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Assessing Ecosystem Services Delivered by Public Green Spaces in Major European Cities

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Abstract

In the last decades, there was a significant population growth in urban areas. In this regard, the European major cities are not an exception; in fact, they are even still more affected by that populational exodus and consequently for an urban growth. Therefore, and considering that the urban parks in the cities are not growing at the same pace, a question is raised: “Are the public green spaces in the European major cities still able to provide the needed ecosystem services to their populations?” Based on the above-mentioned question, the present chapter aims to provide the first insights and answers to this question. Contextually, the study uses a case study research (CSR) method over several European major cities. Besides, GIS tools crossing statistical data are also used to analyze the data and consequently understood and establish a state of the art regarding this relevant issue.

Keywords: ecosystem services, landscape planning, sustainability, urban green spaces

1. Introduction

The original landscapes of our planet have been undergoing transformations by human activities. In Europe, a large part of the original forests existing during the human hunter-gatherer stage has been replaced by agricultural territories and large cities. At the same time, there is remarkably an uneven distribution of the population that results in very low densities in some territories, rural, and very high in urban areas, where significant percentage of inhabitants has been concentrated, throughout a process that has gone developing in the last 150 years [1]. The city was the focus of growth of the states, due, in large part, to the industrialization that led to an increase in the economy, which in turn led to a very rapid expansion and a first concentration of the industries and then of the services. But this great growth caused a disorganized and chaotic development.

Urban planning techniques try to eliminate and prevent urban chaos. In this context, when comparing the pre- and post-industrial revolution growth of the cities, a key difference appears “(...) compared to the old cities with clear boundaries enclosed by walls, post-industrial revolution growth leads to the invasion of the surrounding landscape [2].” The exterior goes from being a threat to the city to being an element threatened by it. The city has evolved in recent centuries toward the need to develop an urban planning concept in which the existence of green spaces became more important. The Industrial Revolution caused the exodus from the countryside to the city and the emergence of epidemics related to lack of health; together with the growing demand for leisure and free time by the population, the need for public green spaces increased.

The Urban Parks Movement (eighteenth century) appears, whose objective was to recreate the presence of nature in the urban environment, in order to improve the quality of life of its citizens [3, 4]. This concept resulted in the creation of the main parks, the first of them in the United Kingdom: “Victoria Park” in London and “Birckenhead Park” in Liverpool; a little later, also in London, “Hyde Park” and “St. James Park”; while in Paris the “Bois de Boulogne” and “Bois de Vincennes” were built and in Madrid “El Retiro.” Urban green spaces are urban areas in which natural or seminatural ecosystems became urban spaces by human influence [4]. They provide a connection between the urban and nature [5]. Green spaces include street trees, green roads, green roof walls, urban parks, and even abandoned unbuilt land. In fact, its creation can be from scratch, modified from existing vegetation, generated by colonization or existing as a natural enclave [6]. Vegetation in cities has multiple benefits that have been the subject of vindication and study throughout the evolution of current urbanism and that have been enriched and concretized by the contribution of research from related fields such as ecology.

The presence of abundant vegetation in cities is ideal with a universal appeal, which goes beyond temporal, spatial, and cultural divisions, associating itself with the concept of environmental quality, which leads to a better quality of life. In recent years there is an important interest in the environmental benefits of green spaces. Thus, a significant number of studies attempt to demonstrate, quantify, and incorporate them into planning. However, they still coexist with the marginality which they are treated in practice [7]. The presence of natural elements and values in the city is today a fundamental condition for the environmental recovery of urban territory. The natural and urban systems are part of the same space, and their integrated management is a requirement of the regional space and a condition of sustainability of the territories and cities. In addition, the agroforestry existence in the peripheries of cities and green spaces within the urban fabric represents an increase in environmental quality, which urban planning must strengthen and improve [3, 8–11].

The visual approach of the green areas constitutes a powerful tool to activate and inspire the daily life of citizens. Besides, a deeper understanding of the ecological processes that occurs in nature, along with the economic and socio-cultural, can help city managers to better integrate all the above-mentioned aspects. This approach must go beyond the superficial, appreciating the stories that landscapes tell and helping to understand the place of humans in nature [12].

Studies on the valuation of ecosystem services (ES) focused on urban areas represent a small percentage in relation to the total number of articles devoted to the subject. Furthermore, Delgado and Marín [13] analyzed the growth of publications in a 24-year interval (from 1990 to 2013), demonstrating their exponential growth, which increased from 1 article in 1991 to less than 250 in 2007 and 1500 in 2013. Of these, only 6% focused on the direct services of the ecosystems associated

with urban areas. According to Ibés [14], the valuation of the ES was originally designed for non-urban systems, so that new models are necessary for a correct assimilation of the services provided by the urbanized environments. In addition, it reflects on the difficulty of finding a balance between geographical, conceptual, and spatial considerations when the ES valuation paradigm applies to urban parks. Therefore, bearing in mind that urban parks cannot generate all the possible ES, excluding the necessary compensation, it will lead more often in losses rather than benefits.

The key components that contribute to the total economic value of ES can be divided into three main blocks [15–16]. The first is related to the direct use and includes both (a) the provision of services (e.g., the production of plant and/or animal biomass) and (b) social and cultural services (e.g., recreational activities, sports, family). The benefits associated with urban parks are mainly framed in the second group, presenting the contributions to the first residual character in general. The second block refers to indirect services (indirect use) that involve (c) regulating (such as the control of air, water or soil quality) and (d) supporting services that are necessary for the production of the rest of services of the ecosystem (e.g., nutrient cycles, soil formation, or water cycle).

The parks contribute to a greater extent in the section of regulating services, with benefits that include the improvement of the air quality or the decrease of the load of nutrients that reach the water courses and are potential causes of eutrophication. The third block is dedicated to other aspects not contemplated in the previous ones. It comprises two sections: (e) option services, referring to the possibility of using a service in the future and maintaining resilience (ability to reverse changes in the ecosystem) and (f) nonuse/exploitation of resources of ecosystem resources for cultural reasons and of preservation for future generations or their intrinsic values. The ES of urban parks contribute more to the aspects related to the second section.

Several authors have evaluated the benefits of the parks valuing some specific ES. Also, Breuste et al. [17] analyzed in three megalopolis the importance from the recreational point of view (Buenos Aires and Shanghai) and climate regulation (Karachi). They demonstrated that urban parks play an extremely important role by offering ES related to recreation and contact with nature. With regard to Karachi, they highlighted the importance of parks in the regulation of extreme weather conditions. Residential areas located near parks had a considerable higher degree of thermal comfort. Setälä et al. [18] assessed the retention of heavy metals and nutrients in the soil, highlighting the role of parks especially in cities with high levels of pollution. Regarding the contribution of the ES in urban parks, Gratani et al. [19] studied and quantified four parks located in Rome to carbon sequestration. Mediterranean-type parks, such as the Romans, sequestered CO₂ throughout the year highlighting the results in those in which the native species of the Mediterranean basin were dominant. The annual economic value of the CO₂ elimination would be equivalent to \$23,537 ha⁻¹. Moreover, Giedych and Maksymiuk [20] studied the Warsaw parks, concluding that the ES contributed by each of them depend on the local conditions and specific characteristics of each of them, the surface being one of the key variables in the regulating services.

Less abundant are the works that analyze and value the set of ES that generate concrete parks. An example would be the holistic valuation of the ES generated by Central Park (New York, USA), estimated at \$ 70 million/hectare/year [21]. Contextually, the present chapter through a case study research method aims to analyze the green urban areas surfaces evolution in seven European major cities.

2. Materials and methods

Initially, land use data monitored by Land Cover Corine (CLC) were obtained (<https://land.copernicus.eu/pan-european/corine-land-cover>) [22] on a scale of 1:100,000, with a minimum mapping unit (MCU) of 25 Ha and using polygonal graphics features that evoke land uses in Europe. Some of the used CLC nomenclature/codes used are shown in **Table 1**.

In addition, the urban boundaries of the cities analyzed were obtained from ESRI-free data, using a layer called Europe Shapefiles. In this case, polygon features were also used.

In this regard, the authors have analyzed these two layers of information – which represent two variables in the same georeferenced position. For this reason, the two layers were transformed into the same reference system, using ETRS1989 Lambert azimuthal equal area, because this projection preserves the areas and is better suited to the different cities to be analyzed.

From the two polygonal cartographic layers, an intersection was made between the two. Thus, polygons corresponding to land uses that are completely included in the boundaries of cities become part of the resulting layer. Also, the parts of the polygons corresponding to the land uses that are partially included and clipped by the boundaries of the cities are also part of this resulting layer. Thus, it was possible to obtain a layer with the land-use polygons within each city.

Once this layer was obtained, we proceed to measure the surface of each of these polygons obtained evocative of the land uses, but in the projection used. In order to do this the ArcGIS 10.3 software was used. Subsequently, using Microsoft Access 2016, selection queries were made. Thus, only polygons whose use was 1.4.1 corresponding to Green urban areas were chosen, that is to say, areas with vegetation urban fabric which includes parks and cemeteries with vegetation. Later, a query was carried out so that the total area dedicated to green urban areas was obtained.

Therefore, seven case studies of European major cities were selected (**Figure 1**). After the case study selection, an analysis for the years 1990, 2000, 2006, 2012,

Level 1	Level 2	Level 3
1 Artificial surfaces	11 Urban fabric	111 Continuous urban fabric
		112 Discontinuous urban fabric
		121 Industrial or commercial units
		122 Road and rail networks and associated land
	12 Industrial, commercial, and transport units	123 Port areas
		124 Airports
		131 Mineral extraction sites
		132 Dump sites
	13 Mine, dump, and construction sites	133 Construction sites
		141 Green urban areas
		142 Sport and leisure facilities
	14 Artificial, nonagricultural vegetated areas	

Table 1.
CLC nomenclature [22].



Figure 1.
Selected case studies. (A) Lisbon, (B) Madrid, (C) Paris, (D) London, (E) Rome, (F) Berlin, (G) Stockholm.

and 2018 was carried out. Nevertheless, for the cities of London and Stockholm for 1990, there was no data.

Finally, thematic maps representative of land uses were obtained for each of the years and cities, highlighting the green urban areas.

3. Results and discussion

From the 11 classes of the CLC, the study only analyzes Level 3 (land use code 141)—regarding green urban areas (**Table 1**). Those results were presented in acres and were assessed for each year of the studied period (1990, 2000, 2006, 2008, 2012, and 2018) (**Table 2**). Contextually, the results presented in **Table 2** enabled to create a graph (**Figure 2**). This graph shows the cities being grouped into three levels. In the first level, we have London with the largest surface of green areas over the studied years—around 12,000 acres. On a second level, we have Stockholm, Madrid, and Paris that slightly have a surface of green urban areas superior to 4000 acres; however, any of those reach the 8000 acres. In this regard, it should be highlighted that in the first studied year (1990), Madrid was one of the cities with lowest values regarding green urban areas surfaces, and in the last studied year (2018) the Spanish capital reaches the third position—as one of the studied cities with the highest value of CLC 141. And in a third level, we have the studied cities with the lowest values of green urban areas, which are Berlin, Lisbon, and Roma, with less than 4000 acres of the land use 141—in fact, with a CLC 141 surface lower than 2000 acres.

Moreover, through the creation of individual graphics for each of the selected cities, it was possible to analyze in detail how the green urban area surfaces evolved over the 5 years studied (**Figure 3**). Through this analysis, it is possible to verify that two cities (Rome and Stockholm) are losing green

City	1990	2000	2006	2012	2018	Dif.	%
Berlin	2896,32	2868,46	2873,66	3102,04	3336,18	439,87	15,19
Lisbon	1204,02	1465,01	1827,66	1783,96	1929,92	725,91	60,29
London	n.d.	11,429,73	12,380,38	12,195,22	12,224,16	794,43	6,95
Madrid	2337,87	3246,07	5798,95	6457,62	6428,88	4091,01	174,99
Paris	4564,59	5183,53	5212,09	5239,16	5187,85	623,26	13,65
Rome	1654,96	1532,34	1456,55	1456,55	1455,86	-199,09	-12,03
Stockholm	n.d.	6954,17	6907,24	6901,44	6869,19	-84,98	-1,22

Table 2.
Outcomes of the analyzed parameters of the green urban areas in European major cities (source: Authors). n.d., no data available; dif., difference between first and last year; %, percentage.

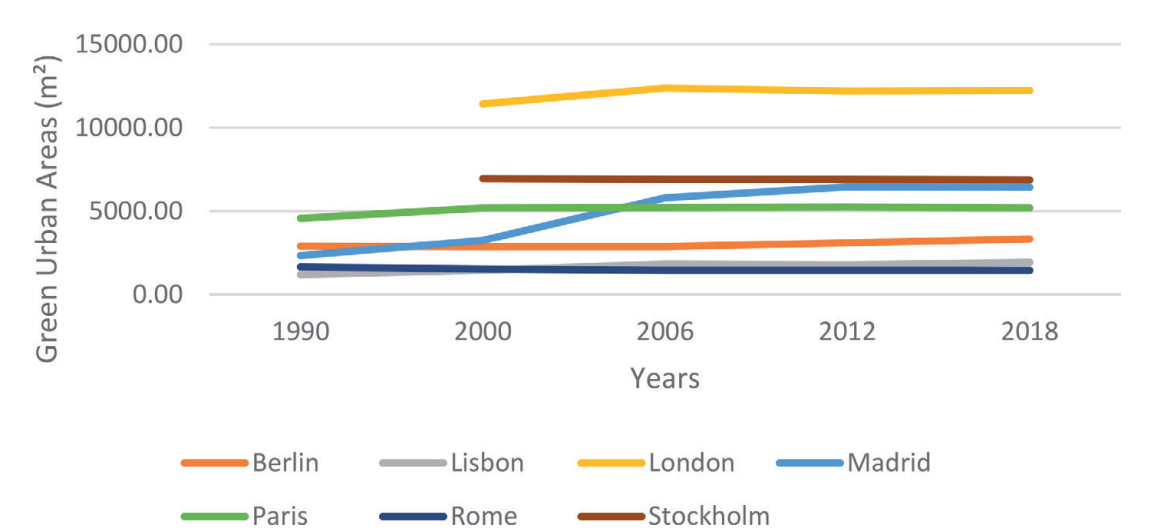


Figure 2.
Evolution of the urban green spaces through the years in the studied European major cities (authors).

urban areas in comparison with the first year analyzed (1990). On the other hand, all the other cities are gaining more green urban areas along the years. From all those cities that show an increase in the land use 141 over the years, it should be highlighted that Madrid and Lisbon show constant growth. In fact, this tendency was also identified in Berlin; however, it only starts in the year 2012 onwards—once the German capital presented a period of growth stagnation (of the land use 141) in the previous years. Besides, in Paris and London, we have been identified the opposite scenario. In Stockholm, the city was lost Green Urban Areas surface when compared to the 1990 reality; however, it was also started a similar growth process (regarding the land uses 141) in the year of 2012 – which is verified in the year of 2018; in an opposite tendency, we have the city of London. The city of London, even it has been passed through an increase of Green urban Areas in the first year studied (1990), is now facing a tendency of decrease in these green surfaces—which started in the year 2006.

Regarding the results in percentage (**Table 2**), Roma and Stockholm have lost 12.03 and less than 1,22% of their green urban area surfaces, respectively. In contrast, the cities that gained more green urban areas have been Madrid, with 174,99%, and followed by Lisbon, Berlin, and Paris (between 60,29, 15,19, and 13,65%). Furthermore, London increases its land use 141 in less than 5%, nevertheless, with a negative tendency (**Table 3**).

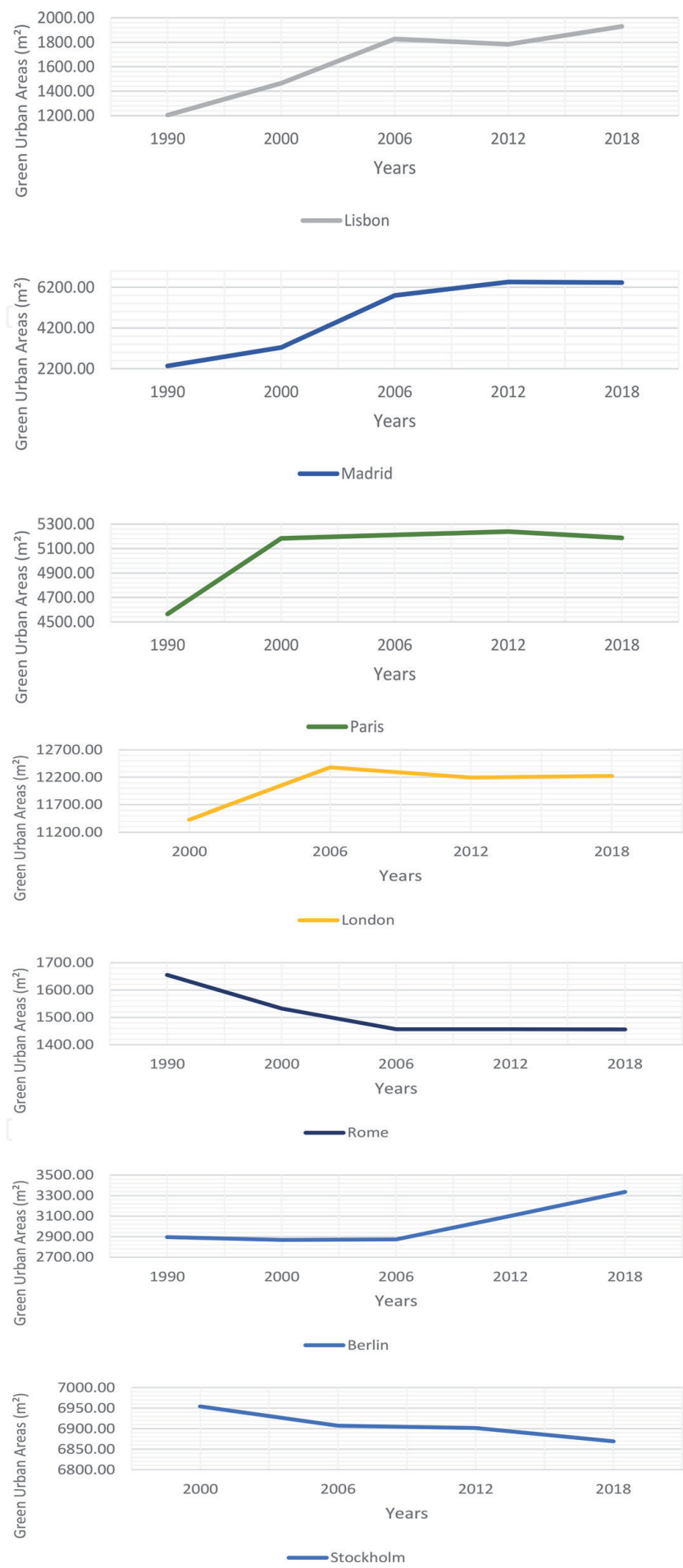


Figure 3.
Evolution of the urban green spaces in European major cities (authors).

Case studies	Population (thousands)			
	1990	2000	2010	2015
Stockholm	1030	1210	1360	2615
Madrid	4940	5320	6380	6586
Rome	3750	3710	3960	4468
Paris	2150	2130	2240	12,524
London	6800	7240	8600	14,855
Berlin	3200	3500	3450	4314
Lisbon	2540	2690	2790	2810

Table 3.
Demographic dynamics of the studied cities [23].

4. Final remarks

Through the present study, it is possible to understand how the green urban areas have evolved within the studied European major cities. Besides, throughout the analysis of patterns of the land use change (CLC 141) along with empirical knowledge of those cities’ territories, it was allowed us to assess the value of those Green Urban Areas within the cities. Therefore, it is possible to say that those green urban areas are not growing in the same pace as the demographic values as well as other land uses in development within these cities [24].

In this regard, and considering the relevance of the ES performed in the urban environments, we believe that in all the analyzed cities, the existing green urban areas are not able to provide the environmental needs for their inhabitants. In fact, even if those environmental needs could differ among the studied cities – once, some presents a higher number of Green Urban Areas than others as well as different demographic growth rates; all the analyzed European Major Cities shows a need for more Green Urban Areas.

Additionally, the performed study enabled us to put forward some noteworthy ideas, related to the relevance of green space infrastructure in urban areas, regardless of their urban nature and of their major land use, which corroborate with the conclusions of previous studies that crossed the relevance of urban green spaces to urban sustainability and development [4, 9–10, 25–32].

In this regard, the creation of more green urban areas in these cities as well as in their metropolitan influential territories is seen as pivotal. Furthermore, guidelines should be provided for the main actors and decision-makers of the planning process to where the efforts toward a sustainable development and growth should be placed—for example to address green strategies and land use reconversion and redevelopment of urban areas.

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