



A GIS-based approach for evaluating public open spaces in Dammam city, Saudi Arabia

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Abstract The Kingdom of Saudi Arabia has experienced rapid urbanization and population growth in recent decades. As a result, Saudi people have sought more public open spaces (POS) for social and physical activities. Moreover, each POS provides valuable services and opportunities for urban population. The Saudi government aims to provide the minimum standard value of per capita POS (9 m²/person) suggested by the World Health Organization (WHO). Therefore, valuating POS spatial characteristics is essential for local planners and decision-makers to prepare future urban and landscape development plans. This study aimed to quantitatively and spatially evaluate the POS in Dammam City. Five types of POS were considered: parks, walkways, plazas, waterfronts, and proposed parks. These types were organized into three assumptions, each targeting the development of certain types of POS. The per capita and service areas for POS were measured for each assumption. The POS per capita was compared with the number of international standards. Finally, the service area was used as an indicator to evaluate POS accessibility. Geographic information system (GIS) functionalities were used to model Dammam City and estimate the indicators required for evaluation. The service area was studied using both buffer and network analysis methods. The findings revealed that Dammam's per capita POS of less than 7 m²/person is less than any

international standard, and that a significant proportion of the city's inhabitants do not have convenient access to POS.

Keywords Landscape planning · Environmental management · Per capita public open space · Public open space accessibility · Service area · Network analysis

1 Introduction

More than 55% of the world's population currently lives in urban areas, and recent projections show that approximately 68% of the world's population will reside in urban areas by 2050. As a result of these figures and projections, people are paying attention to quality of life in urban areas globally [1]. Furthermore, with the growing interest in sustainable development, the concept of sustainability has been incorporated into urban policies and strategies worldwide. For example, the eleventh goal of the Sustainable Development Agenda is to “make cities and human settlements inclusive, safe, resilient and sustainable” [2]. This goal specifically emphasizes the role of open spaces in the sustainable urban environment as Target 11.7 states: “By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, particularly for women and children, older persons and persons with disabilities” [2].

Although open space is a self-defined term, several organizations and researchers have attempted to define it accordingly. UN-Habitats defines it as “all places publicly owned or of public use, accessible and enjoyable by all for free and without a profit motive” [3]. In contrast, the US EPA defines it as “any open piece of land that is undeveloped (has no buildings or other built structures) and is accessible to the public” [4]. These definitions were inspired by the early work of researchers [5], who dealt with open space

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as any land within the urban area that has two characteristics: (i) public owned and (ii) accessible. On the other hand, many publications have emphasized the capability to host and encourage a variety of activities, such as playing, socializing, exercising, and celebrating, as the primary function of public spaces [6].

There are two approaches to categorizing open spaces. The first approach deals with available open space types such as parks, plazas, squares, etc. This approach is known as typology design-related functional system. The second approach is a classification approach that defines open-space classes using their attributes [7]. Different classification schemes for open spaces, each of which focuses on a specific attribute or set of related attributes. For example, the catchment hierarchy scheme classifies open spaces based on the geographical area to be serviced by the open space as local, neighborhood, district, and regional open spaces [8]. Another example is the classification of open spaces as public, semi-public (or quasi-public), or private spaces [9]. This scheme considers public accessibility and ownership attributes to classify open spaces and has its roots in the defensible space theory [10]. In this study, a public open space (POS) refers to any public and free-access area that offers opportunities for social interaction [11]. Public spaces are owned by the community, accessible to anyone, and used for the benefit of the community [12]. Parks and plazas are examples of these spaces.

Urban POS provides valuable services and opportunities for people. Several studies have shown that POS supports social interactions [13] and social cohesion [14], provide recreation and leisure arena [15], encourage physical activity [16], enhances physical and mental health [17], and improve the quality of the environment by reducing air pollution [18] and the effects of the urban heat island [19].

To evaluate POS, researchers generally use two approaches: (1) a qualitative approach to evaluate the intangible elements of POS [20] and, (2) a quantitative approach measuring specific values of POS such as the size and the number of users [21]. Recently, many studies have used the Geographic Information System (GIS) as a tool for the quantitative and spatial evaluation of POS. GIS is a computer-based system for organizing, managing, analyzing, and viewing data about geographic features, it also provides information about the spatial relationships of each of these features with its surroundings. GIS is currently crucial in multi-criteria analysis for landscape planning of POS [22], as well as for the evaluation of POS attributes, such as accessibility [23], spatial patterns [24], and spatial justice [25]. In addition, GIS is used to assess per capita POS as an indicator of Sustainable Development Goals SDG [26].

With its rapid economic development, Saudi Arabia has experienced rapid urbanization and population growth in recent decades [27]. Considering that more than 84% of

Saudi Arabia's population lives in cities [28], Saudi people have been seeking out more POS for social and physical activities. 2030 Vision has indicated that enhancing the quality of life and improving the urban landscape in Saudi cities are national priorities for the next decade [29], indicating the need to evaluate the characteristics and conditions of current potential POS. However, few studies have been conducted in Saudi Arabia to evaluate POS in the main cities, and most of the existing studies have focused on the qualitative characteristics of POS. For example, user benefits related to POS were explored in Jeddah [30], and the reasons behind Jeddah's POS failing to meet people's needs were investigated [31]. Likewise, users' demographic characteristics and level of satisfaction in a sample of three parks in Dammam City were studied [32]. However, there are few quantitative studies. More recently, the per capita area and accessibility of POS in three megacities Riyadh, Dammam, and Jeddah were measured [33].

The evaluation of POS needs to be spatially and quantitatively evaluated because of its particular spatial characteristics. Therefore, this study aimed to evaluate the POS in Dammam quantitatively and answer two questions: (i) Are Dammam's POS sufficient for its residents? and (ii) Can the people easily access the POS? Consequently, a set of proposed indicators were developed and used to evaluate the urban open spaces, the per capita POS, and the service area of the POS.

Evaluating spatial characteristics of POS is essential for local planners and decision-makers to prepare future urban and landscape development plans. This article intends to contribute to how the quantitative spatial characteristics of POS should be investigated and interpreted in the context of improving landscape quality. Since no research dealing with the integration of these indicators has been conducted in Saudi Arabia, this research fills the gap, and can be a reference for future studies in the Saudi's context.

2 Materials and methods

2.1 Study area

Dammam is the capital city of the Eastern Province in Saudi Arabia. It is located along the coast of the Arabian Gulf, and is surrounded by a sandy plateau. The latitudinal and longitudinal extensions of Dammam range from 26° 15' 44.4" N to 26° 31' 50.7" N, and from 50° 18' 2.8" E to 49° 52' 26.5" E, respectively. The city's area is approximately 414.8 km² and it has an elevation ranging from sea level to 70 m. The region is characterized by long hot summers and short moderate winters. Its climate is classified as BWh (hot desert climate) by Köppen and Geiger classification [34], with an average annual temperature of 26.1 °C and average

annual precipitation of 88 mm for the period (1985–2018). In 2010, the population census of the Kingdom of Saudi Arabia recorded the population of Dammam as 900,000 inhabitants. Using a growth rate of 2.5% annually [28], it is estimated that the city's population will exceed 1.5 million inhabitants by 2030, and the population is estimated to be 986,000 in 2020. Dammam consists of 76 neighborhoods that are organized into three municipalities (districts): Central, Eastern, and Western Municipality, hereinafter CM, EM, and WM respectively, as shown in Fig. 1. Dammam is the main industrial port on the eastern Saudi coast and is a center for road transportation between Gulf Countries Council GCC members. Manufacturing and tourism are the dominant economic activities in Dammam.

2.2 Data

QGIS software was used to model the spatial structure and relationships of POS in the context of Dammam. QGIS is an open-source desktop GIS software sponsored by Open-Source Geospatial Foundation (OSGeo) [35]. It has proven to be an effective tool for data collection, organization, analysis, presentation, and restoration of the meaningful information required to understand POS characteristics and their relationships with their surroundings. A geographical database is used to model the study area. It includes seven vector layers to describe the study area, municipalities, neighborhoods, land use, road networks, administrative jurisdiction, and POS.

All layers in the geographical database were georeferenced using the Universal Transverse Mercator for Zone 39 N and World Geodetic System 1984 (WGS84/UTM39N). Therefore, all measurements extracted from these layers will be meter-based.

Several data sources have been used to populate geographical database layers. The Ministry of Municipal and Rural Affairs (MoMRA) provided administrative units and land use, while the General Authority for Statistics (GaSTAT) provided the population. MoMRA data were designed mainly for urban planning purposes and were provided as ready-to-use GIS data. POS was presented as part of land use data and classified based on their respective functions, services, and scale. These classes included parks, proposed parks, walkways, waterfronts, and plaza spaces. These classes were then organized into three potential assumptions, where each assumption represented the development of certain types of POS to serve people. The first assumption targeted both parks and walkways. The second assumption adds waterfronts and plazas to the spaces provided by the first. The third assumption uses five available POS classes, including the proposed park, which means that assumption targets a future situation. The road_network layer was designed to be implemented later in network analysis and to

show the roads and the required attributes for network analysis to investigate the accessibility of POS. These attributes include road type (i.e., motorway, primary, etc.), direction (one-way and two-way), and length. This layer is obtained from OpenStreetMap (OSM) [36].

We selected hundred random POS to evaluate the accuracy of the geographical database presentation and its eligibility to extract accurate results. All selected POS matched their locations and attributes as presented in the geographical database. These hundred POS represent more than 10% of the total POS presented in the geographical database. Therefore, the POS layer was considered accurate.

2.3 Spatial analysis procedure

The procedures of spatial analysis used in this study is illustrated in Fig. 2. It is divided into three main tasks: the first is related to evaluating the current state of POS; the second aims to estimate the per capita POS; and the third aims to evaluate the accessibility to POS using POS service area as an indicator. Each task is discussed below.

Three essential indicators were defined and calculated to compare POS in the administrative unit (i.e., neighborhoods and municipalities). The first indicator is the number of POS per administrative unit, while the second indicator used was the total POS area per administrative unit. Considering the variability in POS sizes, POS relative area was used as a third indicator and is defined as the ratio of POS area to the total area of the administrative unit.

The area of each POS was calculated using GIS facilities, sorted by neighborhood, and the overall area for POS was calculated for each municipality. In this study, the per capita POS for an administrative unit was defined as the ratio of the total area of the POS within this administrative unit to the population of the same unit. The per capita POS was calculated for each assumption (based on the previous definition), then compared to a number of international standards for per capita POS to identify the appropriate assumption that provided an acceptable per capita POS for the city of Dammam.

To measure the service area of each POS, this study assumes that it serves people who live no more than 300 m of walking distance or 800 m using light vehicle from the POS [37]. These values were chosen after discussions with many experts and after considering Saudi climate conditions and social settings. Two GIS-based methods were used to identify the service area for each POS in the study area. The first is a straightforward buffering technique. The second method is a network analysis, which defines the service area for each POS based on the allowed travel distance on the road network. QGIS Network Analysis Toolbox (QNEAT3) [38] plugin was used to measure and map the service area. The isochrone area algorithm provided by the plugin is used to map the service area. In addition, the outputs of

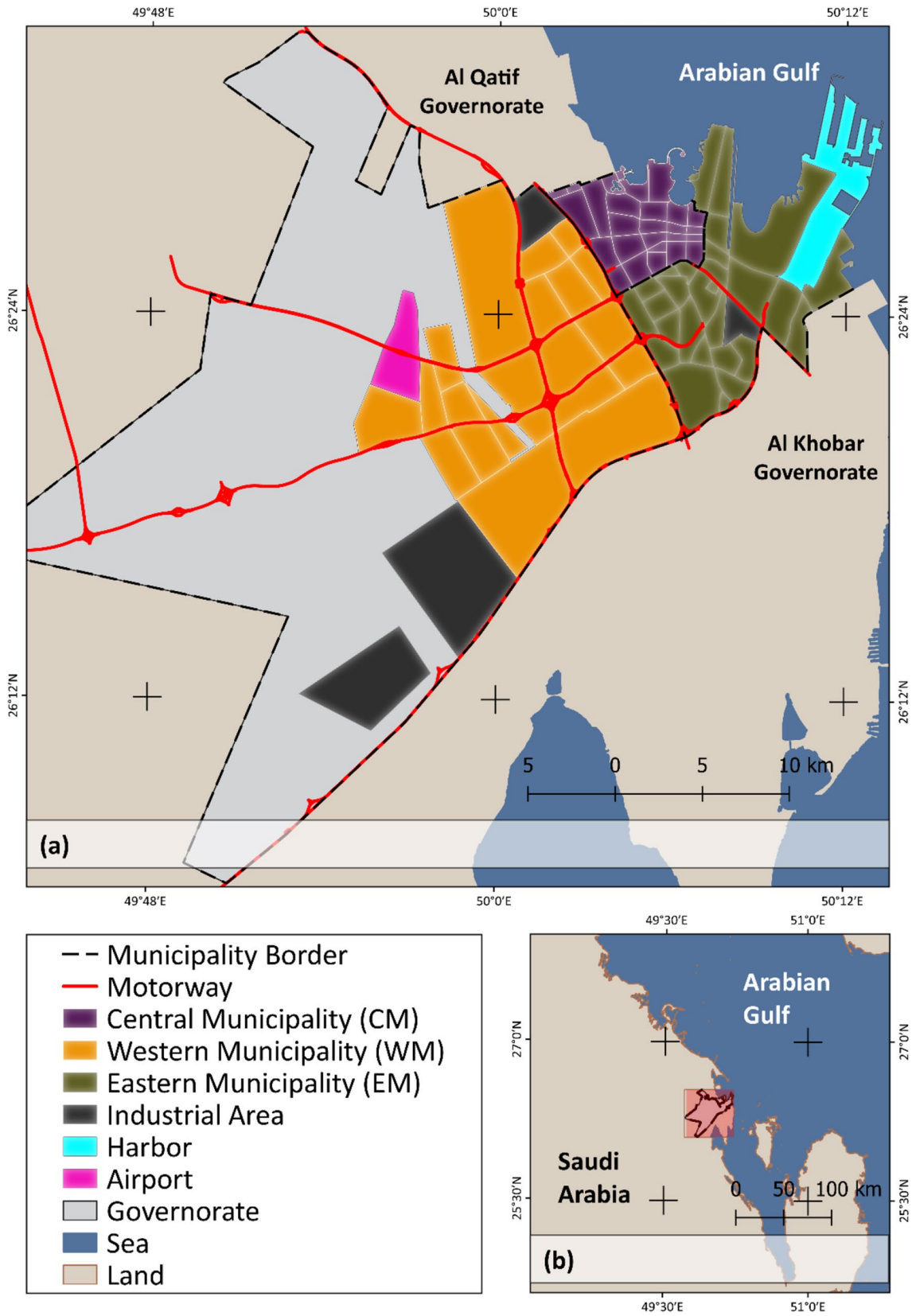


Fig. 1 Geographical settings of the study area **a** the administrative settings and **b** location of the study area on the western coast of Saudi Arabia [This map was produced using base map by Ministry of

Municipal and Rural Affairs (MoMRA) and road network data provided by OpenStreetMap]

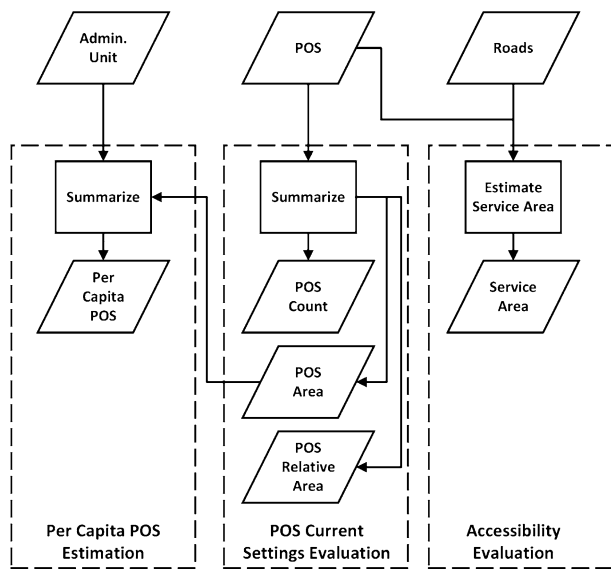


Fig. 2 Flowchart of the spatial analysis procedures used in this study

both methods were cropped to exclude areas outside the Dammam boundary. Finally, the service areas provided for each administrative unit are calculated to compare the three assumptions.

3 Results

3.1 POS current settings in dammam

Dammam City has 76 neighborhoods organized into three municipalities: CM, EM and WM. The total population of Dammam is 985,743 with a population density of 30 people/ha. CM had the smallest area and densest population (115 people/ha). Two states of neighborhoods were identified: existing and emerging. Emerging have been officially declared, planned, partially provided by infrastructure, and partially inhabited. CM has no emerging, while more than 45% of WM’s are emerging. Table 1 summarizes the general characteristics of Dammam municipalities.

Dammam City has 918 POS. In this study, POS were categorized based on function, size, and scale. The total

area of POS in Dammam is 700.75 ha. The total area of Dammam City is 33,391 ha, and the relative area of POS is approximately 2.1% of Dammam City area. Table 2 summarizes the structure of POS in the municipalities using the number, area, and relative area of each type of POS. As seen in Table 2, WM accounts for 61% of the total urban open spaces in Dammam. The majority of POS comprises proposed parks, and both existing and proposed parks occupy nearly the same area.

Figure 3 shows the number of POS in the neighborhoods. WM is richer in POS than the other two municipalities. EM has the lowest POS. Figure 4 shows the area of POS by neighborhood of the three municipalities, expressed in square meters. This indicator is not useful for comparing the area of POS in different administrative units, the relative area of POS is a simple and interpretable indicator that can be used to compare the characteristics of POS in various units. Figure 5 shows the relative area of POS in the neighborhood area. The neighborhoods of the WM have fewer relative areas for POS than other municipalities.

3.2 Per capita POS

Per capita POS is defined as the ratio of the POS area in a given administrative unit to the population of this unit. Although some organizations have proposed standard values, there are no defined international standards for per capita POS. Saudi Arabia has adapted the recommendations of the World Health Organization (WHO) to provide a minimum POS of 9 m² per individual [39].

Three assumptions for POS development were evaluated based on the per capita POS provided by each assumption. The first evaluated the potential of using existing parks and walkways to provide sufficient per capita POS for Dammam residents. The second plaza and waterfronts were included in the evaluation. The third assumption considered five POS types during the evaluation process.

Considering the first, second, and third assumptions, the overall per capita POS for Dammam City was 2.8, 4.57, and 7 m²/person, respectively. Per capita POS for each assumption was calculated for municipality. Figure 6 shows the calculated per capita POS over Dammam’s three municipalities for the three proposed assumptions compared to the

Table 1 The general characteristics of Dammam’s municipalities

Municipality	Area (ha)	Neighborhood			Population	Density (person/ha)
		Emerging	Existing	Total		
CM	3871.90	0	26	26	445,134	115
WM	19,831.41	10	12	22	255,969	13
EM	9688.02	6	22	28	284,640	29
Total	33,391.33	16	60	76	985,743	30

Table 2 Number, area, and relative area of POS types in Dammam

Municipality	Park	Walkway	Plaza	Waterfront	Proposed Park	Total
<i>Number of POS</i>						
CM	42	149	2	6	46	245
WM	71	52	0	2	433	558
EM	66	1	1	0	47	115
Total	179	202	3	8	526	918
<i>Area (ha)</i>						
CM	26.52	25.60	0.32	53.93	35.79	142.15
WM	32.53	4.71	0.00	120.13	163.49	320.87
EM	187.51	2.30	0.69	0.00	47.24	237.74
Total	246.57	32.61	1.01	174.06	246.51	700.75
<i>Relative Area (%)</i>						
CM	0.68%	0.66%	0.01%	1.39%	0.92%	3.67%
WM	0.16%	0.02%	0.00%	0.61%	0.82%	1.62%
EM	1.94%	0.02%	0.01%	0.00%	0.49%	2.45%
Total	0.74%	0.10%	0.00%	0.52%	0.74%	2.10%

proposed standards of the WHO's. Disregarding the third assumption in WM, per capita POS provided by all assumptions in the three municipalities failed to meet any international standards. EM shows proposed per capita POS close to the WHO standards likely due to the absence of waterfronts in this municipality.

Considering the variation in area and population of administrative unit, it is expected that the per capita POS in different administrative units will vary. To explore this potential variation, the per capita POS value was calculated for the neighborhoods for each assumption. The three assumptions were mapped and classified visually to compare per capita POS to the proposed international standards. Per capita POS was not calculated for 17 neighborhoods because these either did not have any POS or are not yet populated.

Figure 7 shows the per capita POS for the three assumptions. According to the first assumption, most neighborhoods have per capita POS lower than the WHO standard. In the second, the per capita POS is still below the standard value suggested by the WHO, but neighborhoods that exceed this value have increased in number. According to the third assumption, more neighborhoods providing POS per capita exceeded the WHO recommended value.

Table 3 shows the classification of neighborhoods based on the per capita POS proposed by the three assumptions. Class limits were chosen according to international standards. For example, the class with a lower boundary of 18 m²/person and an upper boundary of 26 m²/person represents the number of neighborhoods that provide per capita POS greater than or equal to 18 m²/person (which is a value recommended by US Department of Housing and Urban Development HUD and less than 26 m²/person that is recommended by European Union. The zero-frequency class indicates neighborhoods that are uninhabited or have

no POS. Most of the neighborhoods in the three municipalities had per capita POS less than the WHO recommended value.

3.3 Accessibility and service area

In this study, POS attracted and served people living in service area. The service area size and shape were studied using two approaches. The first approach is based on standard buffer analysis, where the service area is defined as a buffer with a fixed distance from the POS. The second approach is based on network analysis which considers the properties of the road networks. The distance values used were 300 m and 800 m. The service area of the city is defined based on the three aforementioned assumptions. Figure 8 shows the service area defined using the buffer method and Fig. 9 shows the service area defined using network analysis. Disregarding the method used to calculate the service area, these three assumptions cannot provide a service area that covers the entire city. However, the third assumption provides a larger service area than the other two.

Table 4 shows the service area defined using the buffer method, calculated in hectares and as a percentage of the total municipality area. In contrast, Table 5 shows the same information for the service area defined using network analysis. Using the buffer method, the service areas defined at 300 m and 800 m covered 20–43% of Dammam based on the first assumption, 22–46% based on the second assumption, and 44–72% based on the third assumption. Using the network analysis method, the service area based on the first assumption ranged from 7–38%, the second from 7–40%, and the third from 18–70% for Dammam.

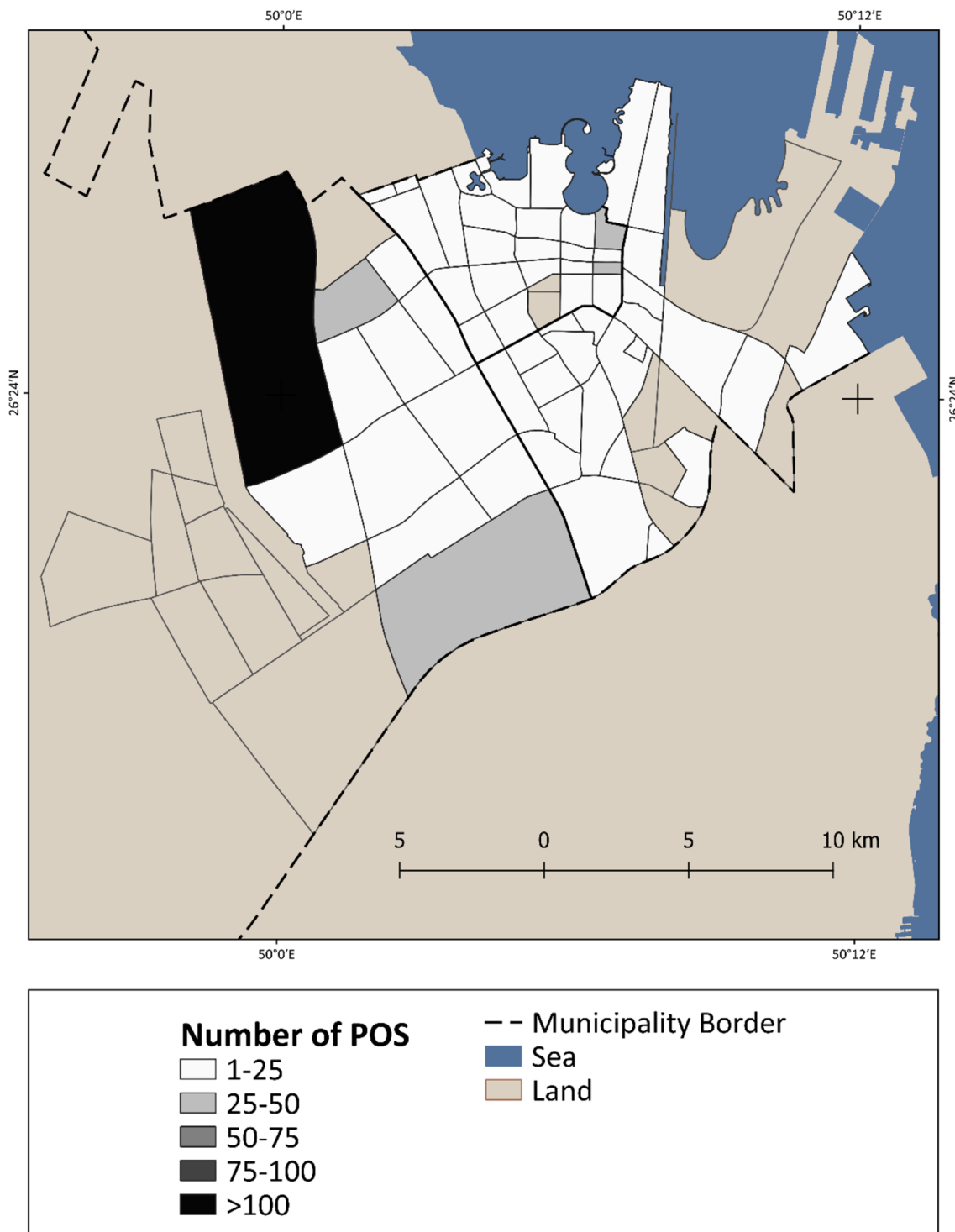


Fig. 3 Number of POS

4 Discussion

POS is essential to improve the quality of life of city residents. However, providing an adequate POS is challenging for city planners, designers, and managers. The first step in

solving this problem is to inventory and evaluate current and potential POS for development. GIS was used to assess the POS in Dammam, a major city in Saudi Arabia. All POS were inventoried and categorized into five categories based on function, scale, and service: parks, walkways, plazas,

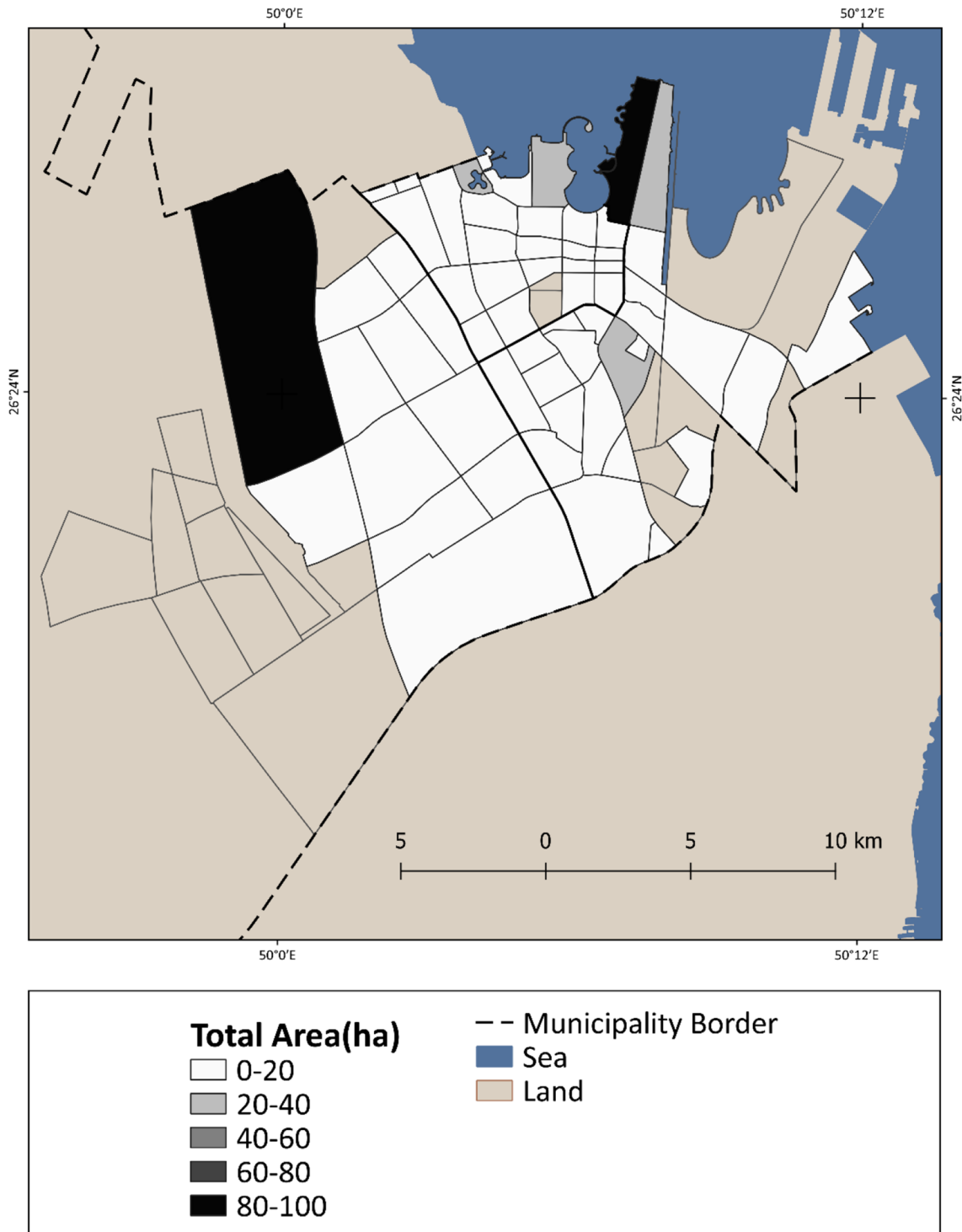


Fig. 4 Area of POS

waterfronts, and proposed parks. Three assumptions were proposed to develop spaces to provide Damman with a sufficient and accessible POS. The first assumption dealt with parks and walkways, the second added plazas and waterfronts, and the third considered all available POS in the city.

The evaluation tools included per capita POS and the service areas that provided access to these spaces.

Since 2018, Saudi Arabia has adopted a strategy to increase per capita POS to reach the minimum standard value proposed by the WHO ($9 \text{ m}^2/\text{person}$) [40]. The per

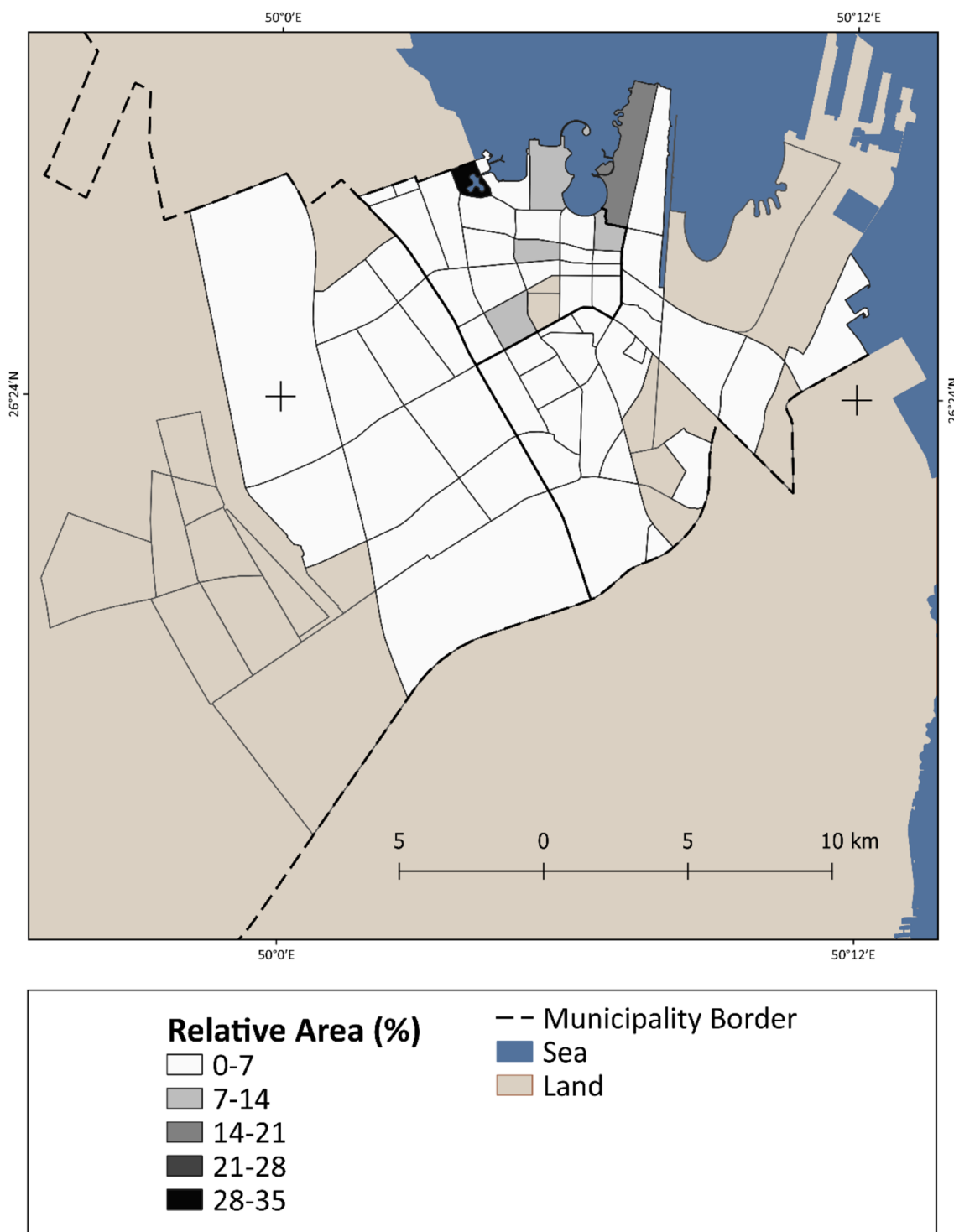


Fig. 5 Relative area of POS

capita POS for Dammam does not exceed 7 m²/person if we consider all available POS in the city. Earlier studies estimated the per capita POS in Dammam as 5.4 m²; however, that study dealt with the Dammam Metropolitan Area, which includes Dammam, Khobar, Dhahran

and Al-Qatif [33]. CM of Dammam has a very low per capita POS according to any standard. EM is better than other municipalities and has a higher per capita POS than other municipalities; however, these values are still lower than the standard. Studying the per capita POS at

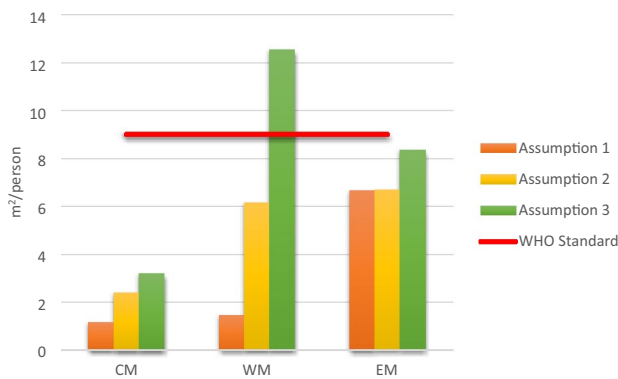


Fig. 6 A comparison for per capita POS to WHO proposed standard for three assumptions

the neighborhood level provides a different perspective: 59 neighborhoods are populated, while another 17 are emerging.

Considering the first assumption, eight neighborhoods had per capita POS exceeding the WHO standard ($9 \text{ m}^2/\text{person}$). According to the second assumption, there are 13 with per capita POS that are more significant than WHO standards. This number becomes 21 neighborhoods when considering the third assumption. The difference in the results for calculating per capita POS at different levels of administrative units can be explained by the variation in the presence of neighborhoods with high population densities and large land areas. However, they lack sufficient POS, causing noise in the data, which affects the outcome of calculating the per capita POS at the municipal level.

Accessibility to POS and their service areas was studied using two GIS methods: the buffer method and network analysis method. Applying the two methods shows that the POS service areas cover most of Dammam City, and the POS can be accessed by walking (300 m) or using light vehicles (800 m), such as bicycles. The buffer method provides a larger service area than the network analysis method. For example, the 300 m service area for Dammam POS calculated using the buffer method is 6837.3 ha, or 20.5% of the area; it is 14384.63 ha, or 43% of the 800 m service area. For the network analysis, the 300 m service area is 2342 ha, or 7.01%, and 12,824.2 ha and 38.5% of the 800 m area. Considering all the assumptions, the buffer method results show that the 300 m service area for urban open spaces covers at least 20% of Dammam's area, while the 800 m service area covers at least 43%. Conversely, the network analysis results show that the 300 m service area covers at least 7% of the city,

while the 800 m service area covers 38% of the entire city. This means that in large areas of the city, residents do not have easy access to POS.

5 Conclusion

The problem of evaluating POS was studied using an estimation approach for per capita POS for different level administrative units, and using the service area of POS as an indicator of accessibility. Per capita POS was estimated as the ratio of total POS area in an administrative unit to its population. Considering the variation in area and population, per capita POS may vary across neighborhoods. Evaluating the per capita POS at the neighborhood level is recommended to obtain more reliable information. Evaluation of per capita POS at a higher administrative level may provide misleading information. The service area of the POS was calculated using two GIS methods: buffer and network analysis. The buffer method is easy to use, does not require complex data, and provides interpretable information. However, the buffer method does not consider natural or artificial barriers that can reduce the POS service area. On the other hand, GIS-based network analysis provides reliable information about the service areas of POS because it considers the users' paths and the natural or artificial barriers that restrict the movement of users. Therefore, the service areas provided by the buffer method more significant and less accurate than those provided by buffer analysis. Network analysis requires large amounts of complex data regarding road networks and characteristics. A comparison of service areas calculated using network and buffer analyses may reveal the areas required to improve POS accessibility.

Although Saudi Arabia aims to increase the per capita POS to match the WHO-suggested standard, the results of this study show that the per capita POS in Dammam is lower than the WHO standard for all development assumptions discussed here. This implies that Dammam City will lack sufficient POS in the future, which is a significant challenge for urban developers. The service area provided by the network analysis shows that a major proportion of the current Dammam residents can access the available and future POS. However, a significant proportion of the residents live outside the POS service areas. Future studies may discuss additional criteria for improving the reliability of this evaluation. Public participation geographic information systems (PPGIS) may serve as a framework for this future purpose and improve our understanding of the role of POS and how they interact with society and impact the environment. Notably, this study demonstrated the capabilities of open data and open-source GIS packages to provide a full framework for urban planning, evaluation, and management.

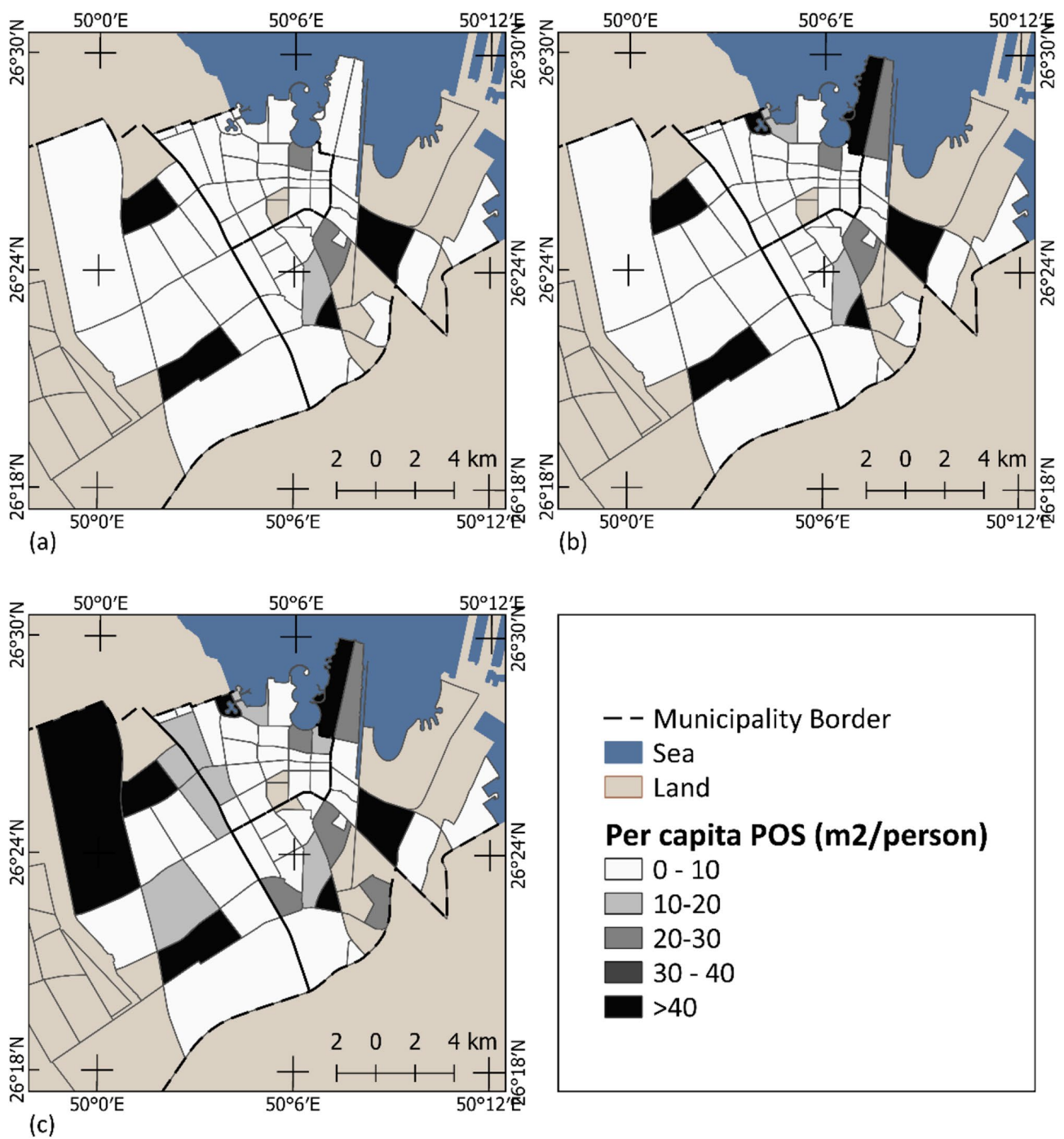


Fig. 7 Per capita POS for a assumption 1, b assumption 2, and c assumption 3

Table 3 Summary of POS per municipality per assumption based on the per capita POS

Per capita POS (m ² /person) class	Frequency						Total
	<9	9–18	18–26	26–30	> 30	Blank	
Municipality							
<i>First assumption</i>							
CM	23	0	1	0	0	2	26
WM	10	0	0	0	2	10	22
EM	18	2	0	1	2	5	28
Total	51	2	1	1	4	17	76
<i>Second assumption</i>							
CM	20	2	1	0	1	2	26
WM	10	0	0	0	2	10	22
EM	16	2	1	1	3	5	28
Total	46	4	2	1	6	17	76
<i>Third assumption</i>							
CM	18	2	3	0	1	2	26
WM	5	4	0	0	3	10	22
EM	15	1	3	1	3	5	28
Total	38	7	6	1	7	17	76

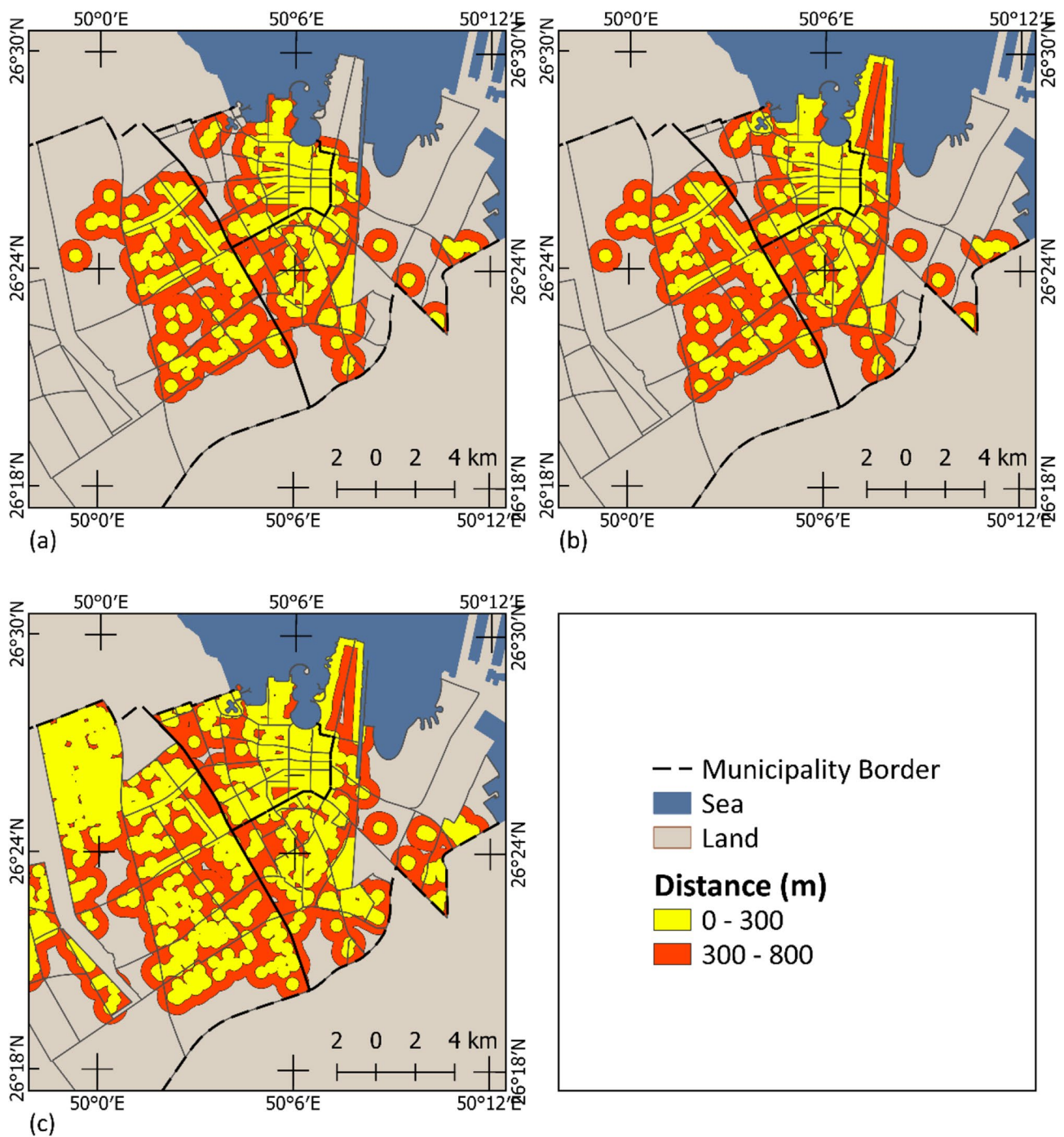


Fig. 8 POS service area using buffer method for **a** assumption 1, **b** assumption 2, and **c** assumption 3

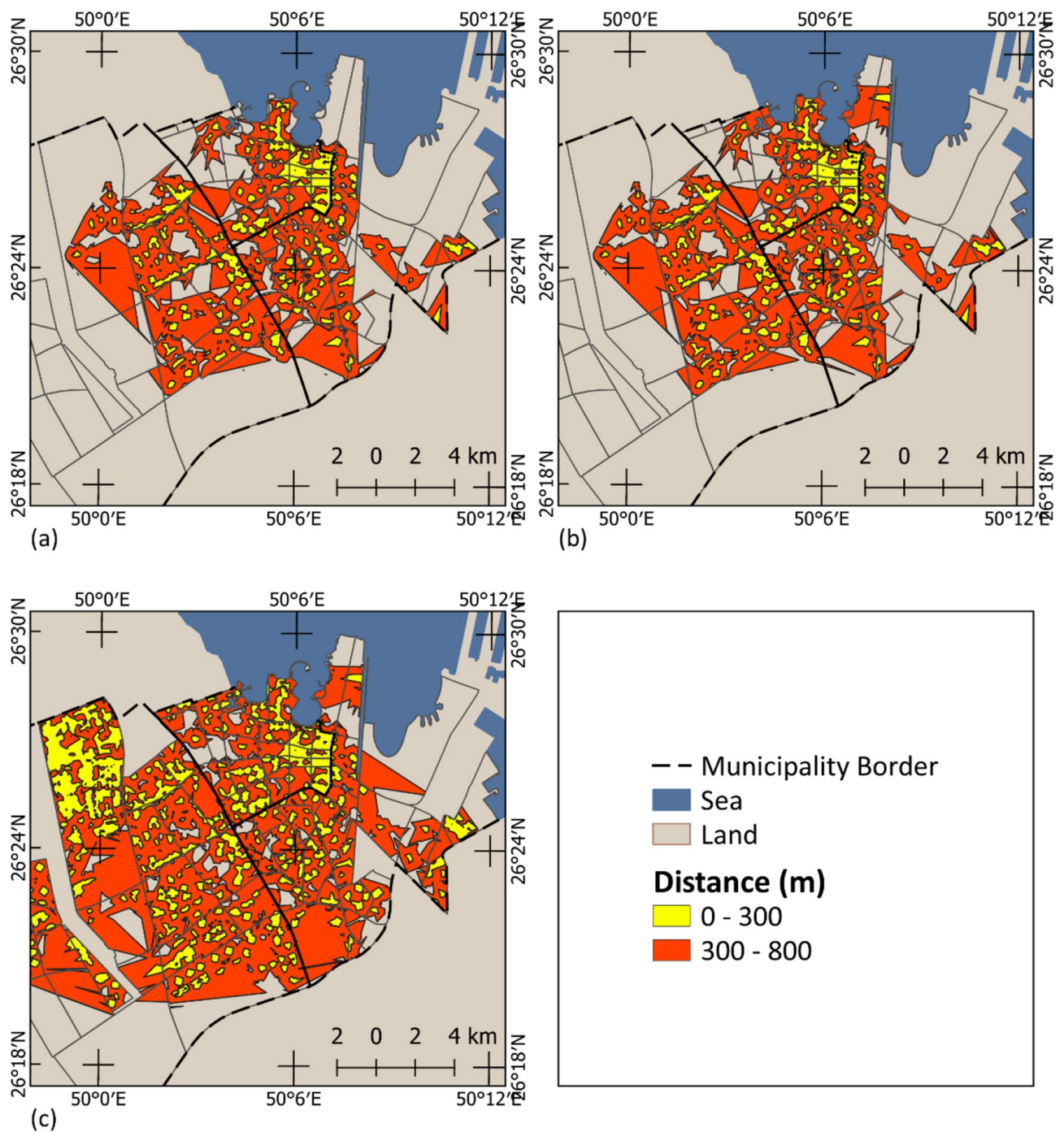


Fig. 9 POS service area using network analysis (Isochrone method) for **a** assumption 1, **b** assumption 2, and **c** assumption 3

Table 4 Service area and its percentage of municipality area based on a buffer method

Municipality	Area (ha)		%	
	300 m	800 m	300 m	800 m
<i>First assumption</i>				
CM	1915.24	2989.42	49.47%	77.21%
WM	2626.37	6352.38	13.24%	32.03%
EM	2295.67	5042.83	23.70%	52.05%
Dammam	6837.28	14,384.63	20.48%	43.08%
<i>Second assumption</i>				
CM	2097.98	3093.83	54.18%	79.90%
WM	2626.37	6352.38	13.24%	32.03%
EM	2800.15	5944.16	28.90%	61.36%
Dammam	7524.50	15,390.37	22.53%	46.09%
<i>Third assumption</i>				
CM	2765.45	3821.03	71.42%	98.69%
WM	8182.15	13,140.54	41.26%	66.26%
EM	3658.03	7125.71	37.76%	73.55%
Dammam	14,605.64	24,087.28	43.74%	72.14%

Table 5 Service area and its percentage of municipality area based on a network analysis (Isochrone method)

Municipality	Area (ha)		%	
	300 m	800 m	300 m	800 m
<i>First assumption</i>				
CM	834.44	2595.99	21.55	67.05
WM	867.41	5889.73	4.37	29.70
EM	639.14	4338.50	6.60	44.78
Dammam	2340.98	12,824.22	7.01	38.41
<i>Second assumption</i>				
CM	868.68	2720.01	22.44	70.25
WM	867.43	5913.61	4.37	29.82
EM	695.82	4890.40	7.18	50.48
Dammam	2431.93	13,524.02	7.28	40.50
<i>Third assumption</i>				
CM	1215.23	3385.24	31.39	87.43
WM	3770.13	13,443.34	19.01	67.79
EM	1058.17	6368.08	10.92	65.73
Dammam	6043.53	23,196.65	18.10	69.47

Declarations

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Ethical approval The material in the study has been ethically approved by all of the paper's authors.

Consent for publication All the authors of the paper give their consent to publish the material presented in the paper.

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