Chapter 10
Regional and Continental-Scale Perspectives on Landscape Pattern

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OBJECTIVES

Landscape patterns vary widely across Earth's surface as a result of both anthropogenic and natural causes. This variation among landscapes can be quantified by using a large number of metrics developed to capture distinctive qualities of spatial pattern. An informed understanding of pattern–process relationships involves landscape comparisons among and within regions. Despite many advances in landscape pattern analysis, informed selection of landscapes for studying pattern–process relationships in real-world situations remains challenging. This lab explores these challenges with objectives designed to enable students to:

1. Think critically about the benefits and limitations of subjective, nonquantitative landscape assessments;
2. Examine the statistical distributions of landscape metrics within or among regions by exploring histograms for commonly used metrics;
3. Learn and implement ways to improve landscape comparisons through selection of appropriate study landscapes based on specified land-cover proportions, arrangements, or gradients; and
4. Gain experience using two practical tools (Metric Finder and Metaland) within the context of realistic landscape monitoring scenarios.

   In Parts 1 and 2, you will conduct your own rankings of landscapes visually and then use Metric Finder to evaluate your work. In Parts 3 and 4, you will use Metaland

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to identify landscapes according to criteria useful in providing a continental perspective on landscape pattern. For each of these exercises, you will need to query and evaluate information from evolving online databases. Links to these tools and databases can be found in this chapter's student guide at http://goo.gl/FTc4gY or via the web site for the book.

INTRODUCTION

Landscape ecologists now have at their disposal a large number of well understood and widely used metrics that quantify landscape **composition** (the relative abundance of different land-cover categories in a landscape) and **configuration** (the spatial arrangement of those land-cover categories). Readily available data and user-friendly software, such as Fragstats (McGarigal et al. 2012) make such analyses routine. However, researchers new to landscape pattern analysis may find it difficult to understand metrics intuitively, and visual assessments of how a set of landscapes vary with respect to particular metrics can be very challenging, and even misleading. Exercises that allow students to "see" landscapes through the lens of different metrics provide a useful foundation for using and interpreting the results of numerical landscape analyses.

Because landscape ecology focuses on the causes and consequences of landscape heterogeneity, landscape pattern metrics are often used as independent variables in research. There are many, many examples of such studies in the published literature, but the type of question is general: How does landscape composition and/or configuration influence a process of interest? The response of interest may be the presence, abundance, or demography of focal taxa, species richness, nutrient loading or water quality in lake or rivers in a given watershed, rates of land conversion that has occurred over a particular time period, spread rate of invasive species, rates of encounter between predators and prey, or many other phenomena that may be affected by landscape pattern. To answer such questions, researchers often need to systematically identify replicated study landscapes that vary in composition and configuration in predetermined ways, and this task can be daunting. In many cases, researchers are left to analyze multiple maps in the hope of finding sets of study areas that vary in the desired manner. Land managers may face similar challenges, such as identifying forest-dominated landscapes in which forest patch sizes are above a threshold size required to sustain species of conservation concern.

Consider the following scenario. In many areas, urban and semi-urban environments are replacing agriculture and forests. This low-density development often greatly increases the amount of edge between forested and non-forested land. Such fragmented forest landscapes are common in New England, USA, which is a region with high prevalence of Lyme disease. Lyme disease is a bacterial, tick-borne illness found throughout eastern North America that causes skin rashes, cardiac abnormalities, and neurological problems. Since its discovery in the 1970s, rates of Lyme disease occurrence have increased steadily, and over 15,000 people are infected each

year. Small mammals, especially the white-footed mouse (*Peromyscus leucopus*), are the most abundant competent hosts for the disease-causing bacterium and a key host for the larval ticks. Landscapes with numerous small patches of forest (and thus high forest edge density) tend to have high populations of white-footed mice, and these are also landscapes where humans are likely to encounter the ticks. Research has shown (e.g., LoGiudice et al. 2003) that ecosystems with a high density of competent hosts are associated with increased rates of Lyme disease, and this is where the connection to landscape pattern occurs. Imagine a study of New England that seeks to initiate a wide-ranging field campaign to survey host abundance and disease prevalence, along a tightly controlled gradient of expected risk of Lyme disease. Given a land-cover map of all of New England, how would you begin to choose 5, 10, or 100 sampling areas to sample? It is often difficult to identify and select landscapes that allow for processes or conditions to be controlled across gradients, or for random sampling among replicated landscapes that share a given set of characteristics.

To help with such spatially extensive and complex challenges, the Metaland (Cardille et al. 2005) and Metric Finder tools have been developed. Built on databases of landscape and class-level metrics generated for large data sets of same-sized landscapes, **Metaland** is designed for understanding variation in patterns across large areas, learning about the statistical distribution of real-world landscape metric values, and selecting landscapes with desired characteristics. It includes values for more than 190,000 contiguous 6.48-km×6.48-km landscapes (at 30-m resolution) across the conterminous US, across several time periods. Despite caveats associated with their use and interpretation (e.g., Gustafson 1998; Li and Wu 2004; Langford et al. 2006; Cushman et al. 2008; Eigenbrod et al. 2011; Turner and Gardner 2015), landscape metrics have been seen to be valuable for finding differences and similarities among landscapes in this comprehensive data set. For example, Cardille and Lambois (2010) used the 1992 Metaland data to discern a widespread imprint of human activities on US landscapes, distinguishing among different types of landscapes based on the similarity of their landscape metric "signature."

This chapter focuses on subjective and objective assessments of landscape pattern, and the interactions between what we perceive and what computations of landscape metrics can tell about the world around us. This set of exercises introduces students to Metaland and explores the associated Metric Finder tool, two resources for understanding differences and similarities among different landscapes and for identifying sets of landscapes that meet predetermined criteria for landscape composition and configuration. You will investigate patterns in land-cover data derived from Landsat imagery for the National Land Cover Data Set (NLCD; Vogelmann et al. 2001; Homer et al. 2007; Fry et al. 2009; Jin et al. 2013).

Part 1. Estimating Landscape Metrics by Eye

In landscape ecology, how hard is it to quantify pattern? How straightforward is it to say that two landscapes are similar, and that another one of them is unlike the others? We begin by determining how well our visual assessments match up with

quantitative measures of landscape pattern. You will describe the patterns you see in sample landscapes, and then compare your visual estimates with calculated landscape metric values.

EXERCISE 1: Visual inspection

Consider six landscapes extracted from the New England region, located in the northeastern USA (Figure 10.1). More than 15 land-cover categories are shown in these images, but you can think of them in four main categories: (1) red and pink for residential and commercial development; (2) green for forest; (3) yellow, brown, and beige for agriculture; and (4) light and dark blue for water and wetlands. Inspect these six landscapes in the figure or at the link provided in the student guide, then compare and contrast their composition and configuration.

Q1 What qualities do you see that are similar or different? You might consider the proportions of different land-cover types and how they are arranged; you might also think about the land-use history that may have driven the patterns you see, or the connections between areas of a given land-use type. Write down your observations, noting at least three similarities and three differences.
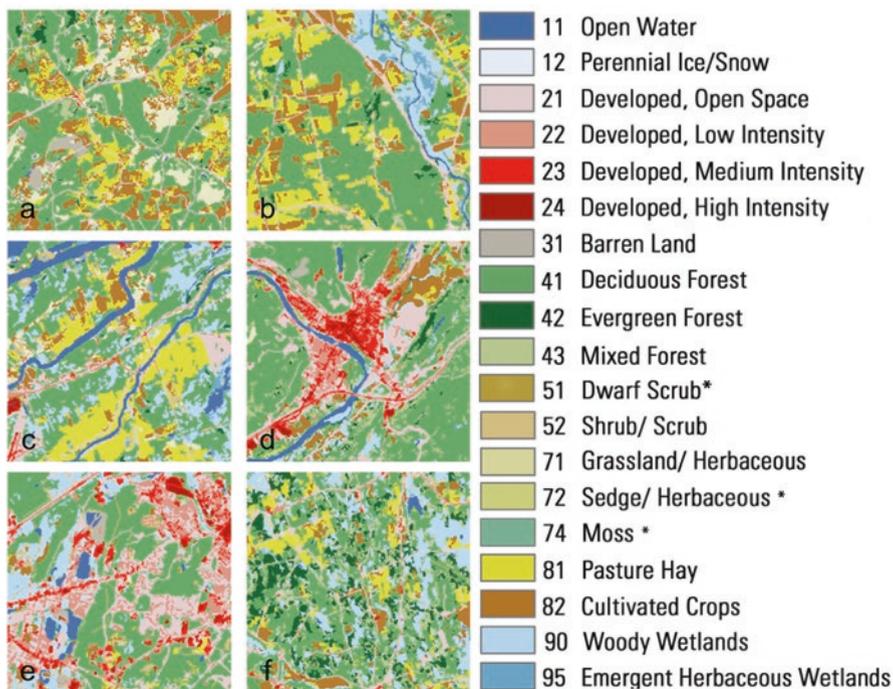

Figure 10.1 Six landscapes from New England, USA. Classification taken from the National Land Cover Data Set for 2001

EXERCISE 2: Ranking using metrics

Any of a large number of landscape metrics can be estimated in a landscape ecological study, but how well can we "see" these values on different landscapes? Some metrics are more intuitive than others, and some landscapes may have distinctive characteristics that are not easily seen. For some commonly used landscape metrics, you will see how well you can assess key characteristics of different landscapes based solely on visual inspection.

Rank each landscape in Figure 10.1 from lowest to highest value according to each of the following metrics:

- Proportion of agriculture
- Proportion of forest
- Proportion of residential and commercial development
- Proportion of water and wetlands
- Total linear amount of edge between all land-cover categories in the landscape
- Contagion
- Shannon Evenness

Q2 Describe the relative ease or difficulty in ordering these landscapes according to each metric. Which metrics were easiest to rank, which were most challenging, and what made them easy or difficult? Next, compare your ranking to the "true" order based on the numerical values, which can be provided by your instructor. How well did you do? When there is disagreement, why do you think this occurred?

Part 2. Metric Finder: Relating Visual Assessments to Landscape Metrics

In a landscape ecology analysis, we may know the type, or "look," of the landscapes we are interested in, but it can be difficult to match metrics with those mental criteria. This section explores a way to identify a suite of landscape metrics that corresponds to visual criteria that you define. The idea is that with a landscape characteristic in mind, you visually determine which two of a trio of landscapes appear most similar, and which one of the three is most different. Using the same logic as an email spam filter that learns more and more about the characteristics of unwanted messages as you identify them, **Metric Finder** learns your preferences as you choose pairs of landscapes according to the criteria you use to judge similarity. In computer science, this is known as a **labeling** approach: you provide the labels of similarity, and Metric Finder gradually reveals which metrics of composition and configuration fit the pattern of pairings that you make. Given more and more iterations of labeling, Metric Finder builds an increasingly confident view of your perception of landscape characteristics. Using this tool can help you to decide which metrics might be useful for a particular study, while also revealing whether some routinely used metrics are easy or hard to distinguish visually in real-world landscapes.
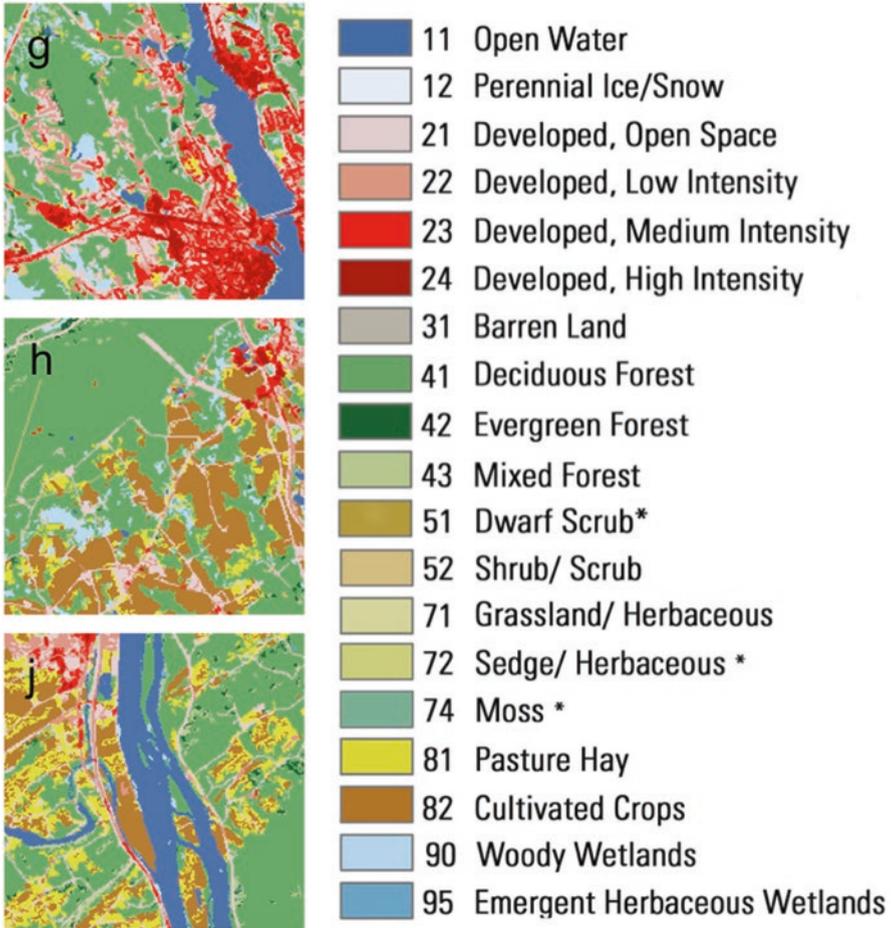
	11	Open Water
	12	Perennial Ice/Snow
	21	Developed, Open Space
	22	Developed, Low Intensity
	23	Developed, Medium Intensity
	24	Developed, High Intensity
	31	Barren Land
	41	Deciduous Forest
	42	Evergreen Forest
	43	Mixed Forest
	51	Dwarf Scrub*
	52	Shrub/ Scrub
	71	Grassland/ Herbaceous
	72	Sedge/ Herbaceous *
	74	Moss *
	81	Pasture Hay
	82	Cultivated Crops
	90	Woody Wetlands
	95	Emergent Herbaceous Wetlands

Figure 10.2 Example set of three landscapes from an iteration of Metric Finder

Imagine different ways in which the three landscapes in Figure 10.2 are similar to and different from each other. For example, Landscapes G and J each contain a river, so a user emphasizing the shape of waterways, or the impact of water on nearby development, might rate them the most similar with respect to those criteria. Alternatively, all three landscapes contain low- and medium-intensity development, and landscapes H and J appear most similar with respect to the amount (and, perhaps shape) of these developed classes. Landscapes H and J are also similar to each other with respect to the amount of core forest, so a forest criterion might consider them more similar to each other than to landscape G.

Metric Finder is designed to interpret such labels of landscape similarity to identify the pattern measures that best distinguish the landscapes, using the unique perspective of each user. To do this, the tool repeatedly presents three landscapes for
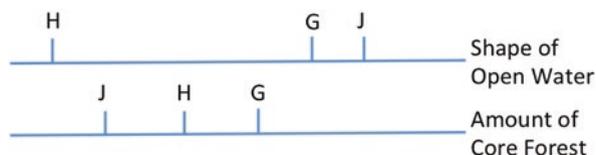
Figure 10.3 Conceptual diagram of two metrics that record different characteristics of three landscapes, G, H, and J. For users who select landscapes G and J as similar, a metric quantifying the amount or shape of Open Water corresponds more closely to their perception than does the metrics of the amount of Core Forest. Users who select landscapes H and J as similar suggests that Core Forest may be important to their perception of landscapes, and that Open Water is not

visual interpretation. While looking at the three landscapes, the user identifies which two of the three look the most similar from his or her perspective—or equivalently, which one of these landscapes is not like the others. Then, for each metric from a predetermined list, Metric Finder evaluates the relative similarity of the three values, estimating the probability of having picked those two landscapes as being similar if the metric had been a criterion considered by the user.

In the iteration of Metric Finder shown in Figure 10.3, the values of the amount of Core Forest are more similar to each other than are the values of the shape metric of Open Water, for which two of the three are much more similar. By Metric Finder's logic, a user who selects landscapes G and J as being more similar is more likely to be responding to the shape of Open Water than to the amount of Core Forest. After the user chooses which two landscapes in a trio are the most similar, Metric Finder adjusts each metric's current estimated score either up or down, depending on the weight of the evidence given the paired landscapes. By interpreting pairings of landscapes in this way, Metric Finder tries to estimate which metrics correspond best to a user's perception of landscape pattern.

In this exercise, you will use a set of more than 650 New England landscapes, each of which is 6.48 km × 6.48 km in extent and represents land cover at 30-m resolution for the year 2001 (Homer et al. 2007). We also will explore this set in a later part of this chapter, extracting the set using Metaland from a much larger set of landscapes representing the continental USA.

EXERCISE 3: Labeling Landscapes Using Metrics of Proportion

1. To begin, you will explore the basic functionality of Metric Finder. The web address of the tool can be found in this chapter's student guide. The tool will load into your browser.
2. Examine the Metric Finder interface. At the top are three landscape images chosen at random from the set of New England landscapes, with selection boxes for each. Below the images are two sets of metrics: one denoting class proportions, such as "Shrub," and one denoting landscape-level metrics, such as *te* for *Total Edge*. Near that is a two-class clustering of the landscapes shown on a map, as well as summary characteristics of the two clusters.

3. Focus first on the *Proportion of Pasture*, a prominent land-use class, whose yellow color in the classification is easy to identify.
4. For the first three landscapes presented by Metric Finder, select the two that appear to have the same amount of Pasture. You can choose a pair either because the amounts of Pasture are both high or because they are both low—the important point is to choose the two that are more similar to each other than to the third nonselected landscape. Recall that for a given Pasture proportion, Pasture pixels can appear in very different configurations.
5. If the decision is too difficult or subtle for a given trio of landscapes, click "Skip" to load a new set.

Q3 When you focus on pairing landscape using the *Proportion of Pasture* as the criterion, how many iterations does it take for Metric finder to detect this by moving it near the top of the list of proportion metrics?

EXERCISE 4: Metrics of Proportion for Rare Classes

Pasture was one of the most frequently occurring land-cover classes, and it is relatively easy to work with. Next, you will examine less-dominant classes.
• Reset the metric probabilities using the Metric Finder interface.
• Now, try to label landscapes using a rare land-cover class, *Medium-Intensity Developed*. In this set of landscapes, less than 1% of the landscape (on average) is *Medium-Intensity Developed*, compared to 12% for Pasture

Q4 Is it easier or harder for Metric Finder to detect that you are distinguishing landscapes using the *Proportion of Medium-Intensity Developed* metric? Do you find that other land-use classes move up and down with the *Proportion of Medium-Intensity Developed* metric? If so, why might this be?

EXERCISE 5: Labeling Landscapes Using Metrics of Configuration

Based on your understanding of landscape metrics from other chapters, you will use Metric Finder to try to pair landscapes with respect to their landscape metrics of configuration. First, reset the metric probabilities and try to distinguish landscapes using the *Contagion* metric, which you learn about in Chapter 4. High values of *Contagion* are associated with more aggregated land-cover patterns, and low values have land-cover patterns that are very dissected. After working to promote *Contagion* to the top of the metrics list, choose another configuration metric (e.g., *Total Edge*) that you think might be straightforward to distinguish among landscapes.

Q5 Explain the conceptual similarities and differences between *Contagion* and the other configuration metric(s) you chose. Why do you think each might be more or less difficult to recognize visually using Metric Finder?

Q6 In comparison to the class-level metrics of proportion of the previous exercise, is it easier or harder to distinguish landscapes using metrics of configuration? That is, is it easier or harder to intentionally move a certain configuration metric to near the top? Why or why not?

EXERCISE 6: Grouping Landscapes with Metric Finder

As it promotes and demotes landscape metrics based on their fit to how you have distinguished landscapes, Metric Finder dynamically groups and regroups landscapes into two clusters based on the results of your labeling. At a given iteration, the metrics chosen as clustering criteria are those having the highest estimated score: thus, as you refine and confirm your criteria by selecting pairs of landscapes, the clustering should gradually come to match the clustering you would expect for your set of criteria. As criteria for the grouping, the algorithm bases its clustering on the three highest-rated composition metrics and the three highest-rated configuration metrics. At any moment, the three highest-rated of each are shown with a green background on the Metric Finder interface.

Using Metric Finder's clustering ability, you can evaluate the usefulness of the set of metrics you are implicitly choosing as you label landscapes. The clustering is shown during this process in several ways. First, the full set of landscapes in consideration by Metric Finder is grouped into two sets with the well-known k-means algorithm; their locations are drawn on a map. Second, a selected group of 15 representative landscapes for the set (Cardille et al. 2012; Cardille and Lambois 2010; Frey and Dueck 2007) are displayed, with their current grouping shown at each iteration. You can form your opinion of the usefulness of a set of metrics using the regional-scale clustering map, the clustering of representative landscapes, and the cluster statistics shown for the high-score metrics.

- Reset the metric probabilities using the Metric Finder interface.
- Develop your own criteria for distinguishing landscapes, and explore with Metric Finder. For example, you might try to separate landscapes with a high proportion of any type of developed land.
- When distinguishing landscapes for this exercise, pay attention to the area of the Metric Finder interface that shows the clustering assignments, projected over all of the landscapes in the set. Because the clustering algorithm considers only landscape metric values and not the geographic position of each landscape, there may or may not be a coherent pattern in the clustering of the landscapes.

Q7 How successful is the mapping of the full set of landscapes according to your identified selection criteria? As you select pairs of landscapes and your desired criteria are gradually confirmed, does the resulting classification of landscapes become gradually more or less stable?

Q8 In your opinion, how successful was the clustering of the representative landscapes into two groups? That is, how well did the clustering of the landscapes

reflect your identified selection criteria? Are regional-scale landscape patterns revealed? If so, what elements of the landscapes appear to drive them?

SYNTHESIS EXERCISE 7: Identifying Metrics for Management

You have been named the director of a newly created Agency for Monitoring Environmental Change (AMEC) for the USA. Your charge is to develop the means for objectively monitoring differences in landscape patterns and their connection to ecosystem processes. In your position, you want to know whether the metrics selected by your colleagues are good candidates to distinguish landscapes in proposed study areas. While working to identify metrics for national reporting of Lyme Disease risk, two colleagues have developed a serious disagreement about which metrics can best represent the New England landscape.

One colleague prefers a simple composition metric, believing that the *Proportion of Deciduous Forest* is easy to calculate and recognize, straightforward for land managers to use, and thus an excellent proxy for landscapes with high amounts of forest edge. The second colleague argues that the total amount of edge between different land-use types, a configuration metric, is of more direct ecological relevance, and that the agency does not need to use an indirect proxy to estimate Lyme Disease risk. The first colleague counters that while the *Total Edge* metric is also easy to calculate with Fragstats, it is a landscape-level metric that includes edges between land-use classes that are not relevant to the research question. She feels that even if there were a strong statistical correlation between *Total Edge* and tick density, differences in values of the *Total Edge* metric are in practice much harder to distinguish and control in real-world landscapes, suggesting, "you can't manage what you can't see." As director, you suggest that each analyst use Metric Finder to look at landscapes with respect to their metric of choice.

With a partner, assume the roles of these two analysts and work side-by-side with Metric Finder in these same New England landscapes, with one trying to distinguish landscapes using the metric of composition, *Proportion of Deciduous Forest*, and the other distinguishing them using the metric of configuration, *Total Edge*. Continue labeling landscapes until the top three metrics of each type attain stable, high scores. Use your judgment about what constitutes a stable high score.

When assessing the landscapes, each analyst should fill out the online form that will record the information about the metrics that were promoted to the top; this should allow you to put your own work in the context of others who have done this exercise. The form can be found via this chapter's student guide.

Q9 Are the two metrics equally easy to recognize in this real-world set of landscapes? When labeling landscapes according to one metric, what are the other metrics that appear to move in sync with them? Are those metrics correlated, or is there another explanation?

Q10 Are the clusters of representative landscapes similar in the work of the two analysts? Do the clusters appear to reflect the criteria you have used to classify them? Are the maps of landscape groupings similar for the two analysts?

Q11 For the two analysts, what are the statistical characteristics of the two clusters "resulting from" the labeling exercise? How might the statistical properties of the clusters be used to evaluate whether one analyst was more successful than the other in this effort?

Q12 The entire set of responses from everyone who has done this lab exercise are recorded in a growing online spreadsheet. A link to the spreadsheet can be found in this chapter's student guide. By inspecting the charts there, you can see the results of others who have played the roles of these analysts, which can help you better understand any differences between your work and that of your partner. Your report can address the following questions: Across all analysts, were the distances between the clusters significantly different between the two types of analysts? That is, is it more effective to focus on one type of metric or the other for this set of landscapes? Do some metrics show up much more frequently than others—if so, why?

Part 3. Exploring Variation in Landscape Metric Values Across a Region

You have now distinguished landscapes based on visual, qualitative assessments of landscape composition and configuration. You have also used a variety of criteria to assess similarity and differences among landscapes. What if you needed to identify a set of landscapes that met specific composition and configuration criteria for a field or modeling study? For example, what if you wanted to explore the effects of forest spatial pattern on seed dispersal, and needed to locate in your study region a set of landscapes with similar amounts of forest cover but different numbers and sizes of patches of forest? Or what if you wanted to study natural enemies of agricultural pests and needed to identify 30 landscapes having similar amounts of cropland but varied amounts of natural vegetation? Could you identify, say, 50 replicates of landscapes with 40% cropland but with high, medium, and low amounts of natural vegetation? This section explores a way to answer questions like these with the Metaland tool, which allows you to identify landscapes according to specified criteria for a regional- or continental-scale perspective on landscape pattern.

EXERCISE 8: Using Metaland to Select Landscapes with Geographic Criteria

- Access the Metaland web site. A link to the tool can be found in this chapter's student guide.
- Select **Understanding and Retrieving Statistical Distributions**. Choose the data set for the 2001 NLCD having tiles that are 6.48 km×6.48 km and covering the continental USA.

- Select **Geographic Criteria > Locations**, then check the boxes for both Latitude and Longitude to prepare to specify landscapes covering the region of New England. New England lies in the box roughly between **Latitude >40.5 and Latitude <45.1**, and **Longitude >−80 and Longitude <−69.5**. Select **Search** using these criteria; the result will return more than 7500 landscapes. On the page showing search results, the locations shown in red are landscapes that satisfy the search criteria. They should be located over the northeastern corner of the image, where New England is located within the continental USA.

Refer to the student guide to access a folder containing images of all of the landscapes returned from the search. In preparation for the next exercise, look through the images of these New England landscapes, noting land-cover patterns and especially the abundance and distribution of Deciduous Forest, represented in green.

EXERCISE 9: Estimating Histograms and Testing Expectations

- On a piece of paper, sketch the histogram that you would imagine to represent the percentage of Deciduous Forest among the landscapes of this heavily forested region. On the *X*-axis, place the numbers 0, 10, 20, … 100. These categories will be percentage values corresponding to different levels of Deciduous Forest abundance for the 6.48×6.48 km landscapes. The *Y*-axis will indicate the percentage of these landscapes that have values in each interval. For example, if you think that about 10% of the landscapes of New England will have a percentage of Deciduous Forest between 50 and 60, draw a bar at *Y*=10 from *X*=50 to *X*=60. Continue for the other ranges of percentages until you have sketched your anticipated histogram.
- Return to the Metaland interface and click **Percentage of Land** to learn about the frequency of different land covers in these landscapes. The page shows the basic statistics for the percentages of each of the land-cover categories within the chosen subset of landscapes.
- Find the entry for Deciduous Forest, and click **View**. On the resulting page you can see a histogram for that metric (proportion—the metric p_i), for all landscapes in your subset.
- In the field below, note the box labeled **Find the percentile of this value**. In this box, you can enter any metric value, and the program will return the proportion of landscapes in your set that have lower values: that is, the percentile of that value. The median value in a set represents the 50th percentile; this is the value for which half the values in the set are lower, and half are higher. Look at the histogram and, through a process of trial and error, determine the median value of this set of landscapes.

(*NOTE:* Using your browser's controls, you can save an image of the histogram itself for use in a report).

Q13 Did your estimate of the histogram of Deciduous Forest differ from that of the actual distribution, and if so, how? What might account for discrepancies between one's estimation of the histogram and the evidence from the

landscape metrics? In what ways does a histogram help assess and understand the makeup of a landscape?

Q14 What are the values at the 33rd, 50th, and 67th percentile in this set?

EXERCISE 10: Histograms of Other Land-Cover Proportions

- Return to the results of the landscape search, and now view the histogram for the Cultivated Crops land cover.

Q15 Consider the following:
(a) Are there substantial differences in the shapes of the histograms of Deciduous Forest and Cultivated Crops?
(b) Were you equally able (or unable) to anticipate the look of the histograms of these land use categories?
(c) Now, consider other land-cover types and their histograms. Is there a pattern to the distribution of landscape percentages among the land covers in this data set?

Q16 If you selected another set with different criteria, do you expect that the shapes of these curves would be similar, nearly identical, or entirely different? That is, do you think that the histograms reveal a basic property of land cover in real-world landscapes?

Part 4. Selecting Study Landscapes Along Gradients

In this section, you will use Metaland to identify landscapes with a wide range of amounts of edge habitat, but only within a subset of landscapes having a certain mix of proportions of deciduous forest and agriculture. With a little additional analysis in a spreadsheet program, Metaland's output can be used to rapidly identify sampling sites along a gradient of landscape metric values. You will identify landscapes according to given characteristics, and use the output to identify landscapes for potential field sampling.

EXERCISE 11: Controlling for Proportion and Total Edge

1. Return to the home page of Metaland and select the NLCD 2001 data set.
2. Use criteria of Latitude and Longitude to select landscapes that have certain landscape proportions within the same rectangular region of New England that was viewed in the previous exercise. As you did earlier, use the selection criteria to specify **Latitude >40.5** and **Latitude <45.1**, and **Longitude >−80** and **Longitude <−69.5**. For the proportion criterion (located in the **Classes** part of

the interface), request landscapes having greater than 30% and less than 50% Deciduous Forest (class 41), and greater than 5% Developed, Open Space (class 21). When done correctly, this request should return more than 650 landscapes. This is the same set used in the Metric Finder section.

3. Refer to the student guide to access a folder containing images of all of the landscapes returned from the search. Make a note of the index field for five or ten of the landscapes that look interesting to you. The index field is the string that looks like: x689y141s2.

4. Return to the Metaland interface and click **View All Landscapes** to see a list of the landscapes for individual inspection. You can view any single landscape and its landscape metric values by clicking **View Landscape** on the right side of the page.

5. For each landscape, Fragstats produces two distinct files for metric values: one for landscape-level metrics and another for class-level metrics. For this lab, we have downloaded the full set of these metrics for these landscapes for you, and done some of the formatting and graphing addressed in the following steps.

6. Refer to the student guide to access the spreadsheet for this section, which contains a number of pages with formulas and graphs that you can use to evaluate the landscapes.

7. The first sheet contains the values as they were pasted into the spreadsheet immediately after downloading them from Metaland. The formulas in Sheet 2 take the values in Sheet 1 and rank each landscape with respect to each metric value. To help you see the sizes of the values, cell values are color coded to indicate whether a given landscape metric value is small, medium, or large in comparison to the other values for that metric in the given subset. Values that are marked "low" are shown in blue and are in the lowest 33% of metric values. Mid-sized values are those between the 33rd and 67th percentile of the metric values in the set and are colored yellow. The largest one-third of values for a given metric is shown in orange.

8. We will use this set of landscapes and metrics to identify a gradient of *Total Edge*. Select the *Total Edge* metric (labeled *te*) between different land use categories of all types. Beginning with this subset, use the page with metric rank values to identify landscapes that are at percentile 20, 40, 60, and 80 with respect to the amount of *Total Edge*. (There may be several landscapes marked as being at a given percentile, due to rounding.) Note the unique identifiers of these landscapes for the next step.

9. Return to the home page of Metaland and select **View Landscapes by Identifier**. Enter the unique identifiers for your four landscapes (from percentiles 20, 40, 60, and 80) in the text box to view their images on one page.

Q17 Judging by eye, do the four landscapes selected along the gradient have substantially different amounts of *Total Edge*? If you forgot the ordering of the landscapes by *Total Edge*, could you correctly sort them by eye for that metric? What aspects of the landscapes make them easier or harder to sort, by eye, according to *Total Edge*?

Q18 Return to the page to **View Landscapes by Identifier**. To the four landscapes you entered just above, add the identifiers of the five that you earlier identified as being interesting. View the summary statistics for these nine landscapes. With respect to *Total Edge*, how do these landscapes compare to those chosen along the gradient? Judging by visual inspection alone, can you correctly insert your four chosen landscapes along the gradient of *Total Edge*?

Part 5. Synthesis

EXERCISE 12: Identifying Landscapes Along Two Gradients

Imagine a situation in which you wanted to identify landscapes along two simultaneous gradients: for example, *Total Edge* (metric *te*) and *Effective Mesh Size* (metric *mesh*). Using the values, colors, and landscape identifiers found in the spreadsheet of Exercise 4, try to find a landscape with low values for each metric—say between the 10th and 15th percentile for each. Is there a landscape listed in the spreadsheet that satisfies these two criteria?

To understand the potential relationships between landscape metrics, the spreadsheet's graphing abilities can be employed. On one of the sheets of the spreadsheet, we have made a scatterplot of the values of the two metrics in the set of New England landscapes.

Suppose you wanted landscapes for a 3×3 field study, built using landscapes selected with low, moderate, and high values for each of the two metrics. The scatterplot indicates where metric values are low (say, between the 1st and 33rd percentile), moderate (between the 34th and 66th percentile), and high (between the 67th and 100th percentile). Suppose you wanted to identify ten landscapes for each of the nine combinations: for example, landscapes with low *mesh* and moderate *te* is one of the combinations.

Q19 Are there enough landscapes for each of the categories of your study? What potential risks are there in identifying these landscapes from the set?

Q20 How could you use the Metaland interface to accomplish this task of finding landscapes?

EXERCISE 13: Complementary Work with Metric Finder and Metaland

Metric Finder is linked to Metaland, and this linkage allows you to select a subset of landscapes in Metaland and explore and compare them in Metric Finder. The option to bring a subset of landscapes to Metric Finder is found on the same page in Metaland, where metric results can be downloaded for use in a spreadsheet.

Assume the role of an analyst tasked with identifying a set of landscapes, for a purpose developed by you or your instructor. For example, you might identify a set

of landscapes in Colorado with no discernable human activity within any of the landscapes, with the ultimate goal of identifying conditions in those landscapes that could make a new park. Develop a protocol for developing and using your subset, in which you:

• Use landscape metric criteria to select a subset of landscapes for consideration
• Export metrics and analyze their values, then use this analysis to select a proposed set of metrics of interest for use within the subset
• Export the results to Metric Finder and use the interface to explore which metrics help you identify landscapes of interest for your park
• Return to Metaland with these new metrics and refine your selection

Write a report in which you describe the protocol and illustrate some of the landscapes that fit your criteria. Include an assessment of the similarities and differences of the landscape sets, the metrics that best describe them, and how the similarities or differences change when subsets of these landscapes are selected by geography.

EXERCISE 14: Designing Regional Comparisons

In your position at AMEC, you are interested in understanding landscape differences among regions. Beginning with the set of New England landscapes as one of two regions to consider, design, and implement a regional comparison of landscape pattern between New England and another region in the USA. Explain your sampling design and the rationale for your selected metrics, what relationships you expected to observe, and present the results of your study of regional differences. Some statistical analysis will be required, as you will be sampling from the 6-km × 6-km landscapes that cover the USA when evaluating regional differences. What are the advantages and limitations of interpreting landscape differences using Metaland and the NLCD data?

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

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