GIS-Based Accessibility Analysis for Neighbourhood Parks: The Case of Cukurova District

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Abstract: The aim of this study was to investigate the adequacy of neighbourhood parks services in the Cukurova district in terms of accessibility, parks' spatial distribution, the size of neighbourhood park areas and use intensity. Additionally, the aim was to identify spatial and planning principles to provide an optimum level of utilisation of neighbourhood parks. Firstly, the main determining standards relating to the size of neighbourhood park areas, population density and service areas were determined through literature searches and expert views. Secondly, after service area values had been assessed for every neighbourhood park, the service area was mapped using a GIS-based network analysis. As a result of the network analysis, it was estimated that 79 % of the study area consisted of residential areas, and the neighbourhood parks (34 units) constituted approximately 3 % of these residential areas. Spatial Plan Construction Regulations propose a service area of 500 m for neighbourhood parks, but there is no attention given to the minimum field size with respect to population density. When the assessment took into account this regulatory value of 500 m, neighbourhood parks' accessibility reached 65 % in the Cukurova district. However, this rate dropped to approximately 30 % when the assessment looked at neighbourhood parks' areas and population densities. Finally, it was shown that the Cukurova district form shows uneven distribution of neighbourhood parks in terms of park spatial sufficiency and accessibility potentials, and suggestions to enhance the service areas of neighbourhood were made according to its findings.

Keywords: Neighbourhood park, accessibility, Geographical Information System (GIS), network analysis, Cukurova

1 Introduction

Urban parks and open green spaces are of a strategic importance for the quality of life of our increasingly urbanized society. Increasing empirical evidence, in fact, indicates that the presence of natural assets (i. e. urban parks, forests and green belts) and components (i. e. trees, water) in urban contexts contributes to the quality of life in many ways. These assets provide important environmental services such as air and water purification, wind and noise filtering, preserving biodiversity in urban areas and microclimate stabilization (ROSA 2014, MOUGIAKOU & PHOTIS 2014, YAO et al. 2014). Parks also allow citizens to enjoy open spaces for leisure activities that promote emotional stability and improved quality of life (LEE & HONG 2013). That is, the availability of accessible and attractive green spaces is an integral part of urban quality of life.

In urban contexts, green spaces include very different areas, such as parks, gardens, urban forests, nature reserves, corridors along waterways, playgrounds and other informal green areas (DAI 2011, LA ROSA & PRIVITERA 2013, LA ROSA 2014). Within many developing world cities, also in Turkey, unplanned and informal settlements have resulted in increased social and spatial inequality, resource consumption and environmental degradation (WRIGHT WENDEL et al. 2012). The ever-decreasing green spaces have become insufficient to meet public demands in terms of accessibility, spatial distribution and the size of the urban green area. As a result, growing attention is being given to the issue of accessibility to urban green

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spaces, with the issue becoming one of the most debated in sustainable urban planning (UNAL 2014).

Accessibility is a broad, flexible and slippery concept (GOULD 1969). The simple definition of accessibility is how fast or far one must go to get there. It indicates the spatial relation between origin and destination, or the degree of connection between that location and all others in a region, although it is often defined as the relative nearness or proximity of one place to another (YIN & XU 2009). During the last few decades, the concept of accessibility, often denoting the level of services in terms of parks' spatial distribution, has been an important element for planning urban green spaces. Accessibility to urban parks is adequate when the population is in harmony with parks' spatial distribution. For urban policies aimed at enhancing the overall accessibility to green spaces and related ecosystem services, it is important to find appropriate tools and indicators able to support choices towards the creation of new green spaces. Particularly, the choice of which areas to be addressed as green spaces should be based on the criterion (among others) of the maximisation of its accessibility in order to allow the highest number of people to have easier access to the green space in terms of time or distance (WRIGHT WENDEL et al. 2012, LA ROSA 2014). When park facilities meet high demands for park services in densely populated areas, the supply is regarded as adequate, and thus accessibility as convenient. This indicates that parks are accessible if they are provided in accordance with the spatial distribution and the demand of the population using the services (LINDSEY et al. 2001, NICHOLLS 2001, WOLCH et al. 2005, LEE & HONG 2013).

In accordance with all of these determinations, the starting point of the study is that urban green spaces must be located within appropriate travel distance for pedestrian access and must have adequate size to serve the existing population. The purpose of this study was to investigate the adequacy of neighbourhood park services in the city of Adana's Cukurova district in terms of accessibility, spatial sufficiency and distribution, size of neighbourhood parks area and use intensity. Additionally, the aim was to identify spatial and planning principles to provide an optimum level of utilisation of neighbourhood parks and to understand which areas are more suitable to be addressed for new green spaces by the municipality's land-use plan.

The paper is structured in the following way: Approaches for GIS-based modelling of the accessibility to neighbourhood parks are discussed in Section 2. The study area and the geodataset used are described in Section 3. The proposed indicators (distance, population density and the size of the park) are described in the methodological procedure in Section 4 for defining the index. The results of the indicators' calculation are given in Section 5, and finally, conclusions are summarised in Section 6.

2 Modelling Accessibility to Urban Greenspaces

Recently, geographic information systems (GIS) studies of urban green space areas have been increasing in number. GIS is used to identify green space areas with high ecological, recreational and aesthetic values to protect certain green space areas from development, to present a GIS-based decision support tool to model planning scenarios related to the creation of new green space areas as part of neighbourhood greening strategies, to quantify the spatial configuration of green spaces that are used in landscape metrics, to assess the accessibility of many proposed green spaces enhancements, to implement a web-based platform and to analyse the delineation of distance-based catchment areas (WOLCH et al. 2005, LWIN & MURAYAMA 2011, UNAL 2014).

GIS has been a useful tool for measuring accessibility to parks in terms of supply and demand. Some of the main research fields cover the identification of areas suffering from lack of accessibility due to many reasons. In recent years, the modelling of accessibility to green spaces has evolved substantially thanks to enhanced GIS features, particularly the development of GIS modules such as the ArcGIS Network Analyst Tool and personal computers' computational capabilities. There are two common approaches, including the **Euclidean Buffer (simple radius methods)** and **Network Analysis** (Figure 1) (NICHOLLS & SHAFER 2001, OH & JEONG 2007, MOSELEY et al. 2013, LA ROSA 2014).

The Euclidean Buffer method has advantages over the computation of ratios of parkland area to population, but several problems arise from its use. First, the Euclidean distance method can provide only an approximate representation of a park's service area, since it assumes 'as-the-crow-flies' movement. In reality, potential users cannot travel in straight lines. Thus, the actual travel distance is almost always greater than the direct distance. The second disadvantage of this method is that it assumes parks to be open to access at all points along their boundaries. This is not always true. In many cases, users must travel out of their way to reach a point of entry. These first two factors are both likely to lead to over-estimation of the size of a park's service area. The third, however, may lead to its under-estimation. It is related to measurement of the specified distance from the centre of the park rather than from its boundary. As the size of a park increases and the distance between its centre and perimeter grows, underestimation of the service area becomes greater due to the inclusion of the park itself within this zone. The final disadvantage of drawing a circle around the centroid of a park is that it does not take into account the park's shape. The less regular this shape becomes, the higher the degree of inaccuracy and misrepresentation of the service area. A linear park would provide a good example (NICHOLLS 2001).

Previous studies that assessed accessibility to urban parks and determined their service areas often employed the so-called "simple radius method" that focuses on the linear distance from parks rather than considering citizens' actual routes to them. Moreover, aspects of the surrounding areas of parks, including the number of benefited users, land uses or development density are not considered (NICHOLLS 2001, OH & JEONG 2007, UNAL 2014). Using the network analysis method of GIS, this study analysed the actual accessibility of pedestrians to urban parks in Cukurova.

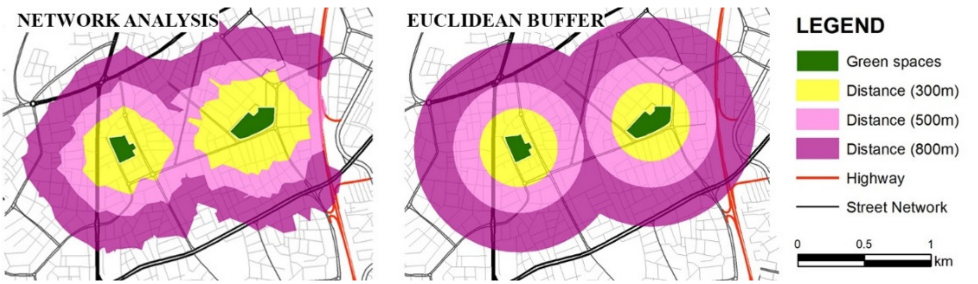

Fig. 1: The example of difference between Euclidean Buffer and Network distance

3 Study Area and Available Geo Datasets

The study area selected for this study is 10 selected neighbourhoods in the Cukurova district, an urban context characterised by high density of urban settlements (37°03′N-35°17′E). The district one of the third crowded population areas in the city of Adana and the most densely developed region in Adana. Cukurova is located on the northern Adana. It is boundaried by the Seyhan river (east of the area) and Seyhan Dam Lake (north of the area) (Figure 2). The study area, 4.283 Ha, covers 21.5 % of Adana's urban settlement area (approximately 20.000 ha). The population reached 339.159 in 2014 (TURKISH STATISTICAL INSTITUTE 2014). Cukurova has undergone significant economic development and rapid urban expansion over the past 30 years. Private green spaces are still relatively rare, however, so the provision of green space services mainly depends on public green spaces. Yet Cukurova is characterised by a relevant shortage of public spaces and services, especially green spaces. Currently the amount of public green spaces is about 1.8 m^2/inhabitant, much less than the minimum amount specified by national legislation (10 m^2/inhabitant).

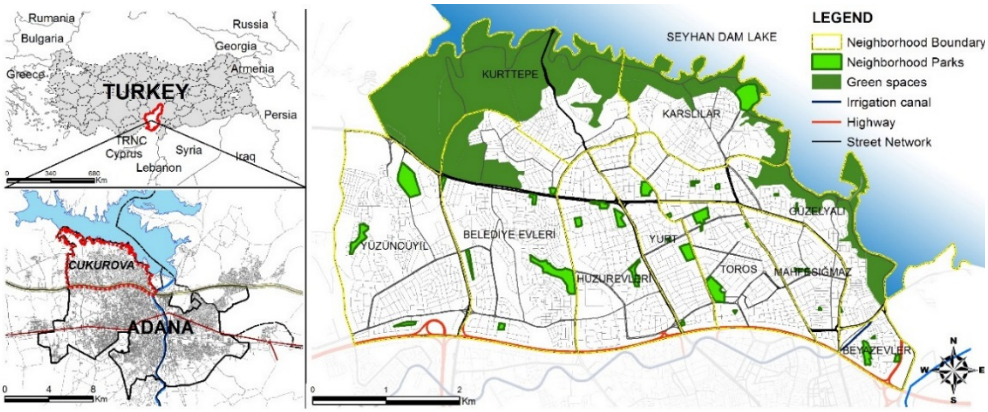

Fig. 2: The study area of Cukurova (Adana/Turkey) and the distribution of open spaces within the municipality

This study used four data sources:

- Geographical distribution of neighbourhood parks, which was obtained directly from survey studies and the latest public green space list published by Cukurova municipal government departments.
- The city's street network (pedestrian roads, crosswalks, overpasses, and underpasses) was prepared from digital and paper maps, scaled 1:1000, and recent Google Maps images.
- Geographic distribution data on urban residential communities, which were obtained from Cukurova municipal government departments, existing maps on a scale of 1/1000, and implementation of the development plan and master plan 1/5000 (May, 2010)
- Neighbourhood population data, which was obtained from the Turkish Statistical Institute, 2014.

4 Methods

The method used in this study consisted of six phases:

- Locating the neighbourhood park gained from survey studies, aerial photography, and the Adana city Implementary Development Plan (1/1000 scale);
- Determining the primary standards by referring to literature and expert views;
- Evaluating quantitative data and calculating the service area;
- Mapping the neighbourhood parks' service areas using the Network Analysis;
- Enhancing the neighbourhood parks' spatial sufficiency and accessibility potentials, and
- Developing suggestions according to final maps.

4.1 Determination of Analysis Standards

The primary indices of neighbourhood park service areas have been identified as a result of receiving expert views and researching the relevant literature. It is designated that accessibility, size of area, population, and quantitative and qualitative characteristics of the neighbourhood parks are used for measuring accessibility to green spaces (GOLD 1980, NICHOLLS 2001, HERZELE & WIEDEMANN 2003, WOLCH 2005, MIYAKE et al. 2010). According to interviews with specialists (landscape architects, urban planners and designers, architects), while '*accessibility, size of area, population*' were included in the assessment due to having certain standards, '*quantitative and qualitative characteristics of neighbourhood parks*' were not included in the evaluation because of their potential to be modified and improved.

4.2 Establishment of Neighbourhood Park Service Indices

'Neighbourhood parks within walking distance' describes the relationship between users or residential areas and neighbourhood parks. The other indices, except walking distance, describe the relationship between the user population that is located in a park's area and the area size of a park. When park facilities meet high demands for park services in densely populated areas, the supply is regarded as adequate, and thus accessibility as convenient. This indicates that parks are accessible if they are provided in accordance with the spatial distribution, optimum field size and the demand of the population using the services (LINDSEY et al. 2001, NICHOLLS 2001, LEE & HONG 2013). Consequently, parks service areas may vary, depending on field size and population criteria.

a) Maximum distance: Neighbourhood parks are required to be located within convenient maximum distance to meet users' daily recreational needs. In sustainable urban development strategies, users must benefit equally from public services, which are considered an important measure in ensuring the accessibility of social justice. These considerations therefore demonstrate the importance and necessary principles of accessibility (YENICE 2012). In this study, the maximum distance from neighbourhood parks was set at 500 m based on the 2014 Regulation on Preparation of Spatial Plans in Turkey.

b) Field size: To provide effective services in the vicinity of residential areas, neighbourhood parks within a particular distance vary in respect to their size (EMUR & ONSEKIZ 2007). So the per capita of the neighbourhood parks must be determined, and the optimum field size of neighbourhood parks must be calculated. Firstly, the number of neighbourhood parks that should be in the area was found by dividing the surface area of the total research area by the effective walkable distance (500 m). Secondly, optimum field size per capita was determined by Altunkasa (2004) as 8 m^2, which has been used in the determination of the size of neighbourhood parks. Field size for population was calculated by multiplying the optimum field size per capita by the user population. The area of the most appropriate neighbourhood park, which was calculated by dividing the area required for the whole user population by the number of required parks, was estimated to be 24.865 m^2 for this research. This predicted value will take a value of 100 on a scale between 0 and 100.

Neighbourhood parks, 24.865 m^2 and above 0-100

c) Population: Firstly, to calculate the population density of neighbourhood parks, the ratio of the impact area intersected with the neighbourhood boundaries was determined. As this ratio applied the population of neighbourhood parks, 'total impact area population (TIAP)' was calculated by Equation 1. Secondly, the amount of neighbourhood parks per capita was calculated by comparing neighbourhood park sizes to the obtained population values. Finally, population density index (PDI) was calculated by Equation 2.

$$\mathrm{NP_x\ TSAP} = \sum_{n=1}^{N} \frac{\mathrm{NBHD_n\ NP_x\ Service\ Area}}{\mathrm{NBHD_n\ area}} \mathrm{x\ NBHD_n\ Total\ Population} \quad \text{(Equation 1)}$$

$$\mathrm{NP_x\ PDI} = \frac{\text{the norm for neighbourhood parks per capita}}{\frac{\mathrm{NP_x\ area}}{\mathrm{NP_x\ TSAP}}} \quad \text{(Equation 2)}$$

where *NP: Neighbourhood park*
TSAP: Total service area population
NBHD: Neighbourhood
PDI: Population density index
X: Neighbourhood park code
The norm for neighbourhood parks 8m^2 per capita 0-100

The stages in the evaluation of the field size and population:

- First stage; each neighbourhood park is given points ranging between 0 and 100 according to the specifications for neighbourhood parks.
- Second stage; conditions that define the criteria of evaluation are determined.
- Final stage; percentage values for each criterion were obtained for evaluation of the obtained quantitative data. Neighbourhood park total scores were calculated by taking the arithmetic average of these values.

Field size and the population connected service area values were accepted as a percentage between the sums of the highest criteria scores (100 points) to obtain a total score for each neighbourhood park. These values were calculated by multiplying the optimum walkability distance to the neighbourhood park (500 m) to these percentage ratios (Equation 3).

$$\mathrm{NP_x}\ \mathit{Service\ Area\ Value} = \frac{\mathrm{Total\ NP_x score}}{\mathrm{Max\ NP\ score}} \mathrm{x\ Maximum\ Distance} \quad \text{(Equation 3)}$$

4.3 Creation of Service Area Maps and Network Analysis

In the creation of maps, GIS-based network analysis modules, such as the ArcGIS Network Analyst Tool from the 'Service Area Analysis (Service Area)', which began with the development of information and computer technology, were used in order to determine neighbourhood parks' service areas according to their spatial distribution.

Network analysis is a useful tool in analysing water distribution, stream flows and traffic flows. Centres, arcs, nodes and impedances are key elements in that analysis (Figure 3). Networks occur segments (Arcs-Nodes), and these segments are defined with the known coordinates of the starting and ending points. Thus, in the first stage, Arc-Node topology was formed to define the service area. In this research, Arcs are defined pedestrian routes that connect citizens to the parks. Impedance refers to barriers that prevent movement between links, and different impedance values were assigned according to route types, such as pedestrian roads, crosswalks, underpasses and overpasses. Therefore, these lengths (walking and crossing roads, underpasses and overpasses) are added walking distance and they are also defined as Arc. Nodes are intersections of links (entrance[s] of the park, crossroads, and road intersections). The network extent is line-shaped, so the service areas of parks were determined by 500 m buffers for pedestrian routes within the network extent. Consequently, it was determined that network analysis could be used to provide the boundaries of the service areas of parks wherein citizens can access them within a given distance.

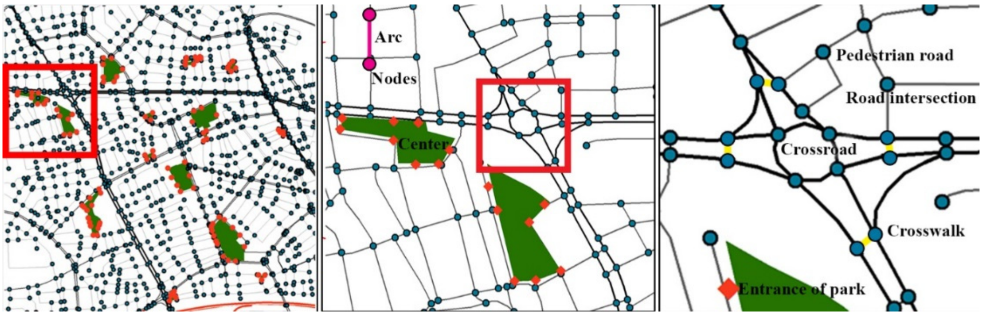

Fig. 3: An example of arc-nodes topology

5 Results

The study was conducted for 34 neighbourhood parks (NP) that were determined by survey studies in Cukurova. The overall results show the calculations and the mapped service areas with optimal field sizes and population criteria. Service areas within a linear distance of 500 m from parks were measured using the network analysis method. As the evaluation criteria is capable of all requirements, a maximum score (100) is considered. Then the NPs' service area values were calculated with associated optimum walking distances and total scores for each NP (Equation 4).

$$\mathrm{NP_x}\ Service\ Area\ Value = \frac{\mathrm{Total\ NP_x\ Score}}{100} \times 500 \qquad \text{(Equation 4)}$$

This formula was applied for each neighbourhood park in the study area. When the results are evaluated, the mean service area for each neighbourhood was calculated from 0 to 500 m. Additionally, every neighbourhood showed a vast disparity in terms of the number of the NP, population and service areas. The number of their parks varied from 0 to 6, and the population ranges were from just under 3.800 to almost 62.000 inhabits (Table 1). While Karslılar (Id 10) has a high NP score and an underpopulated neighbourhood, Mahfesığmaz (Id 6) and Güzelyalı (Id 4) have the lowest NP scores except for Kurttepe, which does not have a NP. Moreover, total NP areas in Yüzüncüyıl (Id 7) and Belediye Evleri (Id 3), where new settlements are located, are higher than in other neighbourhoods (Table 1).

Table 1: Comparison of neighbourhood park service indices

ID	Neighbourhood	Neigh-bourhood Size	The number of NP	Total NP Area	Population	Mean NP Score	Mean Service Area
1	Toros	187 *Ha*	6	86.125 m^2	61.804	30	148 m
2	Huzurevleri	257 *Ha*	4	63.009 m^2	56.826	35	178 m
3	Belediye Evleri	464 *Ha*	6	122.805 m^2	54.176	33	166 m
4	Güzelyalı	263 *Ha*	5	10.391 m^2	43.232	5	25 m
5	Yurt	154 *Ha*	4	54.536 m^2	42.526	30	152 m
6	Mahfesığmaz	127 *Ha*	2	4.885 m^2	33.965	5	27 m
7	Yüzüncüyıl	404 *Ha*	3	124.441 m^2	27.000	75	375 m
8	Beyazevler	66 *Ha*	3	32.837 m^2	9.929	28	140 m
9	Kurttepe	435 *Ha*	0	0 m^2	5.916	0	0 m
10	Karslılar	237 *Ha*	1	80.592 m^2	3.785	100	500 m
	TOTAL	**2.595 *Ha***	**34**	***579.621 m^2***	**339.159**	**38**	**190 m**

These results showed that the service area (500 m), including park areas, covered 1.319 ha, which is about 50 % of Cukurova (2.595 ha). The fifth NPs (from 1 to 5) have 25 parks, and while many of them have less field size, their total service area is high. The highest service area appears in Karslılar (10) due to having the biggest field size NP and being underpopulated. This park score is the same as the restricted service area score. As shown in Figure 4, Yurt (5), Mahfesığmaz (6) and Beyazevler (8) have almost enough service area when 500 m is evaluated. On the contrary, as population and field size are taken into account in the calculations, the service area appears not to be enough. The important factor is the presence of NPs near the borders of these neighbourhoods. Consequently, the effect of a park's location and distribution are as important as the size of the park and the population density (Figure 4).

The most restricted service area for accessibility to NPs was observed in Beyazevler (8) for both estimations. This is because the neighbourhood has 3 NPs, with the biggest one located in the centre of the area. Also, the neighbourhood has the smallest one, which is only 66 ha. There is a noticeably discrepancy in Mahfesığmaz (6) for two calculated service areas. While the 500 m service area cover 93 % of the neighbourhood, the restricted service area sharply decreases to 4 % of the area. At first glance, they have appropriate parks in this neighbourhood, but 96 % of the residents could not access NPs for recreation (Figure 5). In order to improve these areas, either the population would have to be decreased or the number of parks would have to be upgraded.

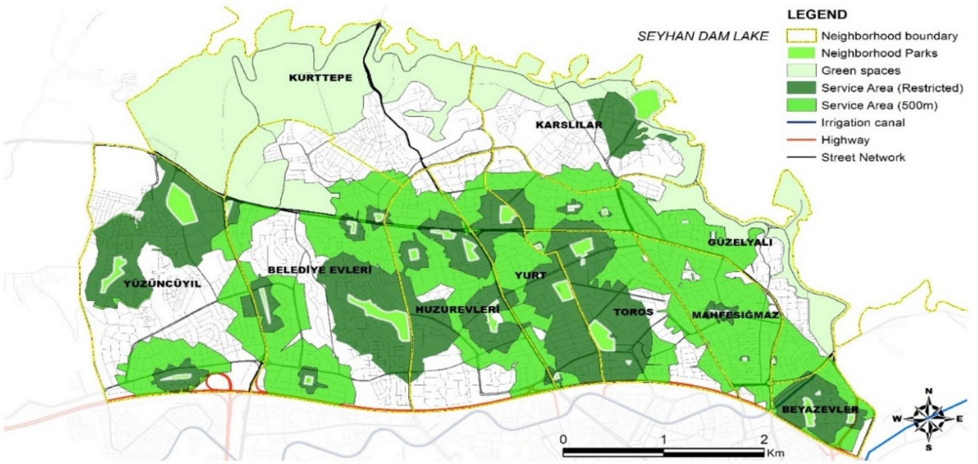

Fig 4: Service areas mapping by Network Analysis

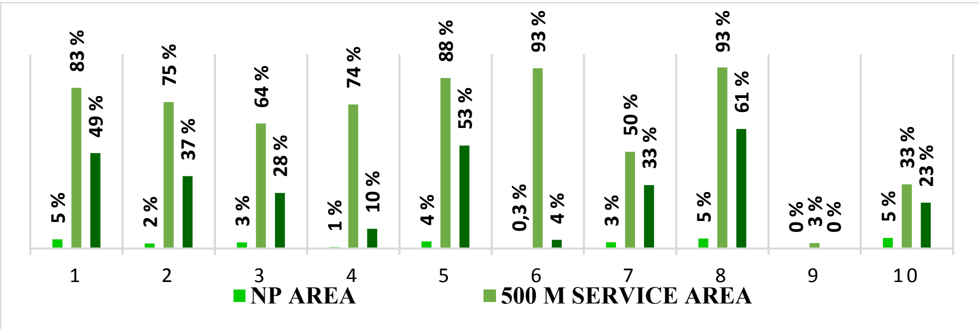

Fig. 5: Comparison of NP service area in each neighbourhood

As shown by the results of the network analysis, 79 % of the study area consisted of residential areas, of which the NPs (34 units) constituted approximately 3 %. The remaining 21 % of the study area was comprised of other green spaces (forest, shrubs, recreational green spaces, etc.). Whereas Turkey's Spatial Plan Construction Regulations propose that service areas must be 500 m for each NP, there is not yet any attention given to the minimum field size in relation to the population density. As a result, if the calculations given by this method take into account this regulatory value of 500 m, NPs' accessibility reaches 65 % in the Cukurova district. This rate drops nearly 30 % when this assessment takes into account NPs' areas and population densities.

Neighbourhood parks play a significant role for their use as resting places. They also promote community welfare among neighbourhood residents. Needless to say, it is desirable that such NPs be easily and conveniently accessed. The accessibility of NPs from residential areas was analysed to evaluate the distribution of neighbourhood parks according to the size of the park and the population density. From this analysis, it was found that more than half of the inhabitants do not directly benefit from their NPs. Thus in those areas, the creation of new NPs that are of a size suitable for the current population density should be made a priority.

6 Conclusion

This study assessed the level of serviceability of NPs. The assessment method focused on park sizes and the population density. The assessment method utilized in this study can be useful in helping to understand the spatial distribution of urban parks more accurately and to establish effective policies for urban park management. We deduced three key points.

Firstly, the realization of neighbourhood parks in accordance with the principles of proper planning is important in terms of the accurate determination of site selection and their relationship with the other utilizations. Neighbourhood parks providing large spaces and diversity can be considered near the borders of the neighbourhood. Thus many individuals living in different neighbourhood can benefit from these parks.

Secondly, the most difficult criterion in terms of improving the quantitative aspects is field size. Therefore, in planning, the optimal size of the park can significantly increase the effectiveness of the service area. However, field size is not enough for contributing to the quality of urban life. Therefore, both field size and the spatial population distribution for neighbourhood parks should be determined according to population density in the development plan. The determination of the minimum field size based on the population is also important in terms of accessibility, especially in new urban development areas.

Finally, legislation, backed by scientific studies that consider aesthetic, functional, and social benefits, for the planning of green spaces as well as of neighbourhood parks should be developed.

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