Ecological Indicators 60 (2016) 668–677

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Validating Landsat-based landscape metrics with fine-grained land cover data

Jason R. Parent*, John C. Volin

Department of Natural Resources and the Environment, University of Connecticut, 1376 Storrs Road, U-4087, Storrs, CT 06269-4087, USA

ARTICLE INFO

Article history:
Received 10 April 2015
Received in revised form 3 August 2015
Accepted 5 August 2015

Keywords:
Land cover
Scale
Grain
Extent
Spatial
High resolution
Landscape
Metrics
Landsat

ABSTRACT

Context: Moderate-grained data may not always represent landscape structure in adequate detail which could cause misleading results. Certain metrics have been shown to be predictable with changes in scale; however, no studies have verified such predictions using independent fine-grained data.
Objectives: Our objective was to use independently derived land cover datasets to assess relationships between metrics based on fine- and moderate-grained data for a range of analysis extents. We focus on metrics that previous literature has shown to have predictable relationships across scales.
Methods: The study area was located in eastern Connecticut. We compared a 1 m land cover dataset to a 30 m resampled dataset, derived from the 1 m data, as well as two Landsat-based datasets. We examined 11 metrics which included cover areas and patch metrics. Metrics were analyzed using analysis extents ranging from 100 to 1400 m in radius.
Results: The resampled data had very strong linear relationships to the 1 m data, from which it was derived, for all metrics regardless of the analysis extent size. Landsat-based data had strong correlations for most cover area metrics but had little or no correlation for patch metrics. Increasing analysis areas improved correlations.
Conclusions: Relationships between coarse- and fine-grained data tend to be much weaker when comparing independent land cover datasets. Thus, trends across scales that are found by resampling land cover are likely to be unsuitable for predicting the effects of finer-scale elements in the landscape. Nevertheless, coarser data shows promise in predicting fine-grained for cover area metrics provided the analysis area used is sufficiently large.

1. Introduction

Landscape ecology seeks to quantify patterns in the landscape in order to understand ecological processes and to more effectively manage natural resources. Maps of the physical land cover on the earth's surface are fundamental to analyzing ecosystems at the landscape level (Yu et al., 2014). The scales of these analyses, including spatial resolution (i.e. grain size) and extent, are important considerations and have been shown to have major effects on landscape metrics (Alhamad et al., 2011; Liu and Weng, 2009; Wu, 2004; Wu et al., 1997; Turner et al., 1989). Data that are too coarse may not adequately represent landscape features that are relevant for a particular analysis (see Akasheh et al., 2008; Gilmore et al., 2008; Goetz et al., 2003). However, land cover datasets vary widely in their spatial resolutions, which are constrained by the remote sensing data from which they are derived, and analysis extents vary widely based on the objectives of the study. Thus, it is critical to understand the effect of grain size and extent in interpreting analyses at the landscape level.

Land cover data are typically mapped using data from satellite or airborne sensors that measure the brightness of solar radiation reflected by features on the earth's surface. The Landsat series of satellites provides the data most commonly used in land cover research (Yu et al., 2014). These data have a grain size of approximately 30 m and thus products derived from these images typically have a similar resolution. Land cover datasets based on Landsat imagery are likely to dominate landscape analyses for the foreseeable future because the Landsat satellite provides global coverage with more than 30 years of temporal continuity.

In the past decade, data from high resolution sensors have become more widely available and researchers have successfully created land cover maps with grain sizes as fine as 1 m (Parent et al., 2015; Arroyo et al., 2010; Antonarakis et al., 2008; Im et al.,

* Corresponding author. Tel.: +1 860 486 2840; fax: +1 860 486 5408.
E-mail addresses: jason.parent@uconn.edu (J.R. Parent), john.volin@uconn.edu (J.C. Volin).

http://dx.doi.org/10.1016/j.ecolind.2015.08.009
1470-160X/

2008; Koetz et al., 2008; Miliaresis and Kokkas, 2007). However, processing high resolution data is challenging for large areas and the limited spatial and temporal availability of these data makes it unlikely to become prevalent in landscape analyses in the near future. Thus, at present, the broader impacts of high resolution land cover may be in providing a greater understanding of how landscape metrics are affected by changes in grain size and analysis extent. This information would help landscape researchers to interpret analyses based on moderate- or coarse-grained data and perhaps allow them to calibrate metric results in order to more accurately represent the landscape.

The primary objective of this paper is to investigate whether landscape metrics based on 30-m resolution land cover data can serve as effective proxies for metrics based on 1-m resolution validation data. We examine three 30-m resolution land cover datasets: (1) a dataset resampled from the 1-m validation data, (2) the 2010 Connecticut's Changing Landscape (CCL) land cover, and (3) the 2011 National Land Cover Database (NLCD) land cover. The CCL and NLCD datasets were derived independently from Landsat satellite imagery. The 1-m resolution land cover dataset was based on 2010 airborne laser scanner (ALS) data and 2012 high resolution multispectral imagery (see Parent et al., 2015). We include a selection of metrics calculated for circular analysis areas ranging from 100 to 1400 m in radius.

A number of studies have shown grain size and extent to have major effects on the results of landscape metrics; however, these effects have been shown consistently to be predictable for certain types of metrics (Simova and Gdulova, 2012; Alhamad et al., 2011; Liu and Weng, 2009; Wu et al., 1997, 2002). These studies typically used Landsat-based land cover to provide the finest level of data and these data were resampled, using either nearest neighbor or majority algorithms, to provide a series of coarser-grained datasets. We are not aware of any study that included data with grain sizes finer than 15 m nor are we aware of any studies that used independent land cover datasets of varying grain sizes. However, data that have been resampled to finer or coarser spatial resolutions inherit the heterogeneity characteristics of the original data (Lausch et al., 2013). Thus, we suspect that resampled land cover data may not a suitable proxy for independent land cover data and may generate misleading conclusions in terms of the ability of coarse-grained data serve as a proxy for fine-grained data. Thus, a secondary objective of this study is to investigate how the use of resampled data differs from the use of independent land cover data in evaluating the effect of spatial scale on landscape metrics.

Previous studies tended to focus on metrics derived using the FRAGSTATS software which includes dozens of metrics that characterize patches and landscape heterogeneity (see McGarigal et al., 2002). In our study, we focus on metrics that were commonly used in the landscape ecology literature and also reported by several studies to have predictable responses to changes in the grain size and analysis extent (Simova and Gdulova, 2012; Alhamad et al., 2011; Liu and Weng, 2009; Wu, 2004; Wu et al., 2002). We focused on metrics with reported predictable responses in order to support our objective of comparing trends between resampled and independent data and also because we did not expect to find predictable responses that were not found in previous studies. The metrics selected for our study include: (1) land cover class fraction, (2) number of patches, (3) total edge length, (4) mean patch area, and (5) the largest patch index (LPI). The land cover class fraction is simply the fraction of the analysis area occupied by the land cover type of interest. The LPI is the percentage of the analysis area occupied by the largest patch of the land cover type of interest.

In addition the metrics described previously, we assess class fractions for a model that characterizes forest fragmentation based on an algorithm proposed by Vogt et al. (2007) and modified for use in ArcGIS by Parent and Hurd (2008). To our knowledge, no previous studies have examined the effects of grain size or analysis area on this model. The model uses the concept of an edge disturbance zone to classify forest grid cells as: (1) *core* cells unaffected by edge disturbance, (2) *perforated* cells within the edge disturbance zone but along a relatively small gap within a larger forest tract, (3) *edge* cells within the disturbance zone and along large openings along the outside of a forest tract, and (4) *patch* cells in small forest patches that are entirely within the edge disturbance zone. The edge disturbance zone consists of forest grid cells that are in close proximity to non-forest land cover. The edge zone has been documented in numerous studies as having altered microclimate (Broadbent et al., 2008; Chen et al., 1999), degraded wildlife habitat (Broadbent et al., 2008), and increased susceptibility to non-native plant invasions (Broadbent et al., 2008; Yates et al., 2004; Brothers and Spingarn, 1992). The depth of this zone into the forest edge can vary depending on the issue of interest; however, a review of the literature found the median reported distance to be 100 m (Broadbent et al., 2008).

2. Methods

2.1. Study area

The study area for this research was located in eastern Connecticut, which is located in the northeastern United States (Fig. 1). The landscape is dominated by temperate deciduous and mixed forests types with the built-up landscape ranging from urban to rural. Natural grasses and shrub lands are uncommon features in the landscape; however, turf grass and agricultural land can be substantial in some areas. Topography can be characterized as hilly with elevations ranging from sea level in the south to 330 m in the north.

The analyses were performed using a sample of 30 3 km × 3 km tiles distributed throughout eastern Connecticut (Fig. 1). We ensured that the sample tiles covered the full gradient of rural to urban landscapes by using the Connecticut's Changing Landscape (CCL) land cover dataset.[1] For a grid of 3 km × 3 km tiles covering eastern Connecticut, we calculated the fractions of each tile that was classified as impervious land in the CCL dataset. Tiles with impervious land fractions of 0–0.33, 0.33–0.66, and 0.66–1.0 were considered to be low, medium, and high intensity development, respectively. Ten tiles were manually selected from each of the 3 levels of urban development to ensure that the sample tiles were geographically separated within eastern Connecticut; urban development and geographic separation were the only factors considered in selecting the tiles

2.2. Data description and processing

This study utilized four datasets: (1) a 1-m resolution land cover, (2) the 1-m land cover resampled to a 30-m resolution, (3) the 2010 CCL land cover dataset, and (4) the 2011 National Land Cover Database (NLCD) land cover dataset. The land cover grids were projected into the UTM zone 18 coordinate system and spatially aligned to the CCL grid for all analyses. All data processing was done using scripts with ArcGIS 10.2.[2]

The 1-m resolution land cover data were derived using a classification algorithm that we developed in previous work (Parent et al., 2015). The algorithm used a series of pixel- and object-based

[1] The Connecticut's Changing Landscape (CCL) land cover data is a 30-m resolution land cover product derived from Landsat imagery and ancillary data. It was developed by the University of Connecticut's Center for Land use Education and Research (CLEAR). See http://clear.uconn.edu/projects/landscape/index.htm.

[2] http://www.esri.com/software/arcgis/arcgis-for-desktop.