Estimation of the fractal dimension of cities in South Europe using data for different built-up densities

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Résumé / Summary

Keywords: fractal dimension, South Europe, Urban Atlas, box-counting, built-up density

The aim of this study is to analyze built-up patterns in a set of cities in South Europe and compare their form using fractal dimensions. To accomplish this, data from the Urban Atlas are used and a methodology is developed for estimating fractal dimensions taking into account the different densities of the built-up areas.

Fractals have been used widely to analyze cities, since they provide a methodology for quantifying the geometrical complexity of urban patterns, using a multiscale approach (Batty & Longley 1994, Frankhauser, 1998; 2015, Lagarias 2007; 2008, Thomas et al 2008, Terzi & Kaya 2011; Chen & Wang 2013, Lu et al 2016). However, studies comparing different cities are relatively sparse (Shen 2002, Frankhauser 2004; Thomas et al 2012; Tannier & Thomas 2013) and usually based on data that are not compatible and/or have not been produced using the same methodology. Therefore, the comparative analysis of European cities based on a common methodology and using up-to-date and compatible land use data is a research issue that has to be addressed.

In the present study, a methodology for estimating fractal dimensions using Urban Atlas data is presented. UA provides land use information for all cities in the European Union with at least 100,000 inhabitants

(ΕΕΑ, 2010). Twenty different land use classes are identified, with six of these representing urban fabric areas corresponding to different built-up densities as identified by the soil sealing degree. Fractal dimensions are estimated in two ways: a) box counting dimensions using a simple distinction between built-up and non built-up areas and based on binary images (maps), b) box counting dimensions taking into account different urban fabric densities and based on greyscale images.

The second approach is necessary since in the UA database built-up data are provided at the city block level and represent the built-up density of the block as a whole. Therefore, estimating the fractal dimension using a binary distinction between built-up and non-built up areas provides results that do not account for the differences in densities. An alternative procedure is therefore implemented that takes into account the six different urban fabric categories of UA. Another option, rather than using the UA data is to use the high resolution soil sealing degree raster provided by the EEA, ranging from 0 for a non built-up cell to 100 for a fully built-up cell, and in this study this is also explored.

Fractal dimensions are estimated using Fraclac, a public domain software (plugin inside Image J) which makes possible the analysis of a binary or a greyscale image (Karperien, 1999-2013). The fractal dimension of the greyscale image (mentioned as FG, Fractal Grey Dimension) represents the difference in intensity of the pixel values, which correspond to built-up density.

Using the proposed methodology fractal dimensions are estimated and compared for 13 cities in Spain, Portugal, Italy and Greece with population more than 1 million people. These cities are considered among the most densely populated urban areas of Europe with central areas characterized by dense urban fabric, while in the suburbs more fragmented and low-density patterns are observed.

Results regarding fractal dimensions show similarities and differences among the case study cities. Fractal dimensions closer to the value of 2 refer to a more homogenous or compact structure, while smaller values (closer to 1) imply a more fragmented and dispersed structure. The variation between the estimated fractal dimensions are attributed to differences in the urban form, the different distribution of urban fabric classes and also the local geographical and historical context as well as the planning regulations applied in each city and country.

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