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EVALUATION OF URBAN BIOTOPES – TOOL FOR BIODIVERSITY PROTECTION AND SUSTAINABLE DEVELOPMENT OF CITIES

Slobodan Jovanović[1*], Dragana Ranđelović[2]

[1]University of Belgrade, Faculty of Biology, Institute of Botany and Botanical Garden, Takovska 43, 11000 Belgrade, SERBIA

[2]Institute for Technology of Nuclear and other Mineral Raw Materials, Franchet d'Espèrey 86, 11000 Belgrade, SERBIA

[*]sjov@bio.bg.ac.rs

Abstract

Cities have a large heterogeneity of habitats (i.e. biotopes) in a relatively small area. Urban biotope mapping is a procedure for determining and describing the size and distribution of different habitats (natural and man-made) in the entire urban area with the intention of creating a biotope (habitat) network. Mapping of urban biotopes and their value assessment is therefore considered to be a valuable tool for the purpose of sustainable development and preservation of biodiversity in cities. Methodology for mapping and evaluation of urban biotopes in Serbia was developed for Belgrade city. Typology for biotope mapping as well as criteria for biotope value assessment were also created. Actual value of selected i.e. representative biotopes, as well as the potential value of all mapped biotopes were assessed. Results of biotope mapping are possible to transform for practical use, and certain recommendations and measures are defined for application in the planning process. So far, only limited use of these information was noticed for the purpose of urban planning, nature protection and scientific researches. Thus, there is a need to promote the projects regarding mapping and evaluation of urban biotopes as a useful tool for biodiversity protection and sustainable development of cities in Serbia.

Keywords: biotope mapping, biotope value assessment, GIS, urban planning

INTRODUCTION

Urbanization is one of the leading demographic trends, thanks to which more than half of the world's population today lives in cities. The percentage of Europe's urban population in 2018 was 74% (Statistic 2018). It is expected that within next 20 years the city population reaches up to 5 billion people, making the planet become global megalopolis. Urbanization always had a strong impact on biodiversity and landscape modification. Due to this, cities and nature have long been regarded as the opposites. As cities became "more urban", they had less natural places in them and vice versa. However, nowadays opinion that the city and nature do not necessarily imply the opposite prevails. Cities can play an important role for nature, in case they do not present a barrier but linkage to the regional biotope system [1–3]. Therefore, the map of urban and suburban biotopes represent a key part of the information system in many cities of the world, and the mapping and evaluation of urban biotopes is a tool for the integration of biodiversity protection into the urban planning process.

Protection and preservation of the urban biodiversity has not been given special attention in the past. This is due to the fact that the green areas in the city suffer from unique and powerful influences such as: the high density of buildings and infrastructure, small size of the isolated (fragmented) nature within the city, intense pressure of visitors etc. However, in spite of this, recent researches show that there are numerous ecologically and economically valuable biological resources in the cities [4–8]. According to Mansuroglu *et al*. [9], besides urban and suburban biotopes being a home for plant and animal species, they are also of importance for environmental design and aesthetics, natural and cultural history, protection of species, environment and landscape elements (water, air, soil, etc.), as well as for ecological research, education, recreation opportunities for urban dwellers and playgrounds for children.

Large influx of population in cities and unplanned urbanization pose a threat to the preservation of total biodiversity on planet Earth. Urban planners in many countries have failed to include environmental concerns in the planning of urban areas [10]. Incorrect urban management is not an inevitable fate of cities. Urbanization and ecology can co-exist, but only with active participation of involved stakeholders, including the private and public sector, as well as the citizens [11]. According to Teofilović *et al*. [10], some scientists in the field of biodiversity protection predict that cities will determine the fate of remaining biodiversity on our planet in the future. Namely, the struggle for life will be acquired or lost in the cities [12]. In this respect, this overview paper aims to affirm the importance and need of a systematic approach to mapping and evaluating urban and suburban biotopes as a useful tool for biodiversity protection and sustainable development of cities in Serbia.

City as ecosystem

Cities represent complex unities with different habitats and ecosystems that are inhabited by man and by other living species. Therefore, modern urban planning should also be an instrument that ensures the functioning and preservation of other living beings, since the existence of the man depends on them.

The city is a typical example of an non-autonomous ecological system, since it does not have its own autonomy. Unlike natural (autonomous) ecosystems, such as forests, meadows, pastures, lakes, rivers or seas, the city is unable to sustain and renew itself. Namely, green plants, as primary food producers, are insufficiently represented in the urban ecosystem. On the other hand, consumers, dominantly man, are present in abundance, while decomposers, as well as the producers, have disproportionately low presence. In such circumstances, in order to maintain itself, the urban ecosystem must take organic matter, water and energy from the surrounding natural and semi-natural ecosystems to meet the needs of many consumers. Because of this, the city is often figuratively described as "parasitic ecosystem" or "biospheric parasite" [1]. Man is the dominant ecological factor that even contributes to modification of climate in urban ecosystems. It is known that the climate of the city significantly differs from the surrounding environment. According to Kuttler [13], the most important features of urban climate include higher air and surface temperatures (urban heat island effect), changes in radiation balances, lower humidity, and restricted atmospheric exchange that causes accumulations of pollutants from a variety of sources.

Cities are typically warmer, drier, nutrient–laden, and floristically enriched by human activity [14]. The diverse vegetation types occurred in certain parts of many cities, and natural and man-made waterways attracts different birds, mammals, insects, and fish. But nutrient enrichment and extensive land conversion often allow a few tolerant species to attain extremely dense populations. The importance of plant diversity to birds, bats, and insects is consistent and suggests that if people allow structurally complex vegetation to occur, invertebrate and vertebrate diversity will prosper. At the same time, human facilitation of invasions by exotic species is general characteristic and probably the greatest concern for biological diversity of cities [14]. During the last two decades the number of studies focused on urban ecosystems in Europe increased, especially related to biological invasions and global environmental changes [4,15–19].

Legislative framework for mapping and evaluate of urban biotopes

Conservation of habitats is generally defined by a number of international documents. The most famous are the Convention on Biological Diversity (CBD - UNCED, Rio de Janeiro, 1992), Berne Convention (Council of Europe, Berne, 1972), and Habitat Directive (EU Habitats Directive 92/43 / EEC). All of them have been ratified by Serbian parliament. Also, development strategies and national legislation require the conservation of flora and fauna as well as their habitats, providing a starting point and obligation for sustainable urban planning.

The most direct approach to this issue is the Curitiba Declaration on Cities and Biodiversity (Curitiba city, Brazil, 2007). This declaration confirms global commitment to integrate biodiversity issues into urban planning and development in order to improve the lives of urban inhabitants and to ensure a sustainable basis for cities.

Mapping of urban and sub-urban biotopes

Compared to the natural areas, cities have a large heterogeneity of habitats (i.e. biotopes) in a relatively small area, which are additionally exposed to direct or indirect human influence. Although urban habitats are often considered to be abound with non-native or alien plants and animals [20,21], flora and vegetation of towns and cities harbour a significant number of specialized species, including rare and threatened ones [22]. Most of them are sensitive to habitat and management changes and thus represent good indicators of the environmental conditions and the socio-economic status of a city [23]. In recent urban management practice, biotope areas are often considered as passive green spaces which resulted in no specific protection measures taken, leaving them open to every kind of human disturbance [9].

Biotope is the basic topographical unit in ecology [24] representing an area of uniform environmental conditions that provides a living place for a specific assemblage of plants and animals. Biotope is sometimes used as synonym with the term habitat, though the first is more accurately delineated to describing an area with boundaries within which plants and animals can live [25]. In terms of mapping, biotope represents a clearly edged surface with a relatively unique structure of vegetation and land use. Urban biotope mapping is a procedure for determining and describing the size and distribution of different habitats (natural and man-made) in the entire urban area with the intention of creating a biotope (habitat) network. The mapping area of urban biotopes includes even empty parcels, abandoned blocks, steep slopes, transport corridors, abandoned agricultural land, etc. [10].

According to Jarvis & Young [26] and Mansuroglu *et al*. [9], two methods of mapping of biotopes in urban environments are commonly used: a) Selective Biotope Mapping, where only the biotopes worth of protection are mapped, and b) Comprehensive Biotope Mapping, where all existing biotopes are mapped. Germany is leading country in the terms of usage of biotope maps in spatial planning studies. Biotope mapping in Germany was started in the 1970s both at provincial and urban levels [27]. Today, biotope maps of 160 cities in Germany (that additionally include detailed information about the geology, water, climate, land use, traffic/noise and energy, etc.) have been prepared and are widely used as fundamental references in urban planning and management. In the later period, the biotope mapping method has been utilised in an increasing number of countries including the UK, Sweden, Turkey, Japan, South Korea, New Zealand and China [28]. Development of remote-sensing technologies and geographical information systems (GIS) offers new possibilities for very accurate and quick mapping of biotopes. The data obtained are more reliable and easy to update [9].

So far, Belgrade is the only city in Serbia that established a system of mapping and evaluation of urban biotopes. Establishment of Belgrade GIS on biotopes is the result of a two-year work on the project "Mapping and evaluation of the biotope of Belgrade" (third phase of the "Green Regulation of Belgrade" project, 2008). Methodology of mapping the urban and suburban biotopes involves several successive phases: a) divisioning the city territory to typical biotopes, b) graphic and cartographic representation of their size and distribution, c) inventorization of contents and specificities of the abiotic and biotic environment, and d) evaluation of the biotopes [3,11]. Previously, it was necessary to define the typology for biotope mapping [29]. The key for biotope mapping is organized in 9 main groups. Within each main group, further biotope classification was carried out at three to four hierarchical levels of resolution (type, subtype, variation, and specific plant community). Using the method of photointerpretation of aerial photographs, the mapping of the territory of Belgrade was carried out at the third hierarchical level of typology, i.e. at the level of the biotope subtype. In the subject area of 77,460 ha, 161,484 individual biotopes were isolated.

The next phase involves the selection of representative biotopes in selected areas of the city, presenting most subtypes previously defined by typology. For representative selected biotopes (504 entities at the level of subtype), detailed field survey of flora, fauna, vegetation, level of disturbance and other parameters defined for evaluation purposes has been done. Each biotope is geometrically defined as a closed polygon having a unique code (IDBiotop) with a certain set of data [10].

EVALUATION OF URBAN BIOTOPES

Evaluation criteria – example of Belgrade city

The criteria and their scale of values which were applied for urban and suburban biotopes assessment in Belgrade were partially defined according to model from Germany [30] but improved, modified and adjusted to Belgrade conditions as follows [10]:

1. Basic biotope importance (Cr 1)

    (5) Priority for conservation habitats (Habitats of special conservation interests on international lists)

    (4) Habitats included in international lists of important habitats

    (3) Habitats with endemic, relict or rare species as edificators

    (0) Other habitats

2. Degree of typicality for natural environment (Cr 2)

    (5) Biotopes with climatogenic (primary) and well-preserved forms of vegetation

    (4) Biotopes with climatogenic (primary) and relatively well-preserved forms of vegetation

    (3) Biotopes with a higher stage of succession - vegetation progradation typical for the natural environment

    (2) Biotopes with a lower stage of succession - vegetation progradation typical for the natural environment

    (1) Initial and pioneer stages of natural succession of vegetation typical for the natural environment

    (0) Biotypes of no significance and connection with natural succession of vegetation typical for the natural environment

3. Age and biotope regeneration ability (Cr 3)

    (5) Very old (about 250-1000 years old) and non-renewable biotopes

    (4) Old (about 75-250 years old) and very hard-to-renew biotopes

    (3) Medium-age biotopes (approximately 20-75 years old) and possibly renewable at least within the similar time period

    (2) Relatively young biotopes (about 5-20 years old), slightly dependent on age and easily renewable without additional care

    (1) Very young biotopes (approximately 0-5 years old), independent of age and very easily renewable almost everywhere

    (0) Biotypes with no possibility and need for estimation of age and regeneration ability

4. Biodiversity richness (Cr 4)

    (5) Biotopes rich in primarily indigenous species of flora and fauna with a significant share of characteristic species

    (4) Biotopes relatively rich in indigenous species of flora and fauna with lower participation of characteristic species

    (3) Biotypes medium rich with species of autochthonous flora and fauna and with the participation of allochthonous species

    (2) Biotope poor in species of autochthonous and allochthonous flora and fauna

    (1) Biotypes extremely poor with species of autochthonous and allochthonous flora and fauna, or without representatives of groups selected for the biotope evaluation

5. Specificity of biotope (endemism - relic - rarity) (Cr 5)

(5) Biotopes with more than 10 endemic, relict or rare species of flora or fauna

(4) Biotopes with 8 to 10 endemic, relict or rare species of flora or fauna

(3) Biotopes with 5 to 7 endemic, relict or rare species of flora or fauna

(2) Biotopes with 2 to 4 endemic, relict or rare species of flora or fauna

(1) Biotopes with at least one endemic, or relict, or rare species of flora or fauna

(0) Biotopes without endemic, relict and rare species of flora and fauna

6. Significance as a habitat for endangered species (Cr 6)

(5) Biotopes with one or more critically endangered (CR) or endangered (EN) species of flora or fauna

(4) Biotopes with one or more vulnerable (VU) species of flora or fauna

(3) Biotypes with one or more flora or fauna species on the lists of internationally and/ or nationally protected species (e.g. species found in different annexes of conventions such as Bern, Bonn, Habitat Directive, Bird Directive, etc. that do not have a defined status of vulnerability, but are treated as species of significance for protection)

(2) Biotopes with one or more species of flora or fauna of lower categories of vulnerability (LR, DD)

(1) Biotopes with one or more species of flora or fauna that are under the control of collection and traffic

(0) Biotopes without endangered or protected species of flora or fauna

7. Level of disturbance (Cr 7)

(5) Biotopes without or with very low level of disturbance

(4) Biotopes with low level of disturbance

(3) Biotopes with medium level of disturbance

(2) Biotopes with a high degree of disturbance

(1) Biotopes with a very large (extreme) degree of disturbance

8. Size, isolation and fragmentation of biotope (Cr 8)

(5) Extremely large compact biotopes (more than 2 minimal surfaces for stable functioning)

(4) Large compact biotopes (between 1 and 2 minimum surfaces for stable functioning)

(3) Isolated biotope belonging to a large mosaic of fragmentally distributed biotopes within the same category

(2) Isolated biotope belonging to a small mosaic of fragmentally distributed biotopes within the same category

(1) Small fully isolated biotope

In addition to the actual (real) value, which represents the current state of each specific biotope, defined primarily by the influence of anthropogenic factor, a potential value category is defined, which reflects the ability of the biotope to reach a certain value in natural conditions without direct and indirect anthropogenic impacts.

Potential value is estimation of the development state that a particular biotope can achieve if anthropogenic impact is excluded. For this type of evaluation, criterion 3 (age and biotope regeneration ability) and criterion 7 (level of disturbance) has not been taken into account, with a certain modification of the criteria related to the degree of typicality for natural environment (Cr 2) and the specificity of biotope in terms endemic, relict and rare species of flora and fauna presence (Cr 5) as key criteria for this assessment [8,10].

Criteria for determining the potential value of biotope are definitely new in this area and provide the possibility that, regardless of the quality and quantity of data collected during the field work on the research of representative biotopes, a general map of the potential biotope value of Belgrade can be made. The set of criteria for determining the potential value of Belgrade biotope is defined primarily on the basis of the generalization of data from the database "Habitats of Serbia" and "Phytocoenosis of Serbia", as well as on the basis of published data on wider analyzes related to problems of diversity, endemism and vulnerability of vascular flora of Serbia [31–33].

Potential biotope value is a special quality assessment that was developed for application in the biotope evaluation of Belgrade (Figure 1). In this way, in practical terms, a preliminary assessment of the value of concrete biotopes is enabled, for example if certain parts of city should be exempted from interventions in the area, or be treated with special care, before detailed data are collected for the estimation of real values.

Urban biotopes value estimation

For the assessment of the real and potential value of biotope in the area of Belgrade, a seventh-grade scale was established, according to [10]:

Grade 1 - Extremely poor biotopes, often resulting in heavy burdened surrounding living spaces. Primarily built areas, such as areas under buildings, roads and covered areas, biotopes extremely poor with species, large areas without vegetation e.g. illegal parking lots, commercial and industrial areas, areas treated with herbicides, etc.

Grade 2 - Extremely impoverished biotopes with limited ability to develop, without refugial function, with intensive use and low diversity of species. Biotopes that can be quickly compensated everywhere. They always burden the adjacent valuable living spaces (eg. sports areas, settlement areas with cultivated ornamental gardens and isolation greenery poor in species, young fallows rich in nutrients, arable land, etc.);

Grade 3 - Depleted biotopes, but capable for development. If necessary with a small refugial function, useful areas with low diversity of species (eg. intense grassland and pastures, intensively used young fallows rich in nutrients, etc.);

Grade 4 - Still valuable biotopes with good development abilities, extensively used in the past and sufficiently structured. The habitat of the medium diversity, in the built areas and in areas with intensive agriculture, with the existing refugial function, as well as the slightly disturbed fallows of old family houses and old garden colonies with high participation of utilitarian species and woody fruit trees, cemeteries, damaged hedges, etc;

Grade 5 – Valuable biotopes, extensively used and with a rich structure. Habitat of a large number of species and with the important function of refugium or buffer in build areas, or in areas with intensive agriculture (e.g. location with ruderal vegetation of older succession stages, extensive grasslands and pastures, hedges, etc.);

Grade 6 - Highly-valued, close-to-nature biotopes with high refugial function, worth of protection, slightly disturbed remains of the former natural areas. They are not used extensively anymore; habitats of endangered species (for example, the old forests close to nature, slightly degraded wetlands and wet meadows, close to nature streams, old hedges/meadows, old grasslands, etc.); and

Grade 7 - Natural or biotopes very close to nature, with prominent values for biotope and species protection, worth of nature protection with international and national significance, remains of the former natural areas or older cultivated ecosystems. They are not used extensively anymore. They represent the habitat of many endangered species (eg. wetlands, peat bogs, natural climatogenic forests, natural meadows or primary scrub, left to nature streams and lakes with a pronounced sediment accumulation zone).

Figure 1 *Map of potential biotope values (grade 5-7) of Belgrade city (extracted from Teofilović 2013)*

On the basis of the defined criteria and grade scale, in the area of Belgrade (within the boundaries of the General Urbanistic Plan), the evaluation of representative biotopes was carried out. Firstly, an estimate of the real value for the 504 representative selected biotopes has been completed based on filed data related to flora, vegetation and fauna (insects, amphibians, reptiles, birds, mammals, fish and zooplankton), as well as the air quality and climate (air temperature and precipitation). In addition to the evaluation of representative biotopes, estimation and potential biotope values estimation were carried out for the entire area of Belgrade [10]. By analyzing the data of the formed GIS database, information that can further serve the city administration, local governments, institutions dealing with urban planning, management and protection of natural resources, education and scientific institutions, as well as citizens, has been improved and moved towards more sustainable development.

Summarization of biotope mapping and evaluation in Belgrade

Some of the important data that came out from this database are: a) the most represented type of biotopes are agricultural fields and vegetable gardens, however, about 7,400 ha of abandoned agricultural lands are recorded in the area; b) about 5000 ha of biotopes belong to a group of fallows, representing the areas covered by ruderal vegetation of different succession stages; c) illegal landfills were recorded on a number of locations on about 400 ha; d) biotopes which are estimated as potentially highly valuable with prominent values for the protection of habitats and species and worth of nature protection of international and national importance were recorded on an area of over 10,700 ha; e) real high-value biotopes and biotopes with prominent values (grades 6 and 7) are located at the following areas: Veliko blato, forland zones of the Danube and Sava, Reva swamp, Zvezdara forest, Big War island, Ada Ciganlija, Makiško polje, Košutnjak, Topčider park, Manastirska forest, Stepin grove, Avala, part of Velikoselski rit, etc. [8,10].

Considering that the mapping and evaluation of the biotope of Belgrade lasted only two years (2005-2007), there was not enough time for the complete this information system. Therefore, it is necessary to permanently update the existing database of representative biotopes, as well as the other mapped biotopes with new data [34].

Transformation of the results for the use in planning

In the period following the formation of the GIS database, the data were used for different purposes and at different levels of detail. Namely, more than 100 excerpts of the database have been prepared, most often for the needs of the urbanistic plans preparation, but also for the needs of environmental impact assessment studies, the project for the protection of natural assets, as well as expert and scientific papers. The level of detail and the way data is displayed in the prepared excerpts depends on the detail of the database for the subject area. Based on this, certain recommendations are defined as well as general and detailed measures to be taken into account during the planning process. Detailed measures depend on the specific space, types of biotope, their values and the immediate environment, while recommendations can be generalized in the following way, according to [8] and [10]:

<u>Biotopes with value 6 or 7</u> - In the planning process the sites of high-value biotypes and biotope with prominent values should be absolutely preserved, and adequate measures for the maintenance of such biotopes should be recommended. Also, in the case of highly valuable

biotopes, it is necessary to carefully plan the areas in immediate surrounding, as inadequate uses would potentially endanger biotopes worth of protection.

Biotopes with values 4 and 5 - In the planning process valuable and still valuable biotopes should be preserved as much as possible, with recommendations for their improvement in order to preserve biodiversity. These biotopes should be considered as habitats of a large number of species with important function of refugium or buffer in built areas (eg. non-built living quarters, etc.).

Biotopes of value 3 - Degraded biotopes that do not set specific requirements in terms of planning, but represent potential as biotopes capable for development. On the premises of these biotopes, if possible, open and green areas should be considered in the context of the green area system planning, thus encouraging their ability to develop.

Biotopes of values 1 and 2 - Extremely poor and highly degraded biotopes with a limited ability to develop, which do not set specific requirements in relation to making planned solutions.

Practical significance and application

The mapping and evaluation of urban biotopes has practical application in number of cases, such as: a) development of environmental impact assessments of various facilities; b) development of landscape plans and plans of the greenery system in cities, c) delineation of protected areas and development of programs of their management d) scientific work in the field of urban ecology [3,11]. The initial step and prerequisite for the successful realization of each of these activities is the biotope map, that is, the information system with relevant data on their biogenic and abiogenic characteristics and estimated values.

Planning of green infrastructure in order to preserve biodiversity has become a practice in the European countries, but also a worldwide. According to Benedict and McMahon [35], green infrastructure is a link between the environment inside and between the cities, settlements and villages. It is a network of open spaces, waterways, gardens, forests, green corridors and alleys, which brings many social, economic and environmental benefits to the local population. Careful planning of green infrastructure can reduce the impact of various stressors such as: urban development, watercourse modification, drainage of swamps, introduction of foreign (allochthonous) species, removal of indigenous species, global climate change, etc. Many species can find suitable habitats in urban and suburban environments, provided people recognize their needs and integrate them into urban development. In order to promote and implement sustainable urban development and protection of biodiversity, the local population and city administration must first identify local wildlife and their habitats, and then provide and support basic needs for their survival (plant cover, food, water, space for living and reproduction).

CONCLUDING REMARKS

The system of urban biotope mapping as well as assessment of biotope value is an inter-discipline comprehensive work which provides a useful database for sustainable planning and urban landscape management. Rapid growth of areas and population in cities is causing inevitable changes (such as concentration of people and infrastructure, microclimate change and degradation of natural values), so mapping of urban biotopes and creation of databases for the purpose of sustainable development of cities and preservation of biodiversity in cities is gaining importance. The number of cities developing informational systems on urban biotopes is growing. Methodology of biotope mapping follows certain general rules, but should be modified for each city and geographical region, especially in regard of biotope typology. Results of biotope mapping are transformed for practical use in planning, and certain recommendations as well as general and detailed measures to be taken into account are defined for application in the planning process. Although ecosystem services are of high policy interest in EU countries and increasingly incorporated in urban planning, "urban green space" generally does not consider the diversity of the spontaneous urban flora, vegetation and fauna as well as their relationships to different or changing environments.

Mapping of urban biotopes in Serbia was conducted in Belgrade in 2008. In addition to the evaluation of representative biotopes, an estimate of the potential value of biotope in the entire area of Belgrade was made as a base for further use in urban planning and management. So far, only limited use of these information and maps was noticed for the purpose of urban planning, nature protection and scientific researches. There is a need to promote ecological planning approach in the Belgrade urban planning process as important factor leading to the preservation and development of urban biotopes.

Considering the size of city and the diversity of its biotopes, the typology of urban and suburban biotopes, as well as the mapping and evaluation methodology used for Belgrade can be adapted to other major Serbian cities such as Novi Sad, Nis, Kragujevac, Kraljevo and others. Smaller cities, however, would require certain adjustment of this methodology and biotope typology to their size and the local characteristics. However, it is necessary for local governments to make strategic decisions about the future planning and development of their cities on the principles of sustainability, especially with regard to the green area system, which presents kind of `green capital` in the terms of an elevated quality of urban life for people and other biota.

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