CHAPTER 7

UNDERSTANDING LANDSCAPE METRICS I

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OBJECTIVES

An extensive set of landscape metrics exists to quantify spatial patterns in heterogeneous landscapes. Developers and users of these metrics typically seek to *objectively* describe landscapes that humans assess *subjectively* as "clumpy," "dispersed," "random," "diverse," or "fragmented" for example. Because the quantification of pattern is fundamental to many of the relationships we seek to understand in landscape ecology, a basic familiarity with the most commonly used metrics is extremely important. While several software programs (e.g., FRAGSTATS [McGarigal and Marks, 1995] and r.le [Baker and Cai, 1992] in the Grass geographic information system) evaluate maps quickly and cheaply, there are no absolute rules governing the proper use of landscape metrics. Thus, in this lab, to help foster the appropriate use of landscape metrics, students will

1. gain familiarity with some commonly used metrics of landscape pattern;
2. distinguish metrics that describe landscape composition from those that describe spatial configuration; and
3. understand some of the factors that influence the selection and interpretation of landscape metrics.

In addition, computer-based sections of the lab (Parts 3 and 4) are provided to meet the following objectives:

1. provide experience with landscape pattern analysis using FRAGSTATS; and
2. illustrate the correlation structure among some commonly used landscape metrics.

In this lab, a set of commonly used metrics in landscape ecology is presented. Emphasis is placed on the understanding gained from actually calculating select metrics by hand (using small landscapes and a calculator) rather than using only a metric-calculation package. Although the landscapes used for the hand calculations are much smaller than those typically input to metric-calculation software packages, the concepts and equations learned in this lab are the same as those used for full-sized images. Sections using FRAGSTATS and actual landscape images are also included to investigate the behavior of landscape metrics in a more realistic setting. The CD contains digital versions (.pdf files) of all the images and figures you will use in this lab, under the directory **"Images"** for this chapter. These images can be viewed using Adobe Acrobat Reader, which is available free on the Web. The CD also contains a pdf file of all the data entry tables, which you should print before starting the lab.

INTRODUCTION

The quantification of landscape pattern has received considerable attention since the early 1980s, in terms of both development and application (Romme and Knight, 1982; O'Neill et al., 1988; Turner et al., 1989; Baker and Cai, 1992; Wickham and Norton, 1994; Haines-Young and Chopping, 1996; Gustafson, 1998). Several of the most commonly used landscape metrics were derived originally from percolation theory, fractal geometry, and information theory (the same branch of mathematics that led to the development of species diversity indices). The increased availability of spatial data, particularly over the past two decades, has also presented myriad opportunities for the development, testing, and application of landscape metrics.

Why are methods for describing and quantifying spatial pattern such necessary tools in landscape ecology? Because landscape ecology emphasizes the interactions among spatial patterns and ecological processes, one needs to understand and quantify the landscape pattern in order to relate it to a process. Practical applications of pattern quantification include describing how a landscape has changed through time; making future predictions regarding landscape change; determining whether patterns on two or more landscapes differ from one another, and in what ways; evaluating alternative land management strategies in terms of the landscape patterns that may result; and determining whether a particular spatial pattern is conducive to movement by a particular organism, the spread of disturbance, or the redistribution of nutrients. In all of these cases, the calculation of landscape metrics is necessary to rigorously describe landscape patterns. However, relating these metrics of pattern to dynamic ecological processes still remains an area in need of further research.

Next, you will examine and manually calculate several commonly used landscape metrics using a calculator and a small landscape to ensure that you understand their underlying mathematics (Parts 1 and 2). Then, once you have a basic understanding of these metrics, two computer-based exercises (Parts 3 and 4) are provided to allow you to calculate metrics using FRAGSTATS and larger landscape images.

EXERCISE

Part 1. Metrics of Landscape Composition

The simplest landscape metrics focus on the composition of a landscape (e.g., which categories are present and how much of the categories there are), ignoring the specific spatial arrangement of the categories on the landscape. In this section, you will examine three metrics designed to assess the composition of a landscape: (1) the proportion of the landscape occupied by each cover type, (2) dominance, and (3) Shannon evenness.

Proportion (p_i) of the landscape occupied by the ith cover type is the most fundamental metric and is calculated as follows:

$$p_i = \frac{\text{Total number of cells of category } i}{\text{Total number of cells in the landscape}}$$

Proportions of different landscape types have a strong influence on other aspects of pattern, such as patch size or length of edge in the landscape (Gardner et al., 1987; Gustafson and Parker, 1992), and p_i values are used in the calculation of many other metrics. Several metrics derived from information theory use the p_i values of all cover types to compute one value that describes an entire landscape. Information theoretic metrics were first applied to landscape analyses by Romme (1982) to describe changes in the area occupied by forests of varying successional stage through time in a watershed in Yellowstone National Park, Wyoming (USA). Romme reasoned that the indices used to quantify species diversity in different communities could be modified and applied to describe the diversity of landscapes. Dominance and Shannon evenness are two such metrics that characterize how evenly the proportions of cover types occur within a landscape.

Dominance (D) (O'Neill et al., 1988) can be calculated as:

$$D = \frac{\ln(S) + \sum_i [p_i * \ln(p_i)]}{\ln(S)}$$

where S is the number of cover types, p_i is the proportion of the ith cover type, and ln is the natural log function. Values for D range between 0 and 1; values near 1 indicate a landscape dominated by one or few cover types, while values near 0 indicate that the proportions of each cover type are nearly equal.

Shannon evenness (*SHEI*) (Pielou, 1975) can be calculated as:

$$SHEI = \frac{-\sum_i [p_i * \ln(p_i)]}{\ln(S)}$$

where S is the number of cover types, p_i is the proportion of the ith cover type, and ln is the natural log function. Values for *SHEI* range between 0 and 1; values near 1 indicate that the proportions of each cover type are nearly equal, while values near 0 indicate a landscape dominated by one or few cover types.

A very important detail to note in the alternative formulations of information theoretic metrics is whether a particular formulation has been normalized to a common scale. Some early applications of dominance and Shannon evenness were not normalized to a common scale (e.g., O'Neill et al., 1988). The nonnormalized forms of these metrics are very sensitive to the number of cover types S in the landscapes, and thus comparisons among landscapes that differed in S were problematic. Normalizing a metric ensures that its values fall within a standardized range, such as from 0 to 1 (and not from 0 to 157, for example!). With D and *SHEI*, the normalization involves dividing the numerator by the maximum possible value of the index (ln S), as shown earlier.

CALCULATIONS

To understand these metrics and calculate them by hand within a reasonable time frame, you will calculate the metrics for two small hypothetical landscapes represented as 10 × 10 grids (Figure 7.1). It may be useful to print extra copies of the images on the CD-ROM, under the directory "Images" for this chapter, for your hand calculations.

Metrics of Landscape Composition in an Early-Settlement Landscape

An "early-settlement" landscape is shown on the left in Figure 7.1. This image represents an area that was previously fully forested, but has lost some forest to agricultural and urban uses. The landscape is composed of a 10 × 10 grid with each grid cell representing an area of one square kilometer (1000 m × 1000 m; 10^6 m^2).

Calculation 1.1: Calculate the proportions occupied by each of the three land covers in the early-settlement landscape. Record the values in Table 7.1 from the CD.

Calculation 1.2: Calculate dominance for the early-settlement landscape and record in Table 7.1.

Calculation 1.3: Calculate Shannon evenness for the early-settlement landscape and record in Table 7.1.

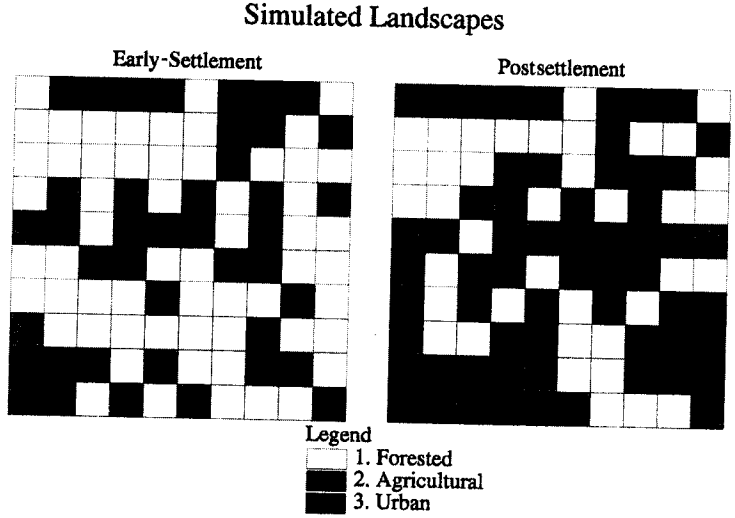

FIGURE 7.1
Hypothetical early-settlement and post-settlement landscape classifications.

Metrics of Landscape Composition in a Post-Settlement Landscape

A "post-settlement" landscape is shown on the right in Figure 7.1. This image represents the same area as the early-settlement landscape, but much later in time. Note that more of the forest has been converted to agricultural use. Additionally, some of the agricultural and forest land in the early-settlement image has been converted to urban use, while some of the early-settlement agricultural land has reverted to forest in the post-settlement image.

Calculation 1.4: Calculate the proportions occupied by each of the three land cover types in the post-settlement landscape. Record the values in Table 7.2 on the CD.

Calculation 1.5: Calculate dominance for the post-settlement landscape and record in Table 7.2.

Calculation 1.6: Calculate Shannon evenness for the post-settlement landscape and record in Table 7.2.

Considering the answers you obtained for both the early- and post-settlement landscapes, answer and discuss the following questions:

Question 1.1. How would you interpret/describe the changes in this landscape between the two time periods?

Question 1.2. Explain the relationship between dominance and Shannon evenness.

Question 1.3. If you were conducting an analysis of a real landscape, would you report both *D* and *SHEI*? Why or why not?

Question 1.4. To compare *D* or *SHEI* across two or more landscapes, does *S* need to be the same for each landscape in the comparison? Why or why not?

Question 1.5. Is there an upper and lower limit of *S* beyond which *D* and *SHEI* will not work?

Question 1.6. Use your calculator to perform some additional calculations of *D* assuming the proportions listed in Table 7.3 on the CD.

(a)Which of these hypothetical landscapes might be considered "similar" when only comparing *D*?

(b)Under what conditions could an interpretation of dominance (or other similar metrics) be problematic?

(c)Considering your interpretation of the data in Table 7.3, what other types of information and/or metrics would be necessary to distinguish these landscapes?

Part 2. Metrics of Spatial Configuration

A variety of landscape metrics are sensitive to the specific spatial arrangement of different cover types on a landscape. In this section, we will consider four components of landscape configuration: (1) patches, (2) edges, (3) probability of adjacency, and (4) contagion.

The **total number of patches** in a landscape results from first defining connected areas (i.e., patches or clusters) of each cover type *i*. Patches are commonly identified by using either of two neighbor rules. A patch may be identified using the **four-neighbor rule,** in which two grid cells are considered to be part of the same patch *only* if they are of the same cover type and share a flat adjacency between them. Alternatively, the **eight-neighbor rule** specifies that two grid cells of the same cover type are considered part of the same patch if they are adjacent *or diagonal* neighbors. In reporting the number of patches, it is important to distinguish whether the calculation is for all patches of all cover types or whether it is only for patches of a certain cover type *i*. In addition to the total number, patches can also be described in terms of their size (i.e., area) and edge-to-area ratio, which will be discussed later.

Mean patch size (MPS) is simply the arithmetic average size of each patch on the landscape or each patch of a given cover type. It is often calculated separately for each cover type as follows:

$$MPS = \frac{\sum_{k=1}^{m} A_k}{m}$$

where m = the number of patches for which the mean is being computed and A_k = the area of the kth patch. The units of area are defined by the user and should always be specified.

Edge calculations provide a useful measure of how dissected a spatial pattern is and can be calculated in a variety of ways. An edge is shared by two grid cells of different cover types when a side (not a corner) of one cell is adjacent to a side of the other cell (i.e., the four-neighbor rule). The total number of edges in a landscape can be calculated by counting the edges between different cover types for the entire landscape. Every edge in the landscape is counted only once.

Edge calculations are sometimes used to compute **edge-to-area ratios.** These may be computed in a variety of ways for a given landscape. For example, the total linear edge in a landscape can be divided by the area of the landscape to provide a single edge-to-area estimate, or edge density. More useful, however, are computations of edge-to-area ratios by cover type or for individual patches.

Edge calculations are sensitive to several factors. Whether the actual borders of the landscape image are considered as edges influences numbers of edges and edge-to-area ratios. (In this exercise, the landscape border will not be considered edge for your calculations.) Computer programs may use slightly different algorithms for totaling edges (e.g., the program RULE, used in Chapter 9, uses a different method for calculating total edge). It is extremely important to be consistent in both algorithm and units within a set of analyses. Additionally, although edge counts are relatively simple to compute from a landscape map, they are quite sensitive to the grain of the map (see Chapter 8, Understanding Landscape Metrics II: Effects of Changes in Scale).

Probability of adjacency ($q_{i,j}$) is the probability that a grid cell of cover type i is adjacent to a cell of cover type j. This metric is sensitive to the fine-scale spatial distribution of cover types and can be computed as:

$$q_{i,j} = \frac{n_{i,j}}{n_i}$$

where $n_{i,j}$ = the number of adjacencies between grid cells of cover type i and cover type j, and n_i = the total number of adjacencies for cover type i.

Probabilities of adjacency are often reported in an $S \times S$ matrix referred to as the **Q matrix.** Because they are probabilities, values for $q_{i,j}$ range from 0 to 1. High $q_{i,j}$ values indicate that the cells of cover type i have a high probability of being adjacent to cells of cover type j, while low $q_{i,j}$ values indicate a low probability. Values along the diagonals of the Q matrix (the $q_{i,i}$ values) are useful measures of the degree of clumping found *within* each cover type. High $q_{i,i}$ values indicate a highly aggregated, clumpy cover type, and low $q_{i,i}$ values indicate that the cover type tends to occur in isolated, dispersed grid cells or small patches.

The calculation of probabilities of adjacency may be performed in only the horizontal or only the vertical direction to detect directionality (referred to as

anisotropy) in a pattern. For example, imagine a landscape composed of alternating ridges and valleys oriented in a north–south direction and in which forest cover occupies the ridges and agriculture occupies the valleys. The probabilities of adjacency would be different depending on whether you moved from north to south or from east to west across this landscape. In this lab, the horizontal and vertical values are averaged into a single measure of adjacency.

Contagion (C) (O'Neill et al., 1988; Li and Reynolds, 1993, 1994) uses the **Q matrix** values to compute an index of the overall degree of clumping in the landscape. Just as *D* and *SHEI* used all p_i values for all cover types to compute one metric, contagion incorporates all $q_{i,j}$ values into one metric for the entire landscape. Contagion is useful in capturing relatively fine-scale differences in pattern that relate to the "texture" or "graininess" of the map. The equation is given by:

$$1 + \frac{\sum_i \sum_j [(p_i * q_{i,j}) * \ln(p_i * q_{i,j})]}{C_{max}}$$

where $q_{i,j}$ = the adjacency probabilities defined above, and $C_{max} = 2 * \ln(S)$, which gives the maximum value of the index for a landscape with *S* cover types.

Values for contagion range from 0 to 1. A high contagion value indicates generally clumped patterns of landscape categories within the image, while values near 0 indicate a landscape with a dispersed pattern of landscape categories. Note that contagion can be computed differently if the $q_{i,j}$ probabilities are computed by another algorithm (Li and Reynolds, 1993; Riitters et al., 1996). Because the contagion metric is computationally intensive, for this exercise it would be tedious to determine this value by hand for even a relatively tiny landscape such as the early-settlement landscape. Thus, for illustration purposes, you will compute the contagion value for only a subset of that landscape.

CALCULATIONS

Metrics of Spatial Configuration in an Early-Settlement Landscape

Refer back to Figure 7.1. Recall that the early-settlement landscape is meant to represent an area that was formerly fully forested, although some of the land has been converted for agricultural and urban use.

Calculation 2.1: Using the four-neighbor rule, calculate the total number of patches for each cover type in the early-settlement landscape. Enter your results in Table 7.4 on the CD.

Calculation 2.2: Using the four-neighbor rule, calculate the mean patch size for each cover type in the early-settlement landscape. Enter your results in Table 7.4.

Calculation 2.3: Calculate the number of edges for each category in the early-settlement landscape of Figure 7.1. Be sure to count both horizontal and vertical edges between cover types; you may find it useful to mark edges in pencil in your lab manual as you count. Enter your results in Table 7.5 on the CD.

Calculation 2.4: Using the results from Calculation 2.3, compute the edge-to-area ratio for each cover type and enter into Table 7.5.

Calculation 2.5: To begin calculating contagion, use Figure 7.2 to calculate the proportions occupied by each of the three land cover types in the *subset* of the early-settlement landscape. Record the values in Table 7.6 on the CD.

Calculation 2.6: Count the adjacencies for all cover types for the *subset* of the early-settlement landscape, as seen in Figure 7.2. Enter the results in Table 7.7 on the CD. Do not count the borders of the map for this exercise. HINT: If you mark each adjacency once as it is counted, you will mark 40 adjacencies.

Calculation 2.7: Note that Table 7.7 is symmetric. In effect, we have counted many, but not all, of the adjacencies twice. In particular, diagonal elements, which represent adjacencies between cells of the same type, have been counted only once. So that each adjacency is counted the same number of times, double the values from the diagonal elements of Table 7.7

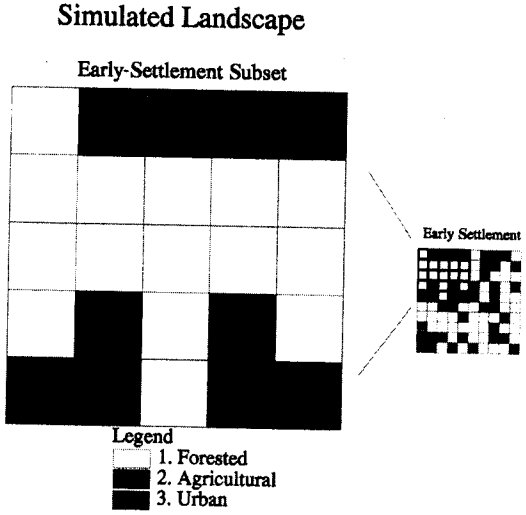

FIGURE 7.2
Subset of the early-settlement landscape used for calculating the contagion index.

and enter them in Table 7.8 on the CD, the **N** matrix. For the nondiagonal elements of Table 7.8, use the same value seen in Table 7.7.

Calculation 2.8: Use the values of the **N** matrix (Table 7.8) to compute the elements of the **Q** matrix (Table 7.9 on the CD).

Calculation 2.9: Calculate the contagion value for the subset of the early-settlement landscape using the elements of the **Q** matrix.

The contagion value: _____

Question 2.1. What characteristics of a landscape will influence the result you obtain for the number of patches and the average patch size?

Question 2.2. What characteristics of the landscape appear to have influenced the contagion value calculated in this section? How would you change the values of the grid cells to raise the contagion value?

Question 2.3. If you were considering a real landscape, do you think it would be reasonable, in general, to save computer time by calculating the contagion value for only a subset of the landscape? What characteristics of a real landscape might inhibit or encourage you to use only a subset?

Question 2.4. Suppose that you are given the task of describing how a landscape changed between two time periods, t_1 and t_2. The map of the first time period contains five cover types; the map from the second time period contains seven cover types because "forest" in t_2 was mapped in more detail—as deciduous, coniferous and mixed forest. How should you proceed with your comparison, and why?

Question 2.5. Two landscapes are the same size and both contain the same amount of a given cover type. Landscape A has 4 patches of that cover type, and landscape B has 17 patches of the same cover type. Which of the landscapes will have the greater length of edge of that cover type?

Question 2.6. From your set of calculations, do you think that after calculating a large number of metrics for a single landscape, additional metrics would provide little new information? How might you attempt to objectively determine an upper limit to the number of useful metrics?

Part 3. Using FRAGSTATS for Automated Landscape Metric Calculation for the Early and Post-Settlement Landscapes

In this section, you will use FRAGSTATS (McGarigal and Marks, 1995) to analyze the landscapes you examined in Parts 1 and 2. FRAGSTATS is available for free, computes a wide variety of metrics, is available in versions to analyze both raster and vector maps, and is probably the most widely used program for landscape pattern analysis. The FRAGSTATS program (Fragstat.exe) as well as the other files you will need for Parts 3 and 4 are on the CD-ROM

under the directory "FRAGSTAT" for this lab. To avoid potential problems, we *strongly recommend* you copy the entire folder for the lab to your computer (not just individual files). Within this directory is another folder called "Document," which contains frag.pdf, the excellent documentation for the program. This document presents a conceptual overview of each metric. Also included are the appendices fraga.pdf, fragb.pdf, and fragc.pdf. (You are strongly encouraged to read these files, as FRAGSTATS will produce many more landscape metrics than you have computed by hand in this exercise.) You will input FRAGSTATS-compatible files (which have been given the arbitrary suffix .fra) for the early- and post-settlement landscapes. You will then be prompted for a variety of information from FRAGSTATS as detailed here to specify your output files and the algorithm to use for your calculations.

INPUT

(a) FRAGSTATS accepts ASCII files as input. We have specified landscape files with the .fra extension. FRAGSTATS will prompt:

```
Enter name of landscape image:
```

Select the appropriate .fra file for your FRAGSTATS run.

(b) FRAGSTATS then will prompt:

```
Enter base name for output files . . .
```

You may enter any string up to eight characters. Suggestions are given in each of the calculations for this section.

(c) FRAGSTATS will then lead you through a series of questions to specify settings for the suite of metrics it calculates for your image. The prompts and their meaning are given below.

```
Enter size of grid cell in meters (must be square):
```

Enter the size of one side of a grid cell for your image. The size of cells for each image is given in each of the calculations for this section.

```
Enter distance from edge in meters to use in core area
determination:
```

In this section, we will not use core area metrics, so hit the Enter key to use the default value. See the documentation for core area metrics for further information.

```
Enter type of input image file:
```

Enter "2" to indicate an ASCII file.

```
Enter number of rows, columns in image:
```

Enter the appropriate number of rows and columns for the image (e.g., "10 10"). The number of rows and columns of each image is given in each of the calculations for this section.

```
Enter the value for interior (positive) background cells
(even if you only have exterior background):
Enter the maximum number of patch types in the landscape
(for relative patch richness):
Enter name of file containing weights for each combination
of patch type:
Enter option for patch ID image:
Enter name of ASCII file containing character descriptors
for each patch type:
What proportion (equivalent to contrast weight) of the
landscape boundary and background class edges should be
considered edge? . . .
```

Each of these questions is outside the scope of this section. Use the Enter key to enter the default value for each of these questions. The FRAGSTATS documentation has more information about each of these prompts if you want a deeper treatment of the capabilities of the program.

```
Use diagonals in patch finding [y/n]:
```

As directed in each calculation below, enter "y" to specify the eight-neighbor rule for finding patches, or "n" to specify the four-neighbor rule.

```
Enter search radius for proximity index:
```

In this section, we are not interested in proximity indices, so hit the Enter key to use the default value.

```
Calculate nearest neighbor distance:
```

We are not interested in knowing nearest neighbor distances, so hit the "n" key to use the default value.

```
Output patch level statistics [y/n]:
```

In this section, we are not interested in knowing details about each patch, but instead are primarily interested in metrics that summarize the entire image. Enter "n".

```
Output class level statistics [y/n]:
```

Although we will not directly use the information contained in the summaries of each landscape category, it is interesting to note that some metrics can be calculated for each class. Enter "y".

OUTPUT

FRAGSTATS outputs information in several files. In this lab, we are concerned with the .ful file, a text file that can be viewed with any text editor. Information about each landscape category is at the beginning of the file, and metrics for the entire landscape are at the end of the file. In these landscapes, category 1 = forested, category 2 = agricultural, and category 3 = urban.

CALCULATIONS

Calculation 3.1: The early-settlement landscape with the four-neighbor rule.

1. Run FRAGSTATS using the esett.fra landscape file. This is a 10 × 10 landscape in which one side of a cell represents 1000 meters on the ground.
2. As the base for output file names, enter "early4".
3. Compare the results given by FRAGSTATS with your answers calculated by hand for the early-settlement landscape in the previous section. (NOTE: FRAGSTATS does not calculate dominance.)

Calculation 3.2: The early-settlement landscape with the eight-neighbor rule.

1. Run FRAGSTATS using the eight-neighbor rule for the early-settlement landscape. Again, use the esett.fra landscape file.
2. As the base for naming output files, enter "early8".
3. Use the same options as in the previous FRAGSTATS run, except when asked about using diagonals for finding patches. At that prompt, enter "y" to invoke the eight-neighbor rule.

Calculation 3.3: The post-settlement landscape with the four-neighbor rule.

1. Run FRAGSTATS using the psett.fra landscape file. This is a 10 × 10 landscape in which one side of a cell represents 1000 meters on the ground.
2. As the base for output files, enter "post4".
3. Use the same options as in the previous FRAGSTATS runs.

Calculation 3.4: The post-settlement landscape with the eight-neighbor rule.

1. Run FRAGSTATS using the eight-neighbor rule for the post-settlement landscape. Again, use the psett.fra landscape file.
2. As the base for output files, enter "post8".
3. Use the same options as in the previous FRAGSTATS runs.

Question 3.1. Organize the results obtained for the four runs (early- and post-settlement landscapes, four- and eight-neighbor rules). Describe how the metrics are affected by the choice of the four- and eight-neighbor rule. Taken as a whole, how do the metrics indicate that this landscape has changed from the early-settlement to post-settlement period?

Part 4. Automated Landscape Metric Calculation for Real Landscapes

In this section, we use FRAGSTATS to compute landscape metrics for real landscapes provided on the CD-ROM. The provided landscapes differ in landscape size, number of classes, and spatial resolution. Two version of each im-

age are provided. The FRAGSTATS-compatible files (.fra) are contained under the directory "FRAGSTATS" for this lab. The folder "IMAGES" contains color image files (*.pdf) that can be viewed and printed using Adobe Acrobat Reader (which can be downloaded for free from the Web).

CALCULATIONS

Calculation 4.1: Madison, Wisconsin
We present two classifications of the same satellite image produced by two different users of the same landscape processing software. Subjectivity inherent in the classification process inevitably produces differences among resultant maps. The two landscapes can be browsed using mad1.pdf and mad2.pdf. FRAGSTATS-compatible files are mad1.fra and mad2.fra. Each landscape has 575 rows and 800 columns, and one side of a grid cell represents 30 meters on the ground.

Calculation 4.2: Las Vegas and vicinity, Nevada.
This landscape can be browsed using lasveg.pdf, and the FRAGSTATS-compatible file is lasveg.fra. This landscape has 547 rows and 796 columns, and one side of a grid cell represents 100 meters on the ground.

Calculation 4.3: Superior National Forest and environs, Minnesota.
This landscape can be browsed using minne.pdf, and the FRAGSTATS-compatible file is minne.fra.

1. This landscape has 187 rows and 234 columns, and one side of a grid cell represents 1000 meters on the ground.
2. This landscape contains cells that are "background" to the classification; they represent Lake Superior to the southeast and Ontario, Canada, to the north. FRAGSTATS will prompt for the value to use for interior background cells:

```
Enter the value for interior (positive) background cells
(even if you only have exterior background):
```

At this prompt, enter "−9999". This will allow the program to recognize that cells outside the classification area, which have a value of −9999 in minne.fra, should be considered as background during metric calculations.

Calculation 4.4: Brazilian Amazon, South America.
This landscape can be browsed using braz.pdf, and the FRAGSTATS-compatible file is braz.fra. This landscape has 729 rows and 942 columns, and one side of a grid cell represents 1000 meters on the ground.

Question 4.1. Which of the landscapes in Part 4 shows the most fragmented pattern, and which is the least fragmented? How did you determine this?

Question 4.2. Using the results produced by FRAGSTATS for this set of landscapes, use a single graph to plot the values of each of the following landscape-level metrics:

Contagion
Patch density (the average number of patches per 100 ha)
Edge density (an expression of edge-to-area relationships)
Landscape shape index (a measure of shape complexity)
Largest patch index (an indicator of connectivity)
Patch richness (the number of patch types)

Note that you can use pencil and graph paper to plot these graphs, or enter the data into a spreadsheet program to produce the graphs and even compute correlation coefficients.
(a) By inspecting the plots, determine which landscape metrics appear to be correlated with each other.
(b) What metrics appear to be relatively independent?
(c) Why do you think these relationships occur?

Question 4.3. How would the correlation among landscape metrics influence your choice of what to report in an analysis that describes landscape pattern or quantifies differences between two landscapes or changes in a single landscape through time?

Question 4.4. What criteria would you use to select the "best" set of metrics to describe a landscape?

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Note. An asterisk preceding the entry indicates that it is a suggested reading.

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CHAPTER 8

UNDERSTANDING LANDSCAPE METRICS II

EFFECTS OF CHANGES IN SCALE

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OBJECTIVES

The perceived pattern of a landscape is influenced by the scale at which the landscape is represented, either in an aerial photograph, satellite image, or data in a Geographic Information System (GIS). This effect of scale has serious implications for the analysis and interpretation of landscape metrics. As such, understanding the range of variability in landscape metrics solely due to changes in scale, and why some metrics are more sensitive to these changes than others, is critical to the appropriate use of landscape metrics. The primary goals of this lab are to

1. explore the quantitative effects of changes in scale (grain and extent) and classification scheme on the computation of landscape metrics; and
2. examine the implications of metric scale dependence for the interpretation of landscape metrics.

In Part 1, to ensure that you fully understand the mechanics behind the different changes in scale, you will change the grain, extent, and classification scheme by hand on a small hypothetical landscape. It is recommended that you work in pairs for this section to divide the workload. In Part 2 you will use the ESRI program ArcExplorer, to examine the effects of changes in scale and classification scheme on landscape metrics by using a large landscape image. In the latter section, the changes in scale and the landscape metric cal-