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Potential quiet areas in END agglomerations

Population accessibility to quiet green urban areas using road and air traffic noise contour maps and Urban Atlas 2018

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The withdrawal of the United Kingdom from the European Union did not affect the production of the report. Data reported by the United Kingdom are included in all analyses and assessments contained herein, unless otherwise indicated.

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Summary

Nearby access to both quiet spaces and green spaces contribute to the health and well-being of local communities. This report assesses potential and green quiet areas and their accessibility in 145 agglomerations partly covering the EEA-38 and the United Kingdom territory.

The results highlight that quiet areas are the larger part of the city in most cities. Also, in most cities, more than 50 % of the population lives in areas potentially quiet. Three main groups of cities have been identified: the largest one is composed of quiet cities with a high share of green areas, with most of the Northern European cities. A second group includes cities where most of the people live in noisy areas. Finally, the smaller group relates to quiet cities with a high share of residential areas. The accessibility to quiet and green areas is quite variable, resulting from several interactions that could not be disentangled. It should be highlighted that a relevant share of people living in noisy areas has access to green and quiet areas.

These results reflect the maximum potential available quiet areas since only two noise sources have been considered: road traffic and aircraft noise.

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1 Introduction

Environmental noise is a pervasive pollutant that adversely affects the health and wellbeing of European citizens and wildlife. Although noise is a product of many human activities, the most widespread sources of environmental noise are those related to transport (EEA, 2020). As a result, noise caused by transport (e.g. road, rail, air) is considered the second most significant environmental cause of ill health in western Europe, behind fine particulate matter pollution (WHO and JRC, 2011; Hänninen et al., 2014).

Noise causes a stress reaction in the human body that may result in numerous harmful health issues ranging from annoyance, sleep disturbance, hypertension, cognitive and hearing impairments, cardiovascular disease, or even premature death (EEA, 2017). According to the Environmental Noise in Europe Report 2020 (EEA Report No 22/2019), «*to achieve a reduction in noise exposure and its subsequent negative health effects, actions need not always focus on areas of high noise levels. Areas of good acoustic quality, namely quiet or tranquil areas, should be preserved. If areas of good sound quality are neglected or ignored, more people may become exposed to noise* ». Besides, quiet areas (QA) are not only beneficial for human health but are also consistent with the need to protect species vulnerable to noise and areas of valuable habitat (Shepherd et al., 2013; Gidloef -Gunnarsson & Oehrstroem, 2007; Oehrstroem et al., 2006b).

In this sense, identifying and protecting areas undisturbed by environmental noise is a requirement of the Environmental Noise Directive END (Directive 2002/49/EC) in Europe, which sets legally binding obligations to reduce and manage environmental noise. It also recognises the need to preserve areas of good acoustic environmental quality, referred to as 'quiet areas', to protect the European soundscape. It distinguishes between two types of quiet areas. Those found in urban areas are referred in the directive to as 'quiet area in an agglomeration' and those found outside urban areas are referred to as 'quiet area in open country'. However, the END does not provide a clear definition of quiet areas, which leaves countries with ample discretion in its interpretation. The idea of quietness currently encompasses many factors, including sound pressure levels, human perception, visual interactions, recreational value, the balance between wanted and unwanted sound, the appropriateness of sound to a given area, and human expectation (ETC/ATNI Report 10/2019). Consequently, current practices about identification, assessment and management of QA in EU Countries, though regulated by the END, appear to be extremely fragmented and heterogeneous (Bartalucci, C., et al. 2012).

Little is yet known of the mechanisms and strength of the salutogenic (health-promoting) benefits that quiet areas may provide (Payne & Bruce, 2019). On the contrary, there is a wide evidence on the health benefits of natural environments for urban dwellers (WHO, 2016), such as increased physical activity levels, social interaction and social cohesion, enhanced psychological restoration (i.e., stress reduction and attention restoration), and better general health and perceived wellbeing (Pereira et al., 2012; Tyrväinen et al., 2014; Gascon et al., 2016; Markevych et al., 2017; Rojas-Rueda et al., 2019; Chen, et al., 2020).

Evidenced pathways between natural environments and health benefits including stress reduction, as well as improved air quality, opportunities for physical activity, and increased social connectivity; will depend on the spatial configuration and characteristics of the physical environment. These can influence behaviours, physical activity patterns, social networks, and access to resources (US Department of Health and Humans Services, 2017). People who live in neighbourhoods with a higher proportion of green space also report better levels of general health (Maas, J., et al. 2006). Other studies go even further and expose that circa 40000 premature annual deaths in European cities could be prevented by increasing exposure to green space (Pereira Barboza et al., 2021). In that regard, the Noise in Europe report 2020 (EEA Report No 22/2019) points out that a combination of green and quiet in an area usually has restorative effects. People chooses green and quiet environments to read and relax in as well as to escape the city buzz (Payne & Bruce, 2019). Research from the Netherlands also suggests that those living in noisy areas have a larger need for quiet areas (Health Council of the Netherlands, 2004). Thus, access to both quiet spaces and green spaces has shown to positively contribute to the health and well-being of local communities (Sallis et al., 2016).

Based on all these scientific evidences, this report proposes and applies a methodology to assess the potential quiet areas (QA) and the accessibility to green quiet areas for people living in quiet and no quiet areas. The methodology has been applied to 145 European cities and use the noise contour maps from roads and aircraft noise inside END agglomeration. A novelty proposed in this report is the application of different approaches to assess potential QA depending on the land cover maps class.

Concretely, the report answers the following questions:

- Which is the availability of potential quiet areas inside cities?
  - Which is the percentage of the city that is potentially quiet?
  - Which are the characteristics of the potential quiet areas inside cities in terms of land use/land cover?
    - How are residential areas distributed between potentially quiet and no quiet areas?
    - What is the percentage and composition of potential quiet and no quiet areas in relation to green areas? And how those green areas are structured?
- How is people distributed inside cities in relation to potentially quiet and no quiet areas?
- Which is the accessibility to green quiet areas?
  - How many people living in potential quiet areas and in potential no quiet areas have access to green quiet areas?
  - Which is the mean surface that one person can reach within 400 meters walking distance from home?

Limitations of the analysis.

- The delineation of urban agglomerations is the responsibility of the Member States in the framework of the Environmental Noise Directive (END) (EU, 2002). Near the boundaries, outside these agglomerations, there may be urban green areas accessible to the population. Our analysis is based on the available layers and therefore also on the noise maps whose coverage is limited inside urban agglomerations.
- There are differences in road mapping across countries and we assume that non mapped roads are below the END thresholds of L_{den} 55 dB.
- There are comparability issues due to lack of consistency in the mapping method employed by countries/cities.
- Available cities are not evenly distributed; most of them are located in Central Europe. Therefore, any comparison should take into account this geographic unbalance. 145 cities have been characterised, of which 129 have had their population's accessibility to quiet green areas calculated.
- This assessment relies on contour maps submitted by Member States according to the END requirements, which sets a minimum threshold of 55 dB L_{den}. Since data covering all noise sources are not available, we use the term 'potential quiet areas'. Moreover, we apply Urban Atlas 2018 as a proxy to remove land use classes that represent non-quiet activities and for which data may not be broadly available (ie airports, ports areas, railways and associated land, mineral extraction and dump sites, fast transit roads and associated land or other roads and associated land.)
- Urban Atlas 2018 has a resolution of 1:10000 and a MMU of 0.25ha, which represents the resolution of the spatial analysis. Moreover, UA2018 is a partially validated product.

Definitions

- **Environmental noise**: There are variations in how environmental noise is defined. For instance, the WHO describes environmental noise generically as that emitted by all sources, except sources of occupational noise exposure in workplaces (WHO, 2018). The END is more specific in its definition, considering environmental noise as unwanted or harmful outdoor sound created by human activity, such as noise emitted by different means of transport — road traffic, rail traffic, air traffic — and industrial activity. In this report, we refer to environmental noise as that defined under the END. Therefore, noise in workplaces, noise from domestic activities, noise from neighbours or recreational venues, noise from wind turbines, or noise caused by military activities is not considered in this report.
- **Quiet areas**: Potential quiet areas in relation to road and aircraft noise below 55 dB L_{den}. We refer to potentially quiet areas since not all noise sources are considered
- **Green area**: Green urban areas (Urban Atlas code 14100). Public green areas for predominantly recreational use such as gardens, playgrounds, zoos, parks, castle parks and cemeteries. Suburban natural areas that have become and are managed as urban parks.
- **Green quiet area:** Green areas below 55 dB L_{den}
- **Noisy areas:** Area with noise levels of 55 dB or higher during the day-evening-night period from road or aircraft sources.
- **Agglomerations**: Part of a territory, delimited by the Member State, having a population in excess of 100000 persons and a population density such that the Member State considers it to be an urbanised area. In this assessment the terms city, urban area and urban agglomeration are used interchangeably.
- **L_{den} (day-evening-night noise level):** the long-term average indicator designed to assess annoyance and defined by the Environmental Noise Directive (END). It refers to an A-weighted average sound pressure level over all days, evenings and nights in a year, with an evening weighting of 5 dB and a night weighting of 10 dB.
- **Road traffic noise**: is the most prevalent source of noise in cities.

2 Data and methodology

2.1 Characterisation of potential quiet areas

2.1.1 Data

The following datasets are used in this analysis:

1. Noise contour maps 2017 for road traffic noise and aircraft noise inside END agglomerations. This data allow us to differentiate between quiet and non-quiet areas, setting the threshold at 55 dB L_{den}.
2. Agglomerations > 100.000 inhabitants. Delineation from Environmental Noise Directive (END). Data available for 157 agglomerations (currently, the END dataset contain 500 agglomerations of more than 100.000 inhabitants, but noise contour maps inside urban areas are only reported on voluntary basis). They are the scope of the analysis.
3. Urban Atlas 2018 (UA) high-resolution land use and land cover data with integrated population estimates for 788 Functional Urban Areas (FUA) with more than 50,000 inhabitants for the 2018 reference year in EEA38 countries and the United Kingdom. Contains population estimates for reference year 2018 at polygon level.

2.1.2 Methodology

The methodology used in this analysis is based on spatial analysis between noise sources (road and aircraft noise sources when available and technically usable[1]) and land uses considering noise propagation in space. Additionally, certain land uses are not perceived as quiet areas or pleasant, independently of the level of noise (ETC/ATNI Report 10/2019). Those include airports, ports areas, railways and associated land, mineral extraction and dump sites, fast transit roads and associated land or other roads and associated land.

UA defines a Minimum Mapping Unit (MMU) of 0.25 ha, but in some cases smaller polygons can be present (e.g. polygons >= 100 m² at the border of the FUA[2]). Therefore, the analysis here presented cannot have thinner resolution than 100 m². However, during the spatial analysis applied some smaller than 100 m² polygons frequently appears. Thus, a process to delete them have been applied recursively after each step. In addition, geometries with area m²/perimeter m ratio <1 have been also deleted.

The first step in the analysis is the characterisation of quiet areas within urban agglomerations. These urban areas are defined by Directive 2002/49/EC (END) as "part of a territory, delimited by the Member State, having a population of more than 100 000 persons and a population density such that the Member State considers it to be an urbanised area". The END also defines quiet area in an agglomeration "as an area, delimited by the competent authority, for instance which is not exposed to a value of L_{den} or of another appropriate noise indicator greater than a certain value set by the Member State, from any noise source".

[1] Some countries delivered noise contour maps inside END agglomerations in spatial line format, therefore, this information cannot be used in the proposed analysis.

[2] https://land.copernicus.eu/user-corner/technical-library/urban-atlas-mapping-guide

The approach used to characterise potential quiet areas differs depending on the noise source and Urban Atlas land cover classes. Urban Atlas land cover classes have been classified (Table 2.1) according to the following criteria:

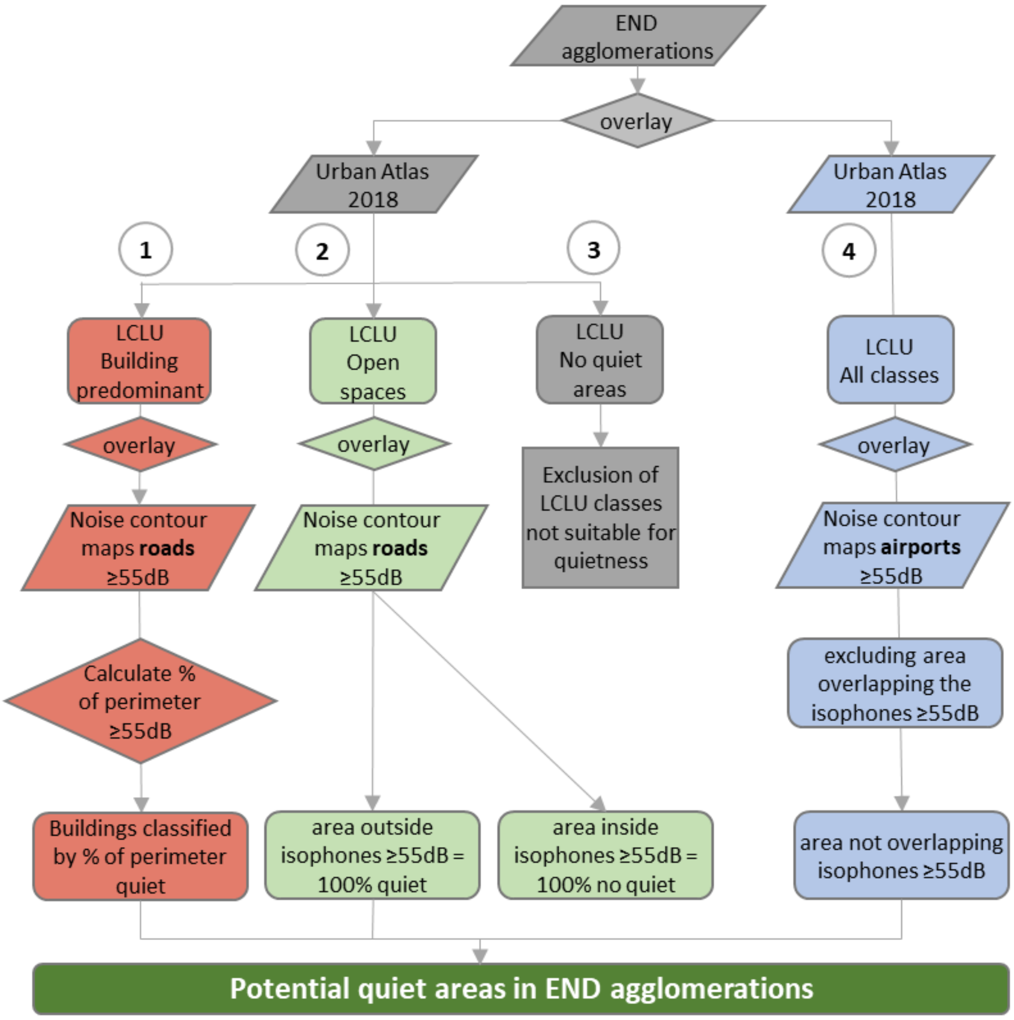
1 Classes where buildings are predominant.
2 Open spaces.
3 No quiet areas.

Table 2.1. Urban Atlas 2018 land use classes on which it is based the potential quiet areas characterisation

Buildings are predominant	**Open spaces**	**No quiet areas**
11100: Continuous Urban fabric (S.L. > 80 %)	14200: Sports and leisure facilities	12400: Airports
11210: Discontinuous Dense Urban Fabric (S.L.: 50 % - 80 %)	14100: Green urban areas	12300: Port areas
11220: Discontinuous Medium Density Urban Fabric (S.L.: 30 % - 50 %)	21000: Arable land (annual crops)	12230: Railways and associated land
11230: Discontinuous Low Density Urban Fabric (S.L.: 10 % - 30 %)	22000: Permanent crops	13100: Mineral extraction and dump sites
11240: Discontinuous very low density urban fabric (S.L. < 10 %)	23000: Pastures	12210: Fast transit roads and associated land
11300: Isolated Structures	24000: Complex and mixed cultivation patterns	12220: Other roads and associated land
12100: Industrial, commercial public, military and private units	25000: Orchards	
13300: Construction sites	31000: Forests	
13400: Land without current use	32000: Herbaceous vegetation associations	
	33000: Open spaces with little or no vegetation	
	40000: Wetlands	
	50000: Water	

This classification is based on the potentially difference of the noise propagation depending on land use -land cover classes. While noise (contour bands) stops at building's façade, it continues its propagation in open spaces. Areas where it is considered that quiet areas could not exist (e.g., airport areas or railways and associated land) have been not included in the analysis of potential quiet areas.

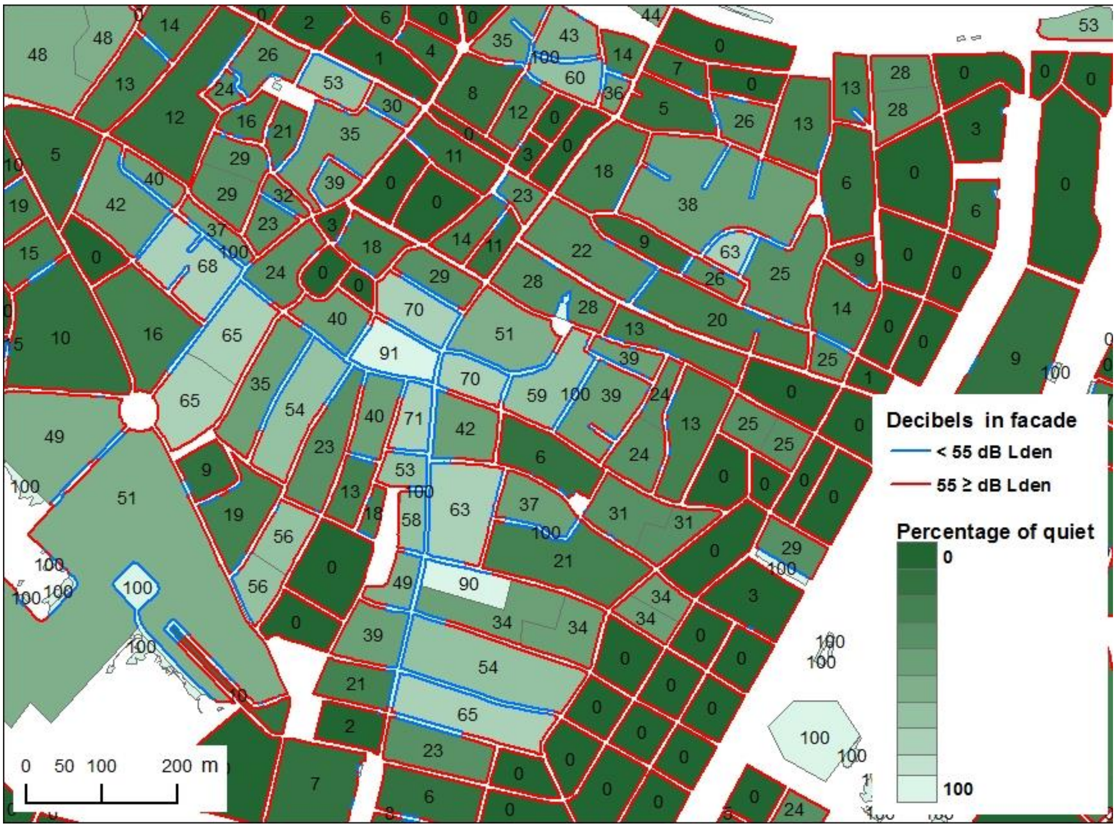
Figure 2.1. Flowchart of quiet areas characterisation. Cases 1, 2 and 3 refers to procedure followed per road noise contour maps, while case 4 defines the procedure followed in relation to aircraft noise inside agglomerations



For Urban Atlas classes where buildings are predominant (Figure 2.1, case 1) an overlay with isophones ≥ 55dB L_{den} from roads is made, and then the percentage of the perimeter of the polygon in contact with this noise contour area is calculated. This results in a classification based on the surrounding streets of the polygons of this set of classes where buildings predominate. This percentage at building level is obtained by overlaying noise contour maps ≥ 55 dB with urban Atlas geometries, allowing to assign to each building predominant polygon perimeter its belonging to a zone greater than or equal to 55 dB. Then, based on the length of its perimeter class, for each polygon its percentage of quietness is calculated, being 100 the quietest and 0 the totally noisy (see Map 2.1 and Map 2.2).

As shown in (Map 2.1,Map 2.2) the analysis allows the classification of building classes from 0 % (in dark green) to 100 % (light green in Map 2.2). A building with 100 % quiet means that the perimeter of the polygon is completely outside the noise contour ≥55 dB L_{den} while a building with 0 % in quiet areas means that all the surrounding streets of the polygon have values ≥ 55dB.

Map 2.1. Percentage of perimeter of Urban Atlas building classes in quiet or non-quiet areas (55 dB L_{den})



Map 2.2. Zoom in to % of perimeter of Urban Atlas building classes in quiet or non-quiet areas (55 dB L_{den})

The results obtained at building level are used to calculate the percentage of quietness at agglomeration level (Map 2.3). This percentage of quietness will be used to calculate the percentage of people living in potential quiet areas using the population estimates for reference year 2018 at polygon level, as input data to determine people's accessibility to green urban areas (see chapter 3). We multiply the population of each polygon by the quietness percentage to obtain the quiet and non-quiet population for each polygon. This methodology allows the identification of quiet roads in the class (12220: Other roads and associated land).

Table 2.2. Calculation of quiet population from percentage of Urban Atlas 2018 polygon quiet perimeter

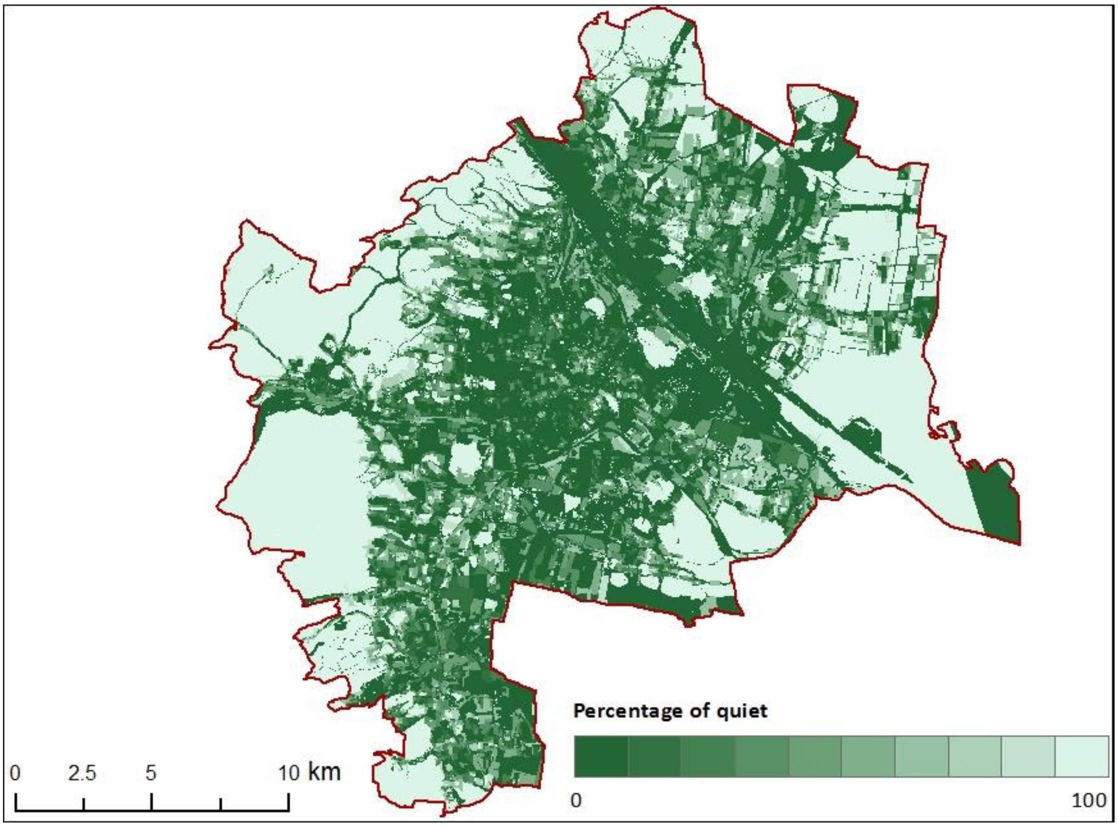
Country	Agglomeration	UA code 2018	Class 2018	Total population	Perimeter quiet (%)	Quiet population
AT	Vienna	11100	Continuous urban fabric (S.L.: > 80 %)	46	13	6
AT	Vienna	11100	Continuous urban fabric (S.L.: > 80 %)	94	0	0
AT	Vienna	11100	Continuous urban fabric (S.L.: > 80 %)	60	41	24
AT	Vienna	11100	Continuous urban fabric (S.L.: > 80 %)	103	55	56
AT	Vienna	11100	Continuous urban fabric (S.L.: > 80 %)	91	23	21
AT	Vienna	11100	Continuous urban fabric (S.L.: > 80 %)	88	36	31
AT	Vienna	12100	Industrial, commercial, public, military and private units	2	9	0
AT	Vienna	11100	Continuous urban fabric (S.L.: > 80 %)	76	20	15
AT	Vienna	11100	Continuous urban fabric (S.L.: > 80 %)	19	18	4
AT	Vienna	11100	Continuous urban fabric (S.L.: > 80 %)	73	38	28
AT	Vienna	11100	Continuous urban fabric (S.L.: > 80 %)	60	29	17
AT	Vienna	11100	Continuous urban fabric (S.L.: > 80 %)	55	70	39
AT	Vienna	11100	Continuous urban fabric (S.L.: > 80 %)	72	91	66

In open spaces classes (Figure 2.1, case 2) the complete area of noise contour bands ≥ 55 dB is used to analyse which areas are potentially quiet and which ones not. Areas outside these polygons will receive a 100 % potentially quiet while areas inside will be labelled as 0 % quiet. Some land cover and land use classes are considered not suitable to be potentially quiet (Figure 2.1, case 3) and are assigned automatically to the potentially non-quiet set.

In the case of the aircraft noise inside END agglomerations (Figure 2.1, case 4) the areas inside noise contour bands ≥ 55 dB are excluded from the potentially quiet areas not taking into consideration the Urban Atlas land cover – land use class covered by the noise contour map. In this case, it is considered that the propagation of noise from aircrafts comes from above and affects all land uses.

The merge of the output of the analysis undertaken in the 4 cases, results in a final layer with values from 0 to 100, being 0 areas potentially not quiet and 100 areas potentially quiet.

Map 2.3. Percentage of quiet areas classification for Urban Atlas classes at the agglomeration of Vienna



Map 2.3 shows the complete classification of the Urban Atlas polygons of the Vienna agglomeration according to the percentage of quietness.

2.1.3 Classification of agglomeration by city size and region

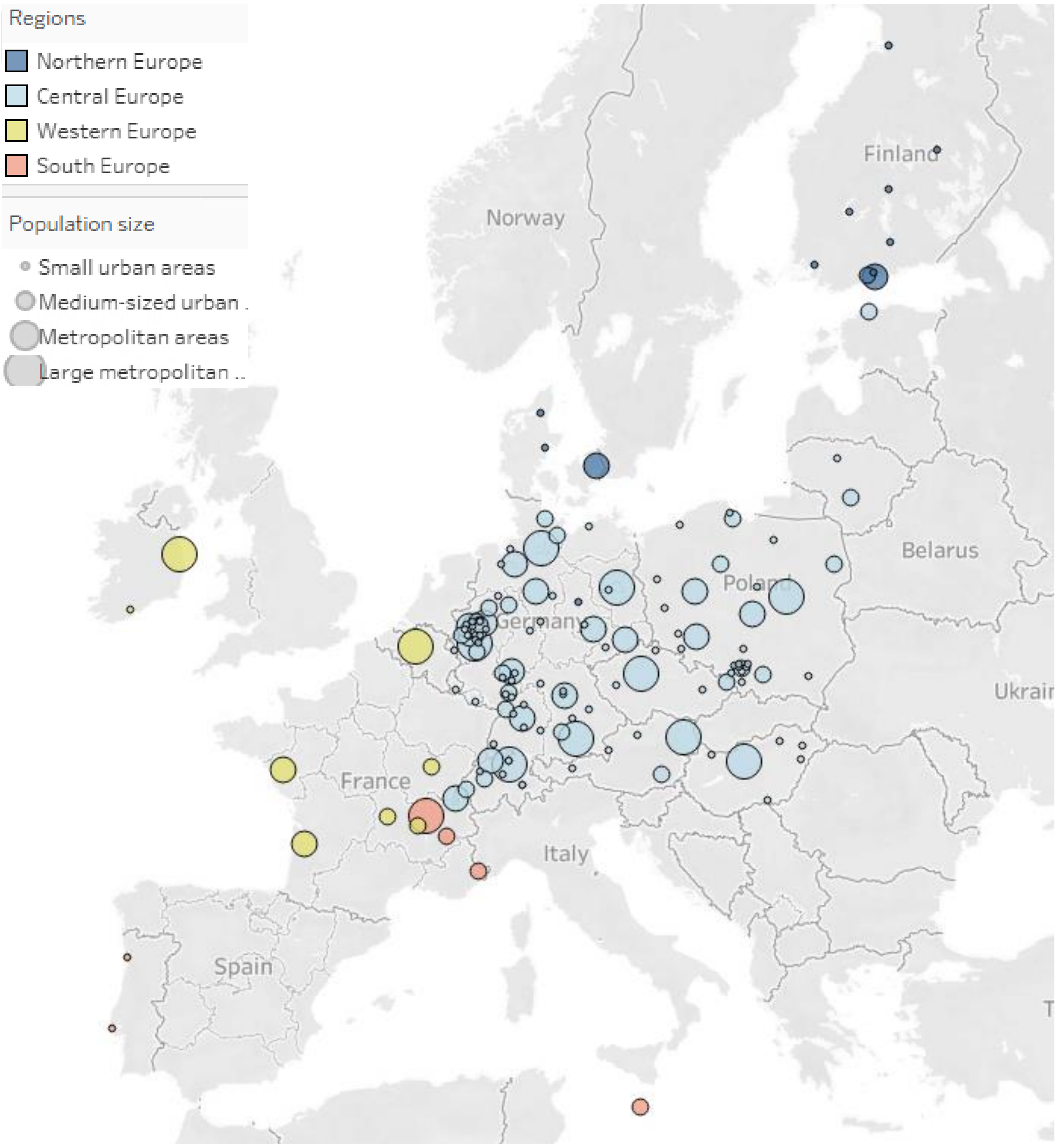
Since the size of the city and its geographic location can be important factors that determine characteristics relevant to the assessment of quiet areas, the following classification of agglomerations have been adopted:

- City size based on the total population of the agglomeration following the four classes established by OCDE (OECD, 12). Table 2.3 and Map 2.4 shows how the population of 145 agglomerations is distributed over the four size classes. The majority of the population lives in the biggest category "large metropolitan areas", being 20,9 million people, corresponding to 35 % of the total. Small agglomerations are however dominant in quantity, hosting 25,8 % of analysed agglomerations.
- Socio-cultural regions (Jordan, 2005; Map 2.4). Welfare, governance structures and cultural aspects are among the key factors that shape the cities and their development. In this classification socio-cultural aspects are used as common denominators to define five main European regions. Historic governance structures and religion are the key criteria of this classification (Jordan 2005). This classification has also been adopted by the EEA to analyse the land take in European cities (EEA, 2021). As can be seen in Map 2.4, the distribution of Central and Northern European agglomerations are dominant. On the other side, there are only six agglomerations for Southern Europe.

Table 2.3. Classification of agglomerations according to total population based on OECD (2012). The population of the agglomeration has been obtained from Urban Atlas 2018

Agglomeration size class	2018 population	no Agglomerations
S / Small urban areas / 50,000 - 250,000	15,203,192	91
M / Medium-sized urban areas / 250,000 - 500,000	10,488,927	31
L Metropolitan areas / 500,000 - 1 mio.	12,507,981	20
XL / Large metropolitan areas / > 1 mio.	20,874,909	12
Total	**58,875,009**	**154**

Map 2.4. Coverage of the agglomerations included in this report. Agglomerations are grouped by regions according to Jordan (2005)



2.2 Accessibility to green urban areas

2.2.1 Overview

The second part of the analysis determines people's accessibility to quiet green urban areas. We determine an area of easy walking distance – 400 m – around quiet green urban areas and then calculate how many people can reach those areas from inhabited Urban Atlas residential polygons. Then we estimate the median surface area of quiet green urban areas than can be reached at this distance by population. Finally, calculation of population-weighted median surface of quiet green urban areas in the agglomeration that can be reached within 400 m of walking distance is solved.

2.2.2 Data

1. Green urban areas in the agglomeration (14100: Green urban areas)
2. Potential quiet green urban areas in the agglomeration (< 55dB L_{den}).
3. Road network data. This analysis requires a road network that contains attributes to enable selection of streets accessible to pedestrians. We used the TomTom Multinet data 2019.
4. Percentage of population living in potentially quiet areas using the population estimates for reference year 2018 at polygon level

2.2.3 Methodology

The first step to calculate the accessibility to green urban areas is to define the threshold of walking time or distance from residential areas to the green urban areas. In previous studies (Poelman, H et al. 2018; ETC/ATNI Report 10/2019) the criterion of 10 minutes on foot was used but, recently, this criterion has been modified to 400 m walking distance following the recommendations of UN-Habitat (UN-Habitat 2020). They defined an acceptable walking distance to open public spaces of 400 meters - equivalent to 5 minutes' walk as a practical and realistic threshold for all groups of people. Our analysis implements also this threshold of 400 meters.

Figure 2.2. Flowchart of quiet green urban areas accessibility inside agglomerations

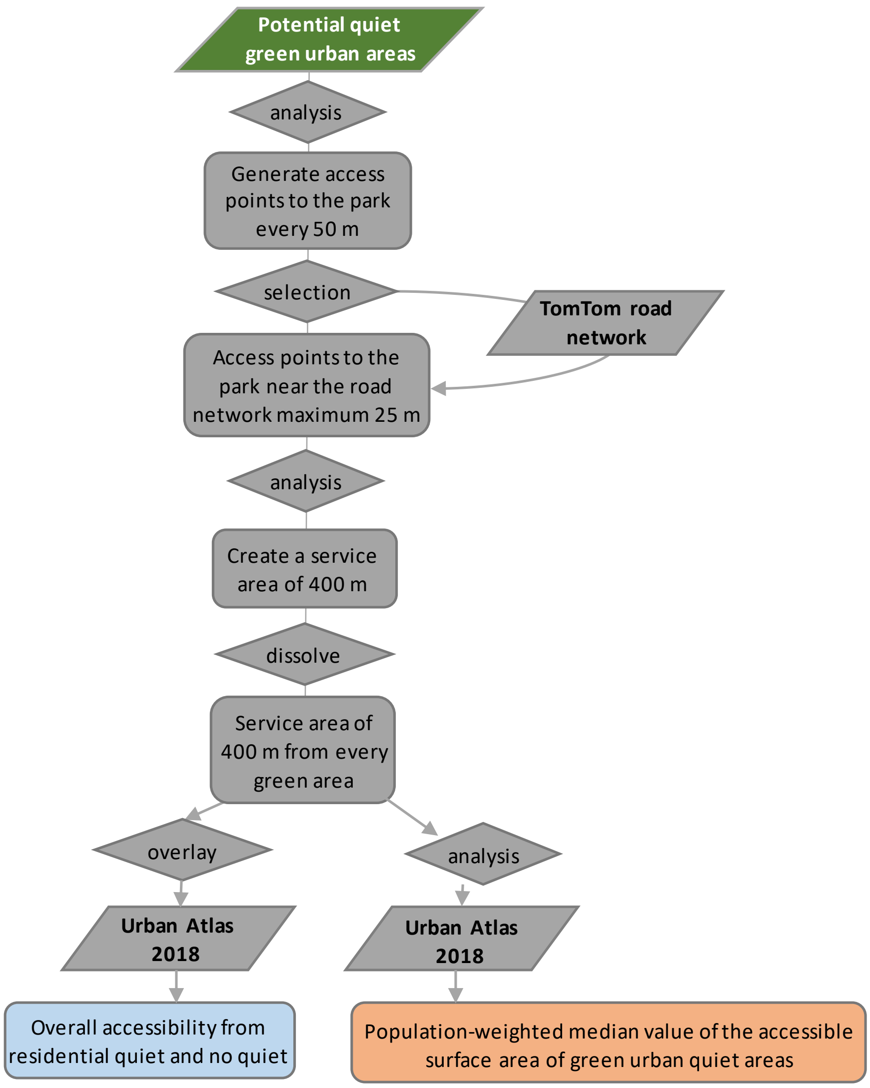
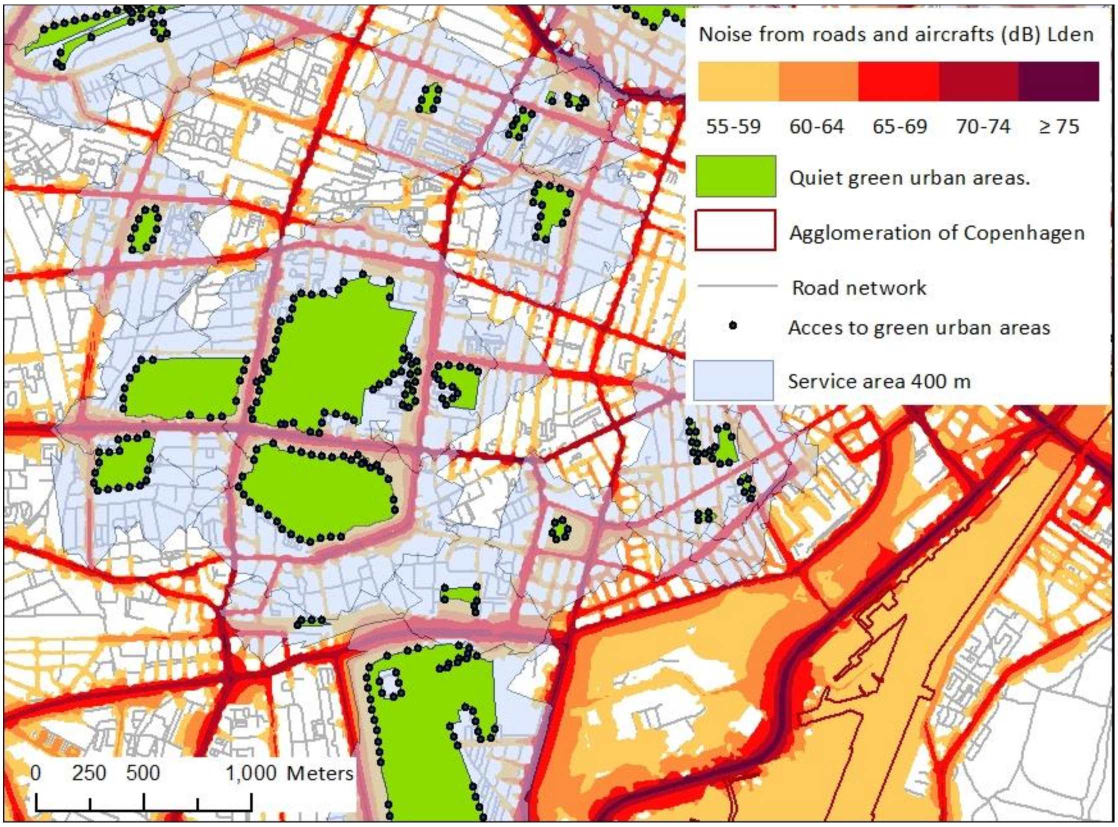


Figure 2.2 explains the methodology followed to calculate quiet green urban areas accessibility inside agglomerations. For calculating accessibility, we need to generate service areas from the green urban areas (Map 2.5). A network service area is a region that encompasses all accessible streets (that is, streets that are within a specified impedance). For instance, the 400m service area for a point on a network includes all the streets that can be reached within 400m from that point. This means that we need to establish the access points to the parks. Some alternatives were considered. One is to intersect the streets with the green areas to obtain access points. This option has the advantage that these access points to the green areas are realistic but leaves out of the analysis small green areas where the streets run parallel to them. To overcome this, a methodology could have been adopted to generate access points at certain distances for green areas without street intersections to complement those that do have them. Finally, for reasons of product comparability, we adopt the methodology proposed by DG Regio in which access points are generated every 50 m along the polygon contour. Next, only the points that are located at maximum 25 m from the street network are kept because points located far away from the street network are considered not suitable to start walking from or to the park.

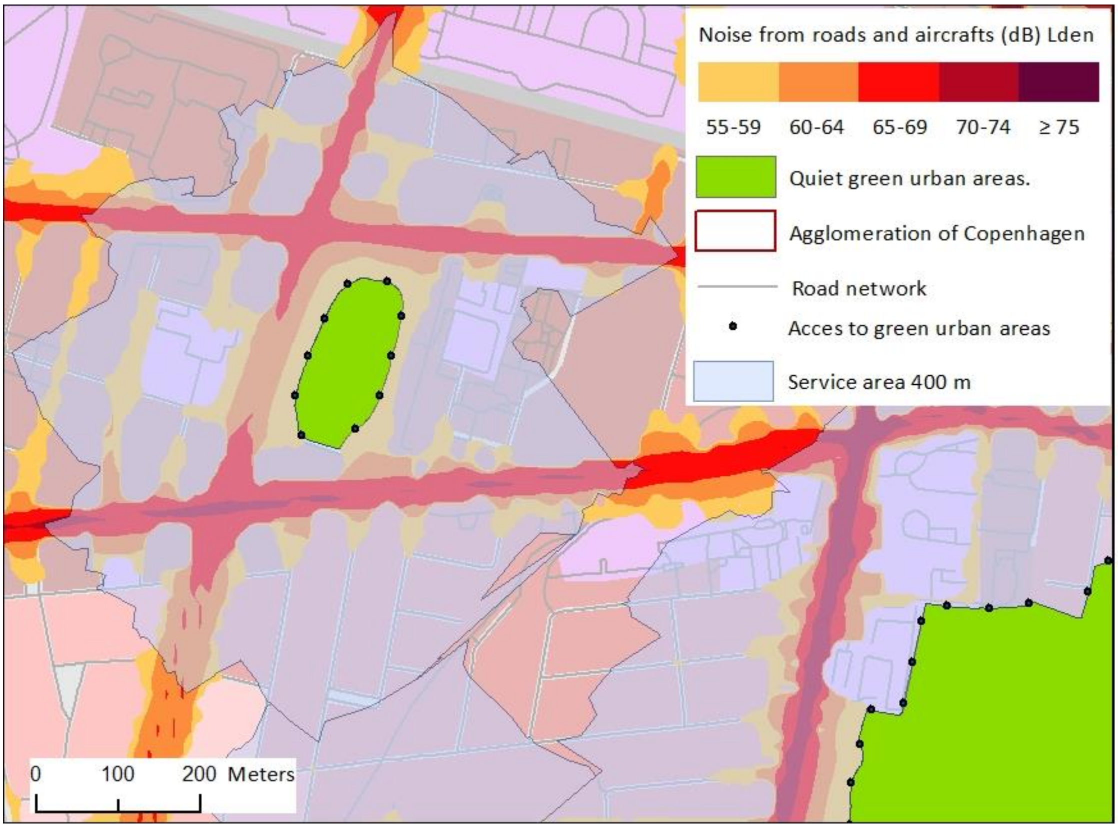
Then, for each of these points we create a service area of 400 m walking distance, we dissolve these by the identifier of each green urban area in order to keep the characteristics of the park, i.e., its surface, then we intersect all the service areas to determine the overlapping areas. In these overlapping areas people have access to more than one green area and are important to identify if we also want to assess to which surface of green urban areas people have access.

Finally, the service areas are intersected with Urban Atlas polygons containing the population. Calculating the population falling inside the service areas by means of areal weighting within each populated polygon (Figure 2.3).

Map 2.5. Quiet green urban areas, access points and service areas at 400 meters



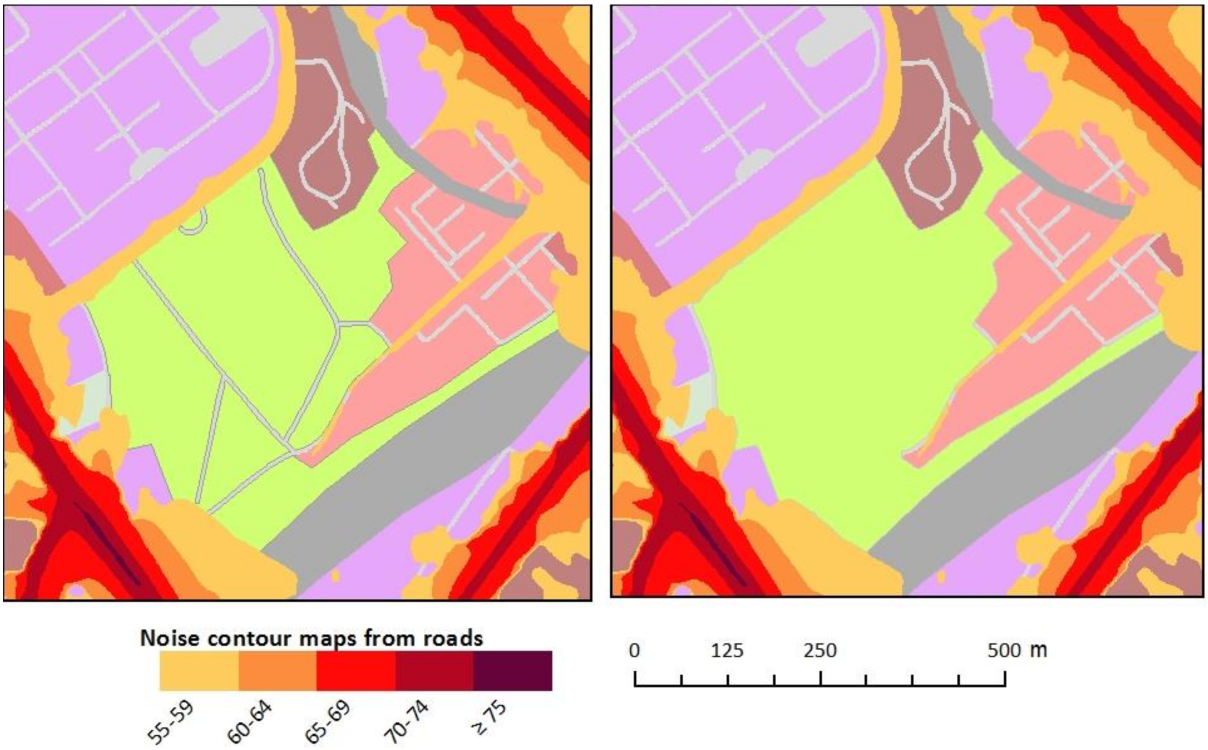
Map 2.6. Detail of quiet green urban area, access points and service area at 400 m



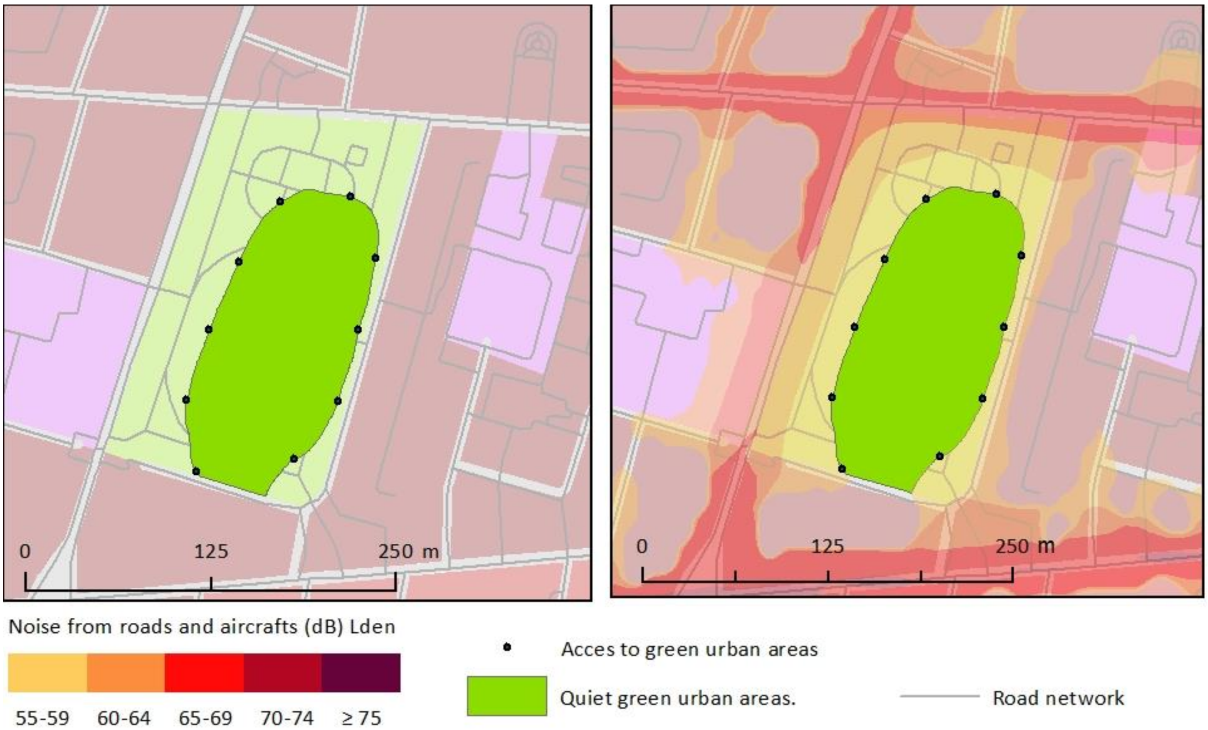
The Urban Atlas resolution implies that some of the larger green urban areas are divided by small roads into several polygons. As we want to count the total surface of the park, we will follow the methodology developed by DG Regio in "A walk to the park" (Poelman, H. 2018), to get the total surface of the green area.

First, we select all the green urban areas. We buffer the selected areas by 4.5 meters. Then we dissolve the buffered areas using the Urban Atlas land use code, to create single part polygons. The dissolved areas are finally buffered by -4.5 meters. The result is that the roads and paths of interest have disappeared, but the external borders of the green urban areas stay the same, as shown on Map 2.7.

Map 2.7. Process of eliminate paths and small roads that separate adjacent green urban areas

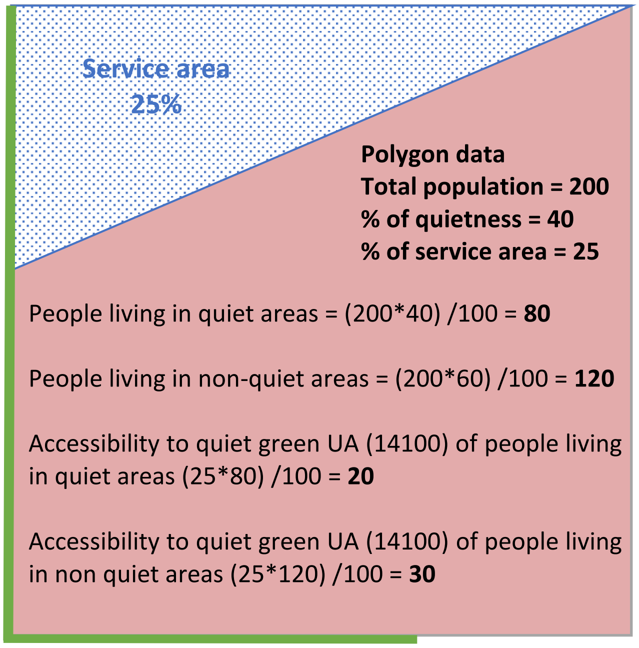


Map 2.8. Accessibility points to potential green urban areas quiet compared with green urban areas (Left). The same area showing noise contour bands ≥ 55 dB Lden (Right)



Map 2.8 shows the detail of the quiet green area and its access points. On the right we can see how the noise ≥ 55 dB L_{den} from roads reduces the green area compared to the image on the left that shows both, the green area from Urban Atlas 2018 and the share of the green area considered quiet (where isophones ≥ 55 dB L_{den}). We calculate the accessibility to this latter quiet green urban area.

Figure 2.3. How to calculate accessibility to quiet green urban areas from residential areas quiet and non-quiet



Service areas are intersected with the population urban atlas polygons, calculating the population falling inside the service areas by means of areal weighting (within each populated polygon).

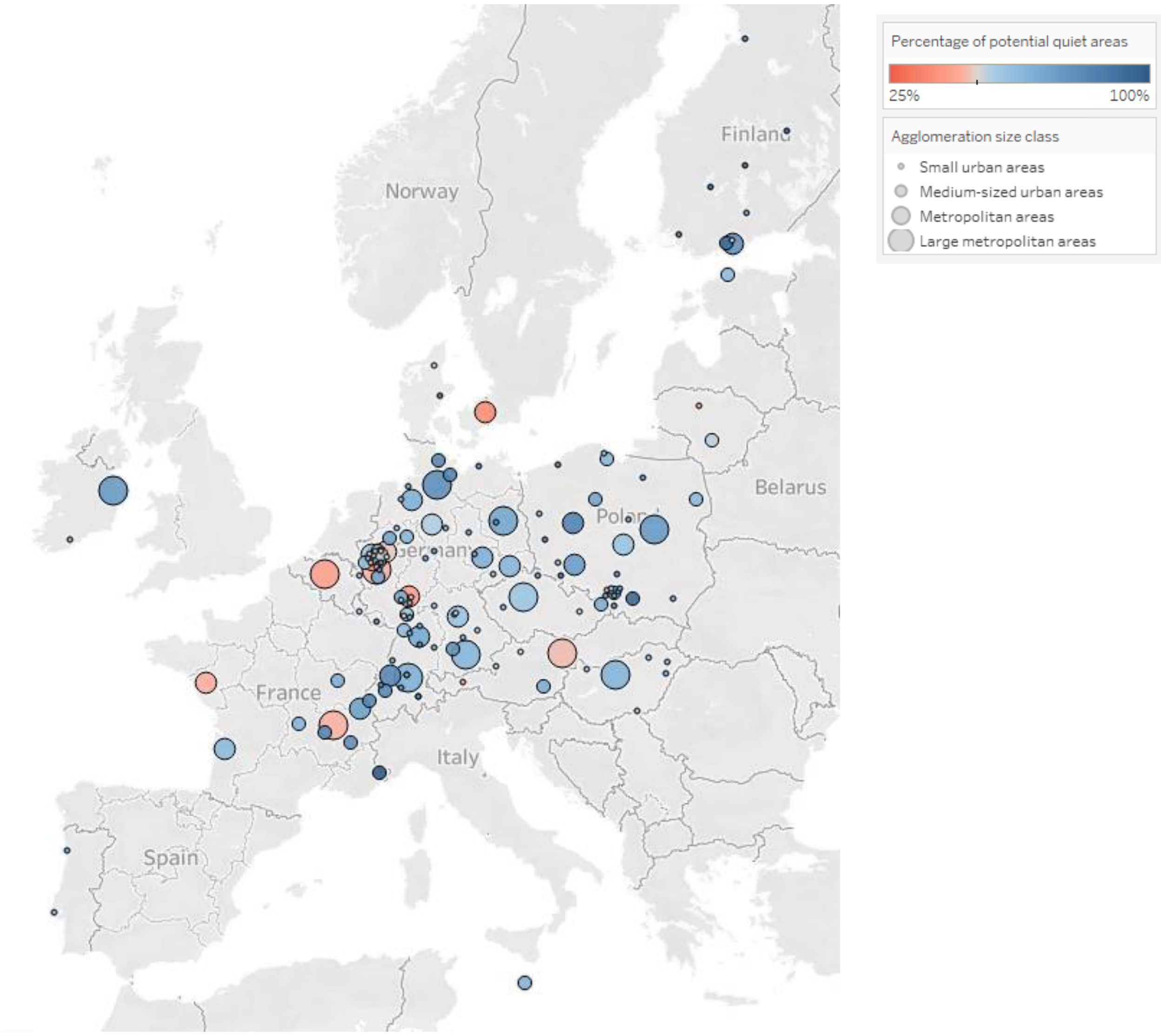
Table 2.4. Summary of data used for each type of analysis

Type of analysis	Data
Characterisation of potential quiet areas	Noise contour maps for road traffic noise in agglomeration (END 2017)
	Noise contour maps for aircraft traffic noise in agglomeration (END 2017)
	END agglomerations > 100.000 inhabitants
	Urban Atlas 2018 (UA) v013
Accessibility to green urban areas	Green urban areas in the agglomeration (14100: Green urban areas) from UA 2018
	Potential quiet green urban areas in the agglomeration (≤ 55dB L_{den}). from UA 2018 and noise contour maps.
	Percentage of population living in potentially quiet areas using the population estimates for reference year 2018 at UA polygon level.
	Road network data from TomTom Multinet data. Functional Road Classes (FRC). Table

3 Results

In most cities (88 %), the potential quiet area spans more than 50 % of its surface (Map 3.1). It should be noted that this report only covers noise from road traffic and aircraft. Therefore, these figures could be considered the maximum extent of the potential quiet areas. The highest share of potential quiet area is found in Espoo, Tampere, Jyvaskyla, Kuopio -all from Finland, Nice from France, Krakow and Walbrzych from Poland. All of them are above 90 % of the total area of the city. On the other side, Copenhagen is the city with the lowest share (38 %), followed by Innsbruck and Düsseldorf (41 % each city). There are no significant differences between cities of different size classes. However, Northern cities tend to have a higher percentage of quiet areas (77 % on average) than Central and Western European cities (64 % and 62 % average, respectively). Southern European cities also have a high share of quiet areas, 70 % on average, although the low number of cities for which data is available is not conclusive.

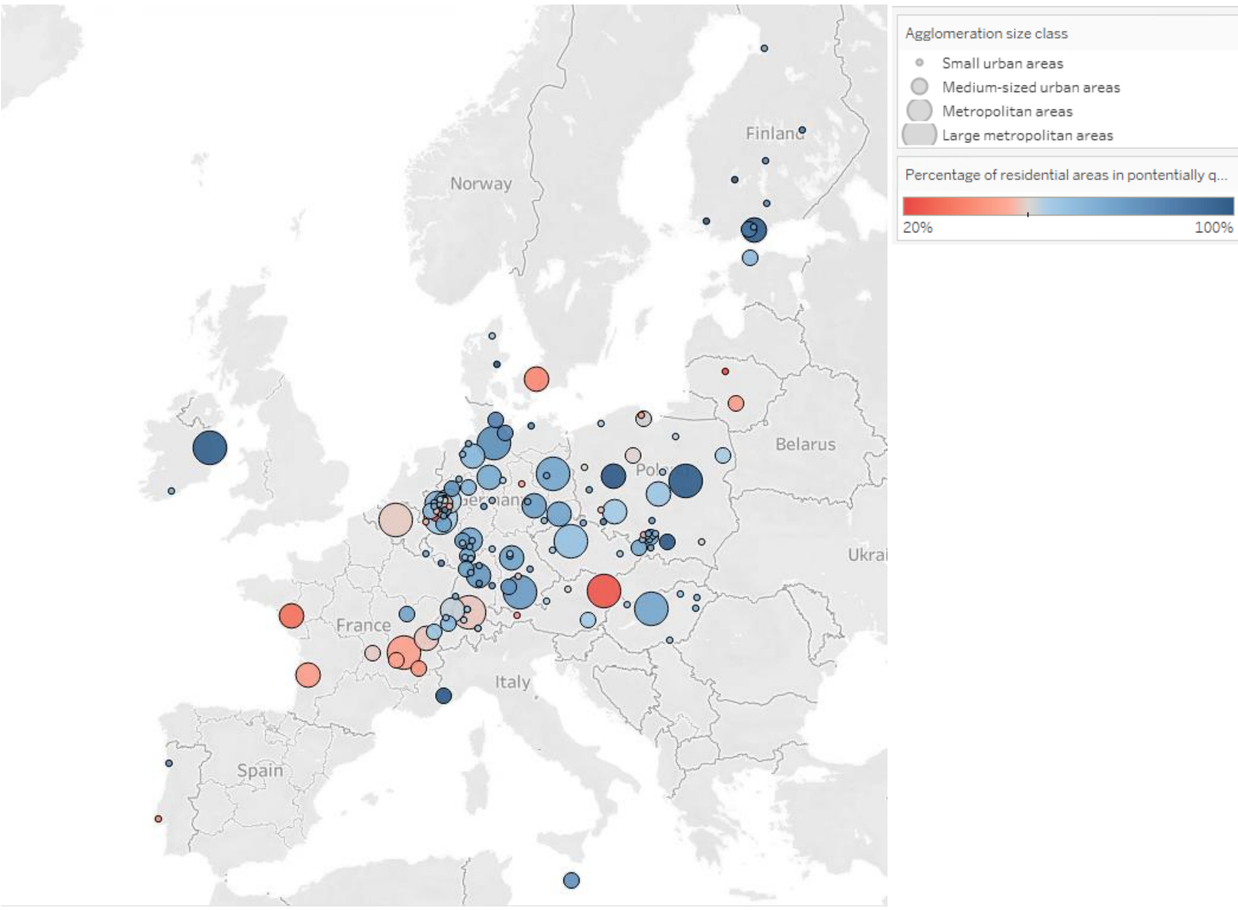
Map 3.1. Percentage of potential quiet areas in European agglomerations



Two land uses have been further analysed since they are relevant for the soundscape of the city and human health: residential areas and green urban areas.

Residential areas are predominantly quiet in 82 % of the cities (Map 3.2). Aarhus, Poznan, Nice, Krakow, Tampere, Turku, Helsinki, Warsaw and Dublin are the cities with the highest share of residential areas below 55 dB L_{den} , in all cases above 90 % of the residential area. On the opposite, Düsseldorf, Siauliai, Vienna and Nantes, residential areas below 55 dB L_{den} only account for 21 to 29 % of the area of the city. These figures corroborate significant differences between Northern countries, with 78 % of residential areas below 55 dB L_{den}, as an average, and 62% in Central Europe. There are no significant differences between the other regions, partly because the low number of cities in Southern Europe.

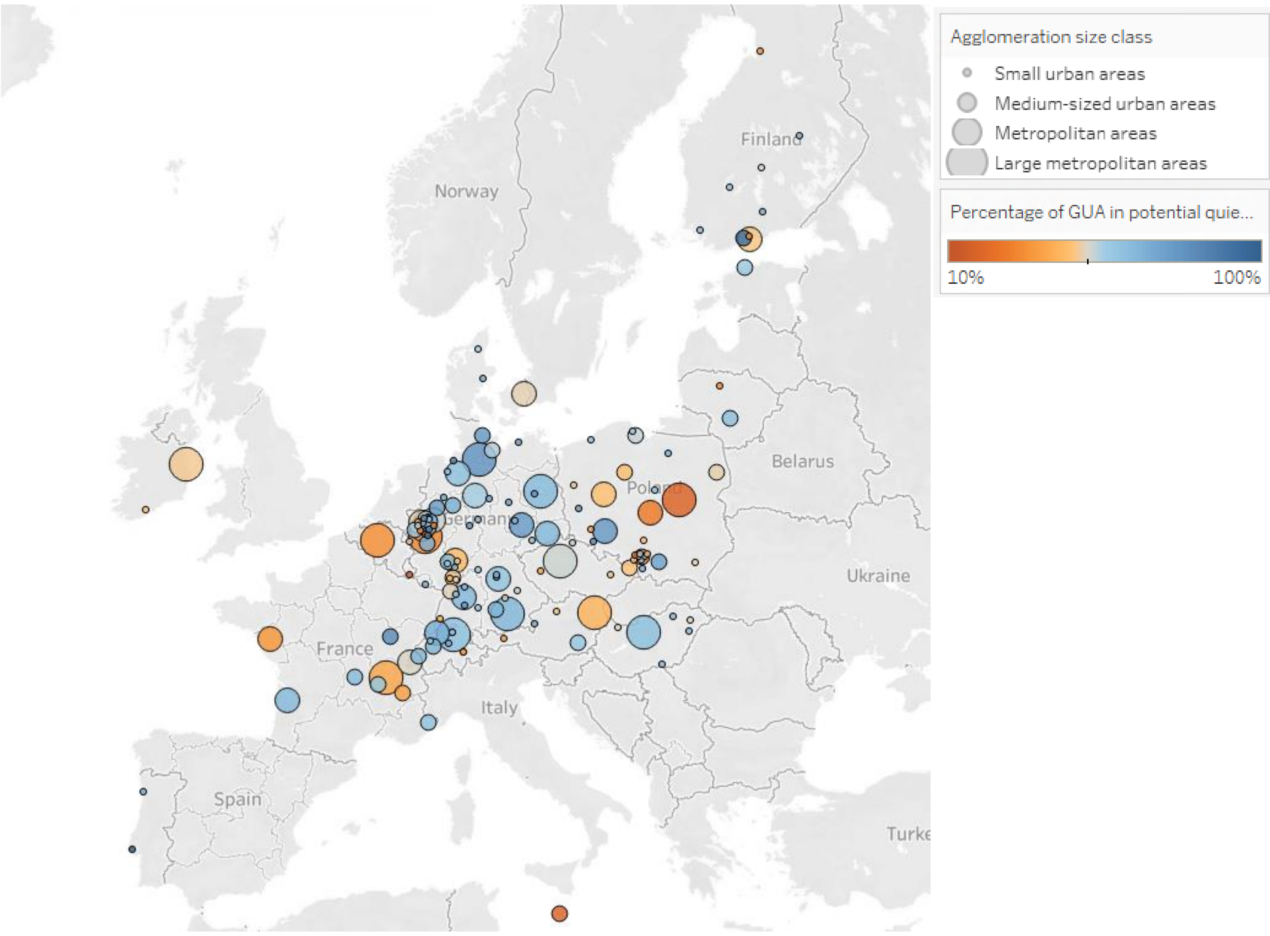
Map 3.2. Percentage of residential areas in potential quiet areas



Natural outdoor environments, including green spaces, play an important role in preserving population health and wellbeing in cities and provide ecosystem services and ecological benefits, besides having recreational, social, and cultural values. Green urban areas are those accessible to the public and, therefore, relevant for the people’s quality of life.

About 65 % of the agglomerations have green urban areas, predominantly in quiet areas. Espoo is the city with the highest share of green urban areas below 55 dB L_{den} (91 %). On the other side, Luxembourg (12 %), La Valletta (18 %), Warsaw (19 %) are the cities with the lowest share of quiet green urban areas. There are no significant differences between population size or by region.

Map 3.3. Percentage of green urban areas (GUA) in potentially quiet areas

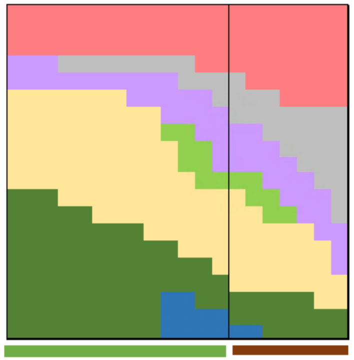
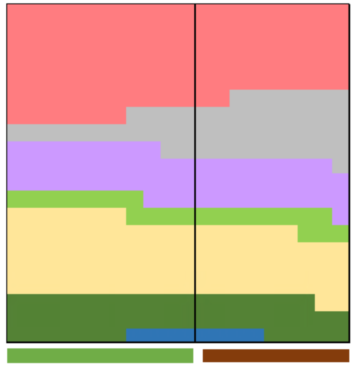
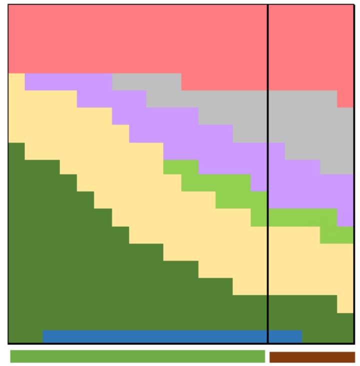


These results reflect that noise propagation and noise environment in the city are local phenomena. Geographic distribution, which could be related to certain land planning practices and culture, or city size, may generate some inertia, do not explain differences in the availability of quiet areas. Therefore, a cluster analysis has been conducted to identify which cities are more similar and which factors may explain these similarities. After several iterations, the most consistent results provided three groups of cities (Table 3.1, Map 3.4). A word of caution is needed, given the unbalanced geographic distribution. Therefore, the results are limited to the group of cities analysed.

The three groups of cities are differentiated by the percentage of the population living in noisy areas and the percentage of the city in quiet areas. An overview follows:

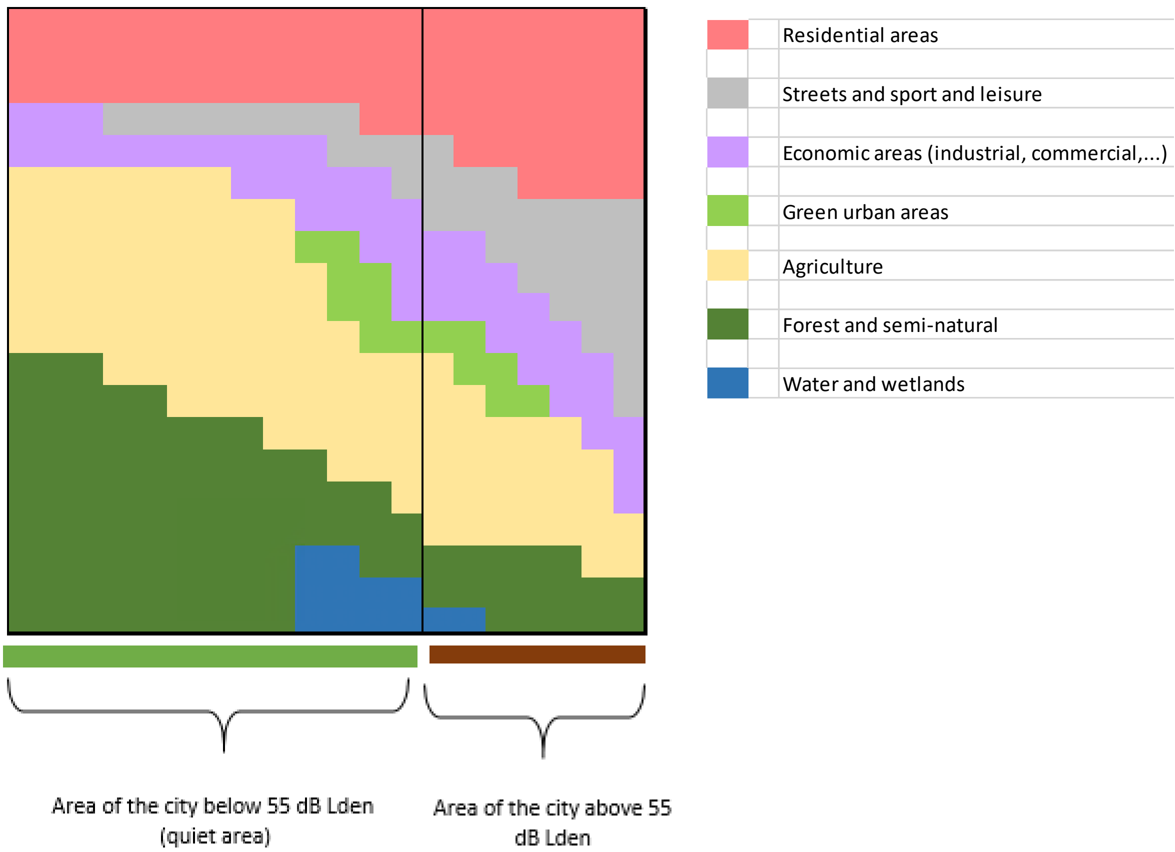
- **Noisier cities**. This group covers about 52 cities. Although most smaller cities are within this group, the size of the city is not determinant. There are significantly more cities from Western and Southern Europe and fewer cities from the Northern countries. Noisy areas are in the city's core, where more people live, and there are fewer green urban areas than the quiet cities. The quiet part of the city is most likely located on the outer skirts of the agglomeration, indicated by the high share of agricultural and forest areas. This group also includes those cities with fewer green urban areas (GUA), as seen in the Map 3.4, where the bubble size indicates the percentage of total GUA. Basel, Bialystok, Gdansk and Clermont-Ferrand are some of the most representative cities.

Table 3.1: The main characteristics of the three groups of cities defined by the cluster analysis. The legend of the figures is provided at the bottom

Group	**Noisier cities**	**Intermediate (quiet residential)**	**Quiet cities (quiet green)**
Land use composition in quiet and noise areas of the city			
Number of agglomerations	52	38	57
Share of the population in noisy areas	58,0 %	39,5 %	28,2 %
Description	Although most of the population lives in the noisy part of the city, more than 50 % of the area of the city is below 55 dB L_{den}.	The 55 dB L_{den} threshold used to define the quiet areas divides the city into two almost equal halves.	Most of the city is below 55 dB L_{den} and most of the population lives in quiet areas.
Land use	There is a clear contrast between quiet areas (left side of the figure) and the right side. Quiet areas are predominantly occupied by natural and seminatural areas, followed by agricultural areas. In contrast, the part of the city above 55 dB Lden (right side of the figure) is predominantly devoted to economic activities, streets and roads, and residential areas.	This group is the one where quiet areas and noisy areas are more similar. The noisy part of the city has a higher share of the transport network (mainly streets) and economic activity.	This group has the smallest noisy area, as a percentage of the total area of the city -23 % on average. Noisy areas have a higher share of streets and economic areas, with a lower contribution of agricultural and natural areas.

Legend of the figures representative of the cluster analysis (Table 3.1)

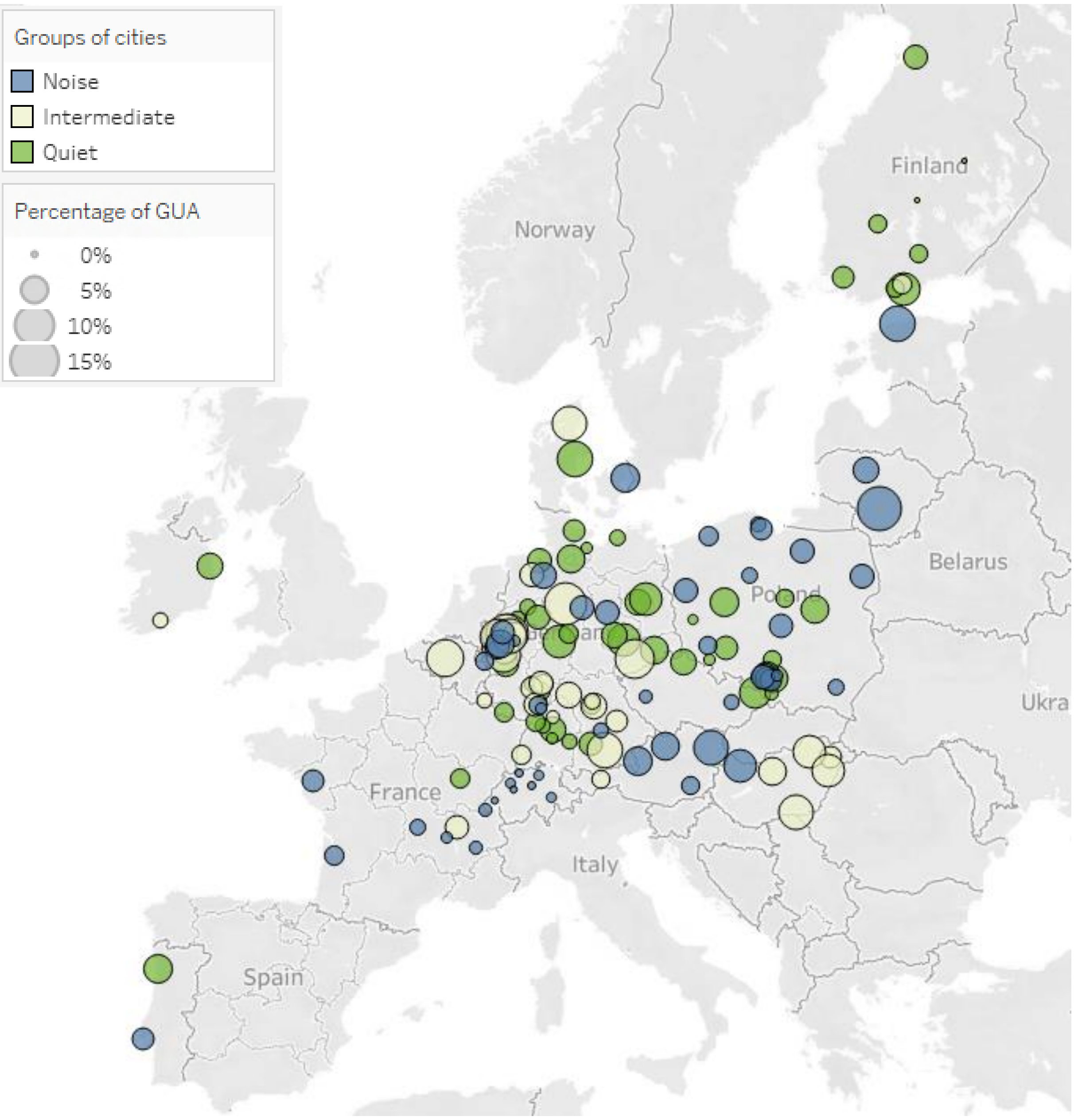
The square represents the total area of the city. The vertical line divides the city into the quiet area (below 55 dB L_{den} , left side) and the noisy area (right side). Colours relate to the land cover composition in each part of the city.



- **Intermediate cities**. This is the smaller group, with 38 agglomerations, covering all ranges of city size and significantly lower cities from the Northern countries. The city is divided into almost two equal halves between noise and quiet areas. However, most people live in quiet areas. This group outstands because the land use/land cover composition of both quiet and noise areas is more similar than the contrasted situation in the other two groups. The share of green urban areas is similar. Aalborg, Cologne or Dortmund are representative cities of this group.

- **Quiet cities**. This is the largest group, with 57 agglomerations. Most of the Northern cities are in this group. Noisy areas have fewer residential areas, more industrial, commercial and transport infrastructure, and less green urban areas. On the other side, quiet areas have a large contribution of natural and semi-natural areas. Helsinki, Bonn, Augsburg, Kassel or Kiel are representative cities of this group.

Map 3.4. Geographic distribution of agglomerations according to its similarity on availability of quiet areas and its characteristics. Bubble size represents the percentage of the city's total green urban areas (GUA), including both in quiet and noisy areas

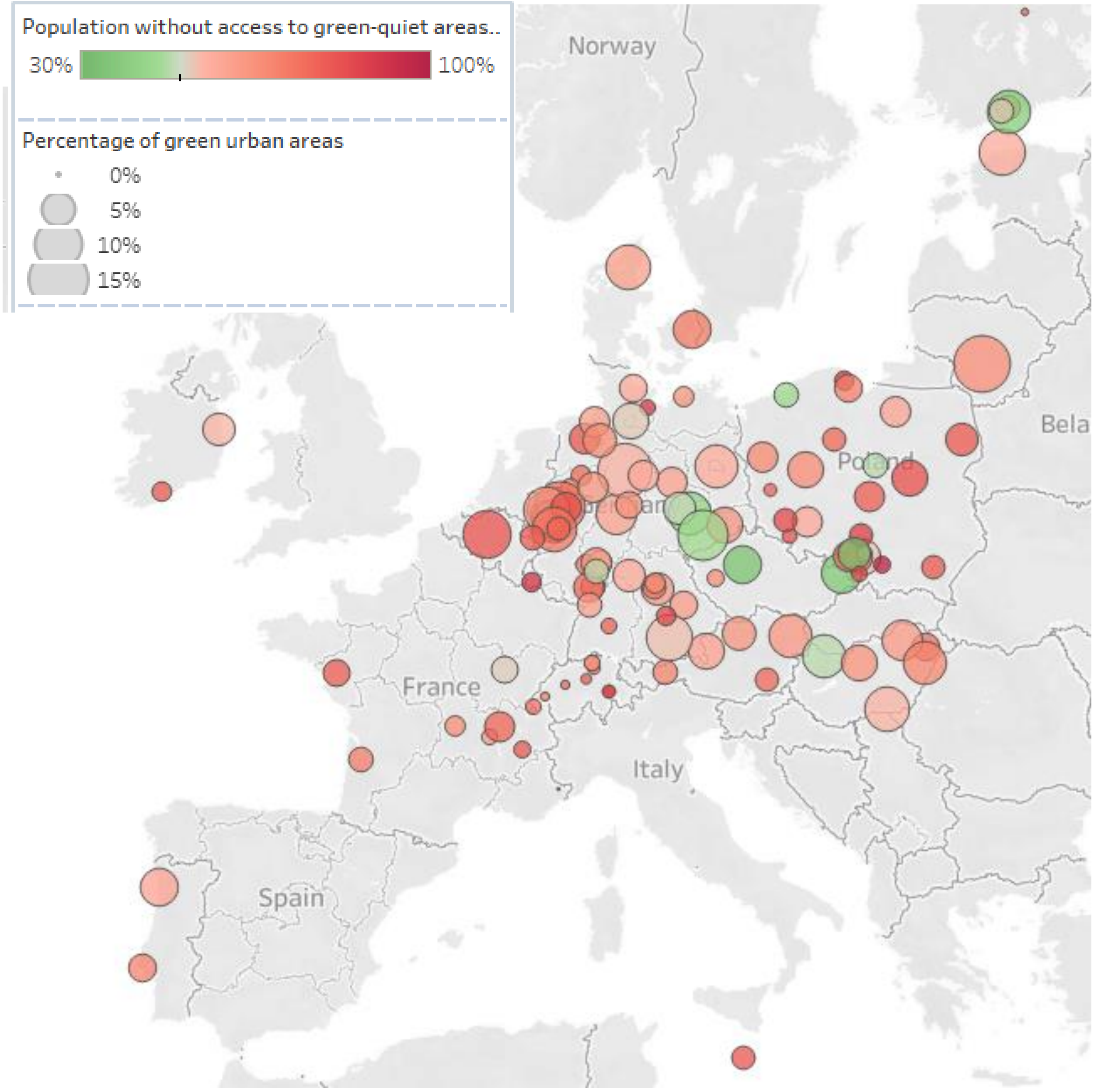


The characterisation of quiet areas already hints at available green space and its distribution. However, these figures alone do not provide any information on accessibility since it requires a more detailed analysis considering the existing street network.

Nearby access to both quiet spaces and green spaces has been shown to positively contribute to the health and wellbeing of local communities (Pereira Barboza et al., 2021). Therefore, it is important that cities ensure adequate access to quiet areas and green spaces, which allow physical exercise, relaxation and restoration from the stress of the city.

About 31,4 million people, 64,5 % of the total population of the agglomerations analysed, has no access to green-quiet areas within 400 m walking distance. Only 11 % of the agglomerations have accessible green-quiet areas for most of their population (Map 3.5). This small group includes Bytom, Ostrava and Helsinki, where people without access accounts for 35 % to 40 % of the total population -the lowest percentage. On the other side, Luxembourg and Rybnik are the agglomerations with a higher share of the population without access (89 % of the total population).

Map 3.5. Percentage of people without access to green-quiet areas. Bubble size indicates the share of the green-quiet areas



The percentage of green-quiet areas partly explains accessibility since the correlation is significant but low (r^2 = 0,38, p<0,01). It has already been described the contribution of other factors to the accessibility, namely the range of sizes of quiet-green patches and its distribution in the agglomeration (Sáinz de la Maza, 2019).

We assessed the accessibility considering separately both the population living in city areas below 55 dB of average day-night noise and those areas ≥ 55 dB (Figure 3.1).

Accessibility to green-quiet areas for people living in noisy areas ranges between 0,16 ha in Luxembourg to 2,2 ha in Walbrzych, with an average of 0,95 ha. Most of the practices found in the literature and reported by the Member States consider 1 ha as a minimum requirement for quiet green areas (ETC/ATNI Report 10/2019). About 56 % of the analysed cities will fall below this threshold, highly relevant since it refers to people living in noisy areas.

Accessibility to green, quiet areas for people living in areas < 55 dB L_{den} is higher than for people living in noisy areas. The median size of the accessible area ranges between 0,13 ha in Brussels to 2,39 ha in Kassel, with an overall median of 1,1 ha. In that case, 49 % of the agglomerations have an accessible area of less than 1 ha.

Figure 3.1 also depicts the distribution of the agglomerations according to the three clusters identified in the previous section. There are significant differences between the most extreme groups (noisier cities and green quiet). The group of noisier cities tend to have more people without access to green-quiet areas, and the median accessible area is lower on average (Table 3.2). Moreover, the median surface of accessible area is lower than 1 ha. On the other side, the group defined as green quiet cities is the one with the lowest population without accessibility, although the average is over 50 %. The median accessible surface is also higher, above 1 ha.

Table 3.2: Accessibility to green-quiet areas by typology of agglomerations (see Table 3.1 for their description). Differences between the groups “noisier cities” and “green quiet” are significant ($p < 0.001$) for all parameters

Cluster	Population without accessibility to green-quiet areas (%)	Median surface area accessible for people living in areas < 55 dB L_{den} (ha)	Median surface area accessible for people in area >= 55 dB L_{den}
Noisier cities	68,9	0,86	0,79
Residential quiet	66,6	1,11	0,98
Green quiet	61,8	1,33	1,09

Figure 3.1. Proximity to potential green-quiet areas, percentage of the population without access and the share of potential green-quiet areas in the total land area (bubble size). Agglomerations are grouped according to the clusters described in the previous section

4 Conclusions

This study provides a methodology to characterize the noise environment in European cities and estimate the accessibility to quiet-green areas. The study focuses on 145 agglomerations where Member States have provided traffic noise and aircraft noise information. Therefore, conclusions should be taken with caution, although the figures can be considered the maximum potential accessibility for the studied cities (129). Additionally, southern European agglomerations are missed mainly, resulting in an unbalanced geographic distribution.

Although most of the green areas are located in quiet zones, the structure of the city and the distribution of these green-quiet areas determine differential accessibility for the population.

Three main groups have been identified:

- Noisier cities. Most of the residential areas concentrate in the noisier part of the city, whereas green urban areas are distributed more towards the skirts of the agglomeration. This group of cities concentrate the highest percentage of the population without access to quiet-green areas. Also, the quiet-green areas near people who have access are below 1 ha.
- Residential quiet. The noisier part of the city tends to concentrate the economic activity. Therefore, residential areas are more located in quiet neighbourhoods (< 55 dB L_{den}). About 66 % of the population has no access to green-quiet areas. The median surface of green-quiet areas for those who have access and live in quiet neighbourhoods (22 % of the population) is about 1,1 ha. The median surface of green-quiet areas for people living in noisier neighbourhoods (13 %) is less than 1 ha.
- Green quiet. The noisier part of the city tends to concentrate the economic activity. Residential areas are more concentrated in quiet neighbourhoods (< 55 dB L_{den}), also characterized by a high percentage of green urban areas. People without access to green-quiet areas is still high (61 %), although this is the lowest percentage compared to the other two groups. The median surface of accessible green-quiet areas is above 1 ha, independently from the area's noise level where people live.

These results indicate the complexity to manage green-quiet areas since there are factors related to the structure of the city that would require mid-long term planning to change. Therefore, the protection of already available green-quiet areas is needed, as reflected in the END, since most of the people in the analysed agglomerations has not easy access to quiet-green areas.

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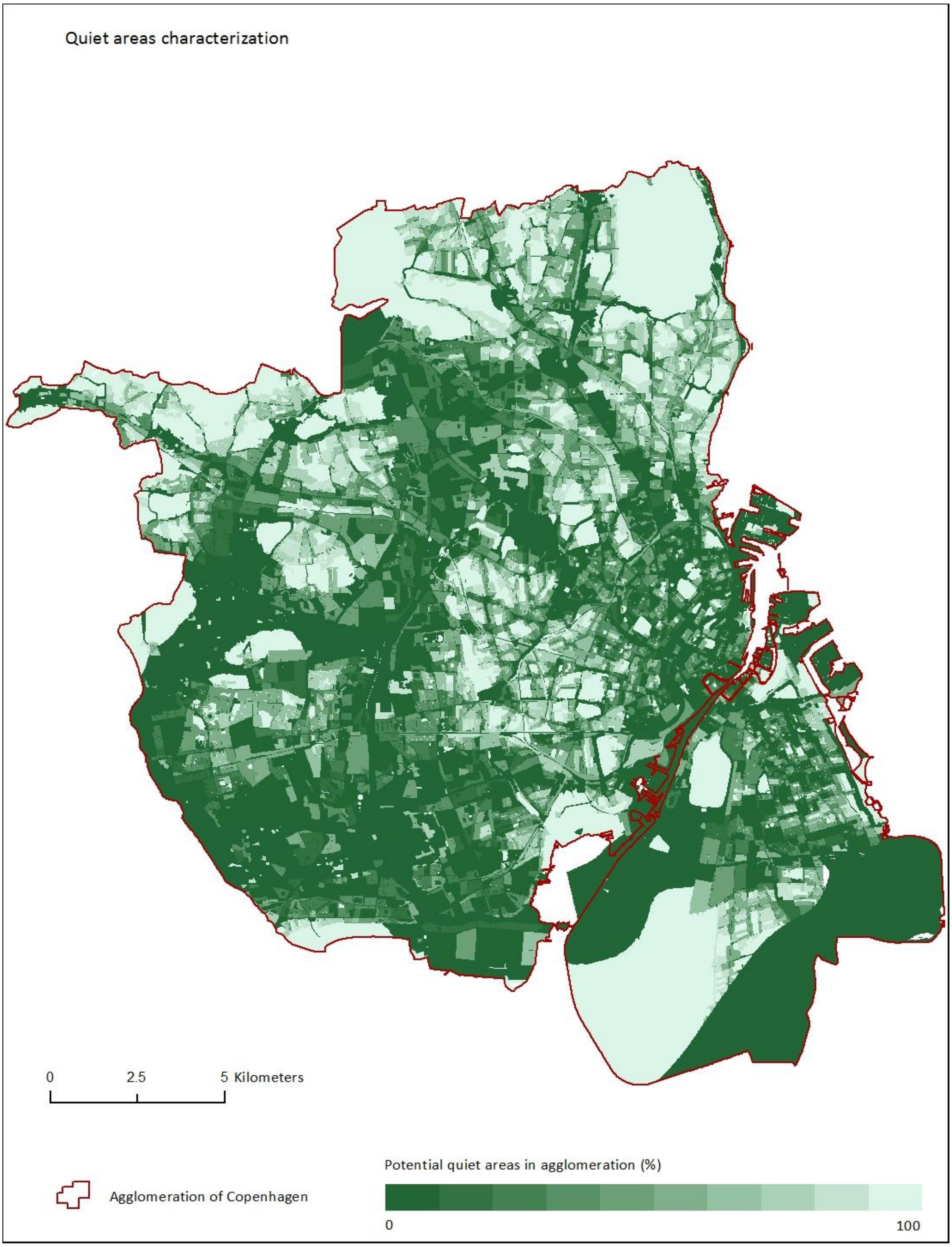
Annex 1
Characterization and accessibility for the agglomeration of Copenhagen



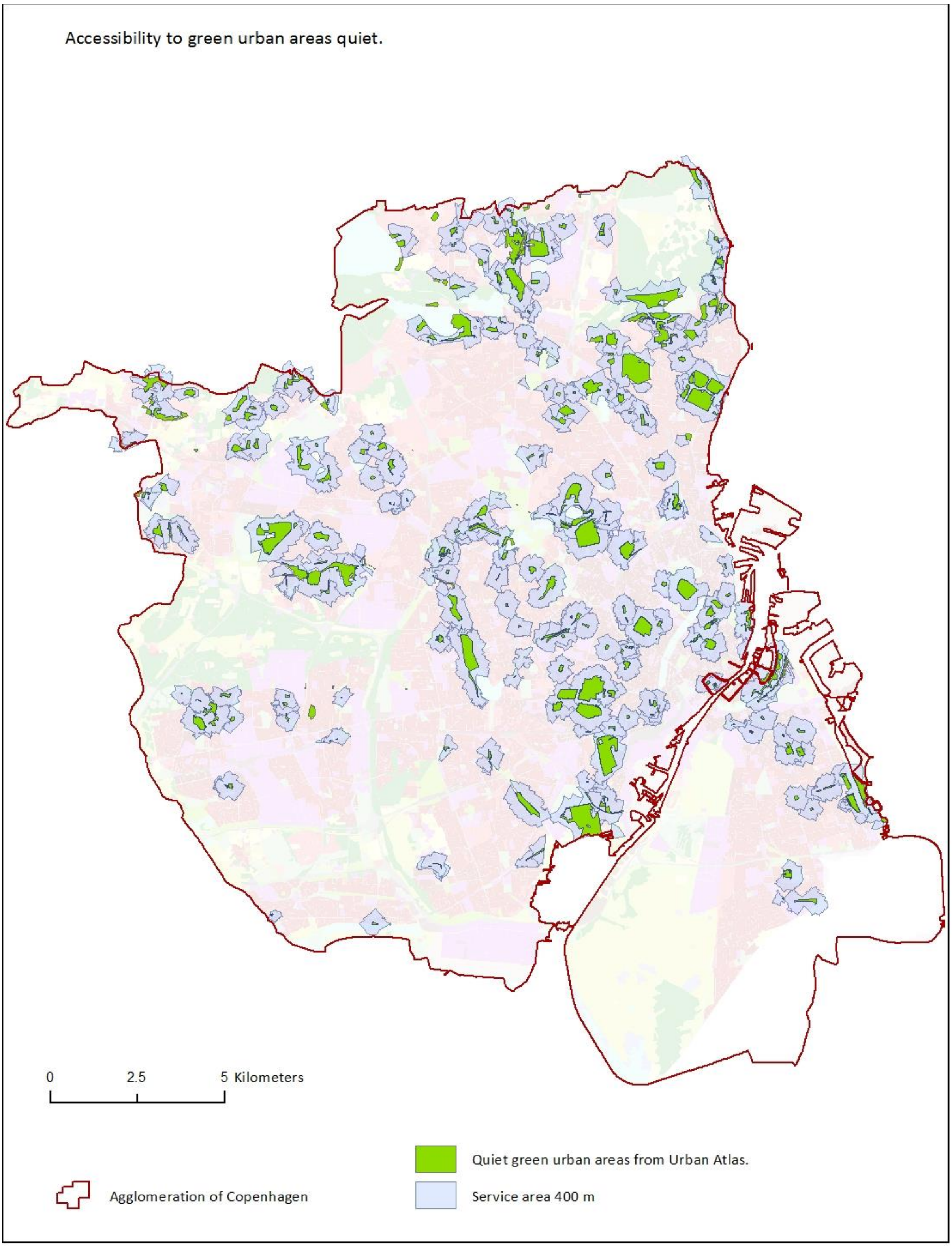

Accessibility to green urban areas quiet.
0
2.5
5 Kilometers
Quiet green urban areas from Urban Atlas.
Agglomeration of Copenhagen
Service area 400 m

Table I. *Tomtom Functional Road Classes (FRC). We use functional road classes <> 0,1,2*

FRC VALUE	Short Description	Long Description
0	Motorways; Freeways; Major Roads	All roads that are officially assigned as motorways.
1	Major Roads less important than Motorways	All roads of high importance, but not officially assigned as motorways, that are part of a connection used for international and national traffic and transport.
2	Other Major Roads	All roads used to travel between different neighbouring regions of a country.
3	Secondary Roads	All roads used to travel between different parts of the same region.
4	Local Connecting Roads	All roads making all settlements accessible or making parts (north, south, east, west and central) of a settlement accessible.
5	Local Roads of High Importance	All local roads that are the main connections in a settlement. These are the roads where important through traffic is possible e.g.: • arterial roads within suburban areas, industrial areas or residential areas. • a rural road, which has the sole function of connecting to a national park or important tourist attraction.
6	Local Roads	All roads used to travel within a part of a settlement or roads of minor connecting importance in a rural area.
7	Local Roads of Minor Importance	All roads that only have a destination function, e.g., dead-end roads, roads inside living area, alleys: narrow roads between buildings, in a park or garden.
8	Other Roads	All other roads that are less important for a navigation system: • a path: a road that is too small to be driven by a passenger car. • bicycle paths or footpaths that are especially designed as such. • stairs; • pedestrian tunnel; • pedestrian bridge; • alleys that are too small to be driven by a passenger car.

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