Urban green infrastructure in Zagreb

an accessibility model

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GREENPEACE

Impressum

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Introduction: Urban green infrastructure

As part of urban green infrastructure[1] parks, urban forests, and public gardens provide important ecosystem services, from mitigating heat island effects and filtering air pollutants to providing habitats for wildlife and recreational opportunities for city residents (Larondelle and Lauf 2020:20).

In the context of the global Covid-19 crisis and social distancing the value of urban green infrastructure has even increased over the last year. While everyday mobility declined, people were discovering their neighbourhood, using local green areas to exercise, socialise, and indulge in other recreational activities (Hanzl 2020: 2; Samuelsson et al 2020: 2). This increase in demand for green areas is clearly evident from mobile tracking data (Google 2020; Venter et al. 2020).

Many cities worldwide responded to increased demand with short-term measures to increase space for recreation and walking, for instance by (partially) closing streets to motor vehicles or creating temporary parks (Hanzl 2020:1). These short-term measures, however, cannot meet the demands for permanent green infrastructure, as has been pointed out by the European Strategy for Green Infrastructure (European Commission 2013).

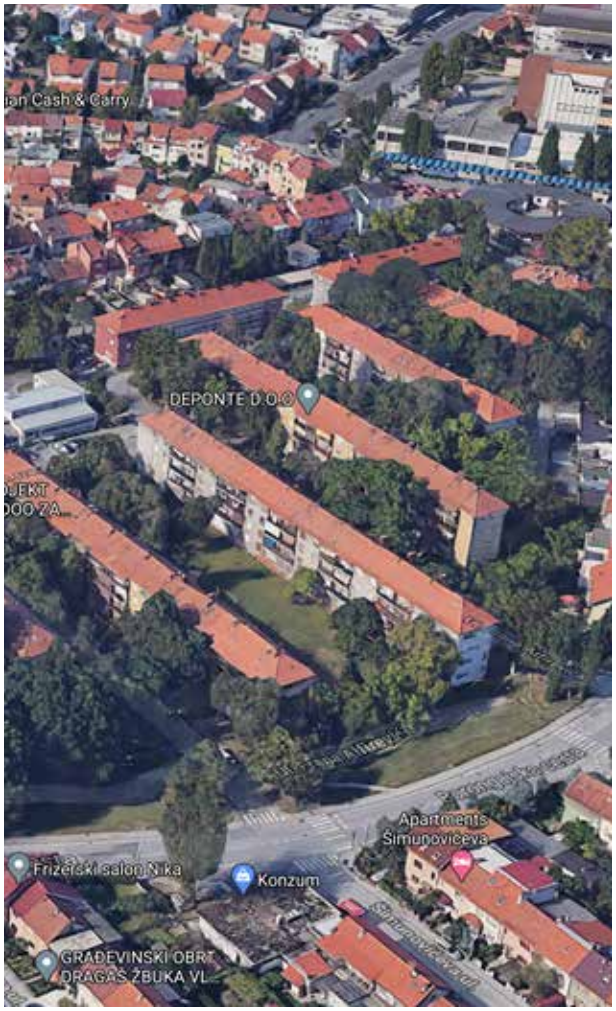
Green areas vary considerably in size and level of amenities (Rigolon 2016: 161), while their use will often depend on the proximity to the place of residence, especially on working days (Gundersen and Frivold 2008). Therefore, mere quantification of the size of green spaces per district or smaller statistical units is of limited use in assessing green infrastructure. This kind of assessment is based on the ratio of green space relative to overall area or relative to district (statistical unit) population and does not take into account that people are not limited to green space within their particular residential unit.

This is why such assessments are replaced by analytical approaches incorporating accessibility in terms of the amount of time and/or distance needed to reach the closest park or green space. Recent years

1 According to the European Commission, green infrastructure can be defined as "a strategically planned network of high quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity in both rural and urban settings." (2013:7).

have seen a growing number of studies analysing the distribution of green areas in different cities and highlighting disparities in accessibility between ethnic and socioeconomic groups (e.g., Lee and Hong 2013; Dony et al. 2015).

Figure 1) Examples of urban green (Google 2021)



Study design

The objective of this study was to analyse real-life availability and accessibility of public green infrastructure in Zagreb as objectively as possible.

Accessibility in this context is expressed as distance to the next park or green space entry point, measured in walking minutes, as it is more relevant to the population than any straight line distance. This allows us to identify different supply patterns, often connected with building structures, as well as underserved areas.

The project provides an empirical insight into the relationship between demand for green infrastructure and supply on a local level. We therefore used two models:

Model 1 covers the supply side by identifying the existing public green infrastructure for close-to-home recreational purposes.

Model 2 is a demand model, primarily based on a network-based calculation of service areas and an overlay with residential population (network-analysis).

The main method used is service area analysis, a specific kind of network analysis which determines the area covered in a certain amount of time and/or distance using a route-network (the next chapter provides a detailed description of this method). Using the so called "popisni krug" (PK, enumeration district) as the statistical unit, the supply side of parks is complemented by sociodemographic information provided by the Croatian Bureau of Statistics. The accessibility of parks and the information about population density per statistical unit are combined to identify areas where green infrastructure is in short supply for a large number of residents. Additionally, certain age groups – those under 19 and over 60 years – are described separately, as those age groups have special demands regarding green urban spaces.

Project specifics

The analysis is limited to public green infrastructure, which means that private green areas, such as gardens or commercial forests, are not included in the model calculation of supply. Moreover, spaces such as school yards or community gardens are not considered public green infrastructure, as they are not accessible by the general public. Since these

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spaces also influence the perception of Zagreb's urban landscape, our analysis will show that even some of the districts considered "green" by their residents lack in accessible close-to-home green infrastructure.

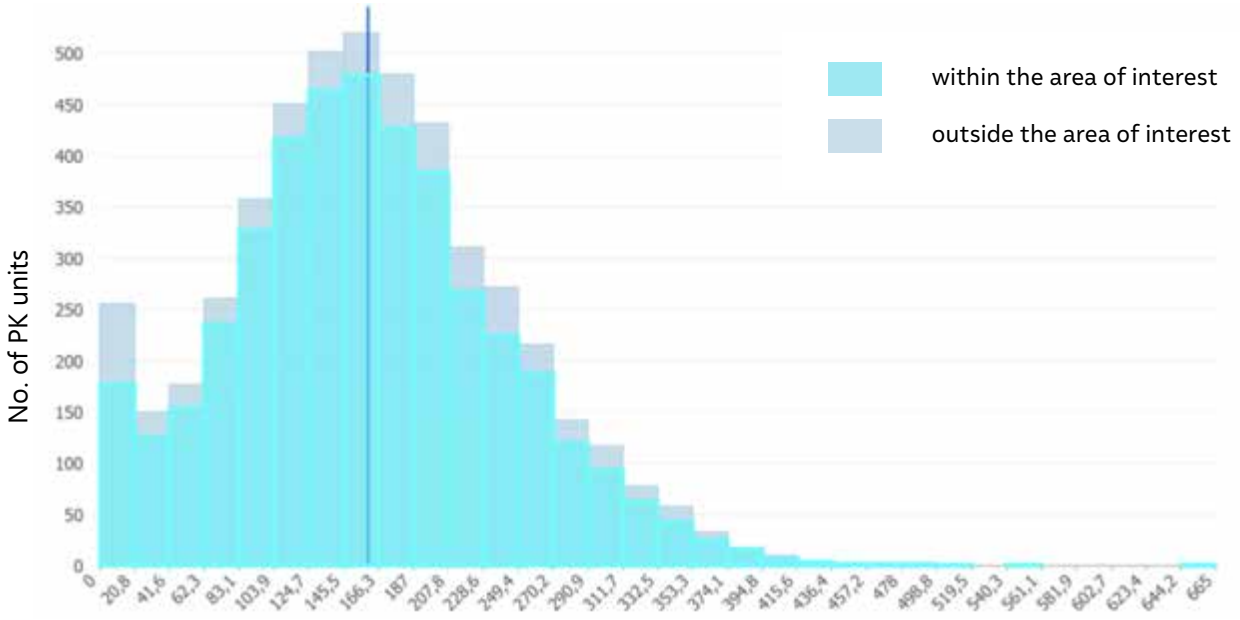
The area of interest for the project was identified in several stages, based on the quality of combined data about the building stock (OpenStreetMap, OSM), pedestrian infrastructure (OSM), census data (2011), and data about green infrastructure (Geoportal Zagreb / City of Zagreb)[2].

Data quality for the eastern and southern parts of Zagreb did not keep up with the rest of the city. Overall, the area of interest covers 87% of Zagreb's population (2011).

Figure 2 shows the share of statistical units within the area of interest by their population size.

2
1. Croatian Bureau of Statistics
2. State Geodetic Administration of the Republic of Croatia
3. City of Zagreb – Office for the Strategic Planning and Development of the City
4. City of Zagreb – Office for Physical Planning, Construction of the City, Utility Services and Transport
5. Zagrebački holding - Podružnica Zrinjevac

Figure 2) Administrative units by population size within / outside the area of interest (own illustration)



PK units by population (in ascending order)

Methodology and data

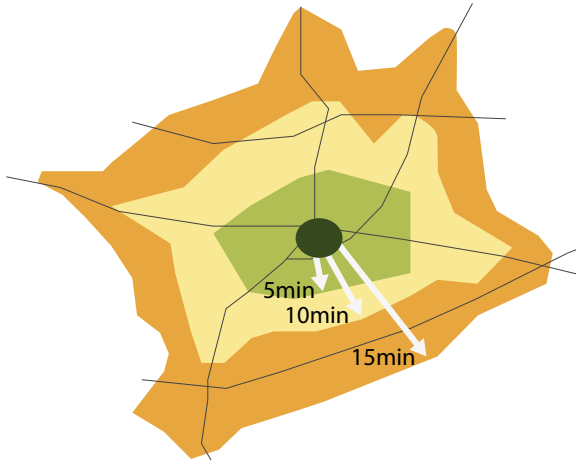
Service area analysis

In order to identify the population in proximity to the parks, service areas were calculated in the Geographic Information System (GIS) using network analysis.

Network analysis uses an approach similar to how car, bicycle, or hiking routing applications work to calculate the "shortest path" in terms of time and/or distance between a single starting point and a single destination – both set individually and interactively by the user. In the GIS-based network analysis it is possible to calculate distances from any point within the area of interest to a pre-defined set of destinations. In our case, points along the street network are set as starting points, whereas the access points to green infrastructure, e.g., park entrances, are set as destination points. The algorithm calculates and returns the shortest path for each point and stores the corresponding information. Finally, points of equal time/distance are connected to delineate multiple concentric service areas for different time intervals: 0–5 minutes, 5–10 minutes, and 10–15 minutes.

As the analysis uses walking times, the calculation is based on Zagreb's network of pedestrian infrastructure. The assumed walking speed is 3.6 km/h, equivalent to 1 m/s, which corresponds to a rather slow walk. Where walking infrastructure crosses barriers, such as main streets or railway infrastructure, the walking speed decreases by a factor of 0.66–0.83, depending on the type of barrier. The coverage within areas enclosed/surrounded by sidewalks, walkways, or footpaths is calculated with a specific algorithm in order to return two-dimensional coverage areas. Streets outside the areas with documented sidewalks are categorised as "walkable". The same goes for mixed areas for pedestrians and cyclists, which are considered usable for pedestrians without any restrictions. In the project, access points are either identified as intersections between the existing walking infrastructure and the outlines of green infrastructure, or, where no such intersection exists according to the available data sources, as three closest points to a segment of walking infrastructure. Figure 4 shows what these access points look like and how they are connected with the pedestrian infrastructure network.

Figure 3) Service area approach (own illustration)



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Data sources and pre-processing

Figure 4) An example of a street map with access points (own illustration)

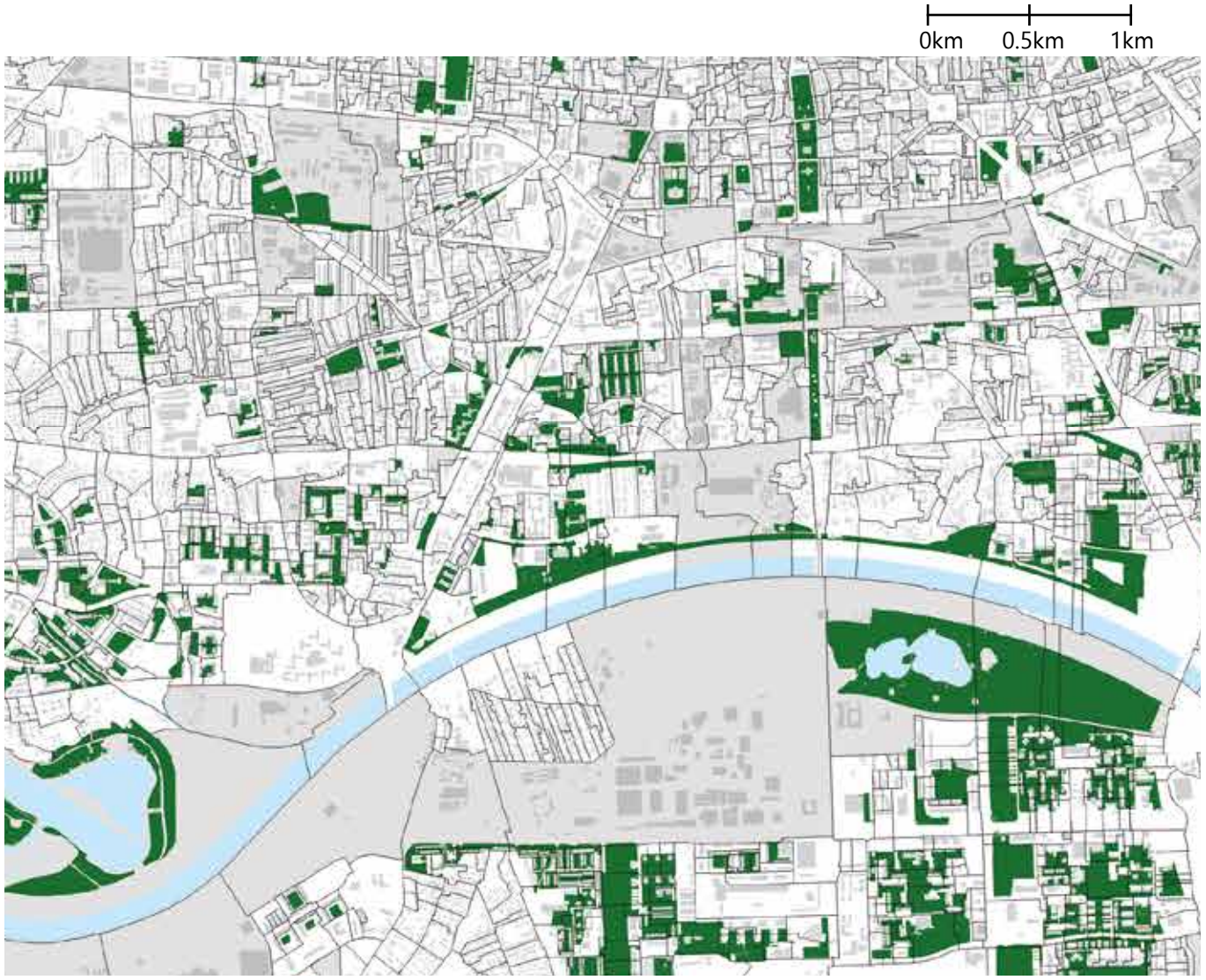
The analysis combines data of different kind from different sources. Green infrastructure for recreational purposes, such as parks, has been identified and characterised based on information and geodata from Zagreb GeoPortal (https://geoportal.zagreb.hr). Katastar zelenila (Green cadastre) maps geo-objects representing areas covered by grass / lawns – (*travnjaci*), playgrounds and sporting areas (*igrališta*), park outlines (*granice obuhvata*), trees in public areas (*stabla*), or park facilities/equipment (*parkovna oprema*). This information on green infrastructure was complemented with aerial photographs (CDOF) from the GeoPortal (2012 and 2018) as well as Google and Bing Maps. Monofunctional playgrounds and parks with and without playgrounds were identified based on park facilities/equipment data, whereas forests with recreational use were categorised as such based on the GeoPortal information on forests and on aerial photographs. To validate the green infrastructure classification and verify public accessibility, an on-site check was conducted between 26 and 29 March 2021.

The street network used for network analysis is based on OpenStreetMap (OSM / Geofabrik), which is also the source of information on walking barriers, including railway infrastructure, main or particularly busy streets, and bodies of water. Street borders of the OSM-derived pedestrian infrastructure network were later manually edited based on aerial photographs (CDOF). Geodata on administrative units were provided by the State Geodetic Administration. Moreover, sociodemographic data, e.g., on age groups, were obtained from the Croatian Bureau of Statistics. This dataset contains 2011 census information on population by administrative units in total and for different age groups.

Public green infrastructure in Zagreb

Map 1 gives an overview of Zagreb's public green infrastructure. All areas coloured in green were included in further analysis not only as green but also as public areas.

The distribution of parks across the city follows specific patterns. Within the area of interest, there are vast forest areas and larger parks in the south of the city. Other large areas are without public green infrastructure. The inner city / wider center has a large number of smaller parks, from those decorative in the old centre to green spaces skirting larger building structures built between the 1960s and 1990s. The latter type is dominant south of the Sava River. Moreover, close to the river there are some bigger lakes surrounded by green spaces, such as Lake Jarun.



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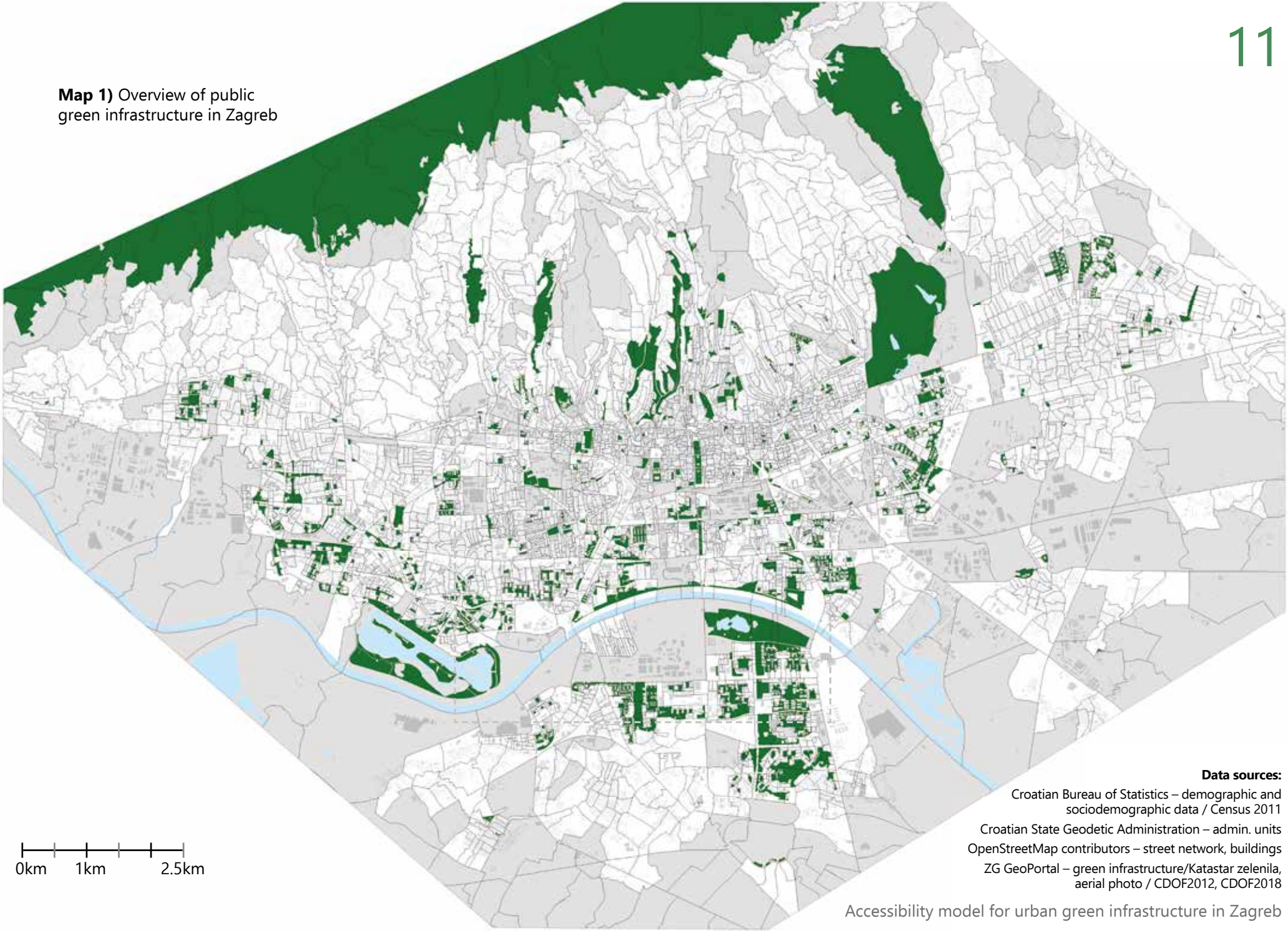
Map 1) Overview of public green infrastructure in Zagreb



Data sources:

Croatian Bureau of Statistics – demographic and sociodemographic data / Census 2011

Croatian State Geodetic Administration – admin. units

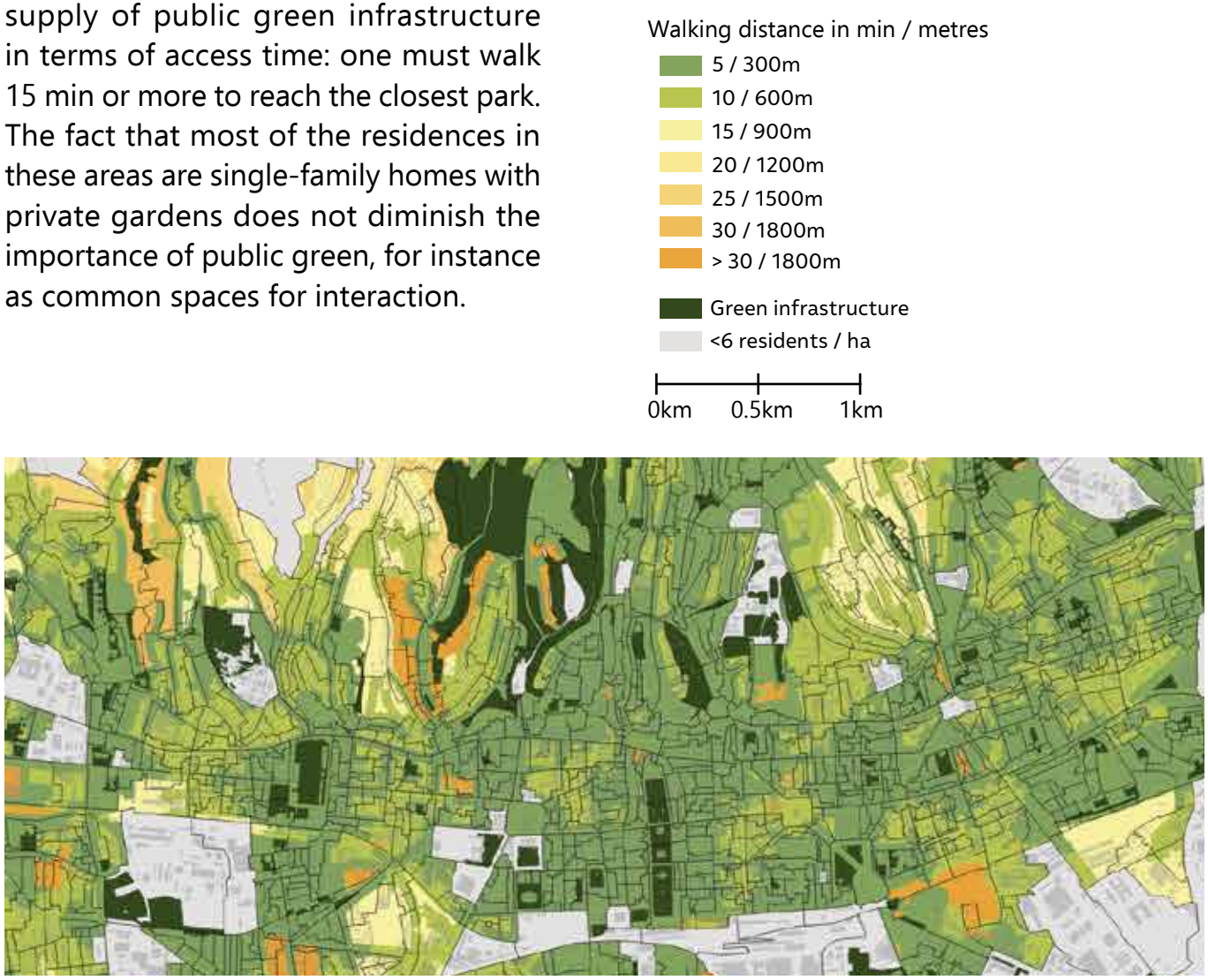
OpenStreetMap contributors – street network, buildings

ZG GeoPortal – green infrastructure/Katastar zelenila, aerial photo / CDOF2012, CDOF2018

Service area analysis: 7 classes

Map 2 *Zagreb – Green infrastructure accessibility analysis / Green infrastructure – service areas* shows the results of the service area analysis. Shades of green to orange indicate the walking time to the closest public green infrastructure entrance. Statistical units with a population density below six persons per hectare are excluded/dimmed to grey. Most of these areas are industrial or non-residential. Small playgrounds occupying <1000 sq m (representing the lowest tenth of the total distribution) have been excluded from analysis, as they are only used by specific user groups.

At first glance, Zagreb looks quite green. Dark green is particularly dominant in the inner city , which means that the closest parks are less than 300 m away from residences. The same is true for half of the area south of the Sava River. On the city outskirts, north and south, there are large orange areas indicating poor supply of public green infrastructure in terms of access time: one must walk 15 min or more to reach the closest park. The fact that most of the residences in these areas are single-family homes with private gardens does not diminish the importance of public green, for instance as common spaces for interaction.



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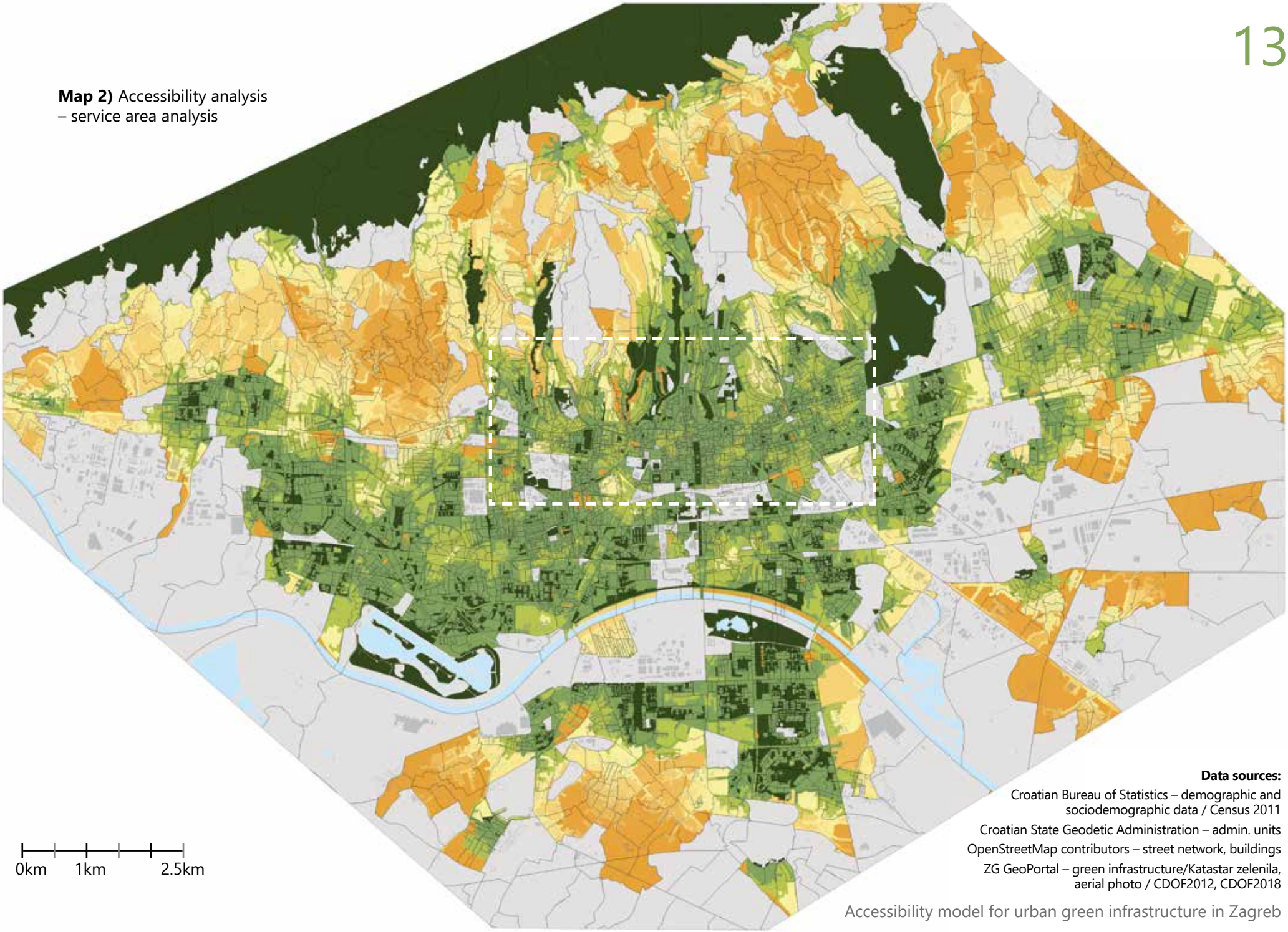
Map 2) Accessibility analysis – service area analysis



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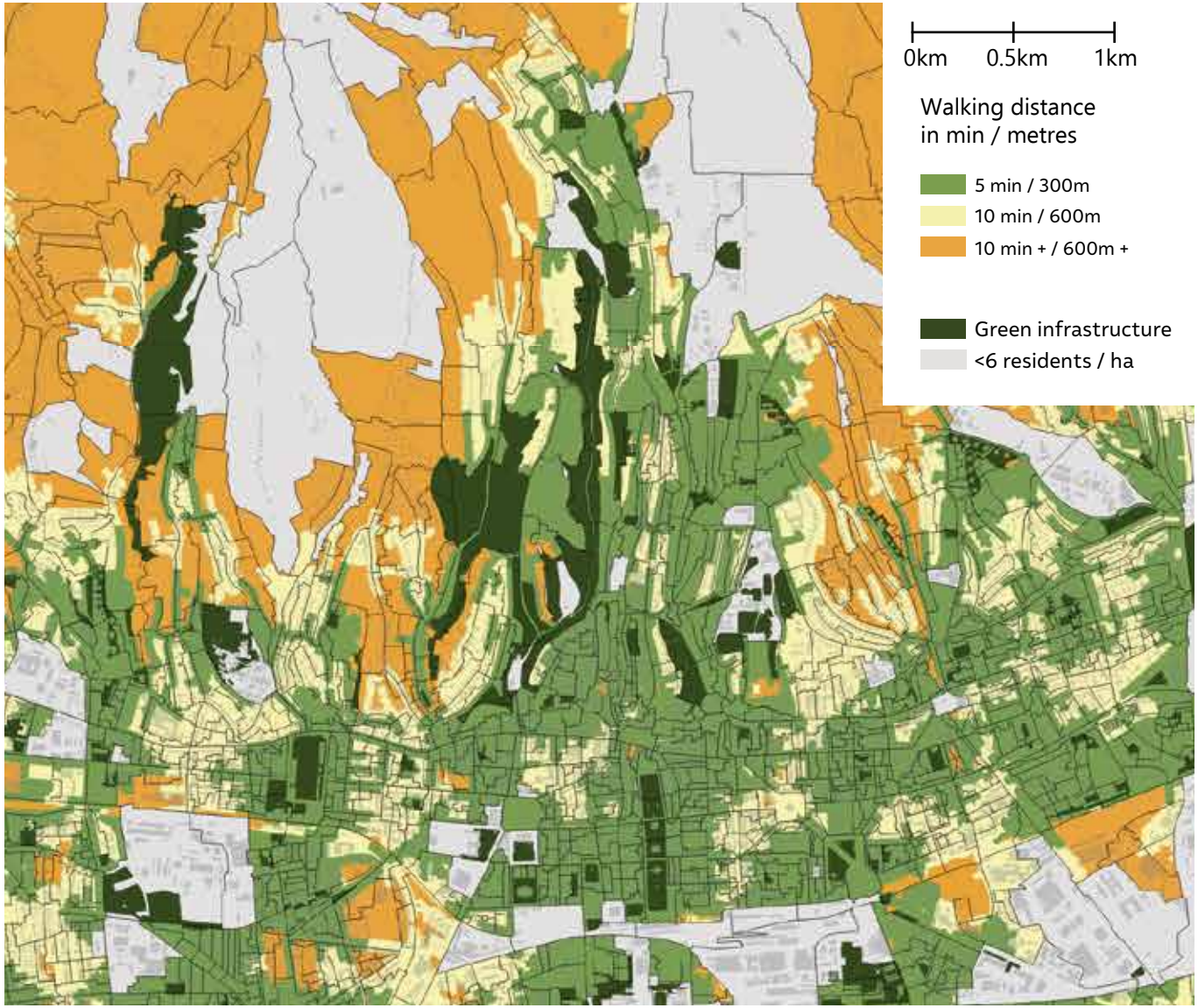
ZG GeoPortal – green infrastructure/Katastar zelenila, aerial photo / CDOF2012, CDOF2018

Service area analysis: 3 classes

Map 3 shows the same analysis of green infrastructure service areas as Map 2 (pp. 12 and 13) but with the number of classes reduced to three (instead of seven). This reduction simplifies the interpretation of green infrastructure accessibility.

Green areas represent closest parks that can be reached on foot in less than 5 min, which corresponds to the WHO recommendation for urban green infrastructure (2016). The residents of orange areas have to walk to the closest public green area for 15 min or more, which is too far from an urbanist point of view.



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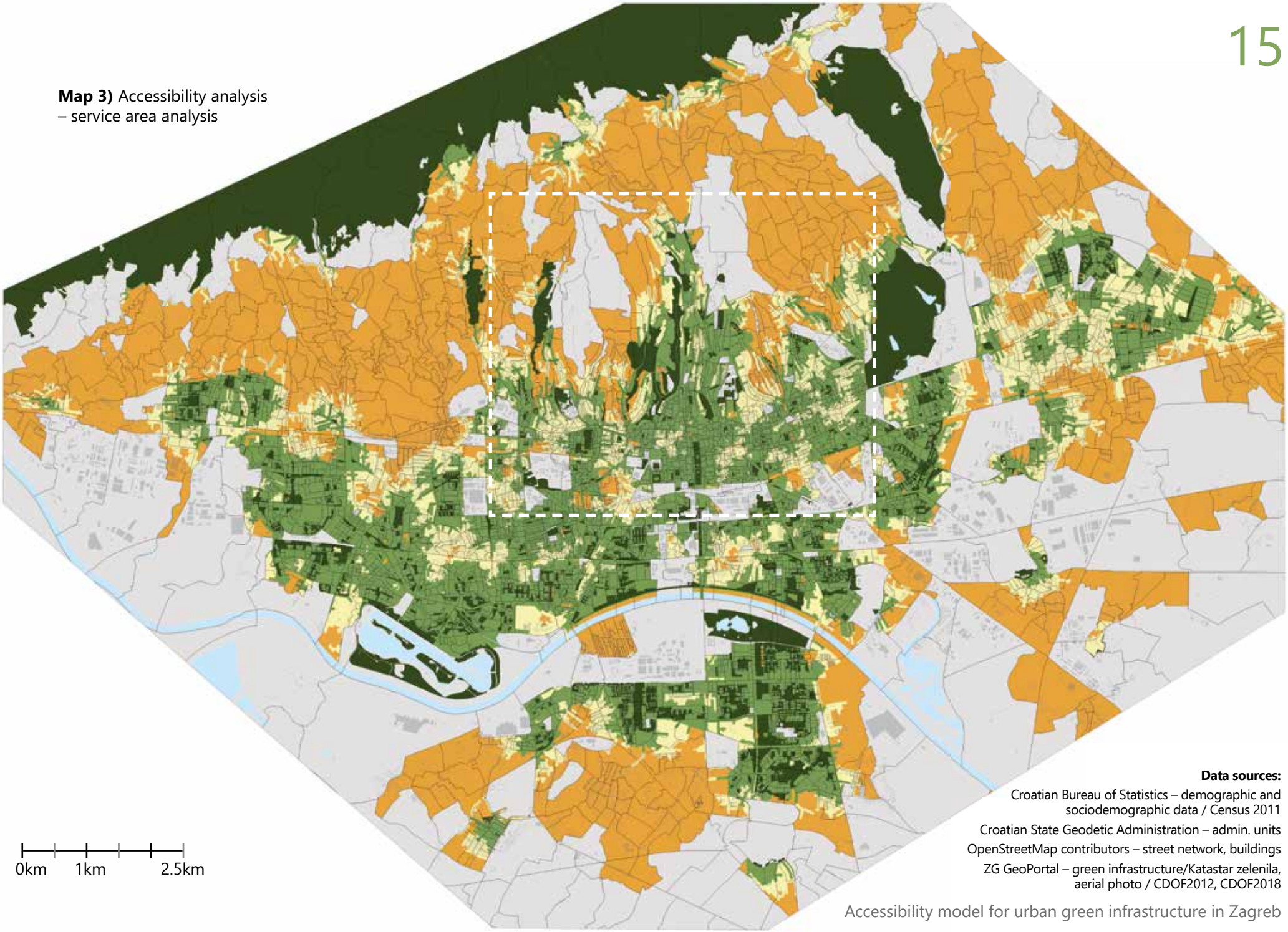
Map 3) Accessibility analysis – service area analysis



Data sources:

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Croatian State Geodetic Administration – admin. units

OpenStreetMap contributors – street network, buildings

ZG GeoPortal – green infrastructure/Katastar zelenila, aerial photo / CDOF2012, CDOF2018

Population within the 5-minute walking distance

The results from the service area analysis served to determine the percentage of people living within the 5-minute walking distance per statistical unit. According to the WHO recommendation, the 5-minute walking distance – which corresponds to the 300 m distance at a walking speed of 1m/s – is a reasonable threshold to assess the quality of access to close-to-home green infrastructure (2016).

As population data per building were not available, we used building footprint size as a proxy to assess population distribution within statistical units. This proxy is calculated from the ratio between the footprint area of a residential building within the 5-min walking distance and the sum of all residential building footprints for each administrative unit individually. For instance, values of 0.9–25% indicate that just up to a quater of the buildings (and thus a small part of the residential population) have access to any green infrastructure within the reference 5-min or 300 m walk.

The map below identifies the areas in which residential population is underserved with nearby public green infrastructure. Moreover, it is used for the analysis presented below.

The graph in Figure 5 shows the share of people living within 300 m to the closest park. About 60% of the population of the area of interest (about 412.500 of 679.000) in Zagreb are living within this distance. As the average share in Europe is 44%, the share for Zagreb can be considered rather high.

Figure 5)
Percentage of population within the 300-metre distance

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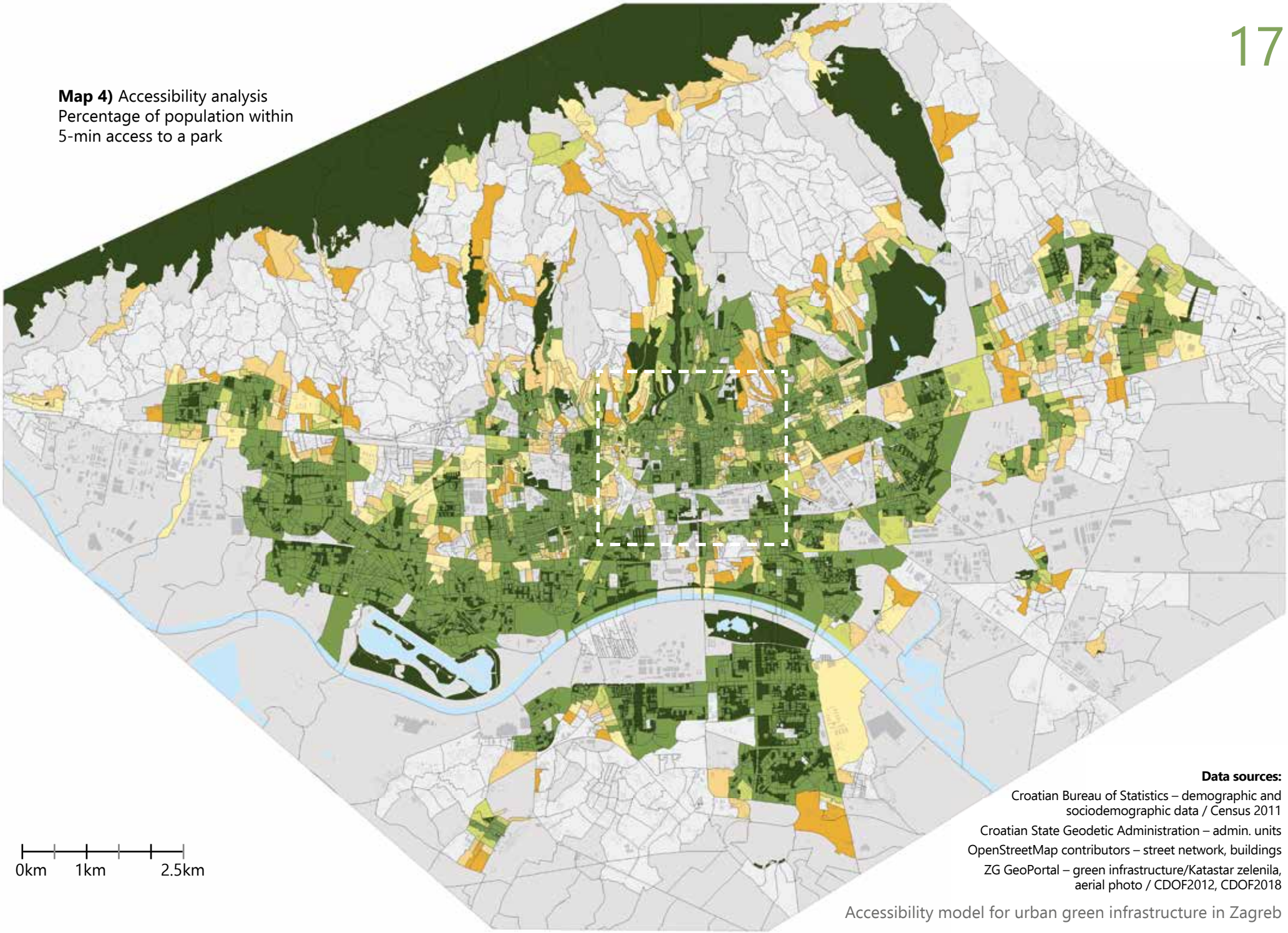
Map 4) Accessibility analysis
Percentage of population within
5-min access to a park



Data sources:

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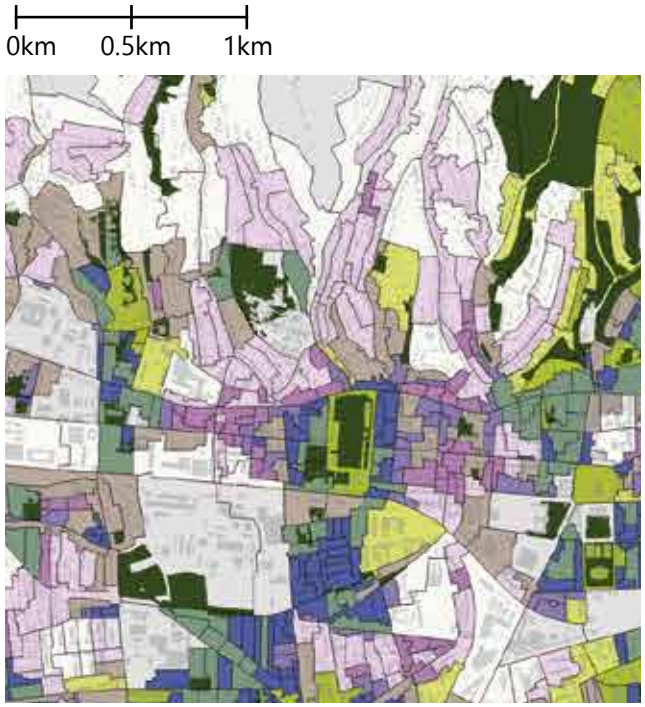
OpenStreetMap contributors – street network, buildings

ZG GeoPortal – green infrastructure/Katastar zelenila, aerial photo / CDOF2012, CDOF2018

Population density and accessibility

The map below shows two dimensions in relation to each other. The vertical (violet) axis on the legend represents population density, while the horizontal (green) axis the percentage of people living within the 5-min walking distance from the closest park entrance. The statistical unit serves as a common scale. The combination of both dimensions allows to identify areas with high population density and low accessibility to green spaces (dark purple). This category can be considered as the most problematic. The map shows the share of population living within the 5-min distance from green infrastructure (compare with Map 4: *Percentage of population within 5-min access to a park*) and 2011 census data by statistical unit (PK). The city centre and the multi-storey residential areas toward the periphery do show a high level of accessibility as well as high population density. This points to a highly likely intense use of the available green infrastructure. A field survey that focuses on the way and intensity of use could help identify the real situation in particular parks and green spaces.

The overall picture is quite mixed and draws attention to specific neighbourhoods, like the areas of interest we take a closer look at later (pp. 30–33). Shades of green indicate that the number of residents per hectare is rather low while their access to parks is good. Blue means that the population density is high and green infrastructure is available in proximity. However, it is likely or at least possible that some of the green areas are not big enough to serve the surrounding neighbourhoods, as the analysis based on available data cannot take potential overuse and the size of public green spaces into account. The WHO recommends at least 9 sq m of green open space per resident (2009). In Zagreb this number is slightly higher (12.7 sq m/resident). As discussed in the introduction, the real meaning of either of these figures is limited, as they do not take into account spatial distribution or usability.



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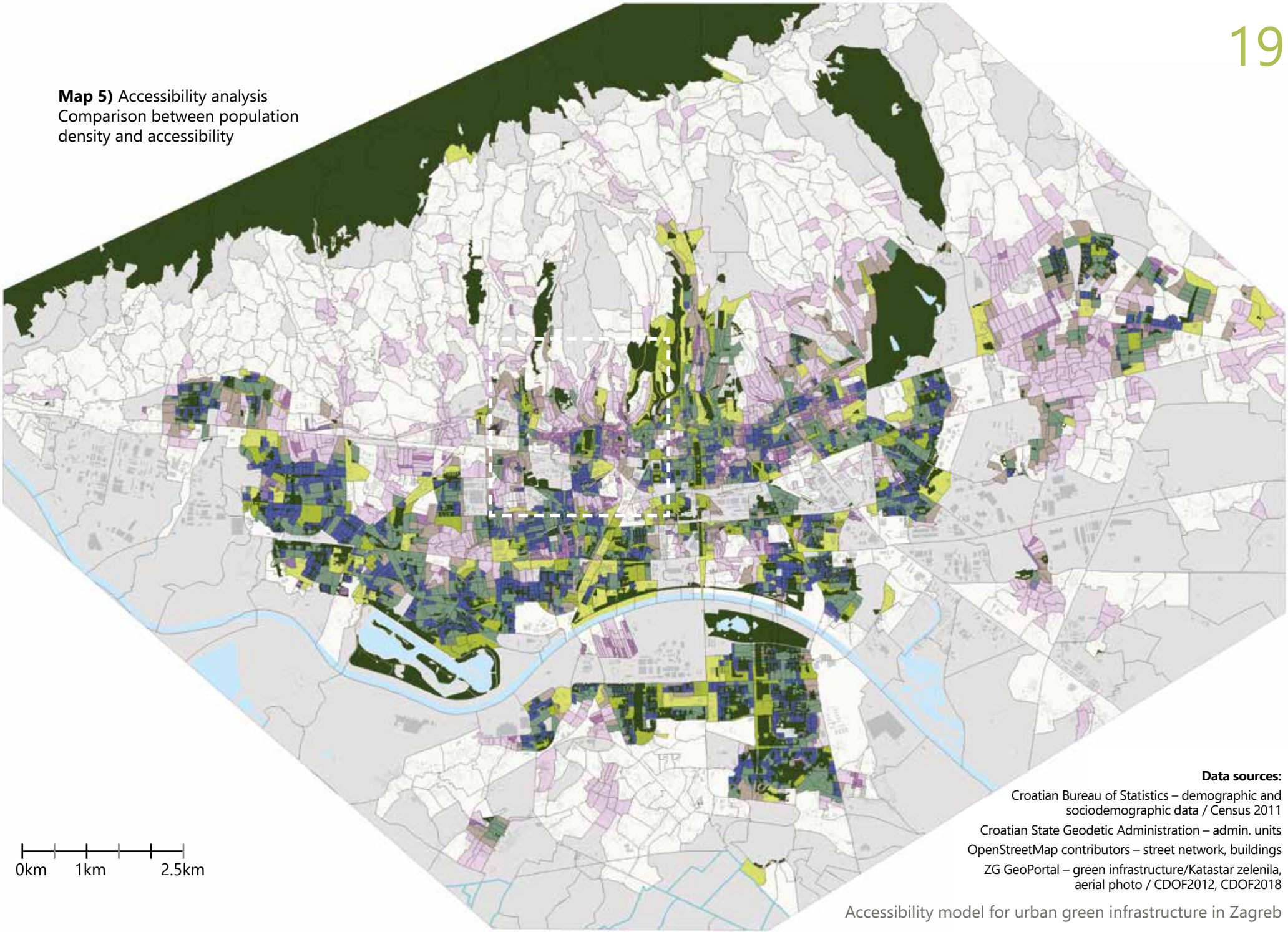
Map 5) Accessibility analysis
Comparison between population density and accessibility



0km 1km 2.5km

Data sources:

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Population density (0–19 yrs.) and accessibility

Like the map *Zagreb – Green infrastructure accessibility analysis – Population – Density vs. accessibility per statistical unit* this map compares two dimensions. The horizontal (green) axis shows the percentage of people living within the 5-minute walking distance from the closest park entrance, while the vertical (violet) axis shows the percentage of people younger than 19 years as per the 2011 census.

There are large areas with an above-average share of children and teenagers, especially on the periphery, of which many are underserved with green infrastructure open to the public[3]. The lower percentage of young people in the city centre (compare with the map *Accessibility analysis – Age group 0–19 vs. 60+ yrs.*) coincides with mid and high population percentages with 5-min access to green infrastructure in the city centre.

3 In terms of data availability, quality, and up-to-dateness, some administrative units show unreliable figures, such as the area on the northern bank of the Sava River, east of Most slobode, where the green space dataset, network data, and the 2011 census data are responsible for unrealistic results.

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Map 6) Accessibility analysis
Comparison between population density (age group 0–19 yrs.) and accessibility

Data sources:

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Croatian State Geodetic Administration – admin. units

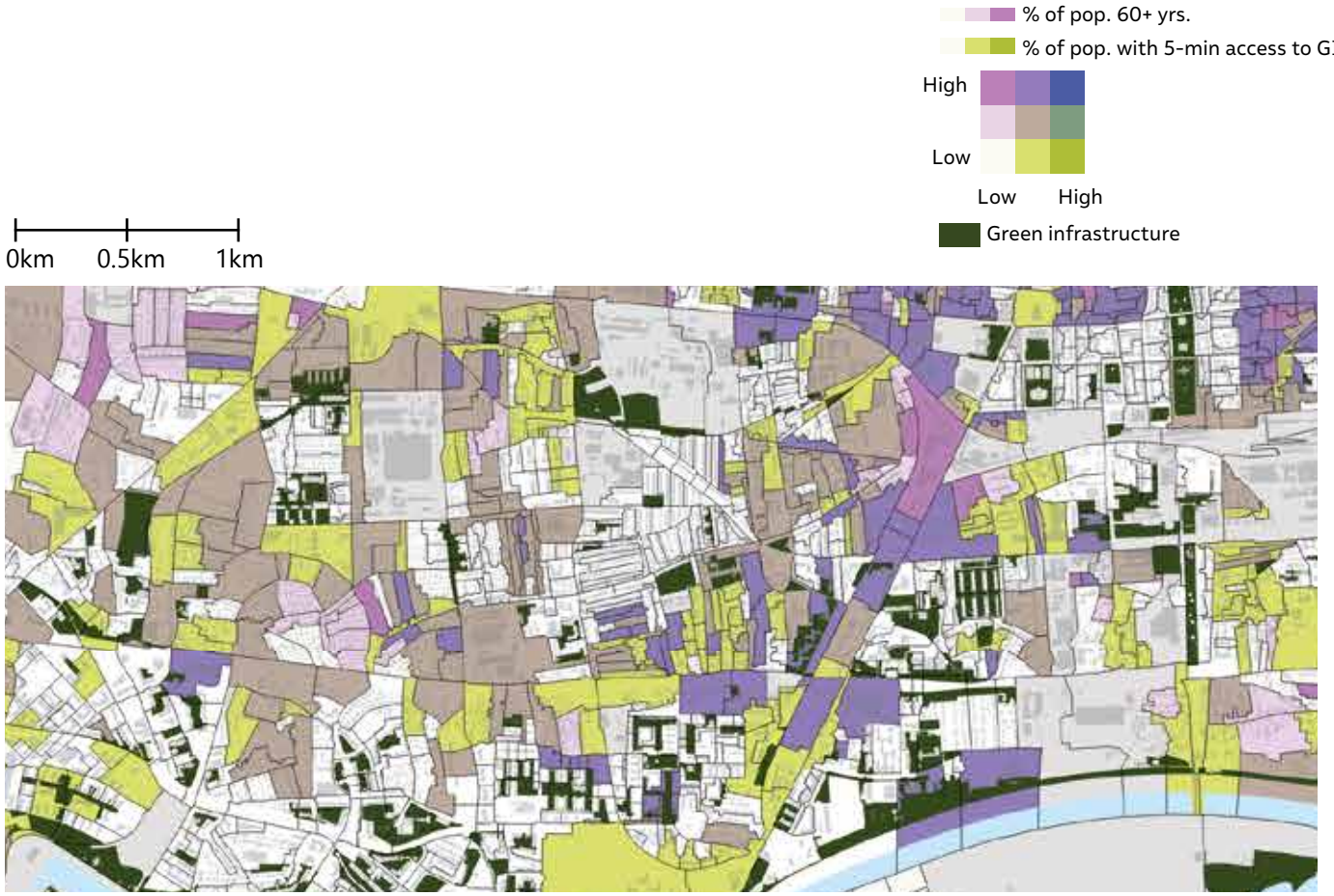
OpenStreetMap contributors – street network, buildings

ZG GeoPortal – green infrastructure/Katastar zelenila, aerial photo / CDOF2012, CDOF2018

Population density (60+ yrs.) and accessibility

Similar to the analysis for young people, this analysis focuses on the 60+ yrs. age group and compares it with the share of population living at the 5-minute walking distance to the closest park.

Due to the above-average share of 60+ agers in the city centre (compare with the map *Accessibility analysis – Age group 0–19 vs. 60+ yrs.* below) the corresponding values on the map are high and so is the availability of green infrastructure within the 5-min walking distance. This points to potentially intense use of the existing green infrastructure. Outside the city centre we can also find areas with above-average 60+ population, many of which are underserved with green infrastructure open to the public. One should bear in mind, however, that our findings are based on census data from 2011.



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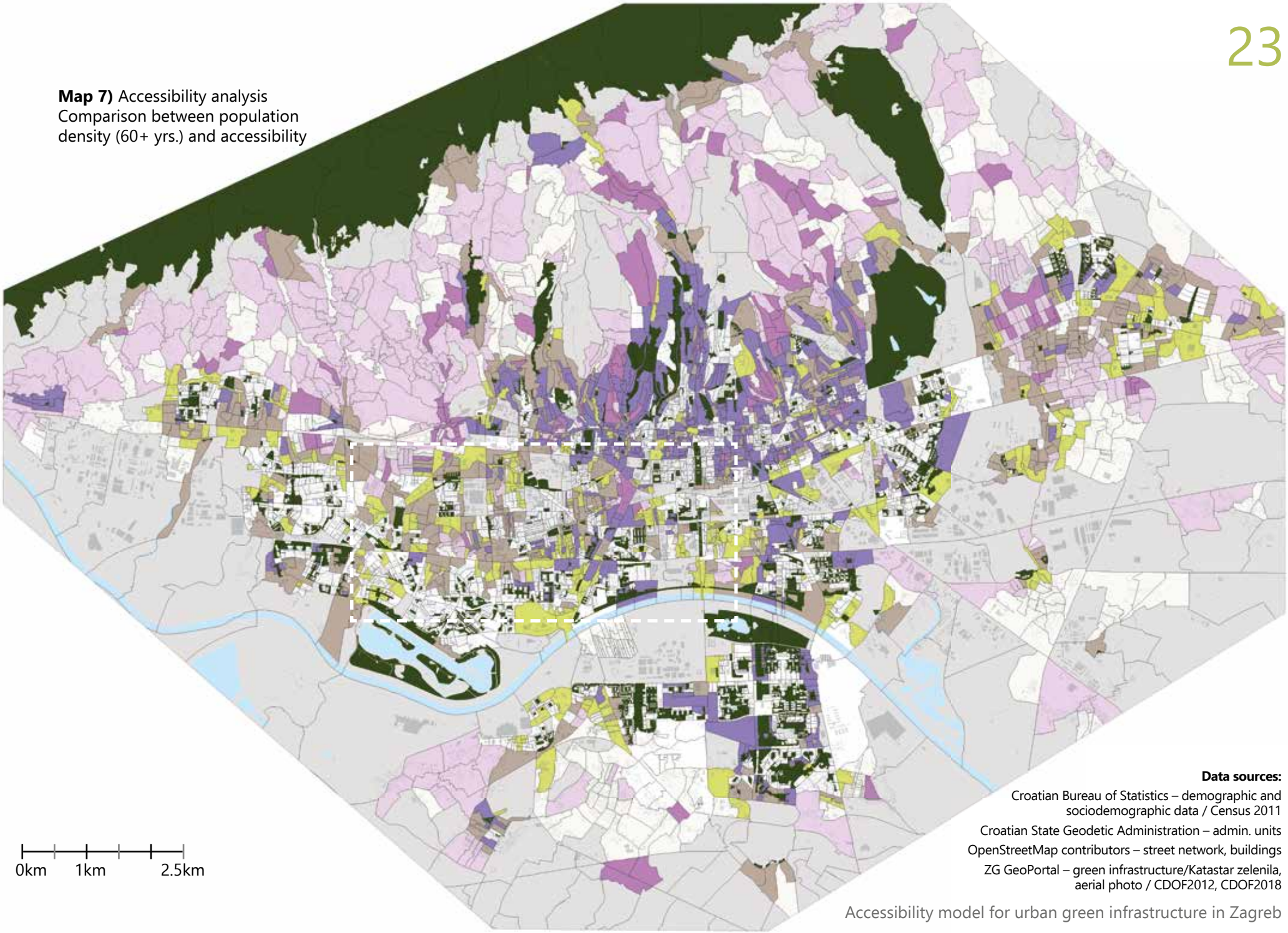
Map 7) Accessibility analysis
Comparison between population density (60+ yrs.) and accessibility



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Population density 0–19 and 60+ yrs.

The purpose of Map 8 is to make it easier to interpret specific age group maps (Maps 6 and 7), as it gives an interesting insight into the spatial distribution of Zagreb's age groups (in 2011). Combined, these maps show a rather similar picture of Zagreb outskirts, where the share of respective age groups is above average while access to close-to-home green areas is limited. On the other hand, the situation in the city centre is quite contradictory. The share of 0–19-year-olds in the inner city is below the city average, while the green infrastructure supply is good, as marked with shades of green on Map 6. In these areas the prevalence of people older than 60 years is stronger, as shown in blue on this map.

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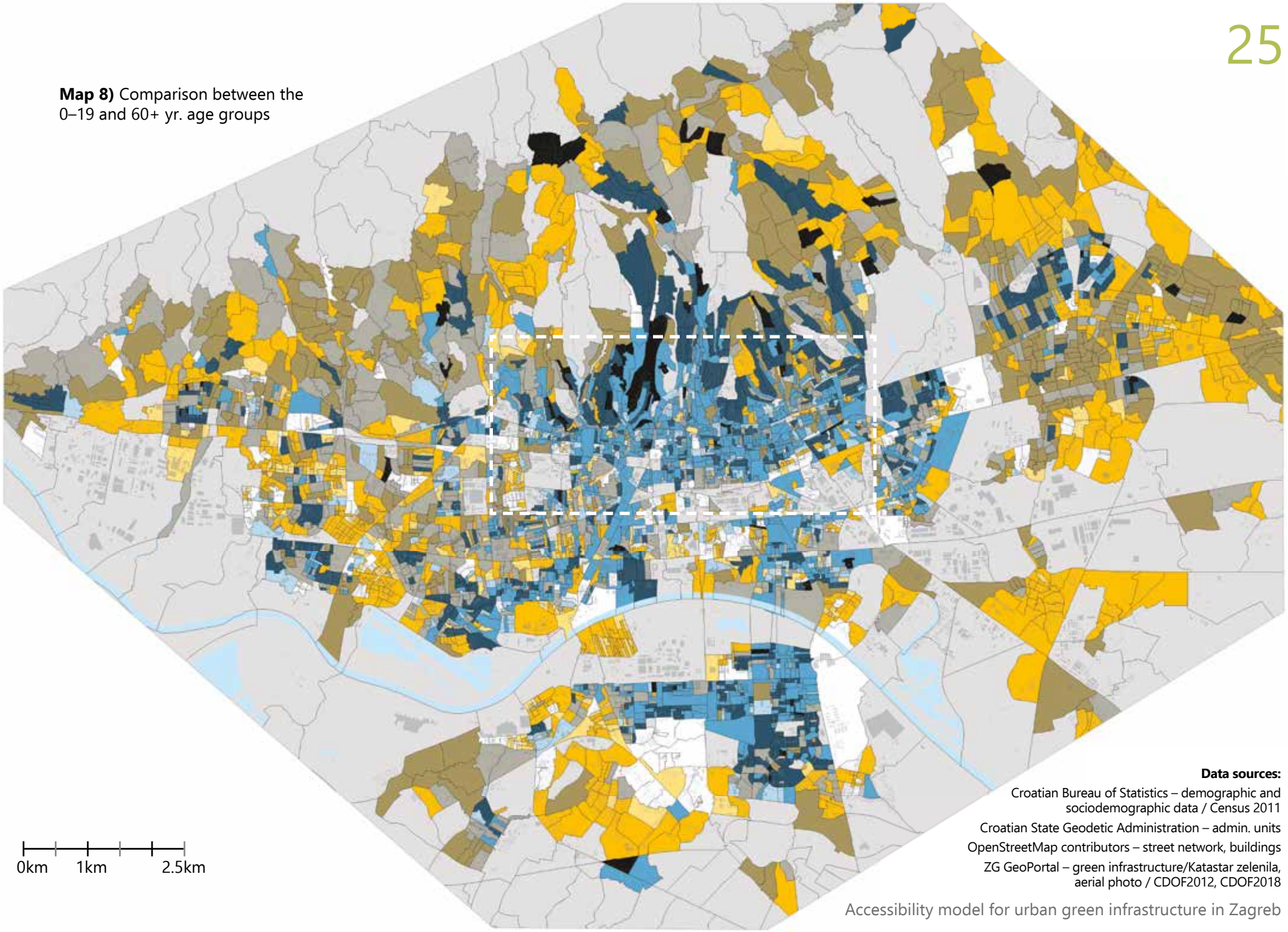
Map 8) Comparison between the 0–19 and 60+ yr. age groups



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OpenStreetMap contributors – street network, buildings

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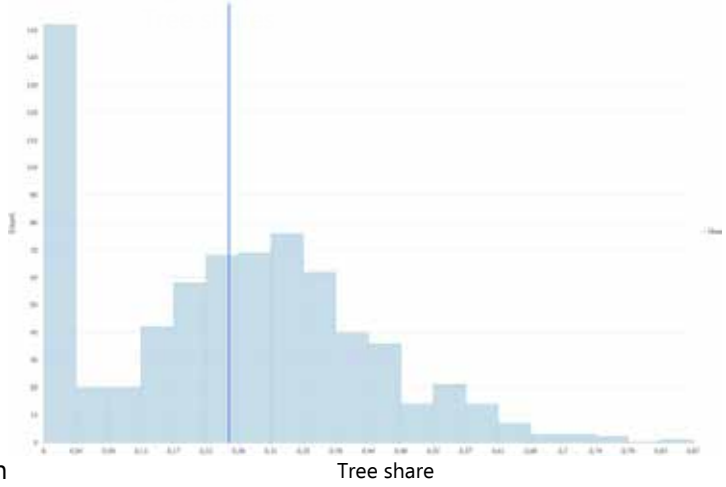
Tree crown analysis (per park)

For the parks trees are essential, as they shelter from sun and rain, provide important ecosystem services, such as greenhouse gas retention, and form the landscape. The map *Zagreb – Green infrastructure accessibility analysis – Tree crown coverage in % of total park area* shows the share of trees in public parks. It compares the sum of crown footprints per park (registered in the Green cadastre) to the total park area. The analysis does not include crown footprints outside public green areas and is limited to trees listed in the GeoPortal dataset, that is, trees managed by the administrative unit or by city company.

Our histogram shows mean distribution of tree coverage in Zagreb, which is 24.6%. However, of about 700 units in total, the histogram does not show any trees for about 150 units not included in the GeoPortal dataset.

Figure 6) Tree share distribution



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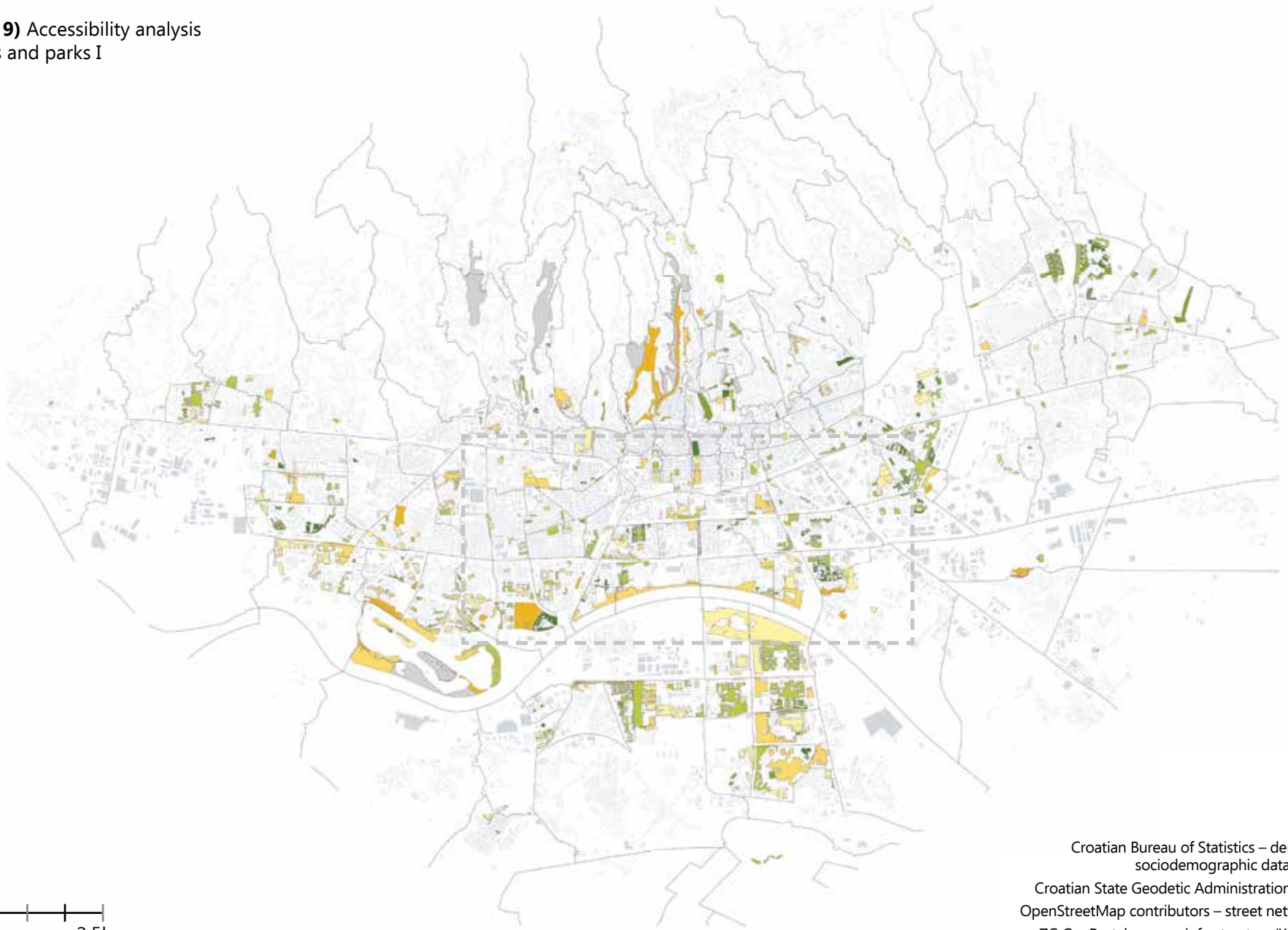
Map 9) Accessibility analysis
Trees and parks I



0km 1km 2.5km

Data sources:

Croatian Bureau of Statistics – demographic and sociodemographic data / Census 2011

Croatian State Geodetic Administration – admin. units

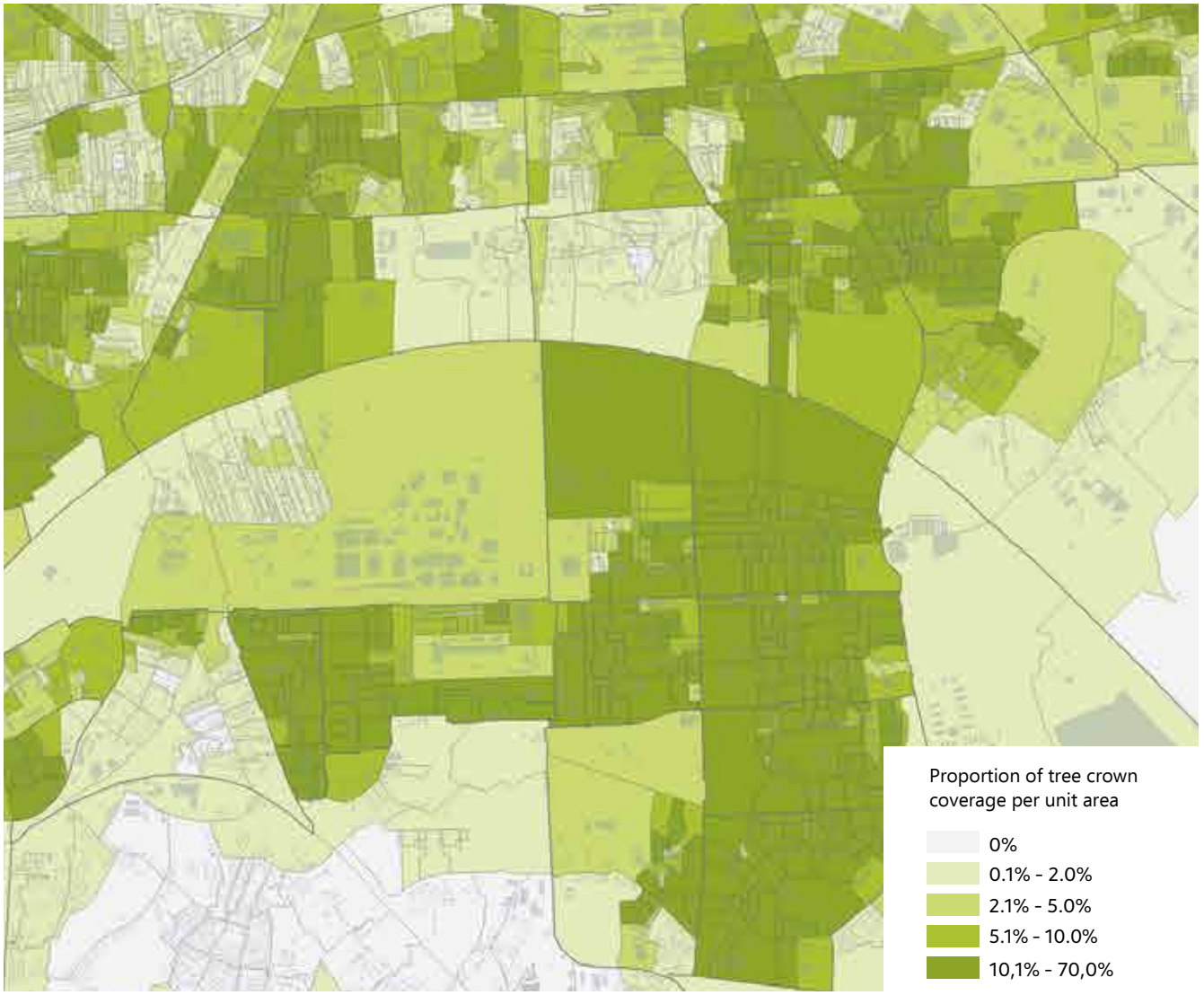
OpenStreetMap contributors – street network, buildings

ZG GeoPortal – green infrastructure/Katastar zelenila, aerial photo / CDOF2012, CDOF2018

Tree Crown Analysis (city-wide)

Map 10 shows the share of tree crown footprints in relation to the total area of Zagreb's statistical units. This analytical approach is designed to consider the effects of trees in their vicinity. For example, avenue trees on the streets that separate two administrative units are affecting both units.

This analysis takes into account all trees managed by the public authorities, including trees in all kinds of public spaces, such as streets. However, it does not include undocumented trees on private properties. As a result, our findings outlined in the map are particularly meaningful for areas which (1) have only a small share of trees on private land (undocumented) or (2) have a quite uniform building type structure. On the other hand, large statistical units at the city outskirts which are dominated by agricultural uses do not provide meaningful results.



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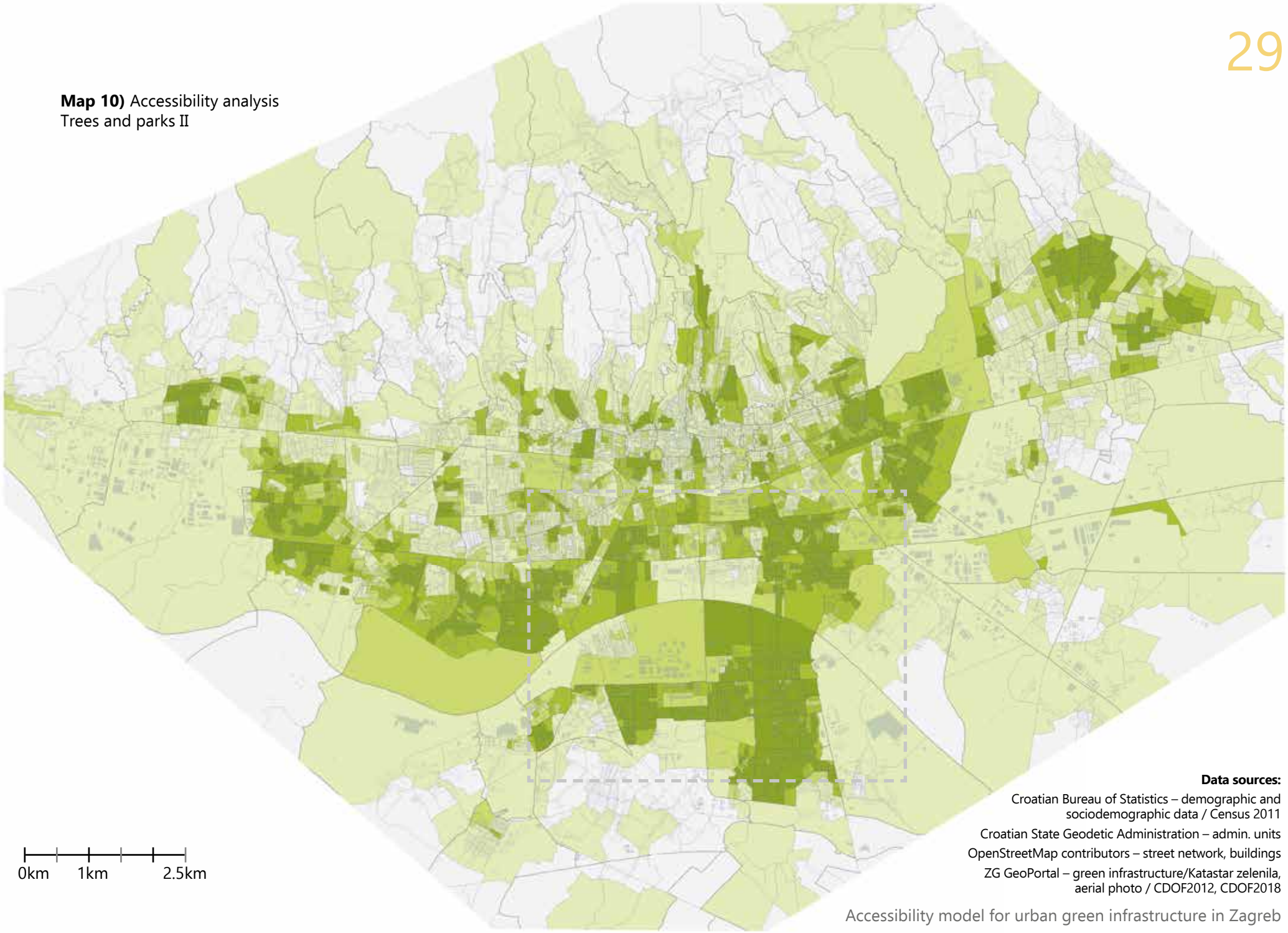
Map 10) Accessibility analysis
Trees and parks II



Data sources:

Croatian Bureau of Statistics – demographic and sociodemographic data / Census 2011

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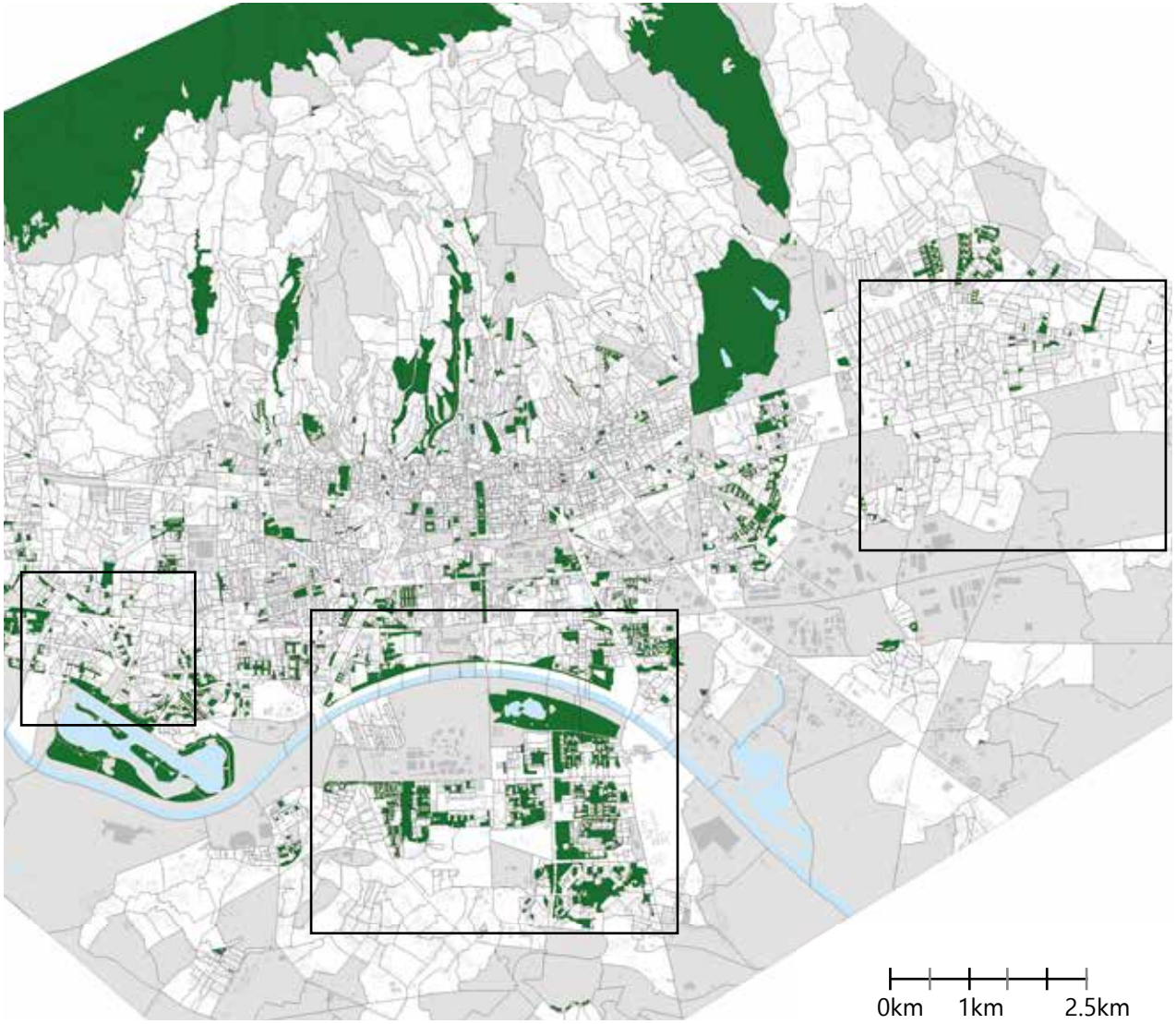
Areas of Interest I

This section zooms in on three areas of interest. Each map shows service areas (in three classes) and a combination of population density and accessibility (bi-variate maps). These areas correspond to different parts of the city and different building types.

Map 11) Overview of the areas of interest



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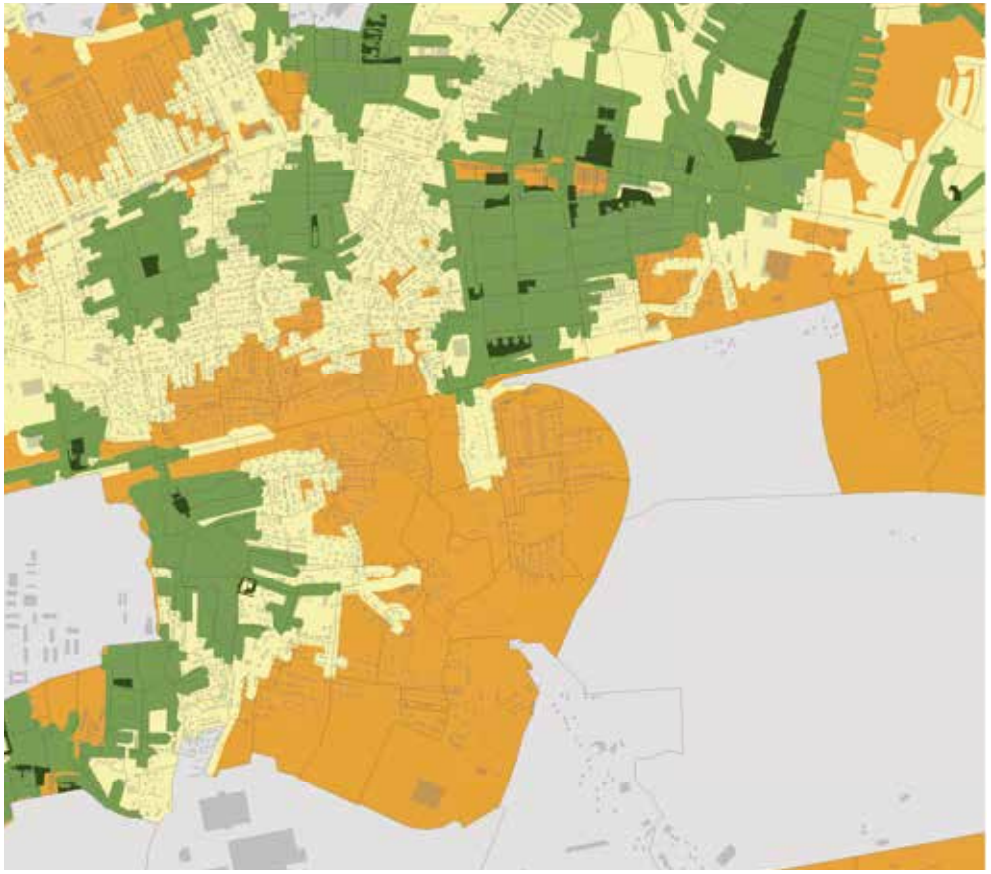
Map 12) Service area analysis Donja Dubrava



Walking distance
in min / metres

- 5 min / 300m
- 10 min / 600m
- 10 min + / 600m +

- Green infrastructure
- <6 residents / ha

Map 13) Population density and accessibility Donja Dubrava

Population density
vs. accessibility per unit

- Population density
- % of pop. with 5-min access to GI

High
Low
Low High

- Green infrastructure
- <6 residents / ha

Data sources:

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Areas of interest II

Map 14) Service area analysis Kajzerica and Dugave

Walking distance
in min / metres

- 5 min / 300m
- 10 min / 600m
- 10 min + / 600m +

- Green infrastructure
- <6 residents / ha

Map 15) Population density and accessibility Kajzerica and Dugave

Population density
vs. accessibility per unit

- Population density
- % of pop. with 5-min access to GI

High
Low
Low High

- Green infrastructure
- <6 residents / ha

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Map 16) Service area analysis Vrbani

Walking distance
in min / metres

- 5 min / 300m
- 10 min / 600m
- 10 min + / 600m +

- Green infrastructure
- <6 residents / ha

Map 17) Population density and accessibility Vrbani

Population density
vs. accessibility per unit

- Population density
- % of pop. with 5-min access to GI

High
Low
Low High

- Green infrastructure
- <6 residents / ha

Data sources:

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Conclusions regarding different building types

In terms of accessibility, 60% of Zagreb population live within the 5-minute walking distance to the closest park entrance, as recommended by the WHO. This is better than the European average of 44% (European Commission 2021). However, if we set these data against population density, it becomes evident that several city areas lack green infrastructure surface per inhabitant. The following paragraphs summarise the situation for areas characterised by different building types, from the historic centre to single-family home areas.

The **city centre** seemingly provides adequate accessibility to green infrastructure such as parks and playgrounds. But some of the larger parks in the centre are predominantly decorative while many of the intensively utilised ones are smaller in size and surrounded by densely populated residential urban areas.

Multi-storey residential areas built between the 1950s and 1990s generally do provide sufficient access to green space. For the most part, these areas follow a consistent planning design with dispersed buildings and socialising/ green areas in-between. Even though the focus was on green areas, many of them were designed with decorative purpose in mind first and only then for close-to-home recreation. Since most of these housing complexes have been there for a long time, vegetation has reached its full growth, rendering the greenery attractive and effective in terms of microclimatic improvements.

Since the 1990s, the urbanism paradigm has changed. Most of the **modern residential neighbourhoods** follow a strict concept of efficiency concerning the use of an area or plot. On the plus side, more attention is being paid to non-green public spaces and, in some cases, improvements in traffic and car-parking by strictly separating pedestrian and motorised traffic zones. The drawback of combining both strategies is that the amount of attractive and usable green space is significantly smaller than in the residential areas of the earlier period. This is why public green space in this kind of environment is even more important than in older neighbourhoods.

The decline of the traditional industrial sector, which started in the 1990s and peaked during the financial crisis of 2008, left its traces in land use patterns. **Brownfield areas** are now part of the cityscape and are subject to redevelopment initiatives. But according to Đokić and Sumpor (2010), current initiatives focus on greenfield investments. Both

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types of development – green fields and brown fields alike – need adequate and sufficient local green infrastructure where residential buildings are constructed on a larger scale. Moreover, this green infrastructure should make part of a more general planning initiative on a regional level, one that will identify green networks and carry them through. The nodes of these networks should be parks and green spaces, and these nodes should be connected by streets. These edges should be set up as attractive areas with avenue trees and other design elements.

Commercial areas are dominated by high-volume projects surrounded by huge areas for car parking, usually in remote areas. There green infrastructure does not seem to be implemented or strategically planned.

Single-family home areas are generally perceived as "green". However, they evidently lack common, non-commercial, and publicly accessible green infrastructure. Private gardens cannot replace public parks and playgrounds for children and teenagers, where people meet outside their private property and share a common space.

Intervention potential and levels

KEEP - DEVELOP - CONNECT

Keep any kind of green space

Extensively used green space within urban areas is under pressure. These are the areas where urban development and expansion are taking place. Implementing new development projects can save green space in more remote parts of the city and help to keep these areas free from intensive land use. Saving green areas in densely populated parts of the city is at least as important. Any opportunity should be seized to promote a development project that helps to increase the quantity and extent of green infrastructure. In addition, people react stronger to losses than to gains and are more sensitive to preserving the greenery they already have.

Develop green infrastructure

Increasing the surface area, number, and quality of green infrastructure will by all means improve the situation in areas with existing deficiencies. People usually perceive any kind of positive changes in their vicinity. New parks – however small, like pocket-parks – are welcome. Especially to groups with time and/or mobility constraints. Any positive shift in quality is welcome, whether it concerns improved amenities/facilities or better maintenance.

Connect green infrastructure

Finding a small spot for a new park is difficult and expensive, especially in the city centre. This is why it is hardly feasible to introduce new green elements to a greater extent. An alternative to increasing the number of parks and green public spaces is to improve accessibility to the existing green infrastructure. Improving accessibility means reducing the effort and time required to reach any of these locations – e.g., by increasing travel speed by using bicycles instead of walking – or by eliminating existing barriers for pedestrians and cyclists – e.g., by increasing the number of pedestrian crossings or setting up cycle tracks. Accessibility can also be improved by improving the travelling experience along the way – whether by bike or on foot – with trees and other green elements. Safe, comfortable, or even enjoyable travel virtually reduces any distance, as it is already experienced as leisure.

In short, Zagreb has the potential to be greener and thus respond to the needs of its residents to spend time in the green and to the challenges posed by the climate crisis and the rising temperatures that come with it.

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Note:

All the reported findings and conclusions are those of the Vienna University of Technology (TU Wien) and not of the institutions which provided raw data, namely the Croatian Bureau of Statistics, Croatian State Geodetic Administration, City of Zagreb Offices, and Zagrebački holding.