

Active Remote Sensing Instruments that direct a beam of energy at a surface and analyze the energy reflected back are active remote sensors. An example is *radar* (radio detection and ranging). A radar transmitter emits short bursts of energy that have relatively long wavelengths (0.3 to 10 cm) toward the subject terrain, penetrating clouds and darkness. Energy reflected back to a radar receiver for analysis is known as *backscatter*. Radar images collected in a time series allow scientists to make pixel-by-pixel comparisons to detect Earth movement, such as elevation changes along earthquake faults (see Chapter 10, Figure 10.1.2, on page 333).

Another active remote-sensing technology is airborne LiDAR, or *light detection and ranging*. LiDAR systems collect highly detailed and accurate data for surface terrain using a laser scanner, with up to 150,000 pulses per second, 8 pulses or more per square meter, providing 15-m (49.2-ft) resolution. GPS and navigation systems onboard the aircraft determine the location of each pulse. LiDAR data sets are often shared among private, public, and scientific users for multiple applications. Scientists are presently studying the effects of Hurricane Sandy along the U.S. East Coast using LiDAR (see Chapter 13, Figure 13.17, on page 424).

Geospatial Data Analysis

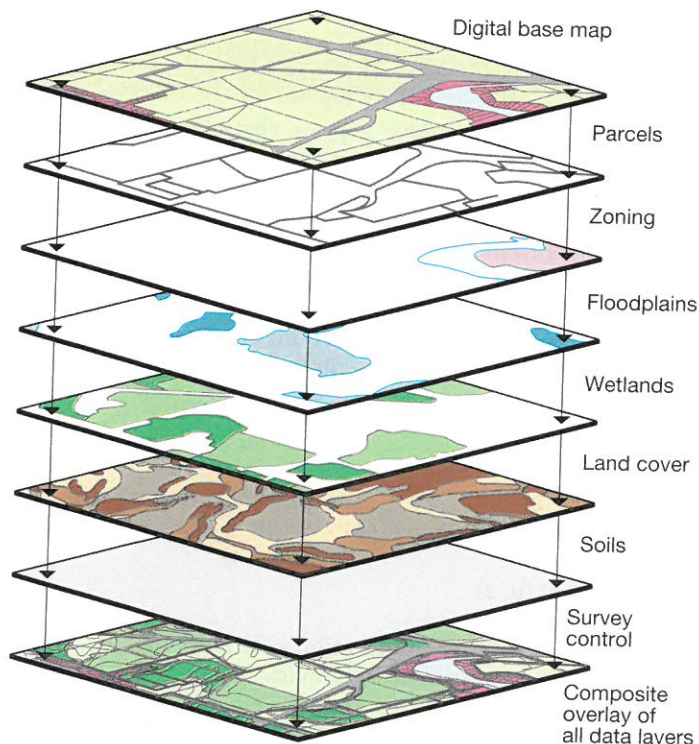
Techniques such as remote sensing acquire large volumes of spatial data that must be retrieved and processed for scientific applications. Scientists use a number of rapidly

developing technologies for analysis and visualization of large data sets.

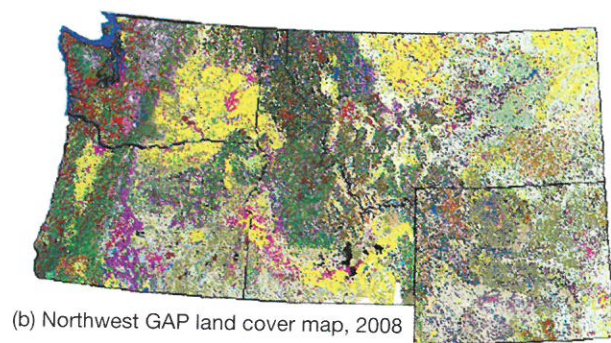
Geographic Information Systems The integration of geographic information from direct surveys (on-the-ground mapping) and remote sensing can be accomplished using a **geographic information system (GIS)**, a computer-based data-processing tool for gathering, manipulating, and analyzing geographic data. In a GIS, spatial data can be organized in layers, or planes, containing different kinds of information (Figure 1.26). The beginning component for any GIS is a map, with its associated coordinate system, such as latitude–longitude provided by GPS or digital surveys (the top layer in Figure 1.26a). This map establishes reference points against which to accurately position other data, such as remotely sensed imagery. Whereas printed maps are fixed at the time of publication, GIS maps can be easily modified and evolve instantly.

A GIS is capable of analyzing patterns and relationships within a single data plane, such as the floodplains or soils layer in Figure 1.26a. A GIS also can generate an overlay analysis where two or more data planes interact. When the layers are combined, the resulting synthesis—a *composite overlay*—is ready for use in analyzing complex problems. The utility of a GIS is its ability to manipulate data and bring together several variables for analysis.

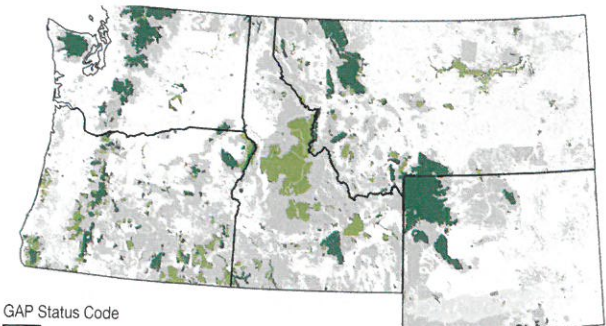
Figures 1.26b and c show two GIS map layers from the Northwest Gap Analysis Program (GAP), a five-state



(a) Layered spatial data in a GIS format



(b) Northwest GAP land cover map, 2008



(c) Northwest GAP protected areas map, 2008

Figure 1.26 Geographic information system (GIS) examples. [(a) After USGS. (b) and (c) University of Idaho, Northwest Gap Analysis Project.]