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Assessing the fragmentation of the green infrastructure in Romanian cities using fractal models and numerical taxonomy

Alexandru-Ionuţ Petrişor[a,b,*], Ion C. Andronache[c], Liliana Elza Petrişor[d], Ana-Maria Ciobotaru[c], Daniel Peptenatu[c]

[a]*Department of Urban and Landscape Planning, School of Urban Planning, "Ion Mincu" University of Architecture and Urban Planning, Bucharest 010014, Romania*

[b]*National Institute for Research and Development in Constructions, Urbanism and Sustainable Spatial Development URBAN-INCERC, Bucharest 021652, Romania*

[c]*Research Centre for Integrated Analysis and Territorial Management, Faculty of Geography, University of Bucharest, Bucharest 010041, Romania*

[d]*Retired architect, Bucharest 021619, Romania*

Abstract

As the share of urban population increases globally each year, man-dominated systems tend to sprawl over the natural ones, substituting and fragmenting them. Urban sprawl is the main cause of many environmental issues, in tight connection with pollution and loss of biodiversity. One of the main consequences is a decrease of the ecosystem services provided by the urban green infrastructure. However, the extent of urban sprawl is spatially uneven due to the spatial structure of human settlements. Among the methods used to pinpoint sprawl, fractal analyses have a good potential for analyzing fragmentation, especially if used in conjunction with statistical methods. This study aimed to assess, in an exploratory perspective, the level of fragmentation in the Romanian cities covered by the Urban Atlas data, and determine its correlation with parameters related to their demographical and physical characteristics. In addition, taxonomical analyses were used to find whether cities or specific components of the green infrastructure can be grouped. The results did not reveal a general trend, although it seems that the green infrastructure consisted of agricultural/ semi-natural/ wetland areas, forests, green areas, sports and leisure facilities and water bodies in all of them, in different shares; with respect to their distribution, the numerical taxonomy analysis indicated that they form classes matching the types of 'nature in the city' previously described by ecologists, despite the particular historical evolution of each city and its particular influence on urban planning. The correlation analysis revealed that the population and its density and the share of the green infrastructure within the total area are significantly correlated

* Corresponding author. Tel.: +4-021-307-7133; fax: +4-021-312-3954.
E-mail address: alexandru_petrisor@yahoo.com.

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with most fractal parameters. Similarly, the fractal dimension of the area, computed using Interactive Quantitative Morphology, seems to correlate with most morphological parameters. However, the taxonomical analysis of cities did not find very relevant groups due to the fact that many large Romanian cities lack Urban Atlas data. The results suggest that the degree of urban fragmentation is correlated especially with the population of cities and its density, reclaiming planning measures aimed at controlling the densification processes (sprawl, gentrification, location of specific activities etc.)

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Keywords: urban sprawl; ecosystem services; biodiversity; homogeneity; planning; fractal dimension; lacunarity

1. Introduction

Emerged some 50 years after the foundation of ecology by Ernest Haeckel as one of its branches, urban ecology had its own parallel evolution, trying to answer questions focused on three directions: ecology *in* the city, ecology *of* the city, and sustainability of the city 1. Disregarded by ecologists in the beginning, cities became an important object of study when ecologists realized there importance; cities host nowadays most of the world's population, with a constant increase of its share 2. The concentration of human population and activities determines numerous impacts against the environment 34, affecting the global resilience 5; cities are responsible for the 'global changes', term introduced in 2011 by Dale *et al*. 6 to coin climate changes, land cover and use changes, and alterations of the energy flows, phenomena which are intrinsically related 57.

The process of urbanization is an underlying cause of land cover and use changes 28 which in their turn are connected to climate changes and the alteration of energy flows. Previous studies have found that urban sprawl causes the conversion and fragmentation of natural systems 91011121314 even to a greater extent than agriculture 10, and is the main threat to non-urbanized areas 15 resulting into the loss of biodiversity 141617 and influencing species and biogeochemical cycles 18. As a consequence of sprawl, urban ecological systems are characterized by the connectivity of natural patches, succession and invasion 519, consisting of fragmented green spaces isolated from the natural systems 20, embedding also natural corridors 921.

Urban sprawl has two consequences; fragmentation refers to a patched or leap-frog land development, while dispersion refers to the expansion of a city from its core 22. Morphologically, fragmentation increases the number of patches and their perimeter, altering their functions (including the provision of ecosystem services) and reducing biodiversity 23, but decreases in the mean patch size 15 and increases the perimeter 2.

In relationship to biodiversity, the size of patches is a good predictor of species richness 9, and edge effects could also play an important role 9, because the isolated patches are more exposed to anthropogenic impacts 1016. While urban sprawl reduces species richness, as fragmentation reduces the areal of natural species 24, influencing the composition of specific assemblages, such as arthropods 16, the abundances of some species might peak due to edge effects 2. In general, biodiversity depends on the spatial structure (size of habitats and distance between them) 12.

The nature of cities has been included in four categories: remains of the natural systems, extension of natural systems, landscaped or managed areas, and spontaneous, invasive or ruderal species 2526. Previous studies have showed that maintaining nearly-natural habitats in cities allows even for the presence of rare and threatened species 1927; the quality of habitats seems to be more important than their