# Chapter 4
# Understanding Landscape Metrics

**Jeffrey A. Cardille and Monica G. Turner**

## 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, for example, “clumpy,” “dispersed,” “random,” “diverse,” “fragmented,” or “connected.” 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. Several software programs evaluate maps quickly and cheaply, but there are no absolute rules governing the proper use of landscape metrics. To help foster the appropriate use of landscape metrics, in this lab students will:

1. Become familiar with several commonly used metrics of landscape pattern;
2. Distinguish metrics that describe landscape composition from those that describe spatial configuration;
3. Understand some of the factors that influence the selection and interpretation of landscape metrics;
4. Gain experience with landscape pattern analysis using Fragstats; and
5. Observe the correlation structure among some commonly used landscape metrics.

J.A. Cardille (✉)
McGill University, Sainte Anne de Bellevue, QC, Canada
e-mail: jeffrey.cardille@mcgill.ca

M.G. Turner
University of Wisconsin-Madison, Madison, WI, USA



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This lab explores the calculation and interpretation of metrics commonly used in landscape ecology. Emphasis is placed on the understanding gained from actually calculating select metrics by hand rather than only using a metric-calculation package. In Parts 1 and 2, you will manually calculate several landscape metrics for a small landscape to ensure that you understand their underlying mathematics. 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 are the same as those used for full-sized images. Once you have a basic understanding of several metrics, a section using Fragstats (Part 3), the most widely used analysis program McGarigal and Marks (1993) and larger landscape images (Part 4) will help you investigate the behavior of landscape metrics in more realistic settings. In Part 5, you explore the capabilities and limits of using landscape metrics for real-world landscape change at different time periods. Parts 1 and 2 can be completed using only pen and paper (and perhaps a calculator). Parts 3–5 require a computer with the latest version of Fragstats. All files needed to complete the lab are accessible online via links you can find on the website for this book.

## 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; Cardille and Lambois 2010). Along with terrestrial landscapes, metrics are also applied in aquatic systems and marine "seascapes" (e.g., Teixido et al. 2007; Boström et al. 2011). Several of the most commonly used landscape metrics were originally derived 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. To a large degree, metric development has stabilized, caveats about proper use and interpretation are understood (e.g., Li and Wu 2004; Corry and Nassauer 2005; Turner 2005; Cushman et al. 2008), and newly developed methods have improved statistical interpretations of metric values (e.g., Fortin et al. 2003; Remmel and Csillag 2003).

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.

In this lab, you will examine and manually calculate several commonly used landscape metrics for a small landscape to ensure that you understand their underlying mathematics (Parts 1 and 2). Then, once you have a basic understanding of several metrics, two computer-based exercises (Parts 3 and 4) are provided to allow you to calculate metrics using Fragstats and larger landscape images. Finally (Part 5), you explore the capabilities and limits of using landscape metrics for the same real-world landscape at different time periods. During the course of the lab, you will calculate a wide range of metrics of landscape composition and configuration, including Proportion, Dominance, Shannon Evenness, Number of patches, Mean Patch Size, Edge:area ratios, Probability of adjacency, Contagion, Patch Density, Edge Density, Landscape Shape Index, Largest Patch Index, and Patch Richness.

## 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 *i*th 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. First developed by Shannon (1948), 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. Romme reasoned that 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:

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

where ***S*** is the number of cover types, $p_i$ is the proportion of the *i*th cover type, and *ln* is the natural log function. The maximum value of this index, given *S* cover types, is ln(*S*); dividing by the maximum value scales the index to range between 0 and 1. Values of *D* 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 Index (*SHEI*)** (Pielou 1975) can be calculated as:

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

where *S* is the number of cover types, $p_i$ is the proportion of the *i*th 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; values near 0 indicate a landscape dominated by one or few cover types.

A very important detail to note in the formulations of information theoretic metrics is whether or not a particular metric has been normalized to a standard scale. Some early applications of Dominance and Shannon Evenness were not normalized (e.g., O'Neill et al. 1988). The non-normalized 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 above.

## 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 $10 \times 10$ grids (Figure 4.1). It may be useful to print paper copies of these small landscapes for your hand calculations.

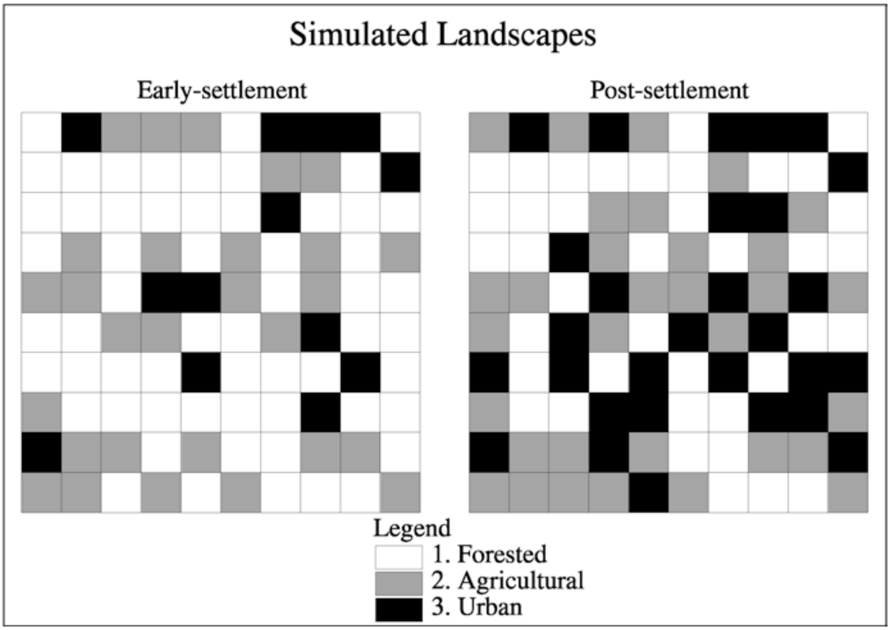


**Figure 4.1** Hypothetical early-settlement and post-settlement landscape classifications

## Metrics of Landscape Composition in an Early-Settlement Landscape

An invented "early-settlement" landscape is shown on the left in Figure 4.1. This image is intended to represent 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 1 $km^2$ (1000 m × 1000 m; $10^6$ $m^2$).

**Calculation 1:** Calculate the proportions occupied by each of the three land covers in the early-settlement landscape. Record the values in Table 4.1.

**Table 4.1** Metrics of landscape composition in an **early-settlement** landscape

| Proportion occupied by: | Result |
|---|---|
| Forested | |
| Agricultural | |
| Urban | |
| Dominance | |
| Shannon Evenness Index | |

**Calculation 2:** Calculate Dominance for the early-settlement landscape and record in Table 4.1.

**Calculation 3:** Calculate Shannon Evenness for the early-settlement landscape and record in Table 4.1.

## Metrics of Landscape Composition in a Post-settlement Landscape

A "post-settlement" landscape is shown on the right in Figure 4.1. This image represents the exact 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 been reverted to forest in the post-settlement image.

**Calculation 4:** Calculate the proportions occupied by each of the three land cover types in the post-settlement landscape. Record the values in Table 4.2.

**Table 4.2** Metrics of landscape composition in a **post-settlement** landscape

| Proportion occupied by: | Result |
|---|---|
| Forested | |
| Agricultural | |
| Urban | |
| Dominance | |
| Shannon Evenness Index | |

**Calculation 5:** Calculate Dominance for the post-settlement landscape and record it in Table 4.2.

**Calculation 6:** Calculate Shannon Evenness for the post-settlement landscape and record it in Table 4.2.

Given the answers you obtained for both the early- and post-settlement landscapes, consider the following questions:

***Q1*** How would you interpret/describe the changes in this landscape between the two time periods?

***Q2*** Explain the relationship between Dominance and Shannon Evenness. If you were conducting an analysis of a real landscape, would you report both $D$ and $SHEI$? Why or why not?

***Q3*** Use your calculator to perform some additional calculations of $D$ assuming the proportions listed in Table 4.3.

**Table 4.3** Proportion of the landscape occupied by three different cover types in four different landscapes

| Landscape | $p_{\text{Forested}}$ | $p_{\text{Agricultural}}$ | $p_{\text{Urban}}$ | Dominance |
|---|---|---|---|---|
| W | 0.10 | 0.80 | 0.10 | |
| X | 0.80 | 0.10 | 0.10 | |
| Y | 0.65 | 0.20 | 0.15 | |
| Z | 0.15 | 0.20 | 0.65 | |

***Q4*** Which of these hypothetical landscapes might be considered "similar" when only comparing *D*?

***Q5*** Under what conditions could interpretation of Dominance (or other similar metrics) be problematic?

***Q6*** Considering your interpretation of the data in Table 4.3, what other types of information and/or metrics would be necessary to distinguish these landscapes?

## SYNTHESIS QUESTIONS

***Q7*** Is there an upper and lower limit of *S* beyond which *D* and *SHEI* will not work?

***Q8*** 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?

***Q9*** The developers of the normalized versions of these metrics chose to normalize them using the maximum possible number of cover types that could ever appear in a landscape. What are some other ways that a metrics could be normalized, and how might this change the results?

## 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 rules for evaluating which cells belong to the same patch. A patch may be identified using the **4-neighbor rule**, where 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 (i.e., horizontal or vertical) between them. Alternatively, the

**8-neighbor rule** specifies that two grid cells of the same cover type are to be considered as part of the same patch if they are adjacent *or diagonal* neighbors. In reporting the number of patches (or any other patch-based characteristic) 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 be described in terms of their size (i.e., area) and edge:area ratio, which will be discussed later.

**Mean Patch Size (MPS)** is 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:

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

where $m$ = the number of patches for which the mean is being computed and $A_k$ = the area of the $k$th 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 of one cell is adjacent to a side of the other cell. The 4-neighbor rule is used for edge counting: diagonals are not used for this aspect of landscape configuration. The total number of edges in a landscape can be calculated by counting the edges between different cover types for the entire landscape. When considering the edges surrounding a given cover type, every edge in the landscape is counted once per cover type. As a result, an edge between a forest and cornfield will be counted once as part of forest edge and once as part of cornfield edge. Edges are sometimes considered with respect to the type of adjacency; in this case, a given forest-cornfield edge would be counted once.

Edge calculations are sometimes used to compute an **edge:area ratio**. Edges 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:area estimate, or edge density. More useful, however, are computations of edge: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 both the edge counts and edge:area ratios. (*NOTE:* In this exercise, the landscape border will not be considered edge for your calculations) Computer programs may use slightly different algorithms for totaling edges. 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 can be very sensitive to the grain of the map.

# CALCULATIONS

## Metrics of Spatial Configuration in an Early-Settlement Landscape

Refer back to Figure 4.1. Recall that the early-settlement landscape is meant to represent an area which was formerly fully forested, but where some of the land has been converted for agricultural and urban use.

**Calculation 7:** Using the 4-neighbor rule, calculate the total number of patches for each cover type in the early-settlement landscape. Enter your results in Table 4.4.

**Table 4.4** Number of patches and mean patch size (in grid cells) using the 4-neighbor rule for categories in the **early-settlement** landscape

| Cover type | Number of patches | Mean patch size |
|---|---|---|
| Forested | | |
| Agricultural | | |
| Urban | | |

**Calculation 8:** Using the 4-neighbor rule, calculate the mean patch size for each cover type in the early-settlement landscape. Enter your results in Table 4.4.

**Calculation 9:** Calculate the number of edges for each category in the early-settlement landscape of Figure 4.1. Be sure to count both horizontal and vertical edges between cover types. This count is done for cells (not patches), and you may find it useful to mark edges in pencil in your lab manual as you count. Do not count the borders of the map for this exercise. Enter your results in Table 4.5.

**Table 4.5** Number of edges and edge:area ratio for the **early-settlement** landscape

| Cover type | Number of edges | Edge:area ratio |
|---|---|---|
| Forested | | |
| Agricultural | | |
| Urban | | |

**Calculation 10:** Using the results from Calculation 9, compute the edge:area ratio for each cover type and enter into Table 4.5.

***Q10*** What characteristics of a landscape will influence the result you obtain for the number of patches and the average patch size?

**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* x *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. The Contagion metric is intended to capture relatively fine-scale differences in pattern that relate to the "texture" or "graininess" of the map. The equation is given by:

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

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 like 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 (Continued)

**Calculation 11:** To begin calculating Contagion, use Figure 4.2 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 4.6.

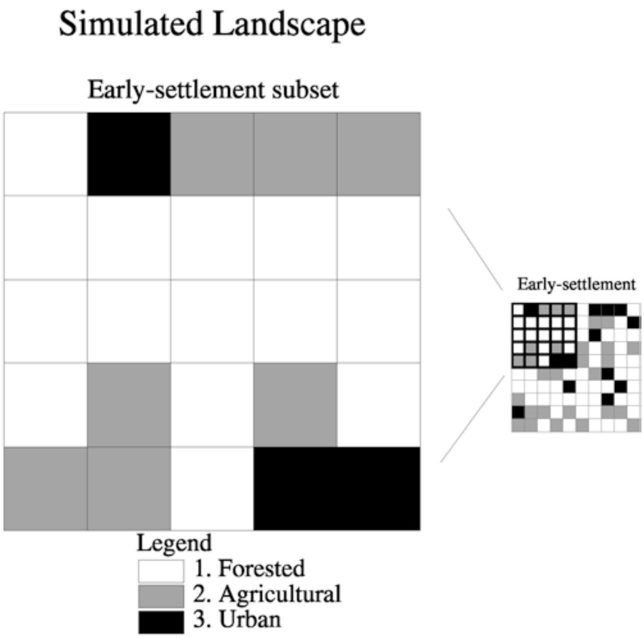


**Figure 4.2** **Subset** of the early-settlement landscape used for calculating the Contagion index

**Table 4.6** Proportion of the landscape occupied by three different cover types in the **subset** of the early-settlement landscape

| Cover type | Proportion ($p_i$) |
|---|---|
| Forested | |
| Agricultural | |
| Urban | |

**Calculation 12:** Count the adjacencies for all cover types for the *subset* of the early-settlement landscape, as seen in Figure 4.2. Enter the results in Table 4.7. 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)

**Table 4.7** Adjacency counts for the **subset** of the early-settlement landscape

| | Category $j$: | | |
|---|---|---|---|
| Category $i$: | Forested | Agricultural | Urban |
| Forested | | | |
| Agricultural | | | |
| Urban | | | |

**Calculation 13:** Note the values along the diagonal in Table 4.7. In effect, we have counted most, though 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 4.7 and enter them in Table 4.8, the **N** matrix. For the non-diagonal elements of Table 4.8, use the same value seen in Table 4.7.

**Table 4.8** **N** matrix for the **subset** of the early-settlement landscape

| | Category $j$: | | | Row total ($n_i$) |
|---|---|---|---|---|
| Category $i$: | Forested | Agricultural | Urban | |
| Forested | $n_{1,1}$ | $n_{1,2}$ | $n_{1,3}$ | |
| Agricultural | $n_{2,1}$ | $n_{2,2}$ | $n_{2,3}$ | |
| Urban | $n_{3,1}$ | $n_{3,2}$ | $n_{3,3}$ | |

**Calculation 14:** Use the values of the **N** matrix (Table 4.8) to compute the elements of the **Q** matrix (Table 4.9).

**Table 4.9** **Q** matrix for the **subset** of the early-settlement landscape

| | Category $j$: | | |
|---|---|---|---|
| Category $i$: | Forested | Agricultural | Urban |
| Forested | $q_{1,1}$ | $q_{1,2}$ | $q_{1,3}$ |
| Agricultural | $q_{2,1}$ | $q_{2,2}$ | $q_{2,3}$ |
| Urban | $q_{3,1}$ | $q_{3,2}$ | $q_{3,3}$ |

**Calculation 15:** Calculate the Contagion value for the subset of the early-settlement landscape using the elements of the **Q** matrix.

The Contagion value for the subset of the early-settlement landscape is: ____________

***Q11*** 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? What characteristics of a real landscape might inhibit or encourage you to make your decision?

***Q12*** Imagine a landscape of large extent for which you couldn't easily calculate this metric. If you could partition the landscape into tiles small enough to compute Contagion in each, could you combine the results in each tile to represent Contagion in the entire extent? What would be the conceptual and practical limits to this approach?

***Q13*** 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?

## SYNTHESIS

***Q14*** Two landscapes are the same size and both contain the same amount of a given cover type. Landscape A has four 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?

***Q15*** 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?

***Q16*** From your set of calculations, do you think 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 et al. 2012) 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. Fragstats can be run in a variety of ways, including from a graphical user interface as a stand-alone program, as a plug-in to ArcGIS, and from the command line. Information about Fragstats is available in the student material for the book, or can be provided by your instructor.

***INPUT AND SETTINGS***

Before calculating a given set of metrics, Fragstats requires settings for the suite of metrics it calculates for your image. Some of the major settings to consider and understand are given below. Each has an impact on how Fragstats interprets the landscape in its calculation of metric values.

- **Grid cell size**: The size of cells for each image is given in each of the calculations for this section.
- **Diagonals in patch finding**: You must specify in Fragstats whether to use the 4-neighbor or 8-neighbor rule for finding patches.
- **Scale of Analysis**: Fragstats can output calculations at the landscape level (i.e., considering all the cover types together), class level (reported by each of the cover types in the map), and patch level (calculated for each patch).

  To complete these sections, we ask you to select the landscape-level and class-level metrics. 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. Although we will not directly use the information contained in the summaries of each landscape category, it is useful to note that some metrics can be calculated for each class.

***OUTPUT***

Fragstats outputs information in several files. In this lab, we are concerned with the **.land** 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

You will input text files containing the land-cover categories for the early- and post-settlement landscapes. You will then use Fragstats to specify your output file name and landscape metrics to calculate.

### Calculation 16: Early-Settlement Landscape with the 4-Neighbor Rule

- Run Fragstats using the **esett** landscape file and the **4-neighbor** rule. This is a 10 × 10 landscape where one side of a cell represents 1000 m on the ground. Use **early4** as the base for output file names. You might make a new folder to contain the results. You may choose which metrics to compute, but you should include several of the metrics you calculated by hand (e.g., number of patches, mean patch size, contagion, and Shannon evenness).

- To verify that you are using Fragstats correctly and that your answers calculated by hand were correct, compare the calculations for the early-settlement landscape from the previous section. You should get the same answers (*NOTE:* Fragstats does not calculate Dominance).

**Calculation 17: Early-Settlement Landscape with the 8-Neighbor Rule**
Run Fragstats using the **8-neighbor** rule for the early-settlement landscape. Again, use the **esett** landscape file. As the base for naming output files, enter **early8**.

**Calculation 18: Post-settlement Landscape with the 4-Neighbor Rule**
Run Fragstats using the **psett** landscape file. This is a $10 \times 10$ landscape where one side of a cell represents 1000 m on the ground. As the base for output files, enter **post4**.

**Calculation 19: Post-settlement Landscape with the 8-Neighbor Rule**
Run Fragstats using the 8-neighbor rule for the post-settlement landscape. Again, use the **psett** landscape file. As the base for output files, enter **post8**.

***Q17*** Organize the results obtained for the four runs (early- and post-settlement landscapes, 4- and 8-neighbor rules). Describe how the metrics are affected by the choice of 4- and 8-neighbor rules. 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 and Interpretation of Multiple Metrics

In this section, we use Fragstats to compute landscape metrics for real landscapes. Calculate at least the following metrics with Fragstats for each of the maps described below. Use the 8-neighbor rule for each of the analyses.

- Contagion
- Patch Density (the average number of patches per 100 ha)
- Edge Density (an expression of edge:area relationships)
- Landscape Shape Index (a measure of shape complexity)
- Largest Patch Index (an indicator of connectivity)
- Patch Richness (the number of patch types)

## CALCULATIONS

**Calculation 20: Madison, Wisconsin, USA**
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 are referred to **mad1** and **mad2**. Each landscape has 575 rows and 800 columns, and one side of a grid cell represents 30 m on the ground. Comparing the results of these analyses illustrates that differences or errors in classification will influence landscape metrics.

**Calculation 21: New England Landscape #1** [Latitude = 40.71754, Longitude = –76.81646]
This landscape is referred to as **x632y165s2** according to its index in the Metaland software (see Chapter 10). This landscape has 216 rows and 216 columns, and one side of a grid cell represents 30 m on the ground.

**Calculation 22: New England Landscape #2** [Latitude = 40.77141, Longitude = –75.29400]
This landscape is referred to as **x651y160s2** according to its index in the Metaland software. This landscape has 216 rows and 216 columns, and one side of a grid cell represents 30 m on the ground.

**Calculation 23: New England Landscape #3** [Latitude = 41.32851, Longitude = –72.06994]
This landscape is referred to as **x689y141s2** according to its index in the Metaland software. This landscape has 216 rows and 216 columns, and one side of a grid cell represents 30 m on the ground.

## SYNTHESIS

***Q18*** Using your Fragstats results, plot the values of the metrics specified above to assess their relationships. For each pair of metrics, graph a scatter plot (metric a on the *Y*-axis, metric b on the *X*-axis); your plots will have five points, one for each landscape.

***Q19*** To compare metrics across the five landscapes, you can make a bar graph with metric values on the *Y*-axis and each landscape map on the *X*-axis. When looking at the maps and the metrics, which of the landscapes above appears to be the most fragmented, and which appears least fragmented? How did you determine this? Use the results of your quantitative analyses to support your interpretations.

***Q20*** 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?

***Q21*** What criteria would you use to select the "best" set of metrics to describe a landscape?

## Part 5. Understanding Landscape Change Through Metrics

In this section, you will explore some of the challenges of using landscape metrics to assess landscape change through time. While it is easy to generate large amounts of data quantifying the landscape patterns of a given area, it is quite challenging to make credible comparisons across time periods. Data sets of the same area for two time periods are often produced with different classification techniques and philosophies, which may make comparisons challenging, at least for some metrics.

You will draw on what you have learned in the previous sections: for example, interpreting and reflecting on the equations that are used to calculate landscape metrics; exploring how some landscape metrics respond principally to landscape composition, while others are more clearly responsive to a landscape's configuration. You will study four landscapes from the **National Land Cover Data Set (NLCD)**, a continental-scale land-cover assessment program using satellite data and ancillary information to track and update land-cover change and stability through time (Vogelmann et al. 2001; Homer et al. 2004; Jin et al. 2013). The landscapes are taken from 6.5 km × 6.5 km regions in New England, USA. For each landscape at multiple times, you will be given the land-cover images, and the values of a large number of landscape-level and class-level metrics from Fragstats runs.

After you have downloaded the data, investigate by viewing the images of the same landscapes at different times and by exploring the landscape metric data using the associated **sandbox** spreadsheet. The spreadsheet allows you to quickly collate the output from multiple runs of Fragstats.

## SYNTHESIS

***Q22*** What are some of the practical obstacles to comparing the landscapes from these two time periods? In your estimation, to what extent are differences in landscape metrics likely driven by differences in landscape data and data-processing approaches, rather than in true changes in the real world?

***Q23*** Choose two cover types and compare the class-level metrics in these landscapes across time periods. Are some land-cover classes more readily comparable than others? If so, which ones?

***Q24*** According to the computed landscape metric values, which landscapes have changed the most between the two time periods? Which have changed the least? For your analyses, you should include both landscape-level and class-level metrics, which may be more informative in answering particular questions than those that are computed for all cover types simultaneously.

***Q25*** Given your experience in this chapter, how well (or poorly) do landscape metric values support your subjective assessment of land-cover change and stability in these real-world landscapes?

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[1] *NOTE:* An asterisk preceding the entry indicates that it is a suggested reading.

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