**EXERCISE 2**
**Contrasting Hierarchical Levels of Organization and Scale**

Next, consider some ecological entity of interest to you. Formulate a question (and hypothesize an answer) regarding its distribution, abundance, behavior, or dynamics. Be prepared to explain how the explanation is related to the next lower hierarchical level, and how the significance is related to the next higher level of organization. Then, ask your question at a different spatial scale, changing either the grain or extent of your observation set. Again, explain the *why* and the *so what* and whether either changed with the scale of your observation.

## CONCLUSIONS

In some fields of biology, such as medicine, hierarchical levels are well defined (e.g., cell, organ, body), and problems of scale may seldom arise. If you want to study blood cells, you reach for a microscope. A landscape is less easily defined, however, and scale must be carefully considered in problem formulation, data collection, and analysis of results. Otherwise, you might reach for a magnifying glass when you really need a telescope.

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CHAPTER 2

# COLLECTING SPATIAL DATA AT BROAD SCALES

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## OBJECTIVES

Spatial data are routinely used by landscape ecologists to formulate hypotheses, examine trends in landscape patterns, and make management decisions. Thus, a basic familiarity with the variety of data sources currently available, and an understanding of differences and similarities among them, is a fundamental part of landscape ecology. The goals of this lab are to

1. demonstrate the methods used to obtain spatial data at broad scales;
2. illustrate the differences among and the limitations of different data sources;
3. convey the challenges of collecting and using spatially explicit data; and
4. combine field and laboratory results to illustrate the connections between ground-level data, remote-sensing data, topographic maps, and Geographic Information System (GIS) data.

As a class, students will collect reference data at several field sites selected by the instructor. The data obtained from field sampling will be compared in the laboratory to data collected from other data sources such as aerial photos, topographic maps, satellite imagery, and GIS layers available for your area.

## INTRODUCTION

Spatial data commonly used in landscape ecology come from a variety of sources, such as field sampling, aerial photos, topographic maps, satellite images, or an existing GIS. The spatial data from these sources are created using different techniques, have their own set of inherent assumptions, and may accentuate or minimize certain landscape features. Different spatial data types also have different sources of error and provide information at different levels of resolution. Thus, the first step in using spatial landscape data often involves verifying the accuracy of the different sources of data as well as determining which sources fit the needs of the project at hand.

**Accuracy assessment** involves verifying the accuracy and legitimacy of spatial data against a reliable source of reference data. Field-collected reference data can also be used *a priori* in the preparation of spatial data. Here, we simplify the procedure in order to give you exposure to as many different types of data sources as possible. The class will work in small groups (three to four people) to collect field data at different sites throughout the local area. The field results will then be compared to data collected from selected spatial data sources in the laboratory.

## MATERIALS

For fieldwork, you will need the provided **Summary Data Sheet** (Table 2.1 on the CD), additional paper for field notes, a pencil, and a road map. A vehicle will be needed as the transects will span several kilometers. Your instructor will provide a map outlining the study area of each group. For the laboratory work, you will use the **Summary Data Sheet,** a pencil, a ruler, a calculator, and the data sources provided by your instructor.

### EXERCISE 1
### Fieldwork

#### DATA COLLECTION

Each group will receive a map outlining the boundaries of their study area of approximately 25 km$^2$. Within the study area, you must position three separate transects, each 3 miles in length (depending on the country you are in and your car's odometer, you may wish to sample transects 5 km in length). Ideally, the transects should be fully representative of the cover types in your area. Therefore, the different transects should be established in different cover types within the area, such as suburban, rural, and natural areas.

For data collection, use the odometer to record the length of each cover type on *one side of the road* as you drive along each transect. Your instructor will provide directions regarding which cover type categories to



use. In the U.S. Midwest, for example, land-cover categories might include agriculture, urban, forest, wetland, prairie, and water (as shown in the Summary Data Sheet). While it may be necessary to make more detailed subcategories, they must all aggregate up to the basic cover categories provided by the instructor. A digital version of the **Summary Data Sheet** has been provided on the CD (Table 2.1 under the directory for this lab), which can be altered to suit your particular categories.

It will also be helpful to take very detailed notes of the location of each transect and note any landmarks (e.g., crossroads) or other important identifying features. This information will be crucial in helping to relocate the transects using the other spatial data sources later. In order to ensure that the appropriate spatial data will be available for the areas sampled, *be certain to stay within the boundaries of your assigned area.*

*NOTE*: As you sample, you will be forced to make decisions and make assumptions about your data, your methodology, your categorizations, and so on. There is not one correct way to sample. Rather, you must consider your purpose for data collection, clearly document your rationale, and *most important, be consistent!*

#### DATA ANALYSIS

After the data collection from your field transects is complete, each group will be responsible for calculating the following summary statistics *for each transect in their area:*

1. Proportion ($p$) of the total length of each transect occupied by each cover type
2. Mean segment length for each cover type
3. Edges, or the number of times you cross a boundary between two different cover types
4. Coefficient of variation (% CV) for each variable ($p$, mean segment length, and edges) for each cover type, across all data sources

The following formulas may be helpful, where $n$ is the number of segments and $x$ is any variable ($p$, mean segment length, or edges):

| Standard Deviation ($s$) | Mean ($\bar{x}$) | Coefficient of Variation (%) |
|---|---|---|
| $\sqrt{\frac{n\sum x^2 - \left(\sum x\right)^2}{n(n-1)}}$ | $\frac{\sum x}{n}$ | $\frac{\bar{x}}{s} \times 100$ |

Results will be reported using **Table 2.1, Summary Data Sheet,** on the CD. These statistics will be computed again after resampling the same transects using the other data sources.

## EXERCISE 2
## Spatial Data Sources

Next, in the laboratory, the data collected at your field site will be compared to other commonly used sources of landscape data. Your task is to locate the same transects you sampled in the field and then resample them using the provided spatial data sources. The same summary data will be calculated for each cover type on each transect. Use the following sources of data provided by your instructor (as available).

### Topographic Maps

Maps are graphic representations of the earth's surface and are based on a set of assumptions and decisions as to what constitutes "important" information. This is governed, to a large extent, by the scale of a map. The scale of a map sets limits on what is represented and what is omitted. The scale of a map is also used to determine the distance that one unit on the map surface represents on the actual ground surface. As an example:

$$\frac{\text{map distance}}{\text{ground distance}} = \frac{1}{500} = 1{:}5000$$

One way to remember the differences between the terms **broad scale** and **fine scale** (as used by landscape ecologists, see Chapter 1, Scale and Hierarchy Theory) and **large scale** and **small scale** (used by geographers in reference to maps) is that to a geographer, a map at a scale of 1:5000 is a larger scale map than a 1:24,000 map because 1 is a larger portion of 5000 than of 24,000 (Monmonier, 1996).

*Question 2.1.* Using the terminology of a landscape ecologist, is a map rendered at a scale of 1:5000 a fine-scale map or broad-scale map relative to a map at a scale of 1:24,000?

A **planimetric map** such as a road atlas shows only horizontal (two-dimensional) information, while a **topographic map** shows the elevation of objects. Differences in topography are often shown using contour lines (Figure 2.1). The slope between any two points can be determined from the contour lines of a topographic map and can be calculated in a very general form as follows (Ciciarelli, 1991):

$$G = D/H$$

where $G$ = the slope gradient between two points, $D$ = the difference in elevation between two points, and $H$ = the horizontal distance between two points.

*Question 2.2.* Interpreting the contour lines, qualitatively identify the area that *appears* to be the steepest, as well as the area that appears to be the flattest, on the topographic map for your area. Then, starting with the steeper area, quantitatively determine the slope using the previous formula. Repeat for the flattest area, using the same length line ($H$) as you used for the steep area. Do your quantitative slope measurements confirm your qualitative map interpretation?

The first topographic map was made in 1879 (U.S. Geological Surgery, 1998). Today, many topographic maps are based on information from aerial photographs. Topographic maps from the U.S. Geological Survey (USGS) at a scale of 1:24,000 are referred to as the 7.5 Minute Quadrangle Series. On these maps, 1 inch represents 2000 feet. Topographic maps can be purchased at low cost from most local USGS offices and are now also available online. Different maps may be available outside the United States.



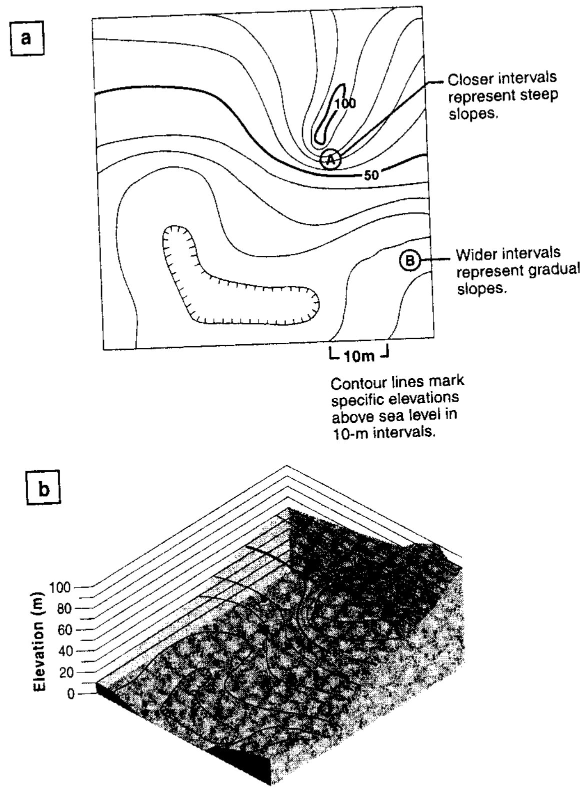


FIGURE 2.1 Representations of topographic relief. Each line represents land at a particular elevation above sea level (in this case, in 10-m intervals). (a) Schematic of topographic features as depicted on a topographic map. Steep gradients are represented by lines close together (area A); while contour lines far apart represent gradually sloping areas (area B). Ridge tops are shown as closed loops, while depressions are shown as crosshatched lines. (b) A three-dimensional representation of the topographic map above.

### Aerial Photographs

The earliest known aerial photograph was taken from a balloon over a village in France in 1858 (Lillesand and Kiefer, 1994). Taken from aircraft today, aerial photographs can be produced at a variety of scales depending on the altitude of the aircraft and attributes of the camera. When examining your photographs, note that the coverage of an area often overlaps in adjacent photographs.

Measuring *exact* distances on aerial photographs can be problematic for a variety of reasons. **Relief displacement** occurs because low-lying areas are in fact farther from the camera lens and appear smaller in size than areas of higher elevation. For example, a 50-hectare field would look somewhat smaller in a low-lying area and somewhat larger in an area of high elevation. This effect is most apparent in areas of very mountainous terrain. **Tilt displacement** can occur if the camera lens (or more precisely, the optical axis of the camera) is not exactly perpendicular to the ground surface when a photo is taken, but rather is at an angle. This will cause farther objects to appear smaller than closer objects even if they're the same size (Warner et al., 1996). **Orthophotos** are aerial photographs that have been "orthorectified"—that is, errors due to various types of distortion have been corrected.

*Question 2.3.* Given an aerial photo with no information on the scale of the photograph, how would you determine the scale? *HINT*: One way to approach this is to consider some popular outdoor sports, or see Ciciarelli (1991; 61).

## Satellite Imagery

Just as its name implies, **remote sensing** involves the capture of images from some remote distance. Remote sensing can provide information on shape, color, position, temperature, moisture content, and the "health" of vegetation (Wilkie and Finn, 1996). This is often accomplished using satellite imagery; however, aerial photographs, acoustic sounding methods, and radar are also examples of remote sensing. Some commonly used satellites for the collection of spatial data are the Landsat and SPOT satellites. Some considerations for selecting satellite versus aircraft imagery are that aircraft fly at a lower altitude and thus generally collect data at a finer resolution, while satellites cover a greater extent. Wilkie and Finn (1996: 53–60) provide a detailed discussion of the costs and benefits of aircraft versus satellite data. However, the technology associated with satellite remote sensing is rapidly advancing and changing, and data are becoming available at ever-increasing levels of resolution.

Most satellite remote sensing is based on detecting the way surfaces reflect and absorb visible and infrared radiation, a subset of the **electromagnetic spectrum** (Figure 2.2). The percentage of incident light of particular wavelengths that is reflected by an object is referred to as **spectral reflectance** (the total quantity of energy reflected is termed **radiance**). Remote sensors detect the radiance associated with a given pixel and then this information is often converted to the spectral reflectance. Different cover types will each have their own spectral reflectance. For example, chlorophyll in vegetation primarily absorbs radiation in the blue and red wavelengths and reflects radiation in the green wavelengths. Thus, a pixel can be **classified** as deciduous forest, water, or barren soil, for example, based on its spectral reflectance.

Imagery consists of certain **bands**—this refers to the wavelengths of light that are detected by the satellite's sensors. For example, Band 1 in a Landsat-TM satellite detects wavelengths from 0.45 to .52 micrometers (or blue wavelengths). Remote sensing satellites can also detect wavelengths outside the spectrum of visible light using infrared bands, allowing the analysis of spatial patterns otherwise invisible to the naked eye. For example, infrared sensors are particularly useful for distinguishing healthy and stressed vegetation and delineating water bodies.



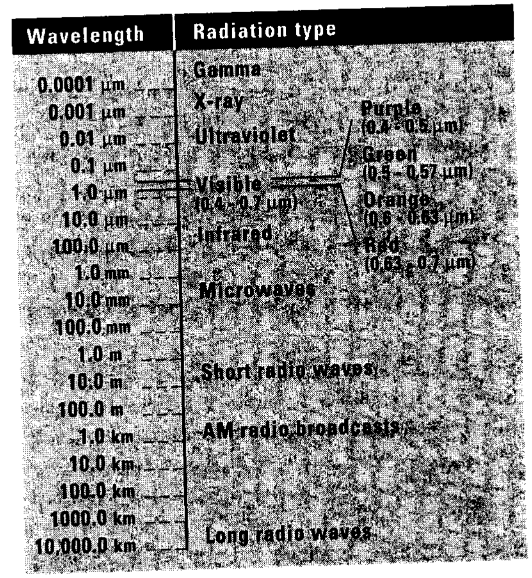


FIGURE 2.2
The electromagnetic spectrum

Satellite imagery of your area will be handed out in class. You may be given either classified or unclassified imagery. If provided with both, it is important that you "sample" the unclassified image first, before you see the categorizations used in the classified image.

## GIS Data

If GIS data are available for your site, they were likely created using some of the data sources you have just examined. Try to determine which other data source matches your GIS data most closely. Chapter 3 (Introduction to GIS) provides a basic introduction to the components of a GIS as well as some experience using one.

## WRITE-UP

Your assignment includes five main parts:

1. Introduction—Briefly describe the objectives of the exercise and how well they were met.
2. Methods
   (a) Discuss your rationale behind transect placement.

   (b) Clearly identify the spatial extent, minimum mapping unit, and classification scheme you used.
   (c) Discuss any other decisions you made during data collection or analysis that are important for the interpretation of your data.
3. Results—Include your completed **Summary Data Sheet** (Table 2.1 on the CD).
4. Discussion—Address the following questions in your discussion:
   (a) Were there consistent differences in the information obtained from the different data sources?
   (b) How different and/or similar were the results obtained by the different methods?
   (c) What explains the differences and/or similarities in your summary statistics?
   (d) How well did your sampling capture the land-cover types at your site?
   (e) How well do your data portray the fragmentation and connectivity of your site?
   (f) From your experience, discuss the apparent utility of each data source. Are particular types of research questions best suited to particular data sources? Which land-cover types are best observed using the different data sources?
5. Appendix—Attach a copy of your raw field notes.

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CHAPTER 3

# Introduction to Geographic Information Systems (GIS)

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## OBJECTIVES

Geographic Information Systems (GIS) are important tools for viewing broad-scale patterns of spatial data, organizing and integrating information about an area, and analyzing that data to answer questions. A GIS can be used to ask, What is the total area of parks and preserves within 100 meters of a stream or lake? or, How many different landowners own property in a given area? or, What is the total length of roads and highways that intersect a large predator's home range? As such, a GIS has wide-ranging applications for both management and research in landscape ecology. In this lab, you will

1. gain an appreciation for the utility of a Geographic Information System as an important tool of landscape ecology;
2. learn the basic components of a GIS and gain familiarity with some commonly used terminology; and
3. gain hands-on experience using a simplified GIS program to pose and answer questions.

The exercises in this lab use a simple spatial viewing tool called ArcExplorer, produced by Environmental Systems Research Institute, Inc. (ESRI). After being exposed to the fundamentals of understanding and using a GIS, you will use your knowledge to perform some basic analyses on GIS data from the Gifford Pinchot National Forest, located in the state of Washington (USA).