NEON Data in the Classroom: Quantifying Spatial Patterns

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Abstract:

Quantifying spatial patterns is the first step to understanding reciprocal interactions of spatial patterns and underlying ecological processes, the main focus of landscape ecology. This open education resource (OER) is developed in partnership with the National Ecological Observatory Network's (NEON) Spring 2018 Data Education Faculty Mentoring Network. The main goal of this OER is to train students in landscape scale data analysis for quantifying spatial patterns. We used raster images from the Harvard Forest (HARV) and the San Joaquin Experimental Range sites (SJER) for this lesson, but it can be adapted for any spatial dataframe including field and remotely sensed data. The specific learning objectives are to: 1) develop informed hypothesis about spatial patterns and complexity using raster data, 2) design a spatial sampling grid and extract data from raster images, (3) quantify spatial autocorrelation of the raster images using semi-variograms, (4) quantify the spatial complexity of the raster images using fractals calculated by semi-variograms, and (5) compare and evaluate different indices for quantifying spatial patterns.

This OER was implemented in an upper level undergraduate course titled "Introduction to Landscape Ecology" at the University of Arkansas. Following discussion of spatial patterns and diverse tools to quantify them, students were given the data, R code (SP-Tutorial.rmd file), and specific questions embedded in the SP-Tutorial.rmd file related to the data, method, and ecological inference of the spatial patterns. Students were able to follow and reproduce the output from the R code. Furthermore, a discussion of applications of semivariograms for predictive and exploratory analyses in ecology before implementing this exercise was helpful in understanding the concept and context of these tools. In conclusion, using open data products generated by NEON and other networks has great potential for enriching students' learning when integrated with foundational ecological concepts.

Instructor's Notes:

This tutorial requires substantial background reading and working knowledge of R. Please make sure your students have read the linked publications before starting this tutorial and you have discussed the theoretical semivariogram and its application in exploratory and predictive data analyses. There are thought questions based on the background material throughout this tutorial, please ask your students to write short answers within the SP-Tutorial.rmd file after each question and submit the SP-Tutorial-Student's Last name.rmd file and the html/pdf output. SP-Tutorial.rmd is an example of starting file for undergraduate students and can be modified to change the level of difficulty for graduate students by removing part of the code. There is a challenge section at the end of this tutorial that is required for graduate students, but optional for undergraduate students. Answers to the thought questions are given below.

Answer to the questions:

Q1. Provide minimum and maximum elevation, and difference between the lowest and highest point for both raster images.

Answer:

Elevation	HARV (m)	SJER (m)
Minimum	305.55	339.24
Maximun	413.90	508.71
Gradient (Max. – Min.)	108.35	168.47

Q2. Compare and contrast the HARV and the SJER raster images based on the elevation histograms.

Answer: The elevation raster and histograms show that the SJER site had greater elevation gradient than the HARV site. However, the HARV site has smaller patches than the SJER field site.

Q3. What is the difference between trend = "cte" and trend = "1st"?

Answer: "cte" indicates constant trend estimate while "1st" indicates detrending using first order polynomial equation.

Q4. Which trend would you pick for further analysis and why?

Answer: I would pick trend = "1st" because after removing the trend, semivariogram shows a well-defined sill indicating presence of trend in the data.

<u>Q5. Provide the values for spatial parameters (nugget, sill, practical range, and spatial structure)</u> for both sites.

Answer:

Parameters	HARV	SJER
Practical Range (3*f)	725.95 m	2856.28 m
Nugget (t ²)	27.28	0
Sill (s ²)	86.24	628.82
Spatial Structure (S) = $s^2 / (s^2 + t^2)$	0.76	1

<u>Q6. Compare and contrast the resulting spatial patterns in elevation of both sites based on the estimated model parameters.</u>

Answer: The range of autocorrelation for the SJER field site is four times the HARV field site indicating larger patches and less crumpled surface. The SJER site display greater spatial structure than the HARV site.

Q7. Compare and contrast two raster images and describe them based on fractal dimension, D.

Answer: The fractal dimension increases with increasing complexity. Based on the fractal dimension of two images, the HARV site is more complex/crumpled than the SJER site. This is also evident from the range of autocorrelation and spatial structure parameters from these two sites. The HARV site has smaller range of autocorrelation leasing to smaller patches and more crumpled surface that the SJER field site that has greater range and larger patches of similar elevation indicating relatively smoother surface.

Q8. What are the advantages and limitations of D in image analysis?

Answer: Fractal dimension is a statistical index of spatial complexity and is useful for comparing multiple images, but it cannot be used for describing or mapping spatial patterns, whereas semivariograms models can be used for mapping.