Indicators for evaluating the role of green infrastructures in sustainable urban development in Romania

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Abstract

Urban green infrastructures are now considered key elements in improving residents' quality of life and creating an appropriate framework for the development of sustainable cities. One of the most efficient method to evaluate the state and performance of urban green infrastructure is using different types of indicators. The indicators for evaluating the benefits, ecosystem services and the role of green infrastructures for the process of sustainable development represent important tools for decision and policy makers. Indicators provide information that can be easily interpreted by decision and policy makers and they facilitate the process of planning, monitoring and evaluation of green infrastructure in urban areas. The focus of our study is to establish which indicators are used for underlining the structural and functional diversity of urban green infrastructures. This paper aims to highlight the indicators and indices being used in Romanian urban areas for measuring their sustainability that include green infrastructures, in the wider understanding of the concept. Throughout the paper, different examples of indicators and indices are provided, emphasizing that by using the proper set of indicators and indices, city authorities can tag a sustainable development label for certain areas. However, an unbiased assessment using some sets of indicators and indices are not always providing unbiased or realistic outcomes.

Keywords: *indicators, urban green infrastructures, sustainability*

Rezumat. Indicatori de evaluare a rolului infrastructurilor verzi în dezvoltarea urbană durabilă în România

Infrastructurile verzi urbane sunt considerate elemente cheie pentru îmbunătățirea calității vieții rezidenților și crearea unui cadru adecvat pentru dezvoltarea orașelor durabile. Una dintre cele mai eficiente metode de evaluare a stării și performanței infrastructurilor verzi urbane constă în utilizarea a diferite tipuri de indicatori. Indicatorii de evaluare a beneficiilor, serviciilor ecosistemice și a rolului infrastructurilor verzi în procesul de dezvoltare durabilă reprezintă instrumente importante pentru factorii de decizie și cei politici. Indicatorii oferă informații ce pot fi ușor interpretate de către decidenții politici and facilitează procesul de planificare, monitorizare și evaluare a infrastructurilor verzi urbane. Studiul nostru se concentrează pe stabilirea unor indicatori ce ar putea fi folosiți pentru a evidenția diversitatea structurală și funcțională a infrastructurilor verzi urbane. Scopul acestei lucrări este de a sublinia indicii și indicatorii utilizați în arealele urbane din România pentru a cuantifica sustenabilitatea infrastructurilor verzi, pentru o profundă înțelegere a acestui concept. Pe parcursul lucrării sunt propuși o serie de indicatori, subliniind faptul că, prin utilizarea setului corespunzător de indici, autoritățile locale pot eticheta un anumit areal ca având o dezvoltare urbană durabilă. Cu toate acestea, o evaluare obiectivă pe baza unui anumit set de indicatori, nu oferă întotdeauna rezultate realiste.

Cuvinte-cheie: *indicatori, infrastructuri verzi urbane, durabilitate*

Introduction

Urban settlements are confronted with a series of environmental, economic and social problems affecting both their structure and functions (Ioja et al., 2014). New challenges such as globalization, emigrant crises or environmental changes have determined international organizations promoting policies and strategies (Habitat I and II, Local Agenda 21, European Urban Charter, Millennium Declaration, Metrex, etc.) with the objective of achieving a sustainable development of cities (Schäffler&Swilling, 2013).

Sustainable urban planning aims at approaching problems in a holistic manner by considering specific scale issues (Norton et al., 2015), integrating the vision of policy makers (Vandermeulen et al., 2011) or selecting the right solution for development (Govindarajulu, 2014). The integration of all aspects in urban planning requires a more strategic, interdisciplinary and socially-inclusive process that increasingly uses green infrastructures in the decision-making process (DG Environment, 2012) as a way to contribute to achieving sustainability and resilience goals (Church, 2015).

A sustainable city is a challenge of present society (Ferrer et al., 2018) as it imposes a new approach in organizing the urban space and connecting urban functions, a demanding task for old urban areas passing throughout history, through successive and sometimes antithetic patterns of planning. Direct effects are present in the transformation of traditional grey infrastructures into modern and sustainable ones (Niță et al., 2018) following the objectives of sustainable development. On the other hand, the race for sustainability sometimes reduces or eliminates local differences in the structural and functional diversity in sectors of the city and, nonetheless, as sustainability is a catalyst for globalization, cities aiming in achieving this goal are likely to lose their authenticity due to

the fact that urban areas no longer address to local community but they address to a globalized world.

The use of green infrastructures in urban planning has increased as it is capable of contributing to a wide variety of policy objectives and goals in a sustainable manner (Bianchini&Hewage, 2012). Green infrastructures represent an instrument of achieving these goals, with their ecological, social and economic benefits being beyond doubt (Tzoulas&James, 2010). Planning with green infrastructures calls for different kinds of information compared to classical processes (Giordano, 2012), especially assessments considering their multifunctionality and the achievement of environmental, economic and social objectives (DG Environment, 2012).

Green infrastructure was originated as a concept in the 19th century in the search of connecting both parks and other urban areas for the benefits of population and also the conservation and connection of natural protected areas for the benefits of biodiversity (Benedict&McMahon, 2006). Urban green infrastructures are represented by a network consisting of: central areas (parks, urban forests, cemeteries, sport facilities), corridors (street alignments, water bodies, protection patches) and stepping stones (compact areas of small sizes – institutional gardens, residential green spaces) (Niță, 2016).

Urban green infrastructures are a concept with a multitude of visions (Newell et al., 2013) but represent in the broadest definition connected networks of multifunctional areas supporting ecologic and social processes (Iojă et al., 2014). Green infrastructures exhibit connectivity and multifunctionality as underlying features, covering a range of varying elements. Green infrastructures are defined by a series of characteristics that allow their evaluation: critical mass (minimal dimension of an element that can be considered as green infrastructure), benefits provided to the population, multifunctionality (the variety of their functions for society and nature also), the replacement of a traditional infrastructure and the degree of anthropic involvement in their maintenance (IEEP, 2011).

The main aim of the present paper is to establish which indicators are used for underlining the structural and functional diversity of urban green infrastructures. The main objectives are (i) establishing typologies of indicators according to aspects of urban green infrastructures they assess and (ii) evaluating the current situation of indicators used in planning documents for evaluating urban green infrastructures.

Typologies of indicators for assessing urban green infrastructures

Green infrastructure indicators can be found in a variety of forms: from simple qualitative or quantitative approaches to complex models accounting for indirect benefits or co-benefits. It is always useful to frame indicators into typologies, allowing both scientists and public administrations to select the most relevant ones.

1. Descriptive and performance indicators

One of the first methods of delineating indicators used in evaluating the contribution of urban green infrastructures to the sustainability of the city is that with two simple categories: descriptive and performance. This simple delineation, used by other studies (de Groot, Alkemade et al., 2010) is very useful in connecting indicators with their contribution to sustainability: state indicators concentrate on the number or surface (characterizing multiple elements of urban green infrastructures), while performance indicators determine the contribution of those elements to the general objectives of the city (Fig. 1).

It is notable that state indicators are easier to calculate and interpret the results, while performance indicators require both good data sources but also in-depth understanding of the mechanisms controlling environmental, social and economic processes at city-level. Both descriptive and performance indicators can be calculated at various spatial scales.

2. Indicators of benefits

A second approach in delineating indicators is in categories according to the specific benefits which we are trying to achieving from urban green infrastructures. Given their multifunctionality, this is challenging, as most of the times green elements provide multiple benefits and even co-benefits at city level (Raymond et al., 2017), but most of the authors delineate indicators on three main categories of benefits: ecological, social and economic.

Ecological benefits regard improving air quality through carbon sequestration and filtration of pollutants, reducing erosion due to rainwater or diminishing the negative effects of noise pollution (Badiu et al., 2016). Ecological indicators can be represented therefore by: Amounts of sequestered Carbon (kg/ha/year), Pollutants (PM10 and PM2.5, SO_2, NO_2, CO, O_3, CO_2) retained by trees or other vegetation (tons/ha/year), Changes in air temperature in vegetated surfaces (°C), Water retention in vegetation and soil (tons/sqkm) or Percent of permeable surfaces (% of constructed spaces).

While some of these indicators are easy to calculate and represent (Fig. 2 – percent of permeable surfaces in urban areas) for most of the ecological indicators intensive studies are required, especially given the high diversity of species and processes in urban green infrastructures and results are not always easily understood by various stakeholders.
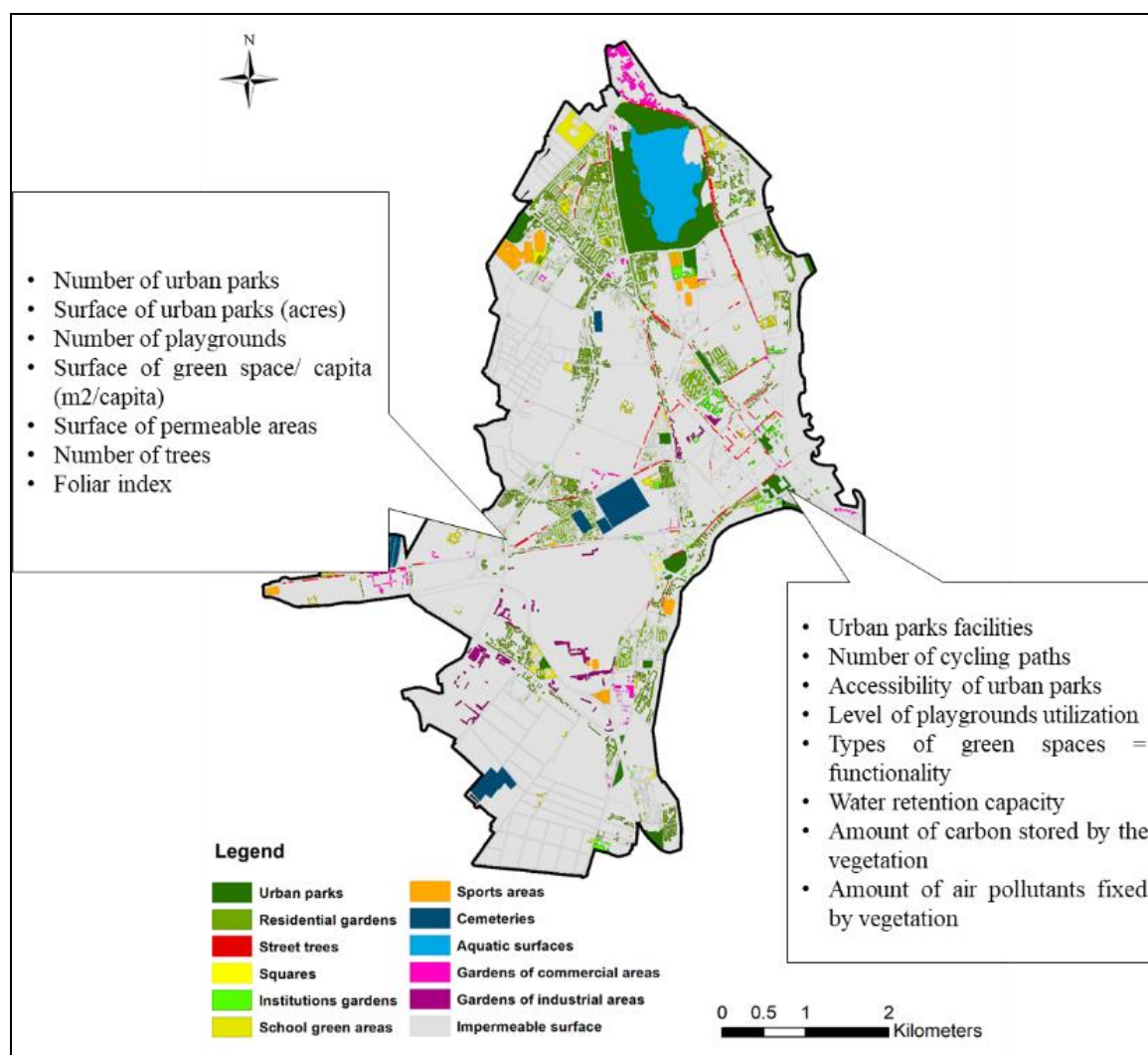

Fig. 1: Examples of state and performance indicators of urban green infrastructures in Constanța, Romania

Social benefits cover a wide range of aspects from the aesthetic improvement of urban landscape to the provision of recreation spaces, providing opportunities for socialization, areas for different sports and improving the general health state of the population. In respect, social and cultural indicators are represented by: number of public recreation sites (no.), accessibility to urban green infrastructures (no. of inhabitants situated at a minimum distances), number and magnitude of events organized in urban green infrastructures (no. of participants), frequencies of visits (no. or duration).

If accessibility (Fig. 3) and other descriptive social indicators are relatively easy to calculate especially using GIS techniques, for other indicators such as social cohesion, health improvement or opportunities for socialization, their calculation is difficult due to data deficiencies and the lack of a clear connection between the urban green infrastructure and its benefits.

Economic benefits include elements such as real-estate changes, reducing energy consumption or providing direct economic incomes from activities associated with elements of urban green infrastructures. Economic indicators can be represented by the real-estate value of buildings in the proximity (euro/sqm), monetary value of medicinal species (euro), reduction of medical expenses (euro/year), energy consumption for air conditioning (euro/year) or the biomass capacity in urban areas (Fig. 4).
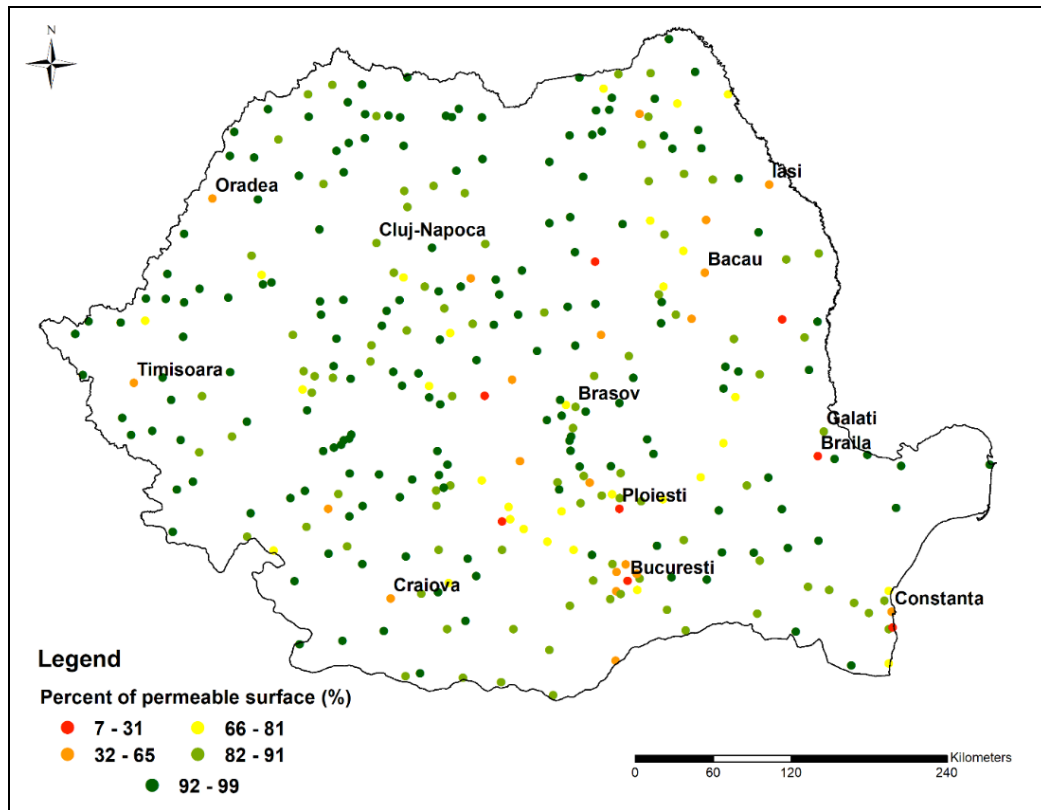
Fig. 2: Ecological and descriptive indicator - permeable surface in urban areas from Romania
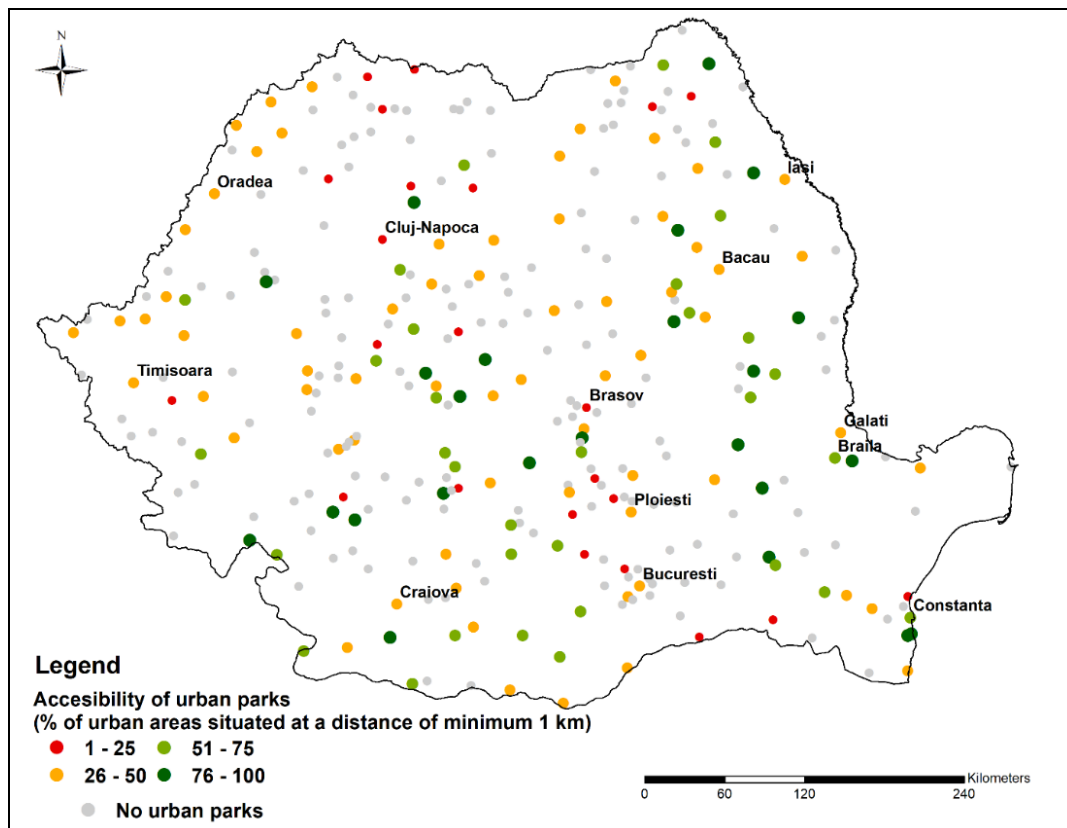
(after Niță, Onose et al., 2017)

Fig. 3: Socio-cultural and performance indicator - accessibility of urban parks in Romanian cities
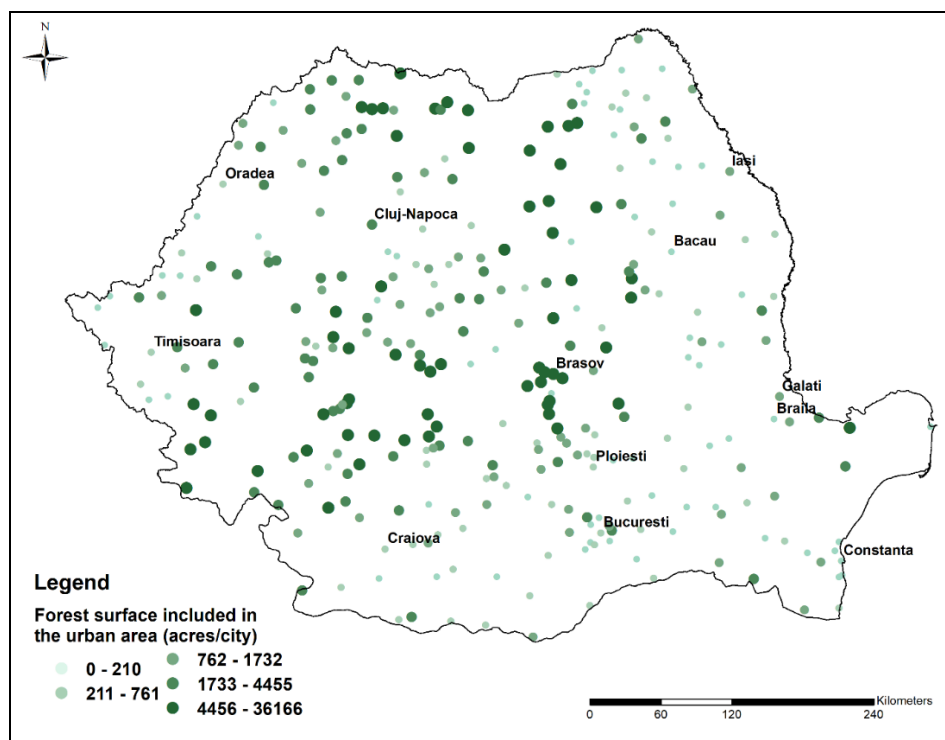
(after Niță, Onose et al., 2017)

Fig. 4: Economic and descriptive indicator - biomass capacity in urban areas

(after Niță, Onose et al., 2017)

Indicators evaluating the benefits of urban green infrastructures represent useful instruments for decision makers and in the same time facilitate the communication between experts and non-experts. Their separation into ecological, social and economic indicators makes it easier to relate them to the sustainable development goals as established at city level (Gavrilidis et al., 2017).

3. Indicators for ecosystem services

One of the most recent approaches regarding the urban green infrastructures benefits is linked by the quantification of urban ecosystem services. Through the evaluation of ecosystem services provided by urban green infrastructure, a tangible value is attributed to these benefits, which is more efficient to manage by the decisional authorities. For the evaluation of ecosystem services in urban environments, the European Commission has published the report Mapping and assessment of urban ecosystems and their services (Rocha et al., 2015) which presents a series of indicators used for quantifying the provision, regulatory and cultural services.

According to the classification of ecosystem services at urban level, they are indicators for the evaluation of urban green infrastructures

(i) provision services - biomass quantity of big and mature trees per forest surface (t/ha), number of species which present medical value, the harvested quantity (no./ha, euro/ha (kg or t)/ha) or forest cover (%);

(ii) regulatory and support services - quantity of carbon sequestrated in the trees canopy (t/ha), the capacity of water storage in vegetation and soil (t/sqkm), reduction of green gas emissions (%), trees shading area (urban climate regulation) (sqm), trees cooling potential (t C/ha) or ecological prints (tCO_2);

(iii) cultural services - suitable space for open air cultural activities (m2), recreational potential (between 0 and 1), spatial distribution of runners and bikers (number of runners and bikers/hour/km), kids playgrounds surface (m2).

Most frequently such indicators are interlinked, as urban green infrastructures provide a wide range of ecosystem services in the same time (Fig. 5), increasing their potential for improving the sustainability of a city.

Presence of indicators in planning documents

Previous studies have analyzed the presence of green infrastructures in planning and strategic documents at urban level (Niță et al., 2017) and demonstrated that despite their importance there are frequently seen as marginal spaces of urban development. Planning documents contain numerous indicators for assessing elements of urban green infrastructures: temporal dynamic of surfaces occupied by urban green infrastructures, newly

established surfaces of urban green infrastructures, forest surfaces, managed green surfaces, distance covered by street alignments, number of green areas such as playgrounds, surface of sport facilities, surfaces of green areas per capita.
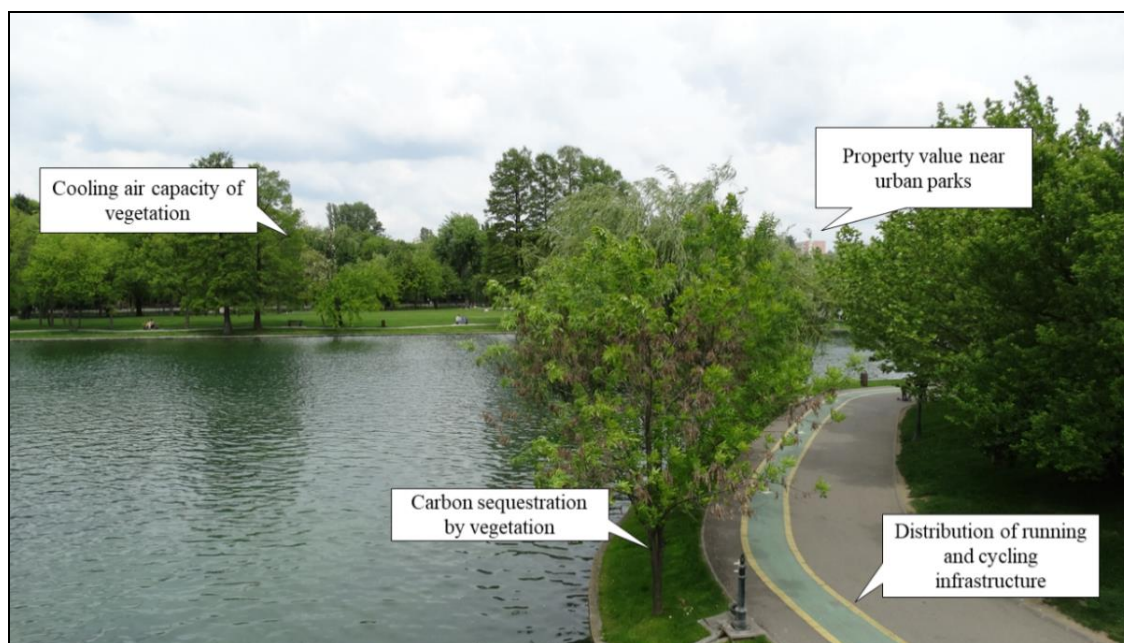

Fig. 5: The variety of ecosystem services delivered by an urban park in Bucharest

It is obvious that most of the indicators are simple descriptive ones, indicating only the state of green at city level. For a better connection between the urban green infrastructures and the sustainability of cities one should also include performance indicators assessing the ecologic, economic and social benefits of urban green. These indicators should be organically integrated both in public policies but also in legislation at various geographical scales (Badiu et al., 2016).

Public administration should seek to firstly create a database of urban green infrastructures in accordance with the reality which could assist in the calculation of indicators and further down to achieving the sustainability goals. In addition, besides indicators which are mandatory to calculate at city level, administrations should develop complementary indicators distributed among all categories, considering in equal manner the social, economic and environmental components, and being part of an integrated system of urban monitoring.

Green infrastructures should have their specific place in the urban ecosystems, in a complementary or often hybrid relation with other infrastructures. The change in the population consumption models will determined profound structural and functional changes in the distribution of urban green infrastructures, aimed at integrating spaces such as playgrounds, areas for pets or area designated for concerts or markets. In their search for contributing to the sustainability of the cities, urban green infrastructures could be developed on abandoned lands (including those with water or soil challenges), open spaces inside the built-up areas (brown-fields) or alternative locations (green roofs or walls).

Conclusion

The article presents the main categories of indicators assessing the contribution of urban green infrastructures to achieve urban sustainability and presented three main typologies: descriptive and state indicators, indicators assessing benefits and those focused on the evaluation of ecosystem services. We found that currently indicators used in planning documents for evaluating urban green infrastructures are mostly simple descriptive indicators. Our results emphasize the need to complementary use different types of indicators in analyses, rather than just descriptive ones and also push for the integration of indicators' results in the process of urban planning.

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