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ASSESSING ECOSYSTEMS AND THEIR SERVICES IN URBAN AREAS: THE CASE OF URBAN ECOSYSTEM CONDITION INDICATORS IN SOFIA, BULGARIA

Ivaylo Ananiev, Vanya Stoycheva, Stoyan Nedkov

National Institute of Geophysics Geodesy and Geography – Bulgarian Academy of Sciences
e-mail: IvayloAnaniev213@gmail.com, vanya.e.stoycheva@gmail.com, snedkov@gmail.com

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Abstract: *As the expectation for the increasing world population by 2050, the expected percentage of people living in urban environments would be above around 70%. That will lead to an increase in the needs of the urban ecosystems and the services they provide. To assess their supply potential, we need a clear overview of their state, as well as future projections for their development. Following the Mapping and Assessment of Ecosystems and their Services (MAES) framework, a methodology for mapping and assessment of urban ecosystems and their services in Bulgaria was developed in 2017. It consists of three main parts: mapping of ecosystem types; assessment of ecosystem condition; and assessment of ecosystem services. In this study, we used the ecosystems database developed during the implementation of the methodology to evaluate the ecosystem condition indicators related to the regulation ES for the case study of Sofia. The indicators with appropriate data were selected to generate maps that represent the ecosystem condition in the case study area.*

ОЦЕНКА НА ЕКОСИСТЕМИТЕ И ТЕХНИТЕ УСЛУГИ В ГРАДСКИТЕ ТЕРИТОРИИ: ИНДИКАТОРИ ЗА СЪСТОЯНИЕТО НА УРБАНИЗИРАНИТЕ ЕКОСИСТЕМИ В СОФИЯ, БЪЛГАРИЯ

Ивайло Ананиев, Ваня Стойчева, Стоян Недков

Национален институт по геофизика, геодезия и география – Българска академия на науките
e-mail: IvayloAnaniev213@gmail.com, vanya.e.stoycheva@gmail.com, snedkov@gmail.com

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Резюме: *Очакванията са, че до 2050 г. населението на света ще се увеличи, а процентът на хората, живеещи в градска среда, ще надвиши 70%. Това ще доведе до нарастване на нуждите на градските екосистеми и услугите, които те предоставят. За да оценим потенциала им за предлагане, се нуждаем от ясен преглед на състоянието им, както и от бъдещи прогнози за развитието им. Следвайки методическата рамка за картографиране и оценка на екосистемите и техните услуги (MAES), през 2017 г. беше разработена методология за картографиране и оценка на градските екосистеми и техните услуги в България. Тя се състои от три основни части: картиране на екосистемните типове; оценка на състоянието на екосистемите и оценка на екосистемните услуги. В настоящото изследване използвахме базата данни за екосистемите, разработена по време на прилагането на методологията, за да оценим индикаторите за състоянието на екосистемите, свързани с регулиращите на екосистемни услуги за територията на град София. Бяха подбрани индикаторите с подходящи данни, за да се създадат карти, които представят състоянието на екосистемите в изследвания район.*

1. Introduction

With the world population expected to increase by 2050, the percentage of people living in urban environments will be above 70% [1]. That will lead to an increase in the needs of urban ecosystems and the services they provide. On a European Union level, the urban ecosystems cover around 22% of the EU's land surface territory [2]. They provide important ecosystem services (ES), the most presented of which are water and air filtration, flood regulation, urban heat island mitigation, habitat provision, etc. [2]. The urban green space is identified as a key source of ES. It includes urban forests, parks, gardens, street trees, etc. [2] and the provision of ES is connected with the urban ecosystem's health. Improving this health will be achieved by a set of restoration targets until 2030 [2].

To assess urban ecosystem's health and supply potential, we need a clear overview of their state and future projections for their development. Several projects have applied the Mapping and Assessment of Ecosystems and their Services (MAES) [3] in Bulgaria. They consist of eight terrestrials and one marine ecosystem [4].

The ecosystem condition could be defined as the overall quality of an ecosystem unit, regarding biological, physical and chemical characteristics, which determines its capacity to provide ES [5]. A common approach to the assessment of the ecosystem condition is the comparison of measurements from the current state regarding the reference state of this ecosystem [6]. The aforementioned is highly applicable to artificial urban ecosystems, as the identified reference state would not be applicable if there is no human influence [6]. However, for artificial urban ecosystems, good condition is expected to represent long-term social-ecological resilience to support human well-being in cities [6].

The primary objective of this study is to evaluate the applicability of the urban ecosystem condition indicators for the assessment of regulating ES, based on the city of Sofia as a case study. We have assessed the available urban ecosystem condition indicators and selected the most prominent from them for further analysis and application for ES assessment.

2. Materials and Methods

2.1. Initial data

The approach prepared for and applied in this study is based on the national methodological framework for mapping and assessing the condition of ecosystems and the ecosystem services they provide. The framework aims to optimize the overall process of defining, mapping, and biophysical assessment of ecosystems and their services in Bulgaria. The methodology applies to the study of urban ecosystems throughout the country, given the existing differences between the areas in and outside Natura 2000, which are caused by the differences in the availability of data on land use and spatial distribution of ecosystems. The methodology provides a set of information on the relevant databases and data sources. The database structure follows the structure in the methodology [7] in terms of the number of vector layers and tables, as well as their scheme and nomenclature tables. The database schema is presented in XML and Personal geodatabase (.mdb) formats that are OCG- and INSPIRE-compatible. It contains three object classes (depending on the type of spatial data—points, lines, or polygons) and three tables containing different information about ecosystems.

Overall, three datasets were used for the assessment of the condition indicators. These are ecosystem subtypes (MAES BG), Urban Atlas classes and updated Urban Atlas dataset with urban green infrastructure. Mapping and Assessment of Ecosystems and their Services (MAES) [3] in Bulgaria have been applied by separate projects, one of which is for the urban ecosystem [7]. We use data for six of the eight terrestrial ecosystem types which cover the case study (urban, cropland, grassland, woodland and forest, heathland and shrub, and freshwater). The case study covers 221.53 km^2 of which 93% are the urban ecosystems (nine out of ten subtypes).

The Urban Atlas dataset is a product of Copernicus, which is the European Union's Space program's Earth observation component [8]. The Urban Atlas consists of a very high-resolution land use and land cover dataset of the Functional Urban Areas (FUA) [8]. We have extracted the part of the case study that covers Sofia FUA while performing additional analyses and cross-walking between the Urban Atlas database (version 2018), ecosystem types, and the newly added classes for urban green infrastructure from the Sofiaplan dataset [9].

To improve the accuracy of the dataset regarding urban green infrastructure (UGI), the main source of ES in urban ecosystems, we have applied the dataset for the UGI from Sofiaplan [9], derived from Sentinel-2 products.

The data for ecosystem condition in the case study area were extracted from the GIS database developed under the national mapping of the ecosystems. Indicators are a subset of multiple possible attributes that can be used to quantify the state of a landscape, watershed, or ecosystem [10]. In this case, the proposed condition indicators assess the state of urbanized ecosystems, and the structure and processes in them [11, 12]. There are 20 indicators (18 basic and 2 optional) in the methodology.

2.2. Processing and analyses of ecosystem condition data

For the processing of the ecosystem condition data, tables containing an assessment of individual indicators and tables containing parameters with values for individual indicators have been reviewed. All data are analyzed with two software packages, Microsoft Excel 2016 and QGIS 3.16. The information from the tables is tied to a spatial layer in a GIS environment to check the individual indicators for the different ecosystem types.

The analysis of the tabular information and their integration into a spatial layer show that all tables with the evaluation of indicators were made based on both quantitative and qualitative data. Almost all indicators have missing information or simply there isn't any available data for individual ecosystem types. After reviewing the tables containing values for the different parameters and going through the same process of analysis and processing, it becomes clear that the values are obtained both based on expert assessment for some of the parameters and quantitative data as well. Again, there is also a lack of data on individual ecosystem types.

2.3. Mapping of ecosystem condition

The mapping of ecosystem condition was done with three different datasets, ecosystem types, Urban Atlas (UA) classes, and the updated UA with green infrastructure. The ecosystem types dataset consists of nine urban ecosystem subtypes. The largest area is covered by J1: residential and public areas; J5: urban green areas (including sports and leisure facilities), and J6: industrial sites (including commercial sites).

The Urban Atlas dataset [8] for the case study consists of 22 of 27 classes overall. On the contrary from the ecosystem types, the highest area is covered by Class 12100, 'Industrial, commercial, public, military and private units', over 21%. Other highly represented were classes 11210 'Discontinuous Dense Urban Fabric (S.L.: 50–80%)' (17.72%) and 14100 'Green urban areas' (15.64%) [13].

The third dataset consists of the updated UA dataset with the additional green infrastructure classes. The UGI was divided into 16 categories, which cover 48% of the case study (the largest area occupied the "Green area in discontinuous urban fabric" and "Ruderal vegetation").

The indicators were assessed based on the quality of the data and their applicability to produce maps. Each indicator was assessed on the following parameters: 1) Assessment availability; 2) Discrepancies between the database and the methodology; 3) Discrepancies between the value and score (within the database); 4) Discrepancies between indicators and parameters; 5) Missing data (based on the number of polygons and/or ecosystem subtypes). The applicability of the indicators was assessed using a used a three-level scale: 0 – not applicable; 1 – yes, applicable; 2 – fully applicable.

3. Results

3.1. Ecosystem condition indicators

The results of the indicators' applicability are given in table 1. Five indicators have the highest score 2 (fully applicable). Only one indicator (soil heterogeneity has the lowest score of 0 (not applicable). The rest of the indicators could be defined as partly applicable and further study and their applicability is needed. Following each indicator's applicability scores, ES, two indicators, plant diversity and air heterogeneity, we selected produce ecosystem condition maps.

Table 1. Applicability of indicators for mapping and assessing ecosystem services (0 – not applicable; 1 – yes, applicable; 2 – fully applicable)

Indicator name	Assessment availability	Discrepancies Methodology/ Database	Discrepancies score/value	Discrepancies indicator/ parameter	Missing data	Overall applicability
Plant diversity	1	1	0	0	0	2
Animal diversity	1	0	0	0	0	1
Habitat diversity	1	0	1	0	0	2
Invasive species	1	0	0	0	0	1
Other biotic heterogeneity (naturalness etc.)	0	1	0	0	0	1
Soil heterogeneity	0	0	0	0	0	0
Hydrological heterogeneity	1	0	0	0	0	1
Air heterogeneity	1	1	0	0	0	2
Geomorphological heterogeneity	1	0	0	0	0	1
Disturbance regime	1	0	0	0	0	1
Other abiotic heterogeneity indicators	1	1	0	1	0	2
Energy balance (capture, storage)	1	0	0	0	0	1
Entropy production	0	0	0	0	1	1
Metabolic efficiency	1	0	1	0	0	2

Other energy budget indicators	0		0	0	1	1
Matter balance (input, output)	1	0	0	1	0	1
Matter storage	0	0	0	0	1	1
Element concentrations (other state variables)	1	0	0	0	0	1
Efficiency measures	1	0	0	0	0	1
Water balance (input, output)	1	0	0	1	0	1
Water storage	1	0	0	0	0	1
Other state indicators	0	0	0	0	1	1
Efficiency measures	1	0	0	0	0	1

3.2. Mapping of ecosystem condition in Sofia

The results of the mapping present the spatial distribution of the two indicators—plant diversity and air heterogeneity (fig. 1). The plant diversity shows better condition with most of the territory with a score of 4 (good condition), and the rest of the territories with a score of 3 (moderate condition). Limited areas have very bad condition (score 1). The second indicator (air heterogeneity) presents different results, as the predominant part of the case study area varies between bad (score 2) and moderate (score 3) condition. Again, limited area has very bad condition. The maps produced using Urban Atlas and Sofiaplan data give more detailed spatial distribution.

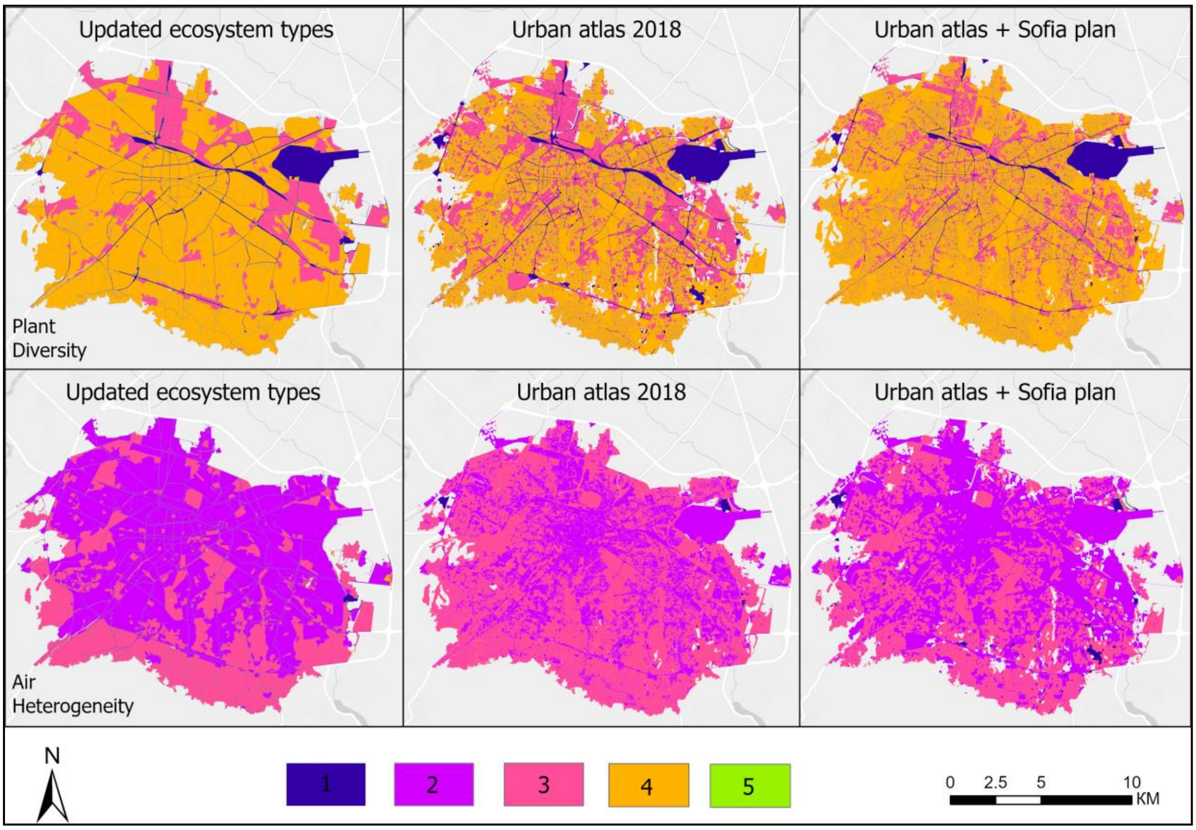

Fig. 1. Urban ecosystem condition indicators assessment with three different databases.
Legend: 1 – very bad, 2 – bad, 3 – moderate, 4 – good, 5 – very good.

Conclusions

In this study, we developed an approach for the evaluation of the applicability of urban ecosystem condition indicators from the national ecosystem mapping under MAES for the case study of Sofia. The available urban ecosystem condition indicators for the case study of Sofia were assessed and the results give the opportunity to select the most appropriate for mapping of ecosystem condition. The proposed approach gives an overview of the current state of the urban ecosystems and their capacity to supply ES. Selecting the MAES BG indicator to assess ecosystem condition and map the ES spatial distribution will be the next step for identifying the key supplying and key demanding areas for each ES.

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