# ASSESSMENT OF THE GREEN INFRASTRUCTURE OF BUCHAREST USING CORINE AND URBAN ATLAS DATA

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**Abstract**. Urban ecology provides the theoretical foundation for assessing the interaction between man and nature in cities. Nature seems to be reduced and malfunctioning, resulting into a decrease in the ecosystem services provided to humans. The new method, based on assessing the green infrastructure, is designed to replace monetary and carbon footprint assessments and be particularly relevant for the urban areas, which grow and change fast and are the main drivers of environmental changes. This study uses 2005-2007 CORINE and Urban Atlas data to look at Bucharest. The results show that, despite of the method, the area occupied by the green infrastructure represents about 1/3 of the total area, corresponding to 50 $m^2$/person, although the green spaces only account for 6.5 $m^2$/person, which is far below the European average (26 $m^2$/person).

**Key words**: urban ecology, ecosystem services, footprint, fragmentation.

## 1. Introduction

In time, urban ecology research focused on three directions: (1) ecology in the city (differences from natural systems), (2) ecology of the city (city as an ecological system), and (3) sustainability of cities (Wu, 2014). The importance of these studies is justified by the fact that more than 50% of current population is urban (Wu, 2014). In the cities, several species exist in addition to humans; ecologists identify hemerophilous, especially synanthropic species, but also ubiquitous, opportunistic and, sometimes, random ones; humans also favor the alochtonous ones, including invasive ones, and domestic ones; most species are present in the green areas (Noblet, 1994, 2005; Petrişor, 2008a, 2010, 2013). The city nature has been classified as: (1) remains of natural systems (urban forests, parks representing former forests), (2) extension of natural systems (agriculture, forests), (3) landscaped areas (green spaces), and (4) spontaneous, invasive or ruderal species (Qureshi and Breuste, 2010; Breuste *et al.*, 2013).

The physical disconnection of the links between species interrupts mass, energy and information flows. Consequently, man-dominated systems do not have primary yield and depend on the additional energy introduced by man in amounts exceeding the contribution of primary producers (Petrişor and Sârbu, 2010). The low diversity results into a decreased stability, understood as ability to mitigate the destabilizing fluctuations; from a succession standpoint, the final consequence is ecological immaturity of man-dominated systems (Petrişor, 2013).

A complementary perspective is introduced by ecosystem services, representing the benefits provided by ecosystems to human society, and classified as: (1) supply (food, water), (2) regulation (flood and disease control), (3) cultural (spiritual, recreational, and cultural benefits), and (4) support (nutrient cycling) (Zakri and Watson, 2003; Watson and Zakri, 2005). This perspective is correlated with the functional one, since the biological yields turns in a normally functioning ecological system into goods and services, offered to the human society (Ianoş *et al*., 2009).

Ecosystem services can be assessed using at least three approaches.
(1) Classical/ monetary: goods and services receive a market value, through substitution or hypothetical markets or indirect methods (Negrei, 1996).
(2) Carbon footprint measures human pressure by estimating the terrestrial or marine area with biological yield that should be regenerated due to the exhaustion of resources and generation of waste (Peptenatu *et al*., 2010; Stan *et al*., 2013), or the natural area required to support a human population with the same lifestyle (Petrişor, 2008b).
(3) Presence of the green infrastructure, representing a strategically planned network of natural and semi-natural quality areas and other environmental features, designed and managed such that it could provide ecosystem services and preserve urban and rural biodiversity (European Commission, 2013). The green infrastructure consists of (1) ecological corridors (trees, green areas, water courses, bicycle and pedestrian paths), (2) urban areas (boulevards, markets, greed facades and roofs), (3) industrial parks, (4) suburban areas (relaxation and healthy lifestyle, encouraging interaction, events and agriculture), (5) sustainable drain systems (ponds, planted canals and wetlands), and (6) coastal areas (Benedict and McMahon, 2002; Gill *et al*., 2007; Tzoulas *et al*., 2007; ASOP Romania, 2014).

In order to assess long term changes, CORINE data have been used extensively for large scale analyses, with the caveat of questioning the results due to changes in methodology and resolution during the three periods covered (Jansen, 2007; Pelorosso *et al*., 2009; Verburg *et al*., 2011; Petrişor *et al*., 2010, 2014). Recently, the European Union released a new set of data, the Urban Atlas, covering urban areas at a better resolution (Hagenauer and Helbig, 2012).

The aim of this study is to analyze the case study of Bucharest in order to assess its green infrastructure using the two available datasets, CORINE (2006) and Urban Atlas (2005-2007).

## 2. Data and methods

CORINE and Urban Atlas data are provided free of charge by the European Environment Agency in a shape file format, usable by ArcView/ArcGIS. The projection is ETRS 1989 Lambert Azimuthal Equal Area L52 M10. In order to use the data, they were re-projected to Stereo 1970 and clipped by the administrative limits of Bucharest (data owned by NIRD URBAN-INCERC).

Since the classification scheme is different for the two data sets, a common classification was generated through a iterative process in two stages: (1) joining classes if one of the datasets provided a more detailed classification scheme, (2) merging similar classes if one of them was not found in one of the data sets. The total area of each class was computed with the X-Tools extension of ArcView 3.X, and classes were 'exploded' into separate polygons using the Edit Tools (ET) extension of ArcView 3.X in order to assess their fragmentation.

## 3. Results and discussion

The comparison of green infrastructure in Bucharest using CORINE and Urban Atlas data for Bucharest makes sense although the two datasets use different classification schemes, because they cover almost the same period (2006 for CORINE and 2005-2007 for the Urban Atlas). The results are presented in Table 1 and Fig. 1 for the entire city and in Fig. 2 for a sample area. Table 1 has three columns; the first two correspond to CORINE and Urban Atlas classification schemes, and the third column presents a joint classification, used by the next analyses. The table shows that the Urban Atlas provides in-depth description of urban features (*e.g.*, urban fabric by density and transportation networks), while CORINE provides an in-depth classification of agricultural features. This could be a shortcoming of the Urban Atlas, especially due to the importance of urban agriculture in European policies (Deelstra *et al*, 2001; Buhociu *et al.*, 2013; Popa and Hărmănescu, 2013).

Table 2 shows the results of applying the joint classification scheme to the two datasets. For each of them the table includes the number of parcels for each class, the total area, and share of the total area from the total area of Bucharest. Surprisingly, the differences occur only among the urban classes, while the totals are very similar. This is visible through the differences between Fig. 1, displaying the green infrastructure of Bucharest, and Fig. 2, analyzing a sample area; while Fig. 1 does not show obvious differences between the two datasets, they are visible in Fig. 2, where small features are lost and large features enlarged. This shows that the Urban Atlas excels in pinpointing the fragmentation of land in urban areas (Herold *et al.*, 2002; Nagendra *et al.*, 2004; Irwin and Bockstael, 2007).

## 4. Conclusions

Using the results above, the green infrastructure represents about 1/3 of the total area, corresponding to 50 $m^2$/person (49.78 for the Urban Atlas and 50.90 for CORINE), although the green spaces only account for 6.5 $m^2$/person (6.46 for the Urban Atlas and 6.61 for CORINE), which is far below the European average (26 $m^2$/person).

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**Table 1**. Harmonization of the classification schemes used by CORINE and the Urban Atlas

| CORINE | Urban Atlas | Final Class |
|---|---|---|
| Sport and leisure facilities | Sport and leisure facilities | Sport and leisure facilities |
| Green urban areas | Green urban areas | Green urban areas |
| Complex cultivation patterns | | Agricultural land |
| Pastures | | Agricultural land |
| Fruit trees and berry plantations | | Agricultural land |
| Non-irrigated arable land | | Agricultural land |
| Land principally occupied by agriculture, with significant areas of natural vegetation | Agricultural + Semi-natural areas + Wetlands | Agricultural land |
| | Land without current use | Agricultural land |
| Broad-leaved forest | Forests | Forests |
| Water bodies | Water bodies | Water bodies and wetlands |
| Inland marshes | | Water bodies and wetlands |

**Table 2**. Comparison between the CORINE and the Urban Atlas classes in Bucharest, Romania

| Land use class | CORINE | | | Urban Atlas | | | Urban Atlas / CORINE (%) |
|---|---|---|---|---|---|---|---|
| | No. parcels | Area (km²) | % total area | No. parcels | Area (km²) | % total area | |
| Sport and leisure facilities | 7 | 2.32 | 0.94 | 106 | 3.84 | 1.56 | 165.29 |
| Green urban areas | 16 | 10.59 | 4.30 | 272 | 11.09 | 4.50 | 104.72 |
| Agricultural land | 37 | 51.67 | 20.97 | 473 | 52.25 | 21.21 | 101.12 |
| Forests | 7 | 6.61 | 2.68 | 24 | 6.95 | 2.82 | 105.13 |
| Water bodies and wetlands | 10 | 12.33 | 5.01 | 63 | 11.28 | 4.58 | 91.47 |
| *Total* | 77 | 83.52 | 33.90 | 938 | 85.41 | 34.67 | 97.80 |

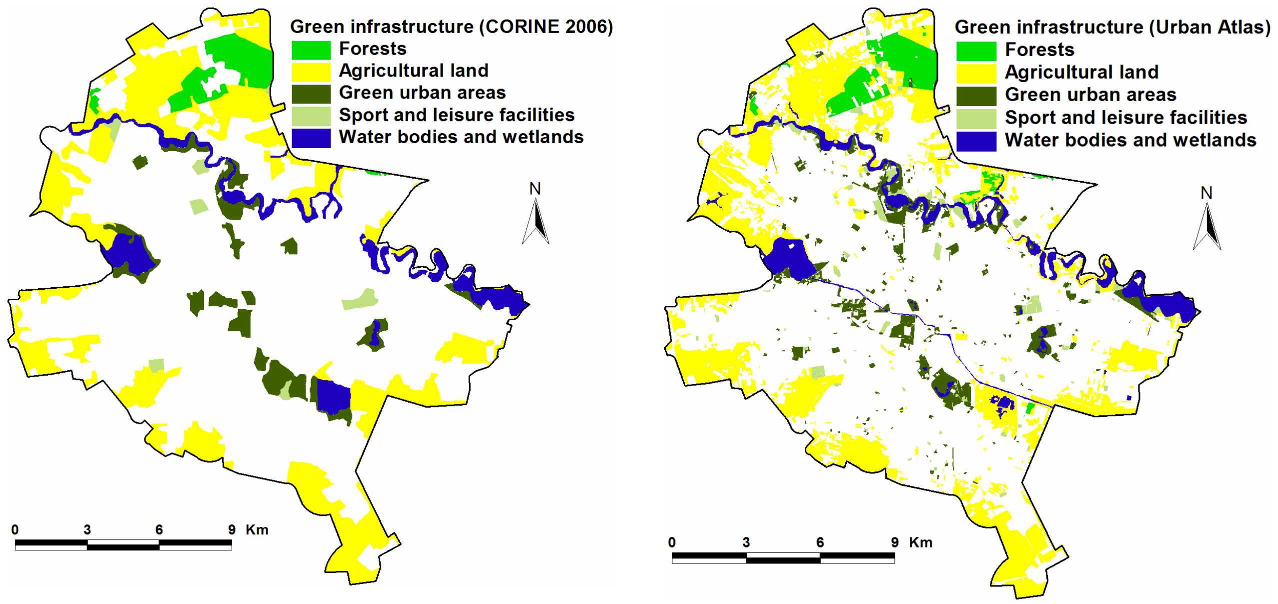


**Fig. 1**. View of the green infrastructure in Bucharest, Romania using CORINE (left) and the Urban Atlas (right)

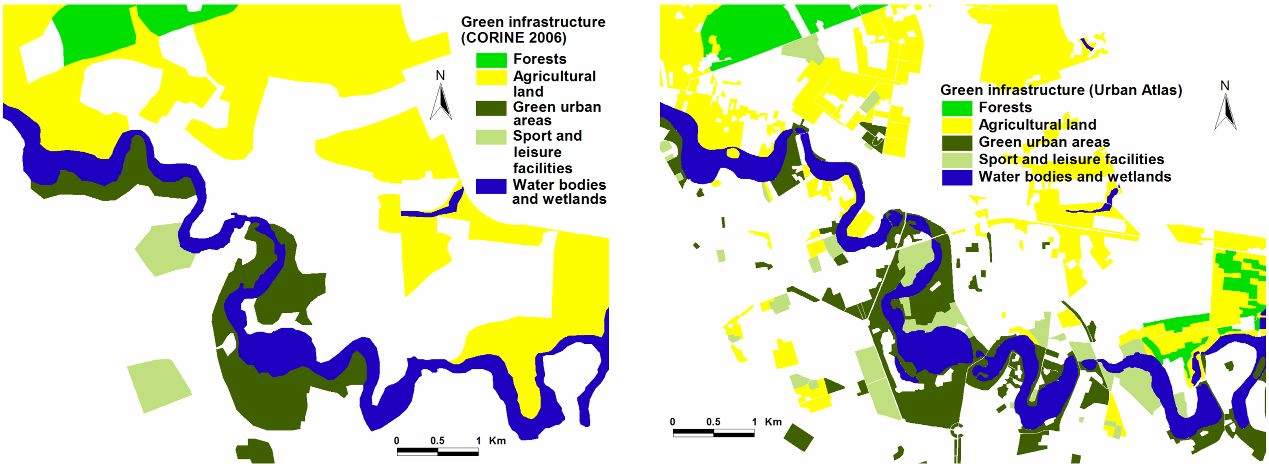


**Fig. 2.** View of the green infrastructure in a sample area from Bucharest, Romania using CORINE (left) and the Urban Atlas (right)

**Received**: 2 February 2015 • **Accepted**: 8 February 2015