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Integrating small-scale landscape elements into land use/cover: The impact on landscape metrics' values

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ABSTRACT

Over the last 30 years the use and misuse of landscape metrics has been widely studied. However, there has been less attention on incorporating small-scale landscape elements into landscape analysis. Data type used in the analysis can be either vector or raster, while the raster format is more widely used. However, using large-scale topographical vector databases has several advantages – they cover whole countries with very detailed and accurate topographical data. Despite the high level of detail, their amount in Mb is small, which allows simultaneously to analyse large areas. The peculiarity of vector data is that small-scale landscape elements are mapped as point elements or lines. For calculating landscape metrics, the integration of these features and LULC (land use/cover) polygons is needed. In the current study we investigated how integration of point and linear elements into polygon layers affects the values of landscape metrics. Adding line buffers influenced metrics' values more than adding point elements. The ensemble of point and linear objects is similar to linear objects. Our study revealed that integrating small-scale landscape elements into land use/cover layers by using buffers gives more realistic values if the buffer size is in compliance with the size of the phenomena in the real world and suitable landscape metrics are chosen. However, the metrics that responded to adding small-scale landscape elements in correspondence with their real world impact on landscape metric values might not always be the best ecological indicators in terms of small-scale landscape elements. Another issue is that values of landscape metrics depend directly on the number of classes determined in the data specification, and on the data model. If the number of mappable point and linear objects changes, or the data model of the linear objects changes, the values of landscape metrics differ.

1. Introduction

Several studies have tried to evaluate how landscape characteristics support the provisioning of ecosystem services. Important features playing an important role in this respect are small-scale landscape elements – point and linear objects, such as ditches, hedge and tree lines, and grass margins (Garcia-Feced et al., 2015). These features are particularly important in terms of creating habitats on agricultural areas and improving biodiversity (Marja et al., 2013). EU Common Agricultural Policy (CAP) 2014–2020 programming period includes payments for farmers setting 5% of their agricultural areas for Ecological Focus Areas (EFA) i.e. hedges, buffer strips, stone walls, etc. (European Union, 2013). Therefore there is a need for methods to assess these small-scale landscape elements.

Within the past 30 years, hundreds of landscape metrics have been proposed by various researchers to analyse the composition and configuration of landscape structure (Uuemaa et al., 2013; Dramstad, 2009). Their usages range from habitat evaluations (Schindler et al., 2008) to addressing the spatial data quality (van Oort et al., 2004).

Less attention has been on the data type used in the analysis. Depending on the data source, one can use either vector or raster data (Zaragozí et al., 2012). The raster format is more widely used for landscape analysis for several reasons. The most important reason is the availability of satellite imagery. Another reason for using more raster data is the ease of conducting complex spatial computations on grids and because there is a greater variety of landscape metrics designed for raster format (Cushman et al., 2008). However, the resolution of raster image is often too coarse to depict the linear elements correctly (Jaeger, 2007). For representing point and linear objects in raster, very high spatial resolution is required, which increases the file size. For example, a 5 km × 5 km topographic map

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sheet with 20 cm pixel size is 2GB. Thus, vector format is more suitable for analysing big territories in detail.

However, large-scale landscape interpretation is provided by national topographic databases which in addition to satellite imagery also offer small-scale landscape elements that are not mapped as areal units at the specific scale but instead are presented as points or lines (like groves or streams). The research provided in 2004 by EuroGeographics showed that 23 European states had covered at least 60% of their territory by topographic data at scale 1:10,000 or larger (EuroGeographics Expert Group on Quality, 2005), which is used for producing topographic maps. The data covers reference themes like administrative boundaries, hydrography, settlements, transport network, elevation, land cover/use, etc. The use of topographic data has so far been inhibited by data availability. By today several national mapping agencies, like the Dutch Cadastre, Land Registry and Mapping Agency (Bakker et al., 2013), the National Land Survey of Finland (2014), Danish Geodata Agency (2014), have made their topographic datasets available to the public to be used freely. This increases the role of detailed topographic data in research and provides substantial alternative to satellite imagery.

One typicality of vector data is that data are presented by three basic geometry types – points, lines and polygons. Land use/cover (LULC) is usually contained in the polygon layers, point and line objects need to be incorporated separately. The most wide-spread way to integrate point and line features, i.e. small-scale landscape elements, and LULC polygons is by intersecting the LULC polygons with buffers generated from the linear features. Linear features have been buffered for the average width of the corresponding feature, with a minimum buffer width of 2 m (Herzog et al., 2001; Lausch and Herzog, 2002), or for constant width (Wade et al., 2003) and in some studies the buffer width has not been mentioned (Moser et al., 2002). None of the referred studies provides any reasoning why certain buffer widths were used. Although several studies have been published on comparing vector and raster data for landscape analysis (Wickham et al., 1996; Zhang et al., 2006; Ramezani and Holm, 2012), we could not find many papers addressing the impact of integrating point and line features into the polygon layer on the values of landscape indicators. Höbinger et al. (2012) tried to assess the effect of field mapped linear landscape elements and found that they had a significant influence on the values of some metrics, for instance patch density. They conclude that fine-scale elements are important to be included into studies evaluating landscape pattern implications for biodiversity. To overcome the problem that some landscape elements are not represented in the patch mosaic model, McGarigal and Cushman (2005) proposed the gradient model for raster data as an alternative representation of landscape structure. Instead of delineating homogeneous and discrete areas, the gradient model represents the landscape structure on the basis of continuous data in which the only discrete unit is a pixel or grid cell in a raster based data model. McGarigal et al. (2009) described a variety of surface metrics that allow for the quantification of landscape gradients and are useful for incorporating small-scale landscape elements into landscape analysis. Another attempt to improve the detection of small-scale landscape elements was made by Hou and Walz (2013) who incorporated the third altitude dimension in landscape structure analysis for that purpose.

The aim of the current research is to analyse how the values of landscape metrics are influenced by integrating point elements and lines into LULC polygons with different integrating methods and buffer widths. We will try to determine landscape metrics that show response in correspondence with the small-scale landscape elements' real world impact on landscape metric values.

2. Data and methods

2.1. Study area

For LULC data, the Estonian Basic Map (1:10,000) in vector format was used. The Estonian Basic Map is a national topographic database which aims to serve as a basis for national thematic maps and registers containing spatial information (Mõisja, 2003). This topographic database is the most detailed and accurate map covering the whole Estonia. It contains more than 120 different feature classes (Estonian Land Board, 2006).

Representing all different landscape regions of Estonia 35 study sites were selected. Landscape regions are geosystems determined by relief forms. Thus, a region differs significantly from neighbouring areas in its geological structure (Arold, 2005). Each study site consists of one Basic Map sheet which covers 5 km × 5 km (Fig. 1). All study sites were chosen so that their land uses are mixed and not dominated by any specific land use, except one site where over half of the study area was covered by urban land use.

2.2. Pre-processing of the vector data

For integrating line (hedges, narrow streams, fences, etc.) and point (groves, trees, heap of stones, boulders, etc.) features into the LULC map, we generated buffers separately for point elements and lines, and tested different buffer widths from 20 cm up to 3.5 m as well as the average width of the phenomenon in reality (Fig. 2). For example, for <2 m ditches, 50 cm buffers and for 4–6 m ditches, 2.5 m buffers were generated. The buffers were always circles for the point elements, line buffers had a flat ending to optimise the area. Before generating buffers for lines, line segments with the same attributes (like type, width, etc.) where dissolved. If one of the attribute values changed or a line was intersected by another line then it was considered another line object (Appendix 1a and c, Supplementary material). It is also possible to create buffers without dissolving lines based on attributes (Appendix 1b, Supplementary material) but this would create too much "noise" and elements that do not exist in reality.

Obtained buffers for the point elements and lines were integrated into polygon layers using two different methods (Fig. 3): (a) buffers overlap the polygons (Fig. 3b); (b) buffers were cut out from the polygons (Fig. 3c). Overlapping is technically easier and requires less geoprocessing. Also the initial number, shape and area of the land cover polygons remains unchanged. However, the shortcoming of this method is the formation of the illogical overlapping. Although in nature there can be phenomena that overlap (for example power lines over a field), there is a wide range of cases where the patch type can only be one or the other (for example ditch cannot overlap field). The second method where buffers are cut out of the polygons avoids overlaps but some artefacts can accompany the geoprocessing. For example, between two very closely located buffers, there may emerge sliver polygons (Fig. 3c) that in reality do not exist and of which number, shape and small area can affect the value of landscape metrics.

Altogether combining these different geometry types (points, lines, polygons), buffer widths (0.2 m, 0.5 m, 1.5 m, 2.5 m, 3.5 m, average width of the phenomenon in reality) and integration methods (cut out and overlapping), and the polygon layer as a comparison layer, gave 37 datasets for all 35 areas (Appendix 2, Supplementary material). ArcGIS 10.2 (ESRI, 2013) was used for geoprocessing all of the datasets.

2.3. Calculating landscape metrics and statistical analysis

According to Zaragozí et al. (2012), there are only two tools using vector data as an input for calculating landscape metrics, namely