SPATIAL ANALYSIS OF THE ACCESSIBILITY OF URBAN GREENSPACE AT THE CITY LEVEL

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ABSTRACT

The aim of this study was to analyse the access people have to urban greenspaces at the city level (Athens) using a combination and by comparing different methods. These two approaches are the Accessible Natural Greenspace Standards (ANGSt) Model and selected urban greenspace indices. According to the results, the accessibility of areas of urban greenspace is sufficient in most of Athens, which indicates that the majority of its residents have access to urban greenspaces. The correlation of accessibility with urban greenspace indices provided a better classification for Athens, in terms of citizens' quality of life, as 20% of the Municipalities have a higher value for greenspace than that recommended by the World Health Organization of 9 m^2. If this percentage is expressed as a population equivalent, only 13.3% of the population of Athens has a higher value than the minimum recommended. In addition, 21% of the population has a much smaller value and, in particular, it does not exceed 2 m^2 of greenspace per capita.

Keywords: accessible natural greenspace standards model; Athens; climate change; multicriteria analysis; urban greenspace indices

Introduction

The intensive urbanization in the 20th century was among the major causes of the significant reduction in urban greenspaces in modern cities. The existing greenspaces were fragmented, because of the required planning ordinaces, without creating an urban network (Aravantinos 1997). Urban greenspace improves the residents' quality of life, particularly in densely populated cities. The multiple benefits that arise from the existence of greenspaces in cities are in the area's microclimatic conditions, such as temperature, filtering of solar radiation and improvement in the neighbourhood's social relations. The causes of Climate Change are divided into two main categories: a) external causes, primarily changes in the global energy balance and in the amount of energy received from the sun, and b) internal causes associated with changes in the composition of the atmosphere as well as the earth's surface and land use – factors directly related to human activities and the corresponding greenhouse gas emissions (GHGs) (USGCRP 2014). According to the United Nations Framework Convention on Climate Change (UNFCCC), Climate Change (CC) is defined as the change in climate that is caused directly or indirectly by human activities (United Nations 1992).

Thus, the appropriate adaptation strategies and necessary actions and measures have to be considered at local, regional, national and continental levels. In order to increase a city's resilience and positively contribute to its sustainability, urban greenspace should be properly designed. In other words, the people should be provided with a means of accessing these areas (Wooley 2003). The quality of public urban greenspace is directly related to the living standards, health and quality of life of a city's inhabitants (Iliadou et al. 2012). Greenspaces can also significantly contribute to the promotion of environmental, social and economic benefits of Green Infrastructure as a planning tool (Papageorgiou and Gementzi 2018).

In Greek cities, urban greenspaces generally arise as surplus land during reconstruction and not as the result of urban planning, which explains the low level of greenspace per capita in comparison to other European metropolitan cities (Pournara 2013). Pozokidou (2018) attempted to model the dynamics of land use and transportaton infrastructure using a simplified urban model for the periurban area of east Thessaloniki considering all factors contributing to urban growth including greenspace.

The term "urban greenspace" has prevailed as a term used to characterize an area that is put aside during the development of a city and remains free of buildings and hosts different forms of vegetation. Urban and suburban greenspace is a sustainability index of the urban fabric. In addition, a main factor in the planning of urban greenspace, apart from its existence, is the accessibility or proximity of these areas. A key indicator of accessibility is proximity of greenspace to a residence or neighbourhood (World Health Organization 2016). However, there are many definitions and research studies on the accessibility of urban greenspace. The most common view is that the accessibility of urban greenspace should be based on its proximity and size (Mougiakou and Photis 2014). For example, as the size of the urban greenspace increases, the area over which it is considered to be accessible also increases.

To better understand the interdependency of urban spaces and human life, an uninterrupted observation and analysis is required. Nowadays, Geographic Information

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Systems (GIS) are a valuable tool used by engineers, planners and policy makers to analyze descriptive information at any spatial resolution. GIS is designed to capture, analyse and process spatial data related to climatic conditions and geomorphology as well as the demography and characteristics of building environments (Goodchild 1985). GIS can easily update maps by incorporating new data that can simply be added to the existing database or map.

Case study: Athens

In this analysis, the area of interest is the metropolitan area of Athens, the capital of Greece, which is one of the most densely populated cities in the country. During the last century, the urban core of Athens developed in a self-contained region called the "Attica Basin", between the Penteli, Parnitha, Ymittos and Aigaleo mountains and the Saronikos Gulf. The "Attica Basin" coincides with the Athens-Piraeus Spatial Unity and is divided into 5 spatial subsections: a) Central Athens, b) South Athens, c) North Athens, d) West Athens and e) Piraeus.

The urban greenspace sustainability index is quite low in Athens, because of the compact urban fabric and high population density (OECD 2014). According to the annual statistical publication of OECD, Athens is 4th from the bottom with only 0.96 m^2 of green area per person (OECD 2014). Urban greenspaces differ in the five Spatial Subsections and also among the municipalities within the same Subsection. Both the network and amount of greenspace per resident are different in each Subsection, indicating a significant variability in the living standards in the "Attica Basin" (Table 1).

An analysis of the financial profiles of the spatial subsections indicates that a high income per capita is accompanied by a high percentage of greenspace per capita, or the residents want to move to areas with a higher percentage of greenspace (Kalavrytinos and Damigos 2006). This is because the marital or personal financial status of people leads them to initiate changes within their city, as they move to areas where there is a better quality of life. In the case of Athens, this fact led to the relocation to the suburbs of a large number of people (Asimakopoulos et al. 2011).

Methods

The Accessible Natural Greenspace Standards (ANGSt) model

The accessibility of greenspace to citizens within a city varies from country to country and from city to city. The Accessible Natural Greenspace Standards (ANGSt) model was developed in 1990 to estimate the access to a natural area within the urban fabric by defining the minimum distance that a citizen has to walk to reach an area of urban greenspace (Buell 2009). Following this approach, an urban greenspace network is classified into the following classes, in terms of there should be at least:

- one accessible 2 ha greenspace within 300 m distance,
- one accessible 20 ha greenspace within 2 km distance,
- one accessible 100 ha greenspace within 5 km distance,
- one accessible 500 ha greenspace within 10 km distance.

Natural urban green areas and greenways, such as public parks, are included in this study as greenspace. Thus, "green" parks, groves and hills within the urban fabric are taken into account.

The cartographic visualization and analysis, in terms of the spatial location and areas characterized as areas of public greenspace, were obtained using GIS. First, a spatial database for the GIS environment was developed. More specifically, the accessibility of urban greenspace was defined based on an influence zone created around the green areas (buffer), which is the distance of a service or means of access. For example, around a 2 ha area of urban greenspace, a buffer zone of 300 m radius is created. Similarly, around a 20 ha and 100 ha area of greenspace, buffer zones of 2 km and 5 km radius, respectively, are created (Fig. 1).

In order to estimate the number of citizens that have access to areas of urban greenspace in Athens, the population, housing, and postcode data in the 2011 Census was obtained from the Hellenic Statistical Authority and analysed (Hellenic Statistics Authority 2016). By joining the population data with the postcodes (city block number), a spatial mapping of the people who have access to an area of greenspace in the corresponding influence zones was obtained. A city block was the spatial unit of the analysis used to estimate the number of people who have access to a corresponding area, because a block is the lowest level of information on the population. The influence zone (buffer) was created in order to define the population served by a specific area of greenspace, regardless of its extent within the limits of the region.

Urban greenspace indices – multicriteria analysis

Multicriteria Definition Analysis (MCDA) is a general framework used in complex decision making situations, with multiple and conflicting objectives. The basic idea of MCDA is to evaluate the performance of alternatives with respect to the criteria that determine the dimensions of the decision making process (Montibeller et al. 2010). MCDA allows decision making to include a range of social, environmental and technical criteria. MCDA provides, also, techniques or algorithms for comparing and ranking different outcomes, even though different indicators are used.

For maintaining the robustness of this analysis, a multicriteria analysis (MCDA) was also used to evaluate the results. The MCDA was done using DEFINITE software that supports decisions based on a finite set of alternatives. By defining the various subsections studied, the criteria under which the evaluation was carried out, the cor-

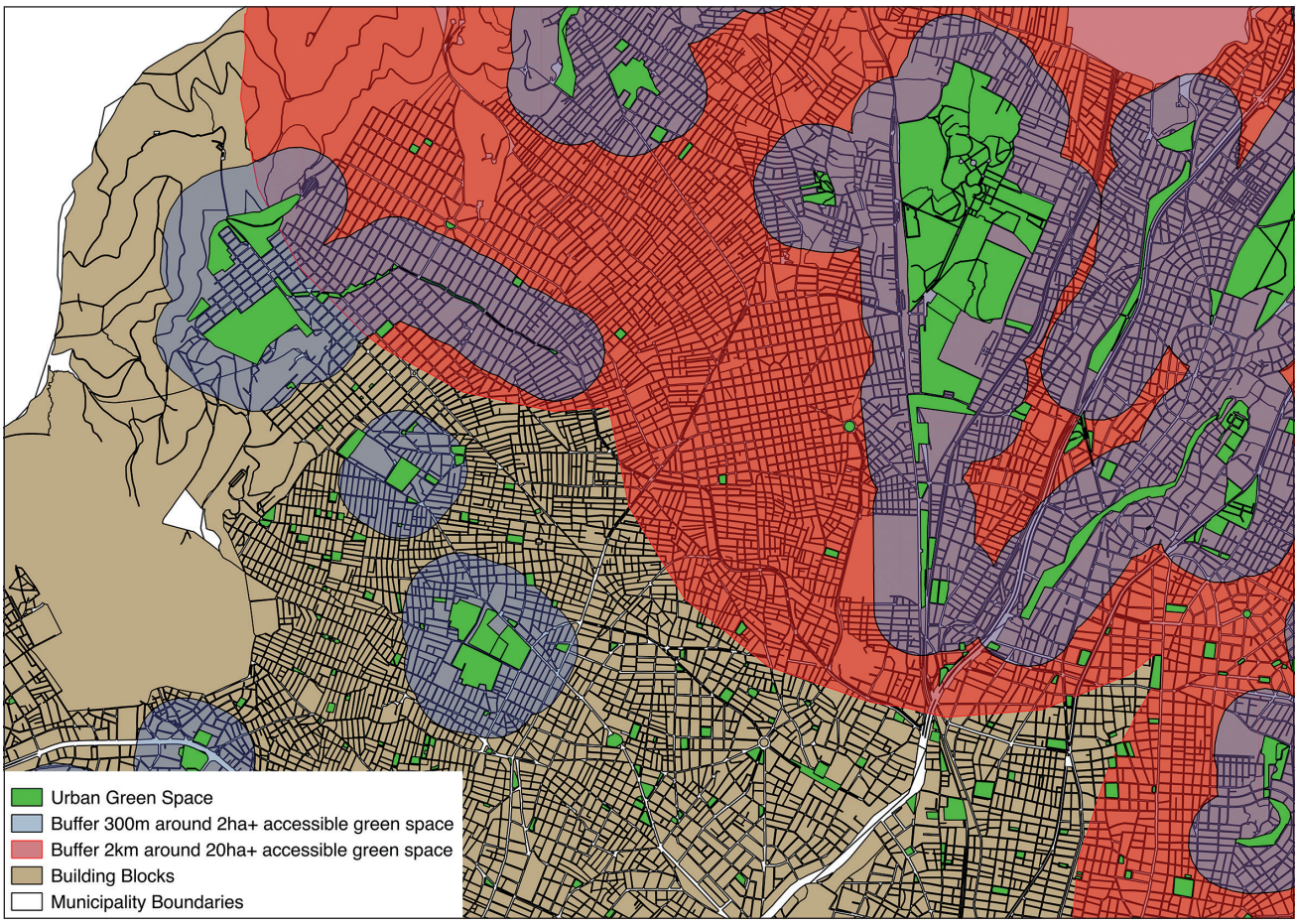

Fig. 1 Buffer zones of 300 m and 2 km, respectively, around 2 ha+ and 20 ha+ greenspace areas.

responding weights that express the relative importance of each criterion were properly defined. In this analysis, all the criteria were considered to be of equal importance.

As the lowest amount of urban greenspace recommended by the World Health Organization is 9 m^2 per capita (OECD 2014), the present analysis of accessible urban greenspace in Athens not only considers public but also private areas of greenspace.

For the term "accessibility", a geometric number based on the Euclidean distance is defined. In addition, a private greenspace index is determined for each Municipality in Athens, based on the building coverage ratio (BCR) that determines the limit of building coverage on a plot. Essentially, it acts as a complementary number for private areas of greenspace coverage. The correlation of accessibility with these two indices allowed a better classification of Athens in terms of its citizens' quality of life. In Fig. 2, a classification of the Municipalities in Athens is shown, based on the percentage of private greenspace obtained from the building coverage ratio. In Fig. 3, a similar classification based on the minimum percentage of urban greenspace per capita in the Municipalities of Athens, as defined by the World Health Organization, is presented.

Based on this approach, only 20% of the Municipalities have a higher value of greenspace than 9 m^2. If this percentage is expressed as a population equivalent, only 13.3% of the population in Athens have a higher value than the minimum recommended. In addition, 21% of the population has a much smaller value and, in particular, it does not exceed 2 m^2 of greenspace per capita.

Furthermore, regarding private greenspace, in 40% of the Municipalities of Athens the coverage of this index exceeds the building coverage, meaning that the building coverage ratio is less than 0.5. That is, 72.9% of the population live on plots of land where the building coverage is greater than the private greenspace coverage.

Results

In this section, the results of the two analyses, ANGSt Analysis and Multicriteria Defintion Analysis, are shown.

Results based on ANGSt analysis

The overall accessibility to urban greenspaces consist of the union of 3 of the 4 greenspace classes: 2 ha, 20 ha and 100 ha, since there are no areas of greenspace of 500 ha or more in Athens. Table 1 summarizes the total population (Hellenic Statistics Authority 2016), the population that has access to greenspace, the percentage population coverage and the index of urban greenspace per capita in the 5 spatial subsections of Athens.

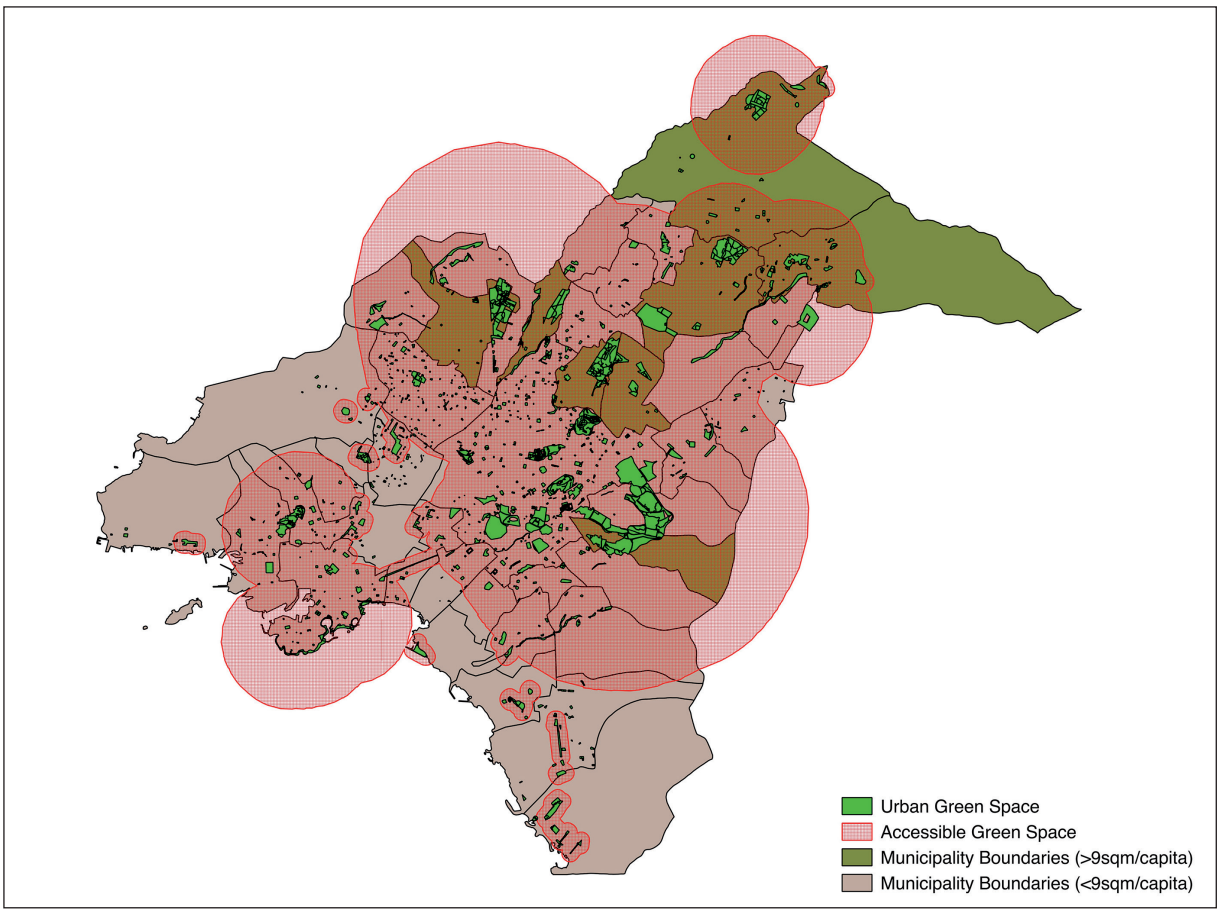

Fig. 2 Classification of Municipalities in terms of the minimum % of urban greenspace per capita.

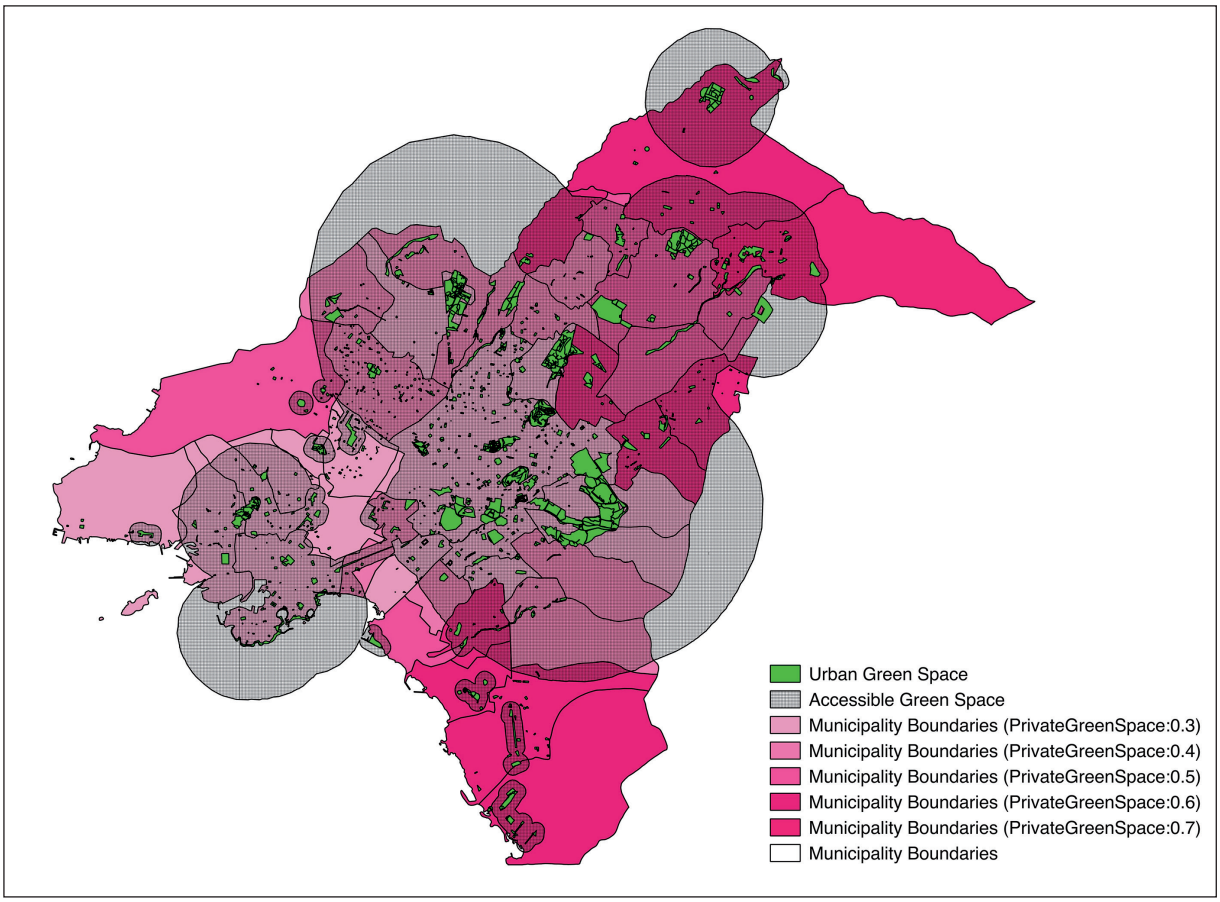

Fig. 3 Classification of the private greenspace index recorded in the different Municipalities of Athens.

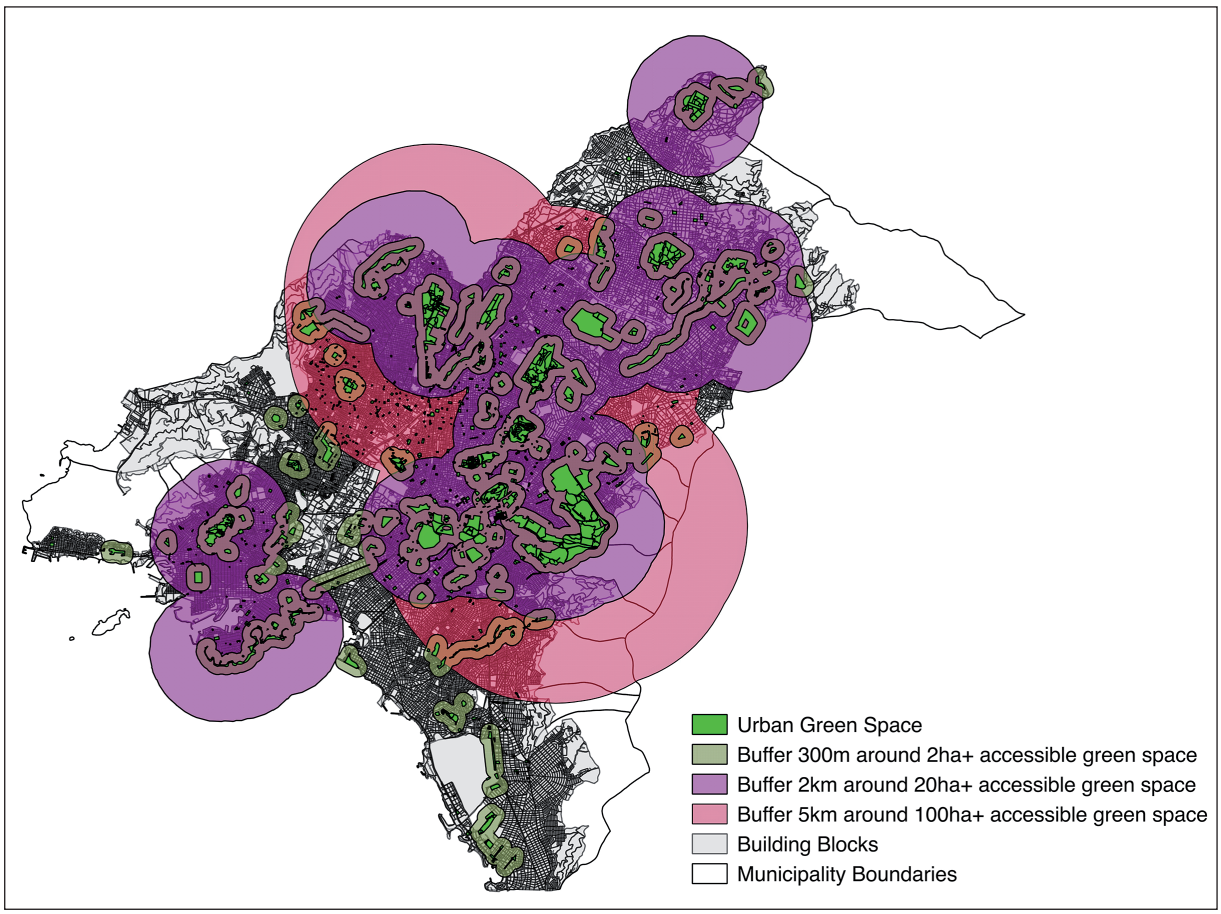

Fig. 4 Athens greenspace accessibility based on the ANGSt analysis.

Central Athens has access to areas of urban greenspace due to the existence of significant groves and hills that have not been built on. North and West Athens also have quite a high percentage of greenspace coverage. Apart from the existence of areas of urban greenspace, the high density of buildings in these three subsections of Athens and the short distance to existing urban greenspaces are the main reasons for the high percentages of accessibility. On the other hand, in the coastal area of South Athens, little urban greenspace exist, except in Piraeus, because the built up area there is far from Athens "green" core (Koliotsis and Papadopoulou 2017). The same trend is recorded for the index of greenspace per capita, which is derived from the General Urban Plan of each municipality (Organization of Planning and Environmental Protection of Athens 2017).

In Fig. 4, the limits of the accessible urban greenspace per class is shown. According to the extracted data on accessible limits, the limit of an area of 2 ha within 300 m means that almost none of the households meet all the ANGSt requirements. In addition, in Central, North and West Athens, most households are within the 20 ha and 100 ha accessible urban greenspace areas, which are mainly located in Central Athens and not in the wider network of greenways. The same pattern is recorded in Piraeus in which there are few areas of greenspace. Finally, in South Athens, there are only a few areas of greenspace and, as a result, the accessibility there is very low.

A key finding of this analysis is that only 19% of the citizens of Athens do not meet the ANGSt requirements and 23% do. In terms of all greenspace area classes, Central Athens had a better coverage. It is remarkable that population coverage and the extent of areas of urban greenspace did not increase accordingly (Table 2). This is due to the spatial location of urban green areas. In other words, accessibility is independent of administrative boundaries and depends only on the size and spatial extent of areas of urban greenspace. This fact explains, for instance, the significant reduction in the population coverage of 20 ha greenspace areas in South Athens, as compared to the corresponding coverage of 2 ha greenspace areas.

Results based on MCDA

In Fig. 5, the overall results of the multi-criteria analysis, with respect to the performance of each Spatial Subsection in relation to each criterion, are shown. As far as the urban greenspace per capita value goes, North Athens is best (1.00) followed by Central Athens (0.99), while the worst is South Athens (0.35). Regarding private greenspace, North Athens again is best followed by South Athens (0.93), while the worst is Piraeus (0.56). The overall results show that, considering the equal importance

Table 1 The Accessibility of Urban Greenspaces in Athens.

Spatial Subsections	Population (Census 2011)	Population (AGNSt model)	**AGNSt Population Coverage (%)**	**Urban Greenspace (m^2/cap)**
North Athens	592,490	523,698	88.4	8.30
West Athens	489,675	397,825	81.2	5.48
Central Athens	1029,520	1029,520	100.0	8.25
South Athens	529,826	205,792	38.9	2.93
Piraeus	448,997	342,928	76.4	3.24
Total	**3090,508**	**2499,763**		
Mean Value			80.9	5.64

Table 2 AGNSt model key findings.

Spatial Subsections	**% of households**		
	within 300 m of 2 ha	**within 2 km of 20 ha**	**within 5 km of 100 ha**
North Athens	33	75	73
West Athens	33	52	73
Central Athens	49	80	100
South Athens	16	2	32
Piraeus	44	58	0
Mean Value	**35**	**53**	**56**

criteria, which assumes that the relation of urban greenspace to the quality of peoples' life is independent of ownership, the best area is North Athens (1.00), followed by Central Athens (0.81), while the worst is Piraeus (0.47).

ANGSt analysis vs. MCDA

The ANGSt analysis of the accessibility to urban greenspaces did not include urban greenspace per capita or private greenspace. Only the actual existence, the spatial location and the proximity to these areas were considered. In Table 3, the overall results and subsection hierarchy obtained from the ANGSt analysis and the urban greenspace indices analysis are presented, which indicate a different ranking. This is explained by the fact that in the first analysis, only the Euclidean distance was considered. Whereas, in the latter analysis, the population-related data was also included in the estimates of urban greenspace indices.

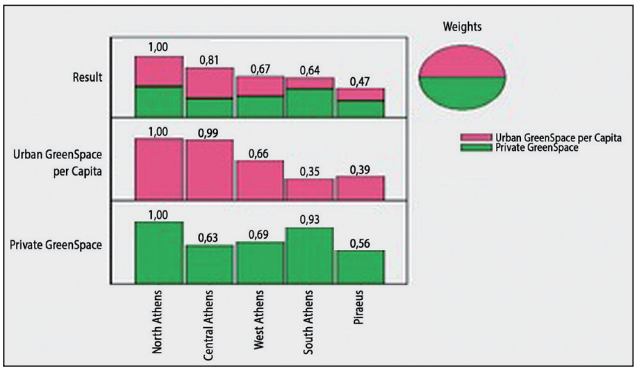

Fig. 5 Results of the multicriteria analysis.

Table 3 Results of the ANGSt model and Urban Greenspace Indices analysis.

Spatial Subsections	**ANGSt Model**		**Urban GreenSpace Indices**	
	Population Coverage (%)	**Hierarchy – Ranking**	**MultiCriteria Analysis Score**	**Hierarchy – Ranking**
North Athens	88.4	2	1.00	1
West Athens	81.2	3	0.67	3
Central Athens	100.0	1	0.81	2
South Athens	38.9	5	0.64	4
Piraeus	76.4	4	0.47	5

Conclusion

The present analysis highlights the accessibility of urban greenspaces in Athens based on the Accessible Natural Greenspace Standards (ANGSt) model. Subsequently, based on this analysis of the data, an estimate of the accessibility of areas of urban greenspace was produced, which gives an indication of the people's ability to access natural greenspace. Based on the results, the majority of the residents in Athens have access to areas of urban greenspace.

The term "accessibility" is poorly understood by many and the concept should be better promoted in order to support the actions of local authorities to improve accessibility and the daily interplay between residents and areas of greenspace. Despite the accessibility being satisfactory, the percentage of greenspace area per resident in Athens is quite low compared with other European cities. This indicates an adequate area of greenspace is as important as its accessibility and the combination of these two indices, among others, can provide a better way of evaluating the quality of the urban environment at the city level. The spatial distribution of urban greenspaces not only affect their accessibility to residents in a particular subsection, but also those in neighbouring subsections.

It is difficult to quantify private greenspaces because the design of such greenspaces is entirely based on each owner. The approach, based on the building coverage ratio, was considered sufficient, given the qualitative differentiation within the urban fabric among the Municipalities.

In this analysis, various methods were used. However, a combination of these methods gave a better estimate of the contribution of urban greenspaces to the quality of the citizens' everyday life. The ANGSt model proved to be a reliable, useful, and effective tool for assessing the current levels of accessibility to greenspaces and comparison of accessibility to areas of greenspace areas within different urban patterns, among different cities and countries. It also provides a standard way of evaluating the accessibility of areas of greenspace and, if necessary, how it can be improved. On the other hand, the multi-criteria analysis also proved to be a reliable tool

for evaluating alternative solutions of complex problems and a measure of the extent to which the various alternatives may achieve the objectives. Finally, GIS proved to be a useful spatial analysis tool for mapping and visualizing the spatial data associated with both the assessment of accessibility and the spatial distribution of areas of urban greenspace.

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