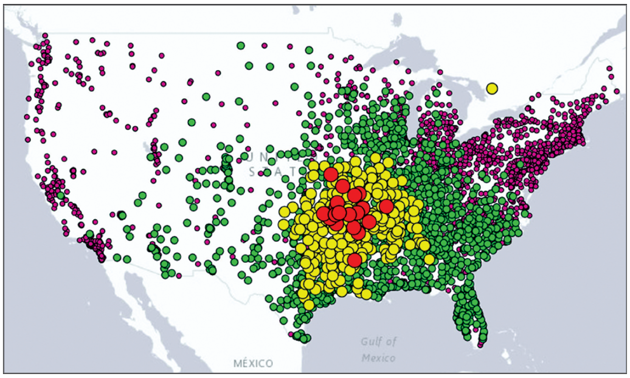


Figure 1.31. Contagious diffusion of Walmart stores. Contagious diffusion represents the outward spread from a point of origin, like rings emanating from a pebble falling in a pond. Walmart began in Arkansas and spread to nearby Missouri and Oklahoma in the 1960s. In the 1970s, stores diffused to surrounding states in the South and Midwest. Walmart continued to spread outward in the 1980s. Ultimately, it reached the West Coast and New England in the 1990s. Explore the chapter 1 web maps at links.esri.com/HG_01. Map by author. Data sources: Thomas J. Holmes. University of Minnesota, Federal Reserve Bank of Minneapolis, and NBER.

found in many American and Canadian cities, specifically because of relocation diffusion.

With COVID-19, infected people from its origin point in Wuhan, China, traveled to other cities in China and around the world, unaware that they were carrying a new, highly contagious virus. The initial "relocation" of infected people brought the virus to new places, immediately leading to further diffusion through another process: expansion diffusion.

Expansion diffusion occurs when the number of people using an idea or item increases. This type of diffusion resulted as Spaniards in the Americas converted the Indigenous population to Christianity and the Indigenous people began using and making steel weapons. Likewise, many nonimmigrants in North America now eat foods from Latin America and speak some Spanish, Portuguese, or other Latin American languages. Through expansion diffusion, culture and technology spread to new people. This type of diffusion also led to diffusion of COVID-19 to an ever-larger number of people as infected individuals traveled to new cities and towns.

Expansion diffusion can be broken down into contagious diffusion and hierarchical diffusion. Contagious diffusion is when a characteristic spreads from person to person on the basis of proximity. In a sense, it is similar to throwing a pebble in a pond, generating waves moving outward concentrically (figure 1.31). Places close to the origin point adapt the new idea or item before places that are farther away do. Using the example of Spaniards in the Americas, the first Indigenous people to be converted to Christianity and to use steel were those who lived close to early Spanish settlements. Diffusion to Indigenous people in more remote locations took much longer. Similarly, more people in the American Southwest than in other US areas eat dishes from Latin America because of their proximity to the southern border and Latino immigrant communities in southwestern cities. Over time, however, Latino culture has spread to places beyond the border and immigrant-heavy cities.

Contagious diffusion of COVID-19 was evident early in the pandemic. At an urban scale, densely populated New York City saw clusters form as the virus spread through close human interaction. Other clusters formed in churches, restaurants, and nursing homes as a single infected person transmitted the virus to those in proximity.

Hierarchical diffusion occurs when something spreads from a person or place of power and influence (figure 1.32). Geographers most often refer to hierarchical diffusion in terms of an urban hierarchy. If cities are ranked by population from large to small, it is more common for a new idea or item to originate in and diffuse to large cities first, then to medium-size cities, and later to small cities and towns. The latest musical trend or fashion typically begins in a large city, and then diffuses to other large cities, even if they are far away—think New York, Los Angeles, London, and Paris. Medium-size cities will pick up on the trend a bit later, and diffusion to small towns will be later still.

COVID-19 diffused first to large cities around the world, those with international airports connected to China and other major flight hubs. New York City, Los Angeles, and Seattle, for instance, were among the first places to record cases in early 2020. From these large gateway cities, the virus then diffused to smaller and less globally connected cities and towns until, ultimately, it reached all corners of the earth.

In addition to urban hierarchies, diffusion can move along an income hierarchy, often from rich to poor. In most countries, the diffusion of things such as higher education, personal computers, and cars with airbags all began in households and neighborhoods with higher incomes. As time progressed, the cost of these innovations decreased, and they became more widely available in neighborhoods with lower income.

Stimulus diffusion occurs when a characteristic spreads to a new place, but rather than remaining in its original form, it stimulates an innovation. For example, US fast-food restaurants have diffused around the world, but those that have been most successful have modified their menus to reflect local culture. For example, rather than a simple diffusion of burgers and fries to Japan, McDonald's offers crab croquette

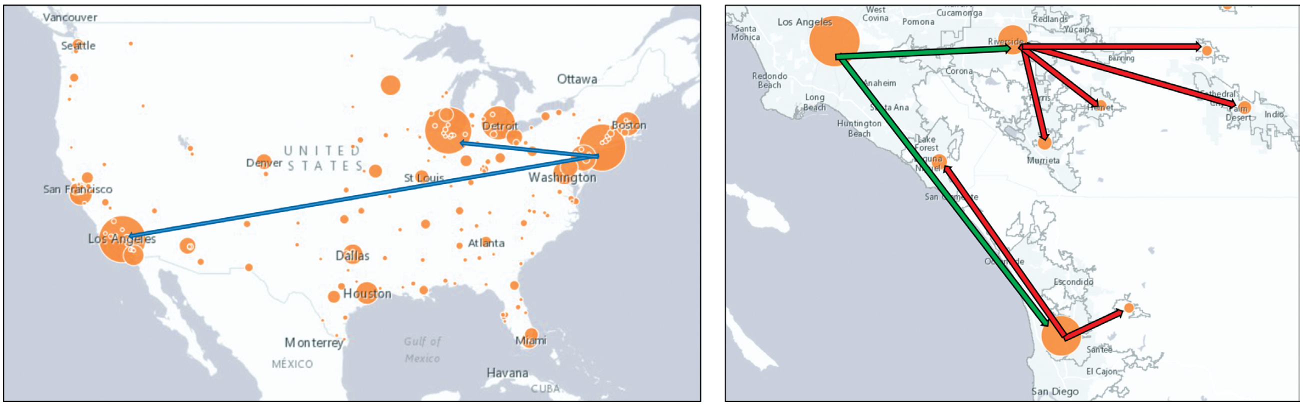


Figure 1.32. Hierarchical diffusion of a hypothetical trend. Geographers often study hierarchical diffusion in terms of urban hierarchies. New trends and products originate in large cities, then diffuse to medium and small cities over time. Maps by author. Data sources: Esri, HERE, Garmin, NGA, USGS.

burgers and fries with white and dark chocolate sauce. McDonald's is a global company, but its diffusion worldwide has stimulated innovation in new menu items. In a similar sense, the idea behind ride-hailing services such as Uber has stimulated new services for hailing rickshaws in India.

Diffusion processes do not flow unimpeded across the landscape but rather face barriers to diffusion. Barriers can be physical or cultural. Mountains, oceans, rivers, dense forests, and deserts can act as physical barriers that slow or stop diffusion. Physical barriers can also include walls, trenches, and other human-built features. Cultural barriers can be just as powerful in stopping or slowing diffusion. Language, race and ethnicity, religion, income, and other cultural differences can limit communication and interaction between groups of people, thus inhibiting the diffusion of ideas and items from one community to another, be it religion and philosophy, music, disease, or technology. Furthermore, cultures that are more conservative and tradition-based sometimes resist the diffusion of new ideas and items from other people and places. The Taliban's prohibition of some music, technology, and clothing in Afghanistan limits diffusion into areas under its control.

Human-environmental interaction

The ecological perspective: Cultural ecology

As discussed so far, spatial patterns are created from the interaction between places and the diffusion of things over space. But these patterns are also the result of another type of relationship studied by geographers: human-environmental interaction. The interaction between humans and the environment is known as the ecological perspective, or cultural ecology—the interplay of human cultures with ecological patterns.

Humans impact the environment in many ways. They alter plant and wildlife distributions by converting natural habitats to farms and cities; they change the course of rivers through dams and canals; they alter the quality of air, water, and soils through pollution; and they remove hills and fill valleys for development projects. Very few places are free of human impacts, and with human-induced climate change, the distributions of plants, animals, crops, and human settlements are likely to be further transformed at a global scale.

Similarly, the environment impacts humans. Human settlements tend to be less populous in areas that are too wet, such as the tropics; too dry, such as deserts; or too cold, such as the far north and far south (figure 1.33). These types of environments are poor for agriculture and make large-scale food production difficult, thus limiting human settlement. The natural environment also influences components of human culture. For example, because of climatic differences, northern Europeans have a traditional diet that is high in fish, meats, and carbohydrates, whereas Mediterranean Europeans have a traditional diet that includes a wide variety of fruits and vegetables. The way people dress is also a function of environment; consider how people dress in sun-soaked Rio de Janeiro, Brazil, and chilly Helsinki, Finland. How people build varies as well,

Figure 1.33. Ittoqqortoormiit Village in Greenland. Arctic settlements such as this village tend to have low populations due to harsh environmental conditions. Photo by Adwo. Stock photo ID: 200898014. Shutterstock.

with wood used in forests, adobe in deserts, steeply pitched roofs in areas of heavy snowfall, and flat roofs in arid regions.

Environmental determinism and possibilism

Environmental determinism is the idea that the natural environment determines much of the spatial patterns of human activity. As in the earlier examples, the environment helps determine where people live or do not live, what types of crops they grow and what foods they eat, how they dress, and how they build their houses. This theory has also been used to explain patterns of economic development. European thinkers once believed that the mid-latitudes, which were not too hot, too cold, too wet, or too dry, led to vigorous, hardworking, and productive societies. In contrast, they thought, tropical latitudes, with their heat and humidity, made hard work so unpleasant that societies remained primitive. Environmental constraints on hard work were said to hold true of hot desert regions and cold high-latitude regions, as well.

Environmental determinism fell out of favor during the 20th century. Historically, many successful societies have formed in areas once considered to have overly harsh environments, from the Mayans of Central America to the great ancient cities of Mesopotamia in the Middle East. More recently, tropical places such as Singapore and Hong Kong have become among the richest in the world, and major urban areas such as Phoenix and Las Vegas have grown in deserts. Irrigation allows for new crops in the desert, whereas fertilizers in the tropics can overcome poor soil quality. As is clear from these examples, environmental conditions do not directly determine the spatial patterns of human activity.

Instead, the concept of possibilism is more appropriately used when studying human-environmental interaction. Possibilism is the notion that the natural environment creates possible outcomes for human activity but that humans can overcome many of the constraints imposed by nature. With human creativity, tropical Singapore used the natural conditions of a harbor located on trade routes between Asia, the Middle East, and Europe to become a wealthy state tied to international trade and services. Human taming of the Colorado River through construction of the Hoover Dam, combined with the invention of air conditioning, allowed for the massive urban areas of Las Vegas and Phoenix to grow. Natural environments offer opportunities and constraints, but because of human ingenuity, they do not determine spatial patterns.

Environmental perception and hazards

Geographers are also interested in how people perceive their environments and how these perceptions influence cultural ecology. Environmental perception relates to the way in which people view the environment and how this view influences their interpretation and use of the natural landscape. One group of people may view the forest as a place for recreational hiking and will want to preserve it in a natural state, whereas another may view it as a source of economic development and will want to harvest timber. Different perceptions lead to different uses of the land.

Humans can perceive natural landscapes in terms of exploitation, preservation, or sustainability. The exploitative approach is to use natural resources and modify natural landscapes in the unlimited pursuit of economic growth. Preservation is aimed at leaving natural resources and landscapes untouched by humans, with use geared, at most, toward limited-impact recreation. In contrast to both, sustainability is the idea that natural resources and landscapes can be used by humans for economic growth, but they must be used in a manner that does not deplete resources and is sustainable in the long run. Lumber can be harvested from forests but only at a rate that allows for regeneration of trees and protection of wildlife and flora; fishing can be sustainable by restricting the number of fish taken per season; natural landscapes can be converted to urban uses or farming as long as waterways are protected and wildlife preserves are incorporated. Sustainability can be accomplished either by cultural norms in a society or by government regulations that restrict overuse.

Environmental perception is useful when studying how people react to natural hazard risk. Many residents of modern urban societies view natural hazards as something that humans can control. People build homes in areas prone to flooding along rivers and coastlines, in wooded and canyon areas at risk of fire, and in areas of landfill subject to earthquake liquefaction. As cities in much of the western United States expand, more homes are being built in scenic yet fire-prone hillside areas. Residents assume that firefighters and forest crews will keep their homes safe, which in many cases is true, but at a great cost in terms of economic resources. Similarly, residents of the eastern and southeastern United States increasingly live along coastal areas subject to hurricanes and other flooding (figure 1.34). Again, the perception is that these scenic areas are safe to live in, resulting in a great deal of housing and urban infrastructure that is exposed to serious environmental risk.

In some societies, people may not believe that humans can control natural hazard risk but rather must leave their fate in the hands of the gods. Still others may avoid living in areas of risk, avoiding flood zones or canyons at risk of landslide or fire. In some cases, perceptions of natural hazard risk can change over time, altering how people inhabit the land. In Chile, a major earthquake in 2010 sent tsunami waves rushing over many coastal towns, destroying tens of thousands of homes and killing more than 500 people. As a result, people's perceptions of coastal risk changed. Reconstruction aimed to mitigate future risk, with some coastal areas being reserved for parkland and housing in high-risk areas being built to withstand future inundation (figure 1.35).

Figure 1.34. Homes destroyed by Hurricane Sandy in Far Rockaway, New York, in 2012. Many people perceive natural hazard risk as minimal, and they continue to build in places prone to hurricane wind and flood damage. Photo by Leonard Zhukovsky. Stock photo ID: 130759928. Shutterstock.

Figure 1.35. Tsunami warning sign in Castro, Chile. After a deadly earthquake and tsunami in 2010, some towns began establishing buffer zones between housing and the coast. Photo by Matyas Rehak. Stock photo ID: 568647175. Shutterstock.

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