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# A method for evaluating raster data layers according to landscape classification scale

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ABSTRACT

Landscape researchers have described different options for landscape classifications and have suggested the approximate size of landscape units for various scale levels of study and the most suitable data layers (representing biophysical characteristics) for differentiating them. The literature already contains examples of evaluating data layers with regard to their information value, their correlation with one another, and so on, but less research has been done on the suitability of data layers from the perspective of the scale of landscape research.

The objective of this paper is to propose a quantitative method to assess different data layers by landscape classification scale. The proposed method is based on systematic sequential multilevel division of the study area, calculating the average moderate coefficient of variation for each scale level, and comparing calculations between scale levels. It can be used to objectively determine which raster data layers are more suitable for defining large landscape units and which are more suitable for defining small ones.

We tested the method for Slovenia, a small country at the junction of the Alps, Pannonian Basin, Mediterranean, and Dinaric Alps with a high landscape diversity. To test the method, we systematically divided the country into smaller units using ten differently structured grids (for the case of Slovenia, we used squares with a baseline of 1, 10, 20 km, and so on up to 100 km). For each data layer, we calculated the average moderate coefficient of variation for each division and compared it with the average coefficient of variation for the highest level, which represented the country as one whole unit. The ratios allowed us to classify the data layers into categories and assess which data layers are more important in landscape classification at a small scale, which ones are more important at a large scale, and which ones function as noise.

As expected, variation diminishes with a smaller baseline in all cases, but the gradient of decreasing variation is different. We also studied the categorization of data layers using a hierarchical classification method.

Following to the proposed method, it is possible to create various categories of data layers by the landscape classification scale for a certain area. The method can be used for any area and is an option for reducing subjectivity in selecting data layers for landscape analysis classification for the most general purposes (e.g., production of landscape classifications for education).

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## 1. Introduction

### 1.1. Landscape analysis and landscape classification

People are always seeking order in landscapes (Haggett, 2001), and so it is not surprising that there are many landscape classifications available for small or large areas based on natural and/or human characteristics (Table 1). All classifications involve abstraction or modeling in order to simplify representation of the real world (Demeritt and Wainwright, 2005). Simplifying reality is unavoidable. For example, the actual landscape is represented through landscape classification maps, which divide a particular area into what are seen as logical and homogenous spatial units. The divisions are supported by quantitative and qualitative analysis of various biophysical characteristics represented through digital data layers (or variables). These are limited by grid resolution and other specifics. Despite visible changes in the natural environment, such as the junction between flat land and mountains (Bailey, 1996), most classifications are arbitrary (Leathwick et al., 2003). Classifications are always subjective, and so it is difficult to speak of their completeness. Subjectivity in classification is a consequence of decision-making when selecting biophysical characteristics, weighting them, defining threshold values, digitizing, and interpolating (see Ellison, 2010; Leathwick et al., 2003; Loveland and Merchant, 2004; Muñoz-Mas et al., 2016; McMahon et al., 2004; Coops et al., 2009). Moreover, landscape classifications are rarely assessed (Kireyeu and Shkaruba, 2010).

*Abbreviations: CV*, coefficient of variation; *MCV*, moderate coefficient of variation; *AMCV*, average moderate coefficient of variation.

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**Table 1**
Examples of landscape classifications. Landscape classifications are made at different spatial levels: local, national, continental, and global.

| Level | Sources |
|---|---|
| Local | Bryan, 2006; Burrough et al., 2001; Castillo-Rodríguez et al., 2010; Zhou et al., 2003 |
| National | Coops et al., 2009; Hargrove and Hoffman, 2005; Kupfer et al., 2012; Leathwick et al., 2003; Perko, 1998; Soto and Pintó, 2010; Špes et al., 2002; van Eetvelde and Antrop, 2009; Wolock et al., 2004; Romportl and Cerny, 2014; Izakovičová, 2014; Szerencsits et al., 2009 |
| Continental | Bohn et al., 2000/2003; European Environment Agency, 1995; European Environmental Agency, 2009; European Environmental Agency, 2016; Jongman et al., 2006; Meeus, 1995; Metzger et al., 2005; Mücher et al., 2003; Mücher et al., 2006; Mücher et al., 2009; Renetzeder et al., 2008; Rivas-Martínez et al., 2009 |
| Global | Bailey, 1996; Olson et al., 2001; Udvardy, 1975 |

For greater research value, it is exceptionally important to base as many landscape classifications as possible on objective arguments. This can be achieved also through the use of quantitative methods, which can increase the transparency of an analysis. Such methods can be used to prepare data, evaluate input (data layers), evaluate output (landscape classification), present results, and update them. A suitable selection removes less important or overly correlated data layers. In this way, one can reduce computing memory and costs, and at the same time improve the performance, clarity, and understanding of the processes studied (Jiang et al., 2008; Goodchild, 2011; Tirelli and Pessani, 2011).

### 1.2. Evaluation of data layers

In selecting data layers, researchers frequently use a trial-and-error approach or rely on experience (Duro et al., 2012), and so research on evaluating data layers is quite important. To comprehensively assess data layers, it is advisable to analyze them from different perspectives.

Testing different computational settings (e.g., buffer sizes), combining different sets of data layers, and evaluating them with regard to their information value or their correlation with one another are methods often used (Armitage and Ober, 2010; Ciglič, 2010; Ishak et al., 2016; Kraft et al., 2004; Melo et al., 2012; Muñoz-Mas et al., 2016; Schindler et al., 2015; Ssegane et al., 2012; Tirelli and Pessani, 2011; Williams et al., 2012; Lecours et al., 2017). Research at multiple scales is more frequent in analyses of landscape metrics and the correlation between different biophysical characteristics (Argañaraz and Entraigas, 2014; Rocchini et al., 2013; Wieland et al., 2011; Wheatley, 2010; Wu, 2004). These usually focus on analysis of relations between landscape metrics and various phenomena (e.g., species distribution or soil types) or landscape metrics values at different scale levels. Some studies examine resolution, the information value of raster data, segmentation, and modifiable areal unit problems (Evans, 1972; Dark and Bram, 2007; Drăguţ et al., 2011; Drăguţ and Eisank, 2012; Šímová and Gdulová, 2012; Woodcock and Strahler, 1987). There are also studies related to social and economic factors and their behavior according to the scale (e.g. Krevs, 1998). However, less research has been done on the suitability of data layers from the perspective of landscape classification scale, which is the focus of this study.

Because landscape classifications can be made at various levels, it is necessary to decide which spatial scale level the research will take place at (Bailey, 1996; Leser, 1976). One has to be aware that the systems' description depends on the scale chosen (Argañaraz and Entraigas, 2014). When developing a classification, one must therefore also determine which biophysical characteristics are appropriate at a particular scale level, or which ones are best for distinguishing landscape units. This is a difficult process because there is (McMahon et al., 2004; Wu, 2004):

– No absolute size for a landscape;
– No uniform and correct scale for ecological regionalizations; and
– No common or optimal scale for describing spatial heterogeneity.

Many authors have logically arranged various biophysical characteristics by using a system of scale levels, although these divisions are arbitrary (Udo de Haes and Klijn, 1994). They describe the approximate size of various landscape units and include recommendations on which biophysical characteristics are suitable for an individual scale level (Anderson and Ferree, 2010; Bohn et al., 2000/2003; Bailey, 1996; Godron, 1994; Klijn, 1994; Klijn and Udo de Haes, 1994; Burrough et al., 2001; Mücher et al., 2003; Špes et al., 2002). For the most part, these are not based on quantitative analyses of actual regions. For example, Klijn (1994) and later Mücher et al. (2003) stated that abiotic characteristics are the ones that largely define the distribution of ecosystems at the global level. Anderson and Ferree (2010) stated that climate characteristics are decisive for diversity at the continental level, and within individual climate zones or areas geophysical characteristics dominate over climate characteristics in explaining patterns. Klijn (1994) and Bailey (1996) worked out a precise division of various spatial units with regard to their scale level of study and also the most important characteristics (Table 2).

Subjectivity in the evaluation process can be reduced by using geographic information systems (GIS) and quantitative methods (Thompson et al., 2005; Loveland and Merchant, 2004; Hazeu et al., 2010). Understanding the relationship between landscape pattern and environmental processes requires quantification of the landscape pattern at multiple scales (Argañaraz and Entraigas, 2014). Thus we believe that there is still much potential for implementing quantitative methods, which could standardize the definition of suitable data layers with regard to landscape classification scale.

**Table 2**
Hierarchy of spatial units and biophysical characteristics corresponding to them according to Klijn (1994) and Bailey (1996).

| Hierarchy of spatial units and biophysical characteristics corresponding to them according to Klijn (1994) | | | |
|---|---|---|---|
| Spatial unit names | Spatial unit size | Scale | Important biophysical characteristics |
| Ecozone | >62,500 $km^2$ | 1:>50,000,000 | Climate, lithology |
| Ecoprovince | 2500–62,500 $km^2$ | 1:10,000,000 to 50,000,000 | Climate, lithology, relief |
| Ecoregion | 100–2500 $km^2$ | 1:2,000,000 to 10,000,000 | Lithology, relief, groundwater, surface water |
| Ecodistrict | 6.25–100 $km^2$ | 1:500,000 to 2,000,000 | Lithology, relief, groundwater, surface water |
| Ecosection | 25–625 ha | 1:100,000 to 500,000 | Relief, groundwater, surface water, soil |
| Ecoseries | 1.5–25 ha | 1:25,000 to 100,000 | Groundwater, surface water, soil |
| Ecotope | 0.25–1.5 ha | 1:5000 to 25,000 | Groundwater, surface water, soil, flora |
| Eco-element | <0.25 ha | 1:<5000 | Surface water, soil, flora, fauna |

| Hierarchy of spatial units and biophysical characteristics corresponding to them according to Bailey (1996) | | | |
|---|---|---|---|
| Spatial unit names | Spatial unit size | Scale | Important biophysical characteristics |
| Ecoregion | $10^5$ $km^2$ | 1:3000,000 | Eco-climate zones; climate with variations due to latitude, continentality, elevation |
| Landscape mosaic, landscape | $10^3$ $km^2$ | 1:250,000 to 1:1,000,000 | Relief forms |
| Site | 10 $km^2$ | 1:10,000 to 1:80,000 | Topoclimate and soil moisture |

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