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Editorial

Special Issue: "Maintaining Ecosystem Services to Support Urban Needs"

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Cities are growing worldwide, in their geographical extent with respect to their general and current macro-economic significance, as well as regarding their total populations. Thereby, land and resource utilization are increasing in and around agglomeration centers, as are the requirements for a good quality of life and health. Current projections of rapid expansion of urban areas present fundamental challenges but also opportunities to design more livable, healthy, and resilient cities [1,2].

Often, the city has been treated in geographical writings as merely a social phenomenon, and at the same time, environmental scientists have tended to ignore the urban perspective [3]. In recent years, social, economic, and environmental considerations have led to a reevaluation of the factors that contribute to sustainable urban environments. In this context, urban green space is increasingly seen as an integral part of cities that provides a range of services to both the people and the wildlife living in urban areas [4]. It is widely accepted that forests, surface waters, parks, and gardens make up a significant part of the quality of life in cities. They represent urban ecological features, provide numerous ecosystem services, such as the adaptation to climate change impacts, and are essential for the urban population in terms of environmental education and contact with nature.

With this recognition and resulting from the simultaneous provision of different services by urban ecosystems, there is a real need to identify a research framework in which to develop multidisciplinary and interdisciplinary research on urban green space and to quantify and communicate its value in terms of ecosystem services accounting in space and time. Studies investigating the effects of urban green space on well-being and health show how important nature is for human well-being in urban areas. All these studies provide helpful information for policy and planning on the optimal amount of green space provision for well-being and health in close vicinity to the residential areas [2].

Ecosystem services (ESs) are direct and indirect contributions of nature to human well-being (according to the Millennium Ecosystem Assessment [5]). ESs can be categorized into provisioning services (e.g., food and raw material supply), regulating services (e.g., pollutant purification and erosion control) and cultural services (e.g., landscape aesthetics, recreation and tourism). Supporting ESs (e.g., soil formation or photosynthesis) enables the services of the other three groups, but they do not deliver so-called final ESs [6].

Urban ecosystems are mainly represented by different types of green spaces in the city [7]. This includes particular parks, urban forests, cemeteries, vacant lots, gardens and yards, landfills as well as road trees, green roofs, and walls. Blue infrastructure (urban water ecosystems) such as streams, lakes, ponds, artificial swales, and storm water retention ponds is part of the green infrastructure [1].

Urban ecosystem services (UESs), directly or indirectly used/consumed by people, support the urban quality of life, including protection from natural hazards [8]. They provide benefits for humans, and thus they are in demand [9,10]. Cities are dependent on ecosystems beyond the city boundaries, but also benefit from internal urban ecosystems [11]. The latter are the focus of this Special Issue in Sustainability. Although urban ecosystems provide only a fraction of the total ESs used in cities, the high density of beneficiaries relative to existing green infrastructure (GI) implies that the social and economic value of services provided locally by urban ecosystems can be surprisingly high.

Over the next few years, the key question of how to manage the balancing act with ongoing processes of urbanization will remain. The increasing demand for houses, flats, and other gray infrastructure needs to be satisfied, but city borders should not expand too far into rural areas and sufficient space for the natural environment should be maintained. Hence, policymakers and scientists are calling for the promotion of a more sustainable urban form, namely compact cities [12]. While policies favoring the compact city include multi-dimensional objectives to secure sustainable development, the main aim of compact cities is to protect the environment from further degradation by urban sprawl.

Can nature exist in a compact city? Modern urban living, growing infrastructure and attractive work and recreational opportunities must be reconciled with the preservation of green spaces and biodiversity. The conservation of biodiversity on all levels is a crucial goal of international environmental policy. This goal increasingly also applies to urban areas. Urban biodiversity should be properly managed to let urban dwellers benefit from its ES [2].

Analyses of investments in nature-based solutions and ecosystem-based adaptation and maintenance of urban ecosystems are gaining interest, particularly where such measures simultaneously generate many other services that enhance human well-being. However, the implementation of green spaces as parts of urban green infrastructure in urban areas is restricted by competing urban land use demands, limited areas for (new) green spaces, and limited public financial resources. Multifunctional green spaces are solutions and approaches to make use of the manifold and overlapping benefits on the one hand and address the restrictive conditions for implementation on the other hand. Nevertheless, their implementation faces several barriers: lacking assessment tools that allow integrated analysis of overlapping ESs, lacking design principles, sectoral views on development and maintenance, and traditional models of responsibilities and funding.

For the future well-being of citizens, the ecological and climate resilience of urban ecosystems needs to be improved and environmental benefits maximized. This requires a common understanding focusing on the integration of urban planning and management with environmental objectives such as urban biodiversity management, ecosystem resilience, adaptation to climate change, public participation in decision-making, and environmental education and awareness. However, Haase et al. [10] emphasize that major challenges remain in assessing and valuing individual UESs, as well as in understanding the spatial distribution, tradeoffs, and synergies of multiple services at the citywide scale.

In this context, the editors of this Special Issue—"Maintaining Ecosystem Services to Support Urban Needs" solicited evidence-based research articles on the following main topics:

- sustainable urban development;
- ecological effects caused by ongoing urbanization;
- growing cities and resource demand;
- assessment of urban biodiversity;
- urban land use change and impacts on ESs;
- functions and benefits of urban green space;
- the relationship between ESs and biodiversity in cities;
- ES flow between cities and urban fringes;
- the quantification of UES demand;
- the maintenance of UESs in practice;
- supply and demand of urban ecosystem types.

This is a broad field, and many colleagues thus felt motivated to submit a contribution. If the paper provided lacked a clear focus on urban ecosystems and their services, it was for the most part promptly rejected. The remaining papers all went through 2–3 rounds of review and revision with the aim of achieving a high quality of research and a wider dissemination of research results.

This Special Issue includes 15 articles from different continents: 7 from Europe, 5 from Asia, 2 from North America, and 1 from Australia (Table 1). Thus, the examples cover a wide range of cities all over the world, with various research emphases, methodologies, and study areas, reflecting the inter-disciplinarity that characterizes urban and land use studies. The scale of consideration varies from small areas (e.g., a park of 2 ha size) to metropolitan regions of country scale (e.g., the administrative area of mega-cities in China). The studies include all forms of green urban open spaces, except particular parks, woodlands and forests, street vegetation, and street trees as well as rivers and lakes.

Table 1. Systematization of focal points of the published Special Issue contributions.

Paper *	City Example (Country)	Ecosystem/Land Use Type Focused on	Ecosystem Services Assessed	Methods Applied
[13]	271 cities (China)	Urban green area at city scale	Per capita green area and city size	Regression analysis, Panel Data Model
[14]	Shanghai, Hangzhou (China)	Land use/land cover classes of the urban region	Bundles of most important classes of all categories	Assessment of regional Ecosystem Services Value (ESV)
[15]	Sydney (Australia)	Green infrastructure at neighborhood scale	Micro-climate regulation	Evaluation of effects using remote sensing data and thermal imagery
[16]	Suburban areas in Lake County (USA)	30 ha heterogeneous green space areas	5 regulating services/disservices	Quantitative and monetary valuation of ecosystem services
[17]	Munich (Germany)	2 urban woodlands	Recreation values	Visitor counting, interviews, travel cost method
[18]	Rome (Italy)	Urban trees and forests	Biodiversity and provision of ecosystem services	Evaluation of ecological coherence and landscape connectivity of new or restored GI elements
[19]	Seoul (Korea)	Urban parks	Access to urban green space	Hedonic price method
[20]	Dresden (Germany)	Total green area	All that are relevant	Analysis of ES consideration in landscape plan
[21]	Bekasi City (Indonesia)	Land use, parks	Not clearly declared	Land use optimization (multi-criteria analysis)
[22]	Chiayi City (Taiwan)	Tropical urban trees	Micro-climate regulation	Evaluation of thermal environment and planting design, screening of appropriate tree species
[23]	Warsaw (Poland)	28 urban lakes	Biodiversity, recreation services	Assessment of benefits on the basis of housing values and time spent on/at the lakes
[24]	Toronto (Canada)	Land use, vegetation, parks	Environmental services (temperature, vegetation)	Modelling the Urban Environmental Quality (UEQ), principal component analysis, GIS overlay
[25]	85 large cities (Europe)	Land use (forest, green urban area)	Food provisioning, climate regulation, recreation, and biodiversity potential	Estimation of ES changes over time based on land cover data (CLC)
[26]	Warsaw (Poland)	82 urban parks	10 regulating and cultural services	Complete diagnosis of the capacity to deliver the ES
[27]	Trnava City (Slovakia)	Land use/land cover classes	Not clearly declared	Land use changes over time periods, their comparison to other cities; assessments by conflict of interest and GreenFrame methodology

* Ordered by publication date.

All papers in this Special Issue have in common that they provide data, information and/or tools towards more ecologically sustainable cities which can be used by urban and regional planners as well as decision makers. For the purpose of this editorial introduction and to summarize important findings, the papers can be grouped under the following aspects (the contributions are assigned to one or more of these categories):

(1) Quantitative aspects of urban ecosystems (the more green space, the better the UES provision?)

Cai et al. [14] observed that the outward expansion of developed land in two fast-growing metropolitan regions of Eastern China resulted in substantially declining productive agricultural land, natural land, and semi-natural land. This led to considerable landscape fragmentation and deteriorated regional ecosystem functioning. The authors highlighted that, in both regions, the status of regional ES degraded significantly, largely due to unplanned and poorly managed urban sprawl. Embedded in the complex ecological-economic-geographical processes, surging urban expansion and population growth in both regions will inevitably require more land for development, and thus will deteriorate regional ESs, which feed the development boom of the human-dominated ecosystem. Therefore, on the regional and national levels, future policies on land use and urban development must reject any land development that is motivated purely by economic goals and impairs ecosystem functions and services [14].

(2) Qualitative aspects and design of urban ecosystems (the better the quality/design, the better the UES provision?) as well as the relationship between ESs and biodiversity

Cities worldwide have been trying to achieve a sustainable urban form to handle their rapid urban growth. Currently, however, we lack integrative guidelines on how to manage trade-offs between urban densification and the provision of green space [20]. Many sustainable urban forms have been studied, and two of them, the compact city and the eco-city, were chosen in the study by Handayanto et al. [21], which were examined in more detail. Four sustainable city criteria (compactness, compatibility, dependency, and suitability) were considered as necessary functions for land use optimization. This study presents a land use optimization procedure as a method for achieving a sustainable urban form. Bekasi City's land use plan (2010–2030) was analyzed after optimizing current (2015) and expected future land use (2030). After current land use optimization, the score of sustainable city criteria increased significantly [21].

The study by Klimas et al. from the United States [16] provides information on small-scale variability in ESs that is important for planning, especially in urban areas (including suburbs surrounding the urban core), where opportunities for creating or improving green space may focus on small public or private lots. Due to larger private lots, suburban areas often offer more potential for green space, and opportunities for development that can include setting aside green space reserves, or "land sparing".

The case study on the metropolitan area of Rome by Capotorti et al. highlights the role of woody species and forest remnants as proxies for overall biodiversity and as main ES providers. The authors conclude that the estimates of the capacities of urban trees and forests to provide key ESs may help to select the most suitable species and communities for forestation programs and GI projects in cities [18].

Sikorska et al. [23] found that a high biodiversity of green infrastructure (lakes in Warsaw) does not contribute to recreational ESs.

Taiwan experiences subtropical and tropical climates, and the thermal environments of outdoor spaces in urban areas are hot, especially at noon and during the afternoon. Improved planting design provides trees with shade and cooling functions that improve the thermal comfort of the outdoor space. The cooling effects involve complicated tree characteristics such as canopy size, tree height, and the optical properties of leaves. However, such tree characteristics are not easy to control in order to improve outdoor thermal comfort. Therefore, planting the appropriate tree species affects cooling functions. In addition, the improvements made by different species to outdoor thermal environments varied greatly in different areas. Consequently, Lin and Tsai [22] concluded that choosing a suitable method to determine the appropriate tree species for planting design is essential.

(3) Evidence-based UES assessments, in particular for recreation and regulating services (ES values as useful arguments to ensure/enhance urban ecosystems?)

Although green space is noted as a potential urban form that can reduce heat extremes for urban residents, quantifications are necessary to show the cooling effects as part of climate change adaptation in cities. Lin et al. [15] evaluated how vegetation cover at the neighborhood scale affects climate regulation services in Sydney in three important spaces within the city—roof tops, streetscapes, and parklands. The findings highlight the importance of promoting or reducing certain landscape covers depending on the land use type in order to maximize the cooling potential of green infrastructure. To provide a way forward and develop win–win management strategies, several actions should be considered: (1) optimization modeling of tree species, canopy cover, and tree placement; (2) changes in pavement and bare soil/dry grass placement within local and landscape-scale scenarios; and (3) implementation of mesoscale atmospheric models to develop a range of future climate scenarios for urban vegetation [15].

Lupp et al. [17] demonstrate methods to describe recreational demand by collecting data from interviews and using camera traps in two forests in the north of Munich for visitor counting. Jogging or Nordic walking were proven to be important recreational activities. Depending on the method chosen, the calculated monetary value of recreation reached up to 15,440 Euro per hectare per year [17].

The monetary value of the cultural ESs of urban parks can be estimated using the Hedonic Price Method (HDM). Park et al. [19] applied this approach in Seoul, the capital of South Korea. The results of the study have significant implications for analyses of the economic impact of urban parks in Seoul and can improve walking accessibility to the parks. They found, first, that, as the distance from the park increases, the value of the park inherent in the housing price decreases, and second, that the more accessible the park is by walking, the higher the park value inherent in housing prices is [19].

Urban lakes, especially those of natural origin, provide ESs, recreation being one of the most important and the most highly valued by the city dwellers. The relationship between the ecological value of the water bodies analyzed by Sikorska et al. [23] for 28 lakes in Warsaw (Poland), measured using naturalness indices, and the ESs they can provide was assessed. The results show that the floodplain lakes located along the urban–rural gradient are of great importance to the citizens due to their recreational potential. However, the provisioning of recreational ESs is weakly correlated with the ecological value of the lakes.

A complete diagnosis of the capacity of urban ecosystems in delivering ESs is lacking. The paper of Giedych and Maksymiuk [26] tries to explore the capacity levels of local regulating and cultural ESs delivered by all Warsaw parks. The study was based on data included in existing policy documents related to environmental and spatial planning for Warsaw, and on an evaluation of Warsaw green spaces. The evaluation included 10 ESs: micro-climate regulation, air quality regulation, noise reduction, balancing rainwater peaks, recreation, social inclusion, physical health benefits, nature experiences, aesthetic appreciation, and sense of identity. Most of the assessed parks (51.2%) exhibit a superior capacity to deliver regulating ESs, whereas, with respect to delivering cultural ESs, only 32.9% of evaluated green spaces demonstrate a superior capacity. The study results show inter alia that the size of a park is a very influential variable that defines the delivery level of regulating ESs [26].

(4) Temporal changes in land use/ESs (how much are the urban ecosystems threatened?)

Studies by Cai et al. [14] in Greater Shanghai and Greater Hangzhou, which are top mega-cities in China, show that the outward expansion of developed land subsequently caused significant landscape fragmentation along urban–rural gradients and caused declines in regional ES functions in both regions. Since the late 1970s, in Greater Shanghai, regulating, supporting, provisioning, and cultural

ES values decreased by 32.1%, 17.9%, 53.7%, and 17.1%, respectively; in Greater Hangzhou, these values decreased by 27.8%, 23.9%, 28.6%, and 22.9%, respectively [14].

Available evidence demonstrates conclusively that urban sprawl has accompanied the development of towns and cities across Europe over the past 50 years: European cities have expanded on average by 78%, whereas the population has grown by only 33%. The dense enclosed quarters of the compact city model have been replaced by free-standing apartment blocks and semi-detached and detached houses, with more than a doubling of the space consumed per inhabitant over that period [28].

More recent developments were analyzed by Szumacher and Pabjanek [25] in 85 large cities from the continental (Central and Eastern) biogeographical region in Europe using Corine Land Cover (CLC) data for 1990, 2000, 2006, and 2012. The main findings are as follows: (1) The increase of forest areas was the highest in 2006–2012, and of urban green areas in 2000–2006, mostly in cities in Germany and the western part of the Czech Republic. (2) The rate of soil sealing was the most intense in Polish cities. (3) There was a decrease in food production and biodiversity potential in all analyzed cities. (4) Climate regulating services experienced only slight changes. (5) There was a very positive trend of the recreation indicator in most core zones of cities in Germany and several cities in the Czech Republic, Poland, and Denmark.

Izakovičová et al. [27] investigated the long-term land use changes (1838–2015, with explicit emphasis on the transformation over the last 25–30 years) driven by urbanization and their environmental effects in Trnava City and compared them with those in similar cities in Slovakia and adjacent countries (Czech Republic, (Eastern) Germany). The analyses show that the transformation processes in urban areas in Slovakia and other post-Communist countries led to increasing pressure on ecosystems and their individual components—in particular, the conversion of productive agricultural land and semi-natural ecosystems into built-up areas accompanied by the negative ecological impacts of habitat deterioration and fragmentation [27].

(5) Relationship between city size and urban benefits (is there an optimal city size?)

City size is not the most important factor determining a city's benefits, conclude Zhang et al. [13]. However, there is a significant difference in the average city benefit between cities of various sizes. Inter alia, relative to urban per capita GDP, city size corresponding to the maximum value of urban environmental services was slightly smaller in investigated Chinese cities, indicating that, although mega-cities may improve economic efficiency, they create environmental problems [13].

For instance, for the assessment of the ES "recreation in the city," on a national scale, Grunewald et al. [29] analyzed the proportion of inhabitants who find nearby green spaces in the sense of daily or leisure-time recreation in 182 German cities. They found that larger cities have greater difficulty ensuring the provision and accessibility of green spaces. However, there was no statistically significant correlation between indicator values and municipal area or between indicator values and population.

(6) City planning and landscape planning aspects (integration of ESs into planning processes?)

Most of the studies have implications for urban planning. Klimas et al. [16] confirmed that incorporating knowledge of small-scale variability in ESs and in disservices on parcel-sized lots (private or public) may improve sustainable planning in urban areas. Faisal and Shaker [24] modeled the Urban Environmental Quality (UEQ) for better city planning and efficient urban sprawl control. Integration techniques, including GIS overlay and Principle Component Analysis, were used to integrate environmental, urban, and socio-economic parameters. The approach can provide fruitful information to model UEQ; however, due to the lack of significance the practical application of this indicator may be limited [24].

The study of Artmann et al. [20] applies the concepts of green infrastructure and ESs to develop a guideline for landscape planning so as to foster compact and green cities. The guideline was tested on the example of the landscape plan of Dresden (Germany), which foresees a compact city in a green network. Results show that the concepts of ecosystems services and green infrastructure can support urban practitioners in structuring the complex interrelations between landscape planning and compact and green cities.

Conclusions

The ecosystem services approach—which is meanwhile broadly accepted—provides a useful framework for assessing the status quo, setting goals, identifying benchmarks, and prioritizing approaches to improving ecological functioning for urban sustainability and resilience (e.g., [6,30]). In the four decades since the introduction of the ES concept as a way to capture human society's dependence on the natural environment, rapid developments in the field have transformed it from a theoretical and conceptual framework into a policy-supporting, accounting, and evaluation tool. More recently, the study of urban ESs is emerging as an important research field for incorporating the benefits of ecosystems for urban health and well-being into policy fields, e.g., city planning, particularly as a tool for improving urban sustainability and resilience [1,2,30].

Studies in this Special Issue demonstrate that socio-cultural and regulating ESs are very important because they have to be provided mainly within the city area. As an example, when expressed as monetary values, recreational services of urban forests outscore other services such as timber production. Thus, the costs or investments for recreation provide values for society as a whole. The results from the Munich study [17] highlight the huge value of urban woodlands and their multifunctional management, as well as their value far beyond the revenues gained from timber production.

Consequently, decisions for public and private green space investment must be made carefully, taking into account whole systems thinking and a more interdisciplinary approach in order to ensure that green infrastructure is being maintained and managed for maximum impact for urban dwellers [15]. Landscape planning can be supported in this regard by monetary and non-monetary accounting as well as by emphasizing the multi-functionality of landscapes and the broad range of ESs they supply. Moreover, the ES concept specifies in particular the social benefits that ecosystem functions provide to people, enables the differentiation between stakeholders, and thus interlinks beneficiaries with ecological assets identified in landscape planning. In this way, the lacking demand side of ESs in landscape planning can be complemented [20]. The interplay between ES supply and demand makes the concept of ESs a powerful tool for approaching compact and green cities. However, one issue that is often highlighted by stakeholders is that the promotion of urban ESs—regardless of how beneficial it may be—will add further complexity to already strained workloads among planners, policy-makers, and urban managers.

The examples of temporal changes of land use and ESs indicate how important monitoring of land use and ESs is for potential spatial planning and regional policy interventions [14,25,27]. Incorporating dynamics of landscapes and ESs into land use planning provides a practicable way for decision-makers to efficiently manage ecosystems and land use, especially in setting program priorities, choosing among environmental options, and communicating the importance of their actions to the public.

Making the monetary and non-monetary value of urban green spaces visible through accounting of ESs could be a chance to consider external costs connected with the degradation of ecosystems. A better understanding of cross-scale dependencies between different ESs is needed to obtain a clearer picture of urban ES flows as well as options and challenges for their safeguarding, depending on scales of responsibilities and policy actions. A further question is how to manage urban growth processes such that negative socio-economic, human, and environmental impacts of urbanization are minimized or avoided, and that socially integrative cities can develop in an environmentally friendly and financially viable way in order to provide favorable living conditions for the population [2].

Research on ESs offers a great opportunity to understand how to analyze and sustainably manage the complexity of urban ecosystems as well as their interaction with social and economic systems. We hope that this Special Issue will contribute to the understanding of ES supply and demand in urban areas, and of their implications for sustainable development, though it is clear that many questions have not been fully addressed by the published papers.

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