Landscape Ecology: Quantifying Spatial Information the Hard Way, Using Microsoft Excel™

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This exercise teaches the basics of landscape ecology to upper level undergraduate biology students. The students are given satellite images and are asked to create thematic maps showing forest and non-forest areas in Microsoft Excel™. Those maps are then used to generate metrics for landscape composition, configuration, and connectivity. The metrics from all students are combined and treated as replicates in a landscape level analysis. In this analysis, the relationships between those metrics are explored using simple linear regressions.

Keywords: landscape ecology, Microsoft Excel, spatial information, fragmentation

Introduction

This laboratory exercise has been designed to teach the basics of landscape ecology to upper level undergraduate biology students. Landscape ecology began as a somewhat abstract set of ideas about the cause and effect of spatial patterns in biology, but has more recently found wider interest and application with advances in GIS (Geographic Information System) and computational technology. While these advances have made the investigation and application of landscape ecology more practical, they have not increased the accessibility of its core concepts to students. Landscape ecology is a conceptually difficult subject for many undergraduates, who often have trouble grasping the significance of spatial patterns to biology. The ability to perform complex analysis of large scale spatial patterns using current technology is impressive, but it has also further separated students (and faculty) from the basic concepts which are at its foundation.

The exercise I have prepared harkens back to the early days of landscape ecology (late 80's), when it was largely conceptual and its ideas were modeled over black and white computer generated landscapes. The students in this lab create similar black and white maps from satellite images of real landscapes, and perform basic analysis of typical landscape metrics based on those maps. The students are given square images with a 10 x 10 grid overlaid and are asked to create thematic maps showing forest and non-forest areas in Microsoft Excel. Those maps are then used to generate metrics for landscape composition, configuration and connectivity. The metrics from all students in the lab are combined and treated as replicates in a landscape level analysis. In this analysis, the relationships between those metrics are explored using the simple linear regressions that Excel will perform automatically.

This lab is recommended for upper level undergraduates, or possibly graduate students. It requires the availability of a computer lab with a minimum of one station per every two students. It also requires some time for the preparation of the satellite images. The exercise should take about two hours to complete and discuss. Although there is background material provided here for the students, typical time constraints may necessitate covering the concepts in lecture first before exploring them in the lab. Students should also have some familiarity with correlation and linear regression, or at least be able to interpret the results of regression analysis. Because this lab is done on computer, it is possible to execute online, using an online class module and file sharing programs such as Google Docs.

Student Outline

Landscape Ecology: Quantifying Spatial Information the Hard Way, using Microsoft Excel™

Purpose

   To quantify the composition, configuration and connectivity of a landscape with the intention of developing an understanding of the underlying relationships between these landscape characteristics.

Introduction

   The term **landscape**, as it pertains to landscape ecology, is an area that is heterogeneous from an organism's perspective. Therefore, the scale at which an organism relates to its environment and perceives heterogeneity will determine the area of its landscape (Turner 1989, Wiens 1989). An eagle's landscape could be hundreds or thousands of acres, while an ant's may be only a few feet.

   A landscape for most species will contain a mixture of habitat and non-habitat areas. At some level of habitat coverage, generally known as the critical landscape threshold, an organism (or population of organisms) is able to pass through a landscape unobstructed, and the landscape becomes connected from that organism's perspective (Turner and Gardner 1991, With and Crist 1995). The connectivity of the landscape should therefore be directly correlated with the percent cover of habitat.

   The configuration of a landscape can also impact its connectivity for the organism. Non-habitat areas can form a large block, preventing movement through the landscape. Landscapes with large blocks of habitat and non-habitat are often referred to as **aggregated**. Habitat can also be **dispersed** which is the opposite of aggregated.

   When a landscape is changed, by human or other forces, this can break larger blocks of habitat into smaller ones, a process known as **fragmentation**. Two models for loss of forest habitat in historically forested landscapes, are the *chipping away model* and the *fragmentation model* (Fig. 1). Both models show an equal loss in forest cover, but fragmentation leads to a dramatically different landscape. If development is proceeding like a wave, chipping away at a forest from the outside, decreased forest cover will not be associated with significant changes in the configuration of the landscape. If forest is being lost through fragmentation, for example - roads are developed into the forest interior and small pieces are cut out from the inside - forest loss should be associated with increased edge and decreased levels of aggregation.
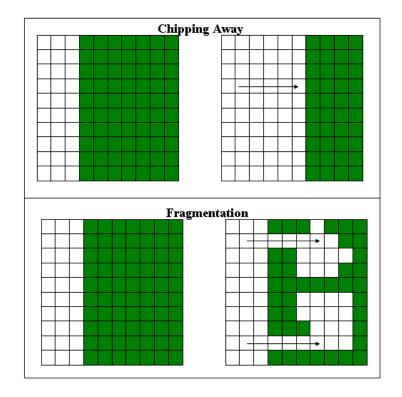

Figure 1. Chipping Away and Fragmentation models of loss in forest cover.

Changes in composition and configuration will tend to positively affect some species while negatively impacting others. We can assume that what is non-habitat for some, is habitat for others. A typical forest landscape can be viewed as home to forest species, non-forest species and edge species, which live at the boundary between forest and non-forest. As you evaluate forest landscapes in this exercise, try to consider their qualities from the perspective of all three types of organisms.

Methods

Thematic Map

Each student will be given 2 mile x 2 mile square satellite image, overlaid with a grid of 100 square cells of equal size. This image will be used to generate a thematic map by the following method:

1. Open an excel spread sheet, highlight the first ten rows and change the row height to 57.0.

2. Highlight the first 10 columns and change the column width to 10. Your cells should now look like squares. (These first two steps will not impact your analysis, but will make the map you generate look more like the landscape you are basing it on).

3. Use the first ten rows in the first ten columns for your thematic map area. For every cell that is at least 50% forested on your satellite image, fill in the corresponding cell on your thematic map with a color (green makes sense).

Landscape Metrics

1. **Composition**. Percent cover of forest (F) will equal the number of colored cells.

2. **Configuration**.

Aggregation (A). Each interior cell (use the interior 8 x 8 square) will be given a score (A) which is equal to the number of alike (out of 8 possible) neighbors to that cell. "A" will then be summed for each map to provide a relative measure of aggregation.

Edge (E) will be quantified by summing the total number of boundaries between white and colored cells on the map. The easiest way to do this is to sum across each row and then down each column.

3. **Connectivity (C)**. Imagine you are an individual, such as a lone coyote, traveling in the forested portions of the landscape. You can travel forward, up, or down in forests but cannot cross open areas and cannot travel diagonally. Make this trip from each of the four sides and see how far towards the opposite side you can reach (reaching the other side, no matter how convoluted your path, is worth 10). Do this from each side and then find the average of those four values for your square.

Analysis of Landscape Metrics

Each student will contribute their data to a chart on the board at the front of the class (one value for each metric from each student). Copy the data from the board into a new spreadsheet in excel.

Graph the following relationships in separate scatter plots: F:A, F:E and F:C with F being your independent variable in each case. Use the trendline function in Excel to construct a linear regression for each relationship, displaying the R^2 value on the chart.

Questions

1. How would you characterize the relationship between forest cover and each of the three other metrics you have measured?

2. Look at the relationship between forest cover and aggregation, and between forest cover and edge. Do these relationships tell you anything about the nature of forest change across this landscape?

3. What impact is forest loss having on forest species, non-forest species, and edge species in this landscape?

4. Can you identify the critical landscape threshold for forest species in this landscape?

Literature Cited

Goodwin, B.J. 2003. Is landscape connectivity a dependent or independent variable? *Landscape Ecology* 18: 687-699.

Pearson, S.M., M.G. Turner, R.H. Gardner and R.V. O'Neill. 1996. An organism-based perspective of habitat fragmentation, pp. 77-95. In Szaro, R.C. and D.W. Johnston (eds), *Biodiversity in managed landscapes: theory and practice*. Oxford Univ. Press, Oxford.

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Wiens, J.A. 1989. Spatial scaling in ecology. *Functional Ecology*. 3: 385-397.

With, K.A. and T.O. Crist. 1995. Critical thresholds in species responses to landscape structure. *Ecology* 76: 2446-2459.

Materials

This exercise requires a computer lab with enough stations so that there are no more than two students to a station (computers must have Microsoft Excel). The lab must come equipped with an instructor's computer station, with Excel and Powerpoint, which is linked to a projector. The instructor will need to supply the 10x10 images (instructions below). To save paper, the instructor is encouraged to supply the images electronically. This will also aid the students by allowing them to open their image in one window and Excel in another.

Notes for the Instructor

Purpose of the Lab

This exercise has three goals; 1) improve students understanding of landscape metrics and concepts in landscape ecology, 2) introduce students to the analysis of spatial information and 3) develop students' skills with Microsoft Excel.

The metrics that are used in this lab are based on universal concepts in landscape ecology, even though they are being measured in a way that is unique to this exercise. There is a wealth of literature on landscape composition and its relationship to landscape configuration and connectivity (suggested reading: Turner 1989, Wiens 1989, Turner and Gardner 1991, With and Crist 1995, Pearson *et al*.1996, Goodwin 2003).

The analysis the student will perform is a simplified version of the analysis being done using sophisticated landscape ecology and GIS software. The thematic map is a simplified version of a map that could be produced from satellite images using ArcView/Spatial Analyst or Imagine Software. The manner in which these maps are analyzed for composition and configuration mimic the automated methods that are also being done using complex algorithms in programs such as Spatial Analyst and Fragstats. Important early papers in landscape ecology (With and Crist 1995, Pearson 1996) used model landscapes based of black and white pixels that were similar to the ones being generated in this exercise. I recommend discussing those papers with your students either before or after this exercise.

The exercise will provide good experience at simple tasks in Excel, such as summing columns and matrices, and in more advanced applications such as inputting formulas and generating professional looking graphics.

Practical Considerations

Images

I recommend generating these images using Google Earth™ and Microsoft Powerpoint™ by the following method:

a. Open Powerpoint and change your dimensions in Page Setup to a 10 inch x 10 inch square.

b. Using 1 inch square boxes, set up a grid of 100 cells across the first slide. Copy that grid and paste it to as many slides as there are maps to prepare.

c. Open Google Earth, find your region of interest and zoom in to a level that looks appropriate (a viewing area of 2-4 miles or 3 – 6 km).

d. Take a screen shot (using "print screen" on your keyboard). Paste onto your first slide and trim it down until it fits into your square, remove all extra information (non-satellite, such as scale bars, etc…) while trimming.

e. Repeat as many times as needed, arbitrarily or systematically moving your window on Google Earth to capture new areas.

Student Excel skills

I have found that students have a range of skill levels with Excel. Some will be very comfortable with the program and will have only a few simple questions. Others will not know how to highlight a column for copying. If you have a collaborative atmosphere in your lab, the more advanced students will often help the less advanced along. I recommend working through the stages of this exercise as a group so that no one student is left behind. Because different versions of Excel are out there, which require slightly different approaches to these tasks, I recommend familiarizing yourself with these procedures using whatever version the students will be encountering in the lab, before the day of the lab.

Acknowledgements

Literature Cited

Goodwin, B.J. 2003. Is landscape connectivity a dependent or independent variable? *Landscape Ecology* 18: 687-699.

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About the Author

Timothy Menzel earned a B.A. in political science from Rowan College (now Rowan University), a B.S. in biology from Richard Stockton College, an M.S. in biology from Southeastern Louisiana University and a Ph.D. in entomology from Mississippi State University. He then worked as a research scientist at the National Center for Physical Acoustics at the University of Mississippi, studying insect acoustics, before becoming an Assistant Professor of Biology and Environmental Science at Piedmont College in Demorest Georgia in 2008.

Sample Results

Figure 2. Sample landscape generated using Google Earth and Microsoft Powerpoint.
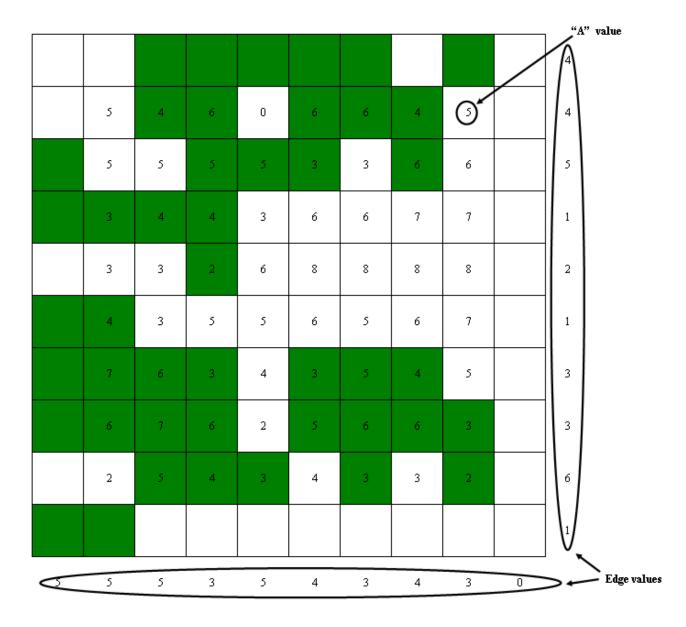
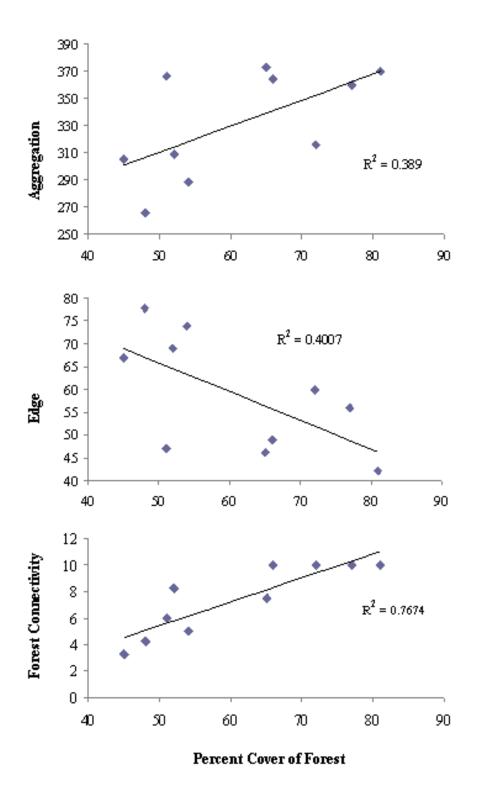**Figure 3.** A typical thematic map to be generated by one student.

Figure 4. Sample relationships between percent cover of forest and other landscape metrics (n=10).

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