



The Urban Mask Layer as Reference Geometry for Spatial Planning: Moving from German to European Geodata

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Abstract

In view of rising urbanisation around the world, it is vital to improve the analysis and evaluation of spatial settlement structures in order to ensure the sustainable design of associated transformation processes. Geodata and the maps derived from urban datasets can contribute significantly to understanding the characteristics of settlement structures. In this context, urban areas with a concentration of settlement elements form an important reference geometry. In Germany, such an urban mask is termed *Ortslage* and is included as an object type in the official topographical basic geodata (ATKIS). It would be useful to have a similar urban mask at European level, especially as a layer of the Urban Atlas within the framework of the Copernicus Land Monitoring Service. Here we present a GIS-supported algorithm to generate such a layer from Urban Atlas data. The method is demonstrated on 30 European cities showing a wide range of urban structures. Further, we compare the physical shape of the *Ortslage* with the urban mask, here illustrated by the city of Leipzig, Germany. As a basic example of the planning relevance of this method, we consider and discuss the metric *shape complexity of the urban space* for the cartographic comparison of cities. Furthermore, we address the question of a mixed automated-manual technology in the delineation of the urban mask. The regular updating of the Urban Atlas data within the framework of the Copernicus Land Monitoring Service opens up the possibility of integrating analyses based on the urban masks into the European Spatial Observation.

Keywords Urban mask · ATKIS · Urban Atlas · Generalisation · Settlement structure · Urban metrics

Zusammenfassung

Angesichts der weltweit zunehmenden Urbanisierung ist es unerlässlich, die Analyse und Bewertung räumlicher Siedlungsstrukturen zu verbessern, um die nachhaltige Gestaltung der damit verbundenen Transformationsprozesse sicherzustellen. Geodaten und die daraus abgeleiteten Karten können wesentlich zum Verständnis der Merkmale von Siedlungsstrukturen beitragen. Urbane Räume mit einer Konzentration von Siedlungselementen bilden in diesem Zusammenhang eine wichtige Referenzgeometrie. Eine solche urbane Maske wird in Deutschland als *Ortslage* bezeichnet und ist als Objektart in den amtlichen topographischen Geobasisdaten (ATKIS) enthalten. Eine vergleichbare urbane Maske auf europäischer Ebene wäre vor allem im Rahmen des *Copernicus Land Monitoring Service* als Layer des *Urban Atlas* wünschenswert. Hier wird ein GIS-gestützter Algorithmus zur Generierung eines solchen Layers aus den Daten des *Urban Atlas* vorgestellt. Das Verfahren wird an 30 europäischen Städten demonstriert, die ein breites Spektrum urbaner Strukturen aufweisen. Außerdem wird die physische Form der *Ortslage* mit der urbanen Maske verglichen, hier dargestellt an der Stadt Leipzig. Als grundlegendes Beispiel für die planerische Relevanz dieser Methode betrachten und diskutieren wir die Metrik *Formkomplexität des Siedlungskörpers* für den kartographischen Städtevergleich. Darüber hinaus wird die Frage einer gemischten automatisch-manuellen Technologie bei der Abgrenzung der urbanen Maske behandelt. Die regelmäßige Aktualisierung der Daten des *Urban Atlas* im Rahmen des *Copernicus Land Monitoring Service* eröffnet die Möglichkeit, Analysen auf der Grundlage von urbanen Masken in die europäische Raubeobachtung zu integrieren.

Schlüsselworte Urbane Maske · ATKIS · Urban Atlas · Generalisierung · Siedlungsstruktur · Urbane Metrik

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1 Introduction

A wide range of human activities is concentrated within settlements. This makes urban areas primary consumers of natural resources. With regard to planning for sustainability, decision-makers need detailed information of the built environment as well as urban greenery, the two main components of the settlement structure. Furthermore, the functions of housing, employment, education, supply and recreational use, which are concentrated in urban areas, can boost sustainability if the spatial mix is intelligently planned (EU 2007, 4). This can also be ensured by the careful delineation of urban areas.

The cartographic representation of any administrative reference unit will contain polygons of the urban area as well as open space. Such delineation of the urban area can be realised using basic topographic geodata. Clearly, this entails the spatial identification of the interior vs. the exterior, i.e. the creation of an urban mask for geospatial analysis and evaluation of the settlement structure. In international studies, the analysis of urban spaces frequently considers only built-up structures. The term “urban mask” is used in this narrow sense, for example in the context of the two global geo-databases Global Urban Footprint (GUF) and Global Human Settlement Layer (GHSL) (Minghini et al. 2017). Both sets of geodata, which are derived from remote-sensing data, are grid-oriented and focus on built-up areas while ignoring urban green. A rural–urban mask derived from CORINE Land Cover (CLC) 2012 is provided by the Copernicus Climate Change Service as an additional data source for 100 European city regions to calculate urban heat islands (Copernicus Climate Change Service 2019). The minimum mapping unit in the CLC data and consequently in the rural–urban mask is 25 ha. Unfortunately, this primarily rural–urban delineation does not provide a suitable geometry for detailed analyses. A comparable urban mask is not yet publicly available for the thematic context and scale of the European Urban Atlas, i.e. minimum mapping unit: 0.25 ha (EU 2016).

In Germany, an urban mask geometry is included as an object type in the official topographical basic geodata (ATKIS): the so-called *Ortslage* (AdV 2018, 224). This object type, which has been translated as “urban site”,¹ has a minimum size of 10 ha. It encompasses built-up areas and urban green spaces within the administrative city area. The urban mask is already recognised as an important reference unit for urban, regional and environmental planning. Depending on the availability of data, urban masks can describe the spatial extent of settlements as well as their

characteristic features, thereby assisting in a wide range of strategic planning tasks at small and medium scales as well as relevant scientific studies. This is demonstrated by many examples in planning and research that use the geometry of the ATKIS urban site.

One important use of the urban site is in the assessment of infill development potential (BBSR 2013, 2014). Such assessment entails analysing existing basic geodata to determine gaps between buildings as well as the potential for redensification, leading to the establishment of potential land registers of infill potential, e.g. at the level of the federal states (Hintzen and Petersen 2016). Further, parameters of settlement structure at spatial resolution considerably below the municipal level are needed to conduct intelligent strategic settlement and infrastructure planning. This can be usefully supported by the ATKIS urban site (Schiller and Bräuer 2013). Other researchers use the basic geometry of the urban site to distinguish between urban and extra-urban areas to pinpoint potential areas for future settlement development (MWEKL 2011). In the analysis of urban sprawl, the calculation of dispersion (according to the Swiss measurement concept) can be based on the settlement area boundaries of the urban site (Schwarzak et al. 2014). This ATKIS object type is also an important intersection geometry in analyses of urban greenery: Increased surface temperatures have been found in less greened urban site areas as compared to the respective administrative city area (Frick et al. 2020). When regional authorities are planning sites for wind farms, the visual impact and pressure of wind turbines on settled areas is often insufficiently taken into consideration. Taeger and Ulferts (2017) present a GIS-based approach to identify and assess potential conflicts between proposed wind farm sites and settlements at regional level using the ATKIS urban site. Such considerations are already included in regional planning documents (Regionalplanung Thüringen 2020). When planning efficient NGA (Next Generation Access) network extensions, it can be helpful to focus on settlement areas so as to significantly reduce costs and achieve a high level of development (Fornefeld et al. 2015). Here too the tool of urban sites can be helpful. The Southern Upper Rhine Regional Association uses the delimitation of urban sites to map and evaluate so-called biotope complex types while considering the factors of usage and nature conservation (Regionalverband Südlicher Oberrhein 2010). Walz et al. (2011) and LIKI (2019) consider urban site polygons as fragmentation elements when developing indicators on landscape fragmentation. Such indicators measure the extent to which the landscape is fragmented by technical elements; thereby, disturbing the local nature and wildlife as well as recreational activities.

Deilmann et al. (2017) discuss various aspects of the balance between compactness, efficiency and the environmental quality of settlement areas. They claim that the built

¹ <https://www.ioer-monitor.de/en/methodology/glossary/u/urban-site>.

environment and urban greenery should be explicitly linked in spatial terms, arguing that the delineation of an urban mask from open space in the surrounding area is necessary for the geospatial analysis of settlement structures. Such an urban mask refers to the urbanised areas of a city within its administrative boundaries, containing the contiguous built-up area as well as the spatially- and functionally-related areas of transport, recreation, vegetation and water.

These examples of the various applications in Germany of the geometry of an urban mask illustrate its manifold potential for urban, regional and landscape planning as well as research tasks. Therefore, it would be useful to have such an urban mask at European level, especially as a layer of the Urban Atlas within the framework of the Copernicus Land Monitoring Service (EU 2016). This paper presents a GIS-supported algorithm to generate such a layer from Urban Atlas data. We will demonstrate the method on 30 European cities that cover a wide range of urban structures. Further, the physical shape of the ATKIS urban site will be compared with that of the urban mask, here in the case of Leipzig, Germany. Subsequently, one basic urban metric (shape complexity of the urban space) will be presented and discussed as representative of a number of urban planning tasks which could potentially benefit from the tool of the urban mask. Furthermore, we address the question of a mixed automated-manual technology in the delineation of the urban mask.

2 Data and Methods

2.1 Delineation of a European Urban Mask

First it is necessary to define what we mean by an “urban mask”.² For our analysis, this term is similarly defined as the term *Ortslage* or “urban site” in official German spatial surveys. The following definition is given in the documentation of the ATKIS Basic Landscape Model: “An ‘*Ortslage*’ is a contiguous built-up area. It encompasses ‘residential areas’, ‘industrial and commercial areas’, ‘mixed-use areas’ and ‘areas of special functional character’ as well as areas which have a close spatial and functional relationship to these dedicated to transportation, watercourses, areas occupied by ‘buildings and other facilities’, for recreation, sport and leisure, as well as ‘vegetation areas’” (AdV 2018, 224). Cartographically, an urban site represents a settlement polygon, geometrically bounded by a continuous line. In contrast to this ATKIS object type, the urban mask defined here is created by merging directly adjacent polygons into one polygon, thereby reducing the number of settlement polygons.

Only spatially detached polygons are preserved geometrically as such.

As part of the Copernicus Land Monitoring Service, the Urban Atlas provides detailed vector data on land cover and land use for numerous city-regions in Europe (Montero et al. 2014). Such data are available with a largely standard nomenclature of 28 classes at scale 1:10,000 for the reference years 2006 and 2012. The dataset for the year 2018 is currently being put together and not yet validated. For the year 2012, the Urban Atlas is available for almost 700 European city-regions (“Functional urban areas” or FUA) as open geodata (Copernicus Land Monitoring Service 2018). These include all EU cities with more than 100,000 inhabitants as well as their commuting zones. A mapping guide contains the product description, mapping guidance and class description for the Urban Atlas (EU 2016).

As described in the introduction, the Urban Atlas geodata contains no specific layer for urban masks. To remedy this deficit, we have developed a GIS method to delineate urban masks using Copernicus data at medium scale. In this regard, we are following up on the investigations by Schumacher and Deilmann (2019a), 37 ff. to compare urban fragmentation in selected European cities. In that research, the authors defined urban masks by means of automated steps and final manual editing of polygons governed by predefined criteria. These criteria provided some scope for the subjective determination of delineation while taking account of unique local factors; however, this entails extensive mapping work by experienced cartographers. In the current paper, the method is further refined to make exclusive use of objective criteria. In principle, therefore, it can be applied without the need for any manual editing of polygons.

Reflecting the official definition of urban site, ten relevant land use classes were selected from the nomenclature of the Urban Atlas (EU 2016) as components for the urban mask (Fig. 1). These classes, representing both built-up and green urban areas, are as follows:

- Continuous and discontinuous urban fabric (built-up area and associated land, predominantly residential structures) (five classes),
- Industrial, commercial, public, military or private units (one class);
- Construction sites and land without current use (two classes);
- Green urban areas (public green areas for predominantly recreational use such as gardens, zoos, parks, castle parks and cemeteries) (one class);
- Sports and leisure facilities (one class).

In general, the Urban Atlas contains polygon geometries rather than line geometries; in contrast to ATKIS, this also concerns the road and rail networks. The Urban

² The details presented in this section are largely borrowed from Schumacher and Schiller (2020, 343–344).

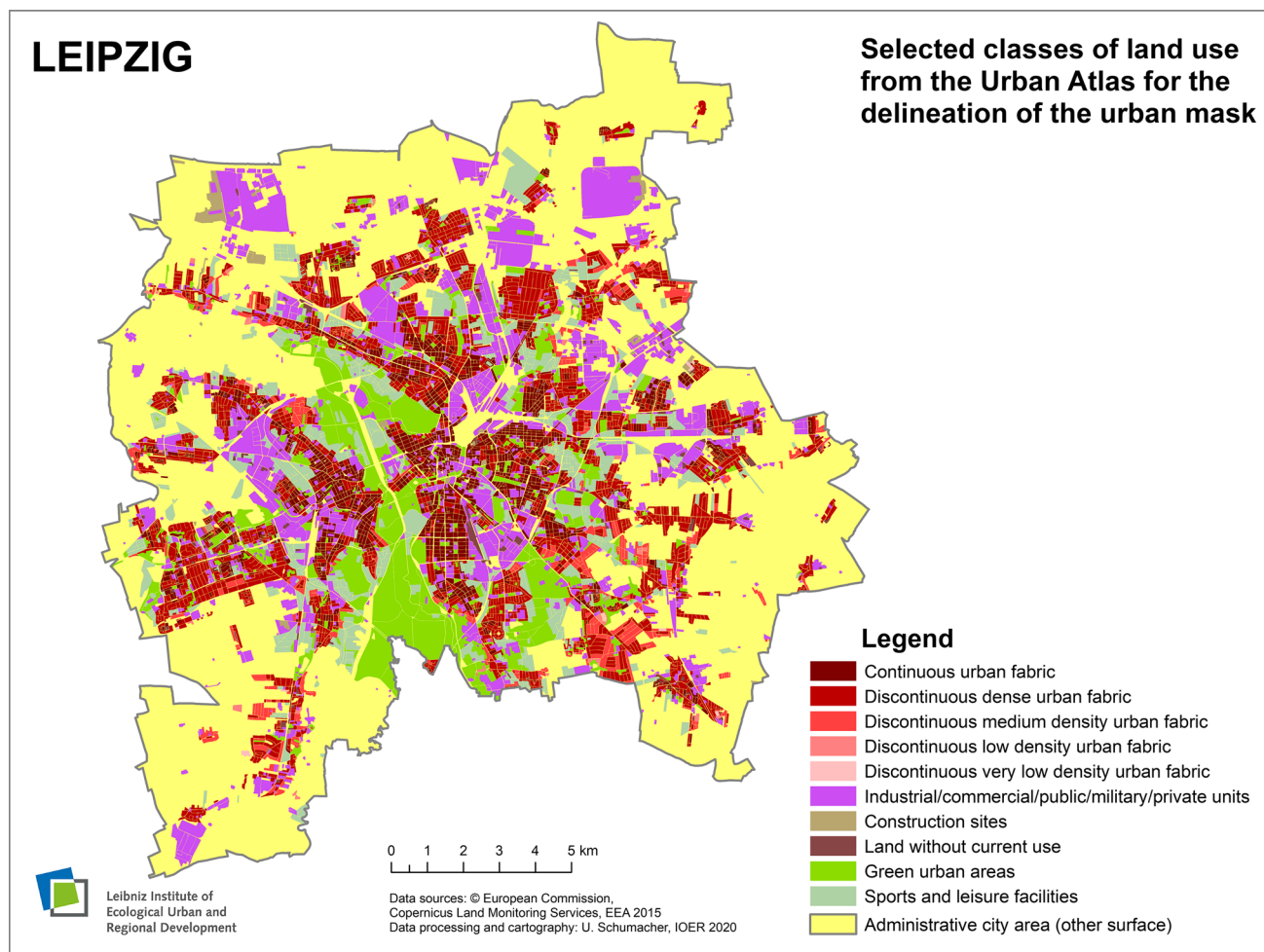


Fig. 1 Selected classes of land use from the Urban Atlas 2012 (above) and delineation of the urban mask (below), mapped for the city of Leipzig

Atlas includes only two classes of road transport (“Fast transit roads and associated land”, “Other roads and associated land”) and one class of railway transport (“Railways and associated land”). The polygonal geo-objects of these transport classes are not distinguished as being within the settlement area or in open space. However, the streets and squares in the settlement area are part of the urban site (see above definition in the ATKIS model). Therefore, the transport areas from the Urban Atlas cannot be simply assigned to the urban mask because these would spread out like a spider’s web from the settlement into the open space. Instead, such transport areas, if they are located within the urban site, are implicitly assigned to the urban mask by the procedure described below. It should be noted that shipping and air transport are ignored because neither has a close functional connection with built-up areas.

An urban mask is delineated by means of cartographic generalisation. In this study we applied a procedure from the ESRI ArcGIS toolbox: “Delineate Built-Up Areas”

(ESRI 2019). This method was originally developed to define polygons for the mapping of built-up areas, whereby densely clustered arrangements of buildings are visualised as generalised polygons in the process of downscaling. The procedure is thus concerned with the spatial grouping of building footprints—for example for the quantification and monitoring of urban sprawl (Harig et al. 2016).

In our study, however, the procedure “Delineate Built-Up Areas” is transferred to another application while making use of different input data: To define urban masks we use polygons of built-up areas and urban green spaces rather than building footprints. Accordingly, the applied GIS processing gives a different kind of generalised output data, which approximates to the definition of urban site mentioned above. The main disparity between the objects in the ten considered classes of land use and the areas resulting from the definition of urban site is that roads and other gaps in the settlement area (e.g. small water bodies) are not explicitly taken into account.

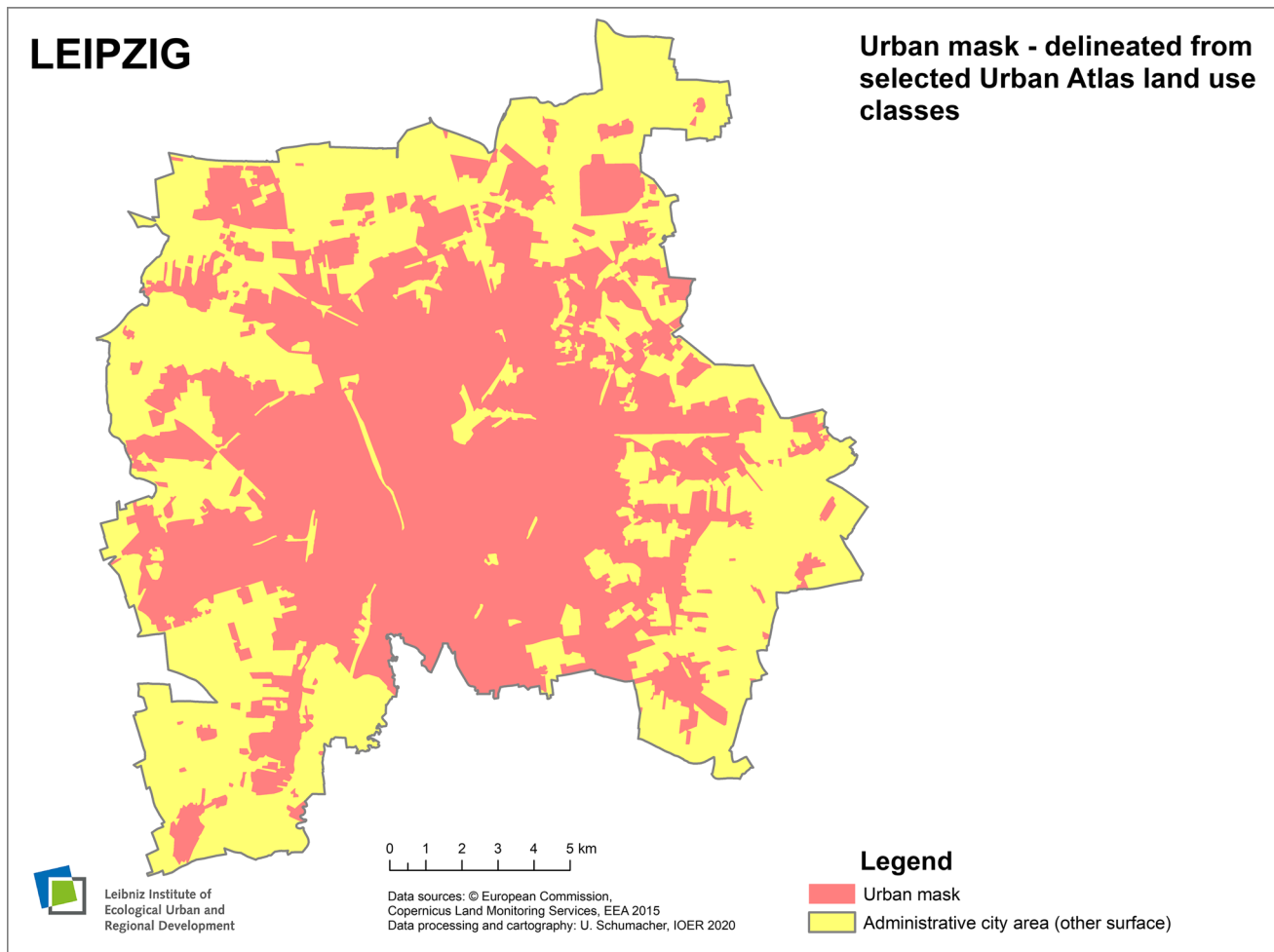


Fig. 1 (continued)

To bridge these gaps, criteria were developed based on the following considerations (ESRI 2019):

- Input polygons that are closer than the *grouping distance* are considered together as candidates for representation by one output polygon in the urban mask. Areas of transport infrastructure have a maximum width that corresponds to the definition of “grouping distance”.
- The *minimum detail size* defines the relative degree of detail in the output polygon of the urban mask. This is approximately the minimum permitted diameter of a hole in the input polygon. The real size and shape of holes are also determined by the input polygon placement and grouping distance.
- The *minimum building count* corresponds to the minimum number of input polygons that has to be combined to create an output polygon in the urban mask.

Expert assessments were used to help quantify these generalisation parameters. In addition to the authors of this

paper, four experts with long-standing practical experience in the field of GIS-based settlement structure analysis and mapping of settlements and open spaces were involved. This resulted in the following parameters governing the delineation of the urban mask:

- Grouping distance: 50 m,
- Minimum detail size: 50 m,
- Minimum building count: 1.

An area of 0.25 ha (50 × 50 m) corresponds to the minimum mapping unit of artificial surfaces in the Urban Atlas (EU 2016, 8). The option “Minimum building count = 1” means that all relevant settlement polygons are included in the algorithm. Furthermore, so-called “sliver polygons” in the open space smaller than 1 ha are deleted from the preliminary settlement mask. This value corresponds to the minimum mapping unit of agricultural areas, (semi-) natural areas, wetlands and water in the Urban Atlas (EU 2016, 8).

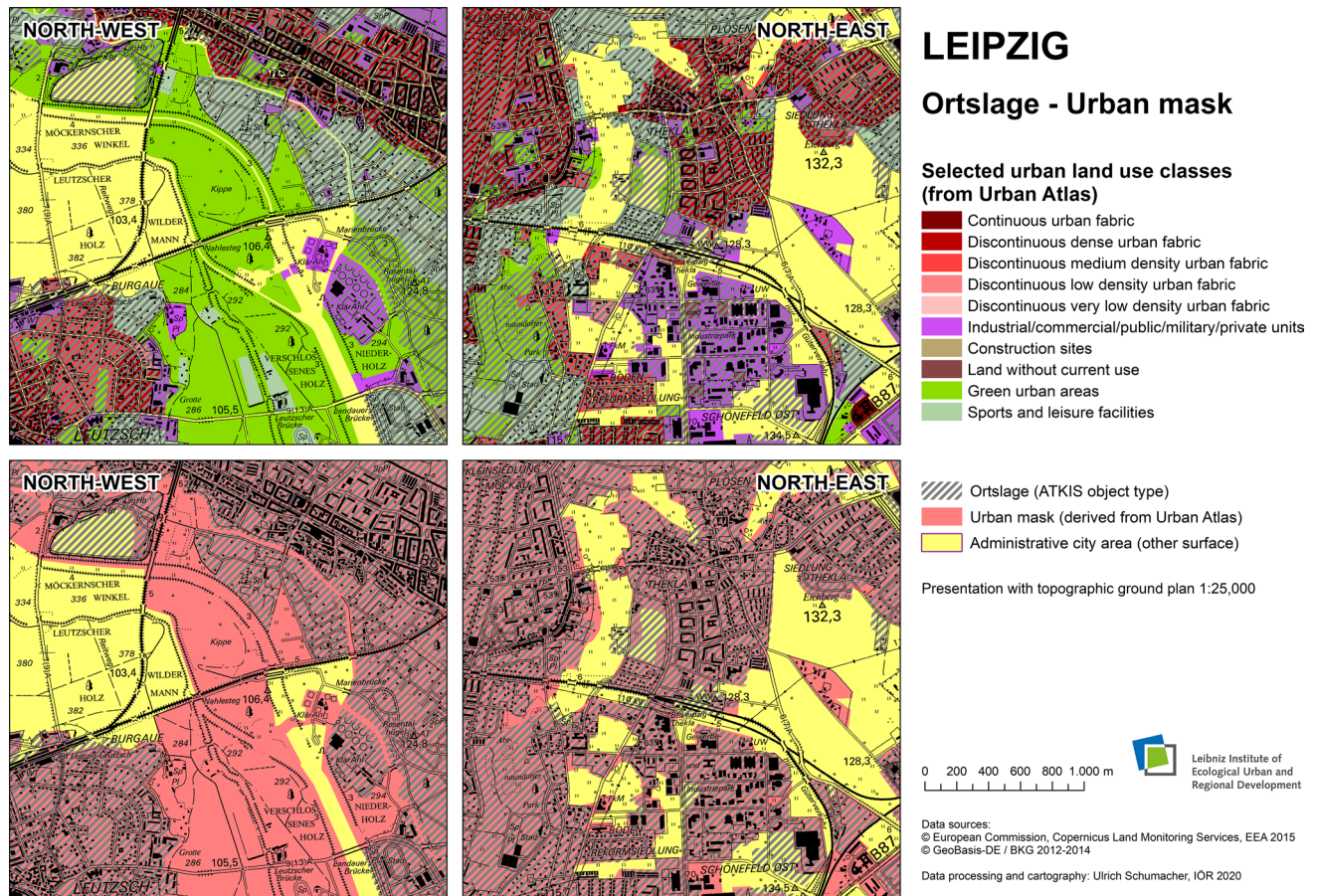


Fig. 2 Overlay of selected land use classes of the Urban Atlas with the ATKIS object type *Ortslage* or urban site (above) and overlay of the urban mask with the ATKIS urban site (below), mapped for two areas in the city of Leipzig

After applying the ArcGIS procedure “Delineate Built-Up Areas”, there are usually still gaps in the urban mask. Therefore, after discussion with experts, it was decided that holes smaller than 3 ha within the preliminary settlement mask should be filled in and merged into the final settlement mask in the interests of the cartographic generalisation of polygon geometry.

Figure 1 illustrates the procedure for the objective delineation of an urban mask, here applied to the city of Leipzig. Two levels of abstraction are presented: Fig. 1a (above) shows the polygons of the ten selected classes of land use which can be distinguished with the data of the Urban Atlas; Fig. 1b (below) shows the result of the generalisation process to create the urban mask.

2.2 Exemplary Comparison of the German *Ortslage* with the European Urban Mask

The urban mask, derived from the European Urban Atlas, largely corresponds to the object type *Ortslage* or urban site from the German ATKIS Basic landscape model. In detail, however, some differences are revealed, especially regarding complex polygonal structures. This applies less to the urban centres than to the transition areas from settlement to open space, as can be seen on the north-west (Fig. 2, left) or north-east periphery (Fig. 2, right) of the city of Leipzig.

In the map section showing the north-west of Leipzig, larger areas of riverside forest with water bodies and a dump site can be seen in addition to built-up districts with allotment gardens and parks. The ATKIS urban site (hatched) encompasses the built-up areas, allotments and parks including a lake, but not the riverside forest, watercourses and the dump site. In contrast,

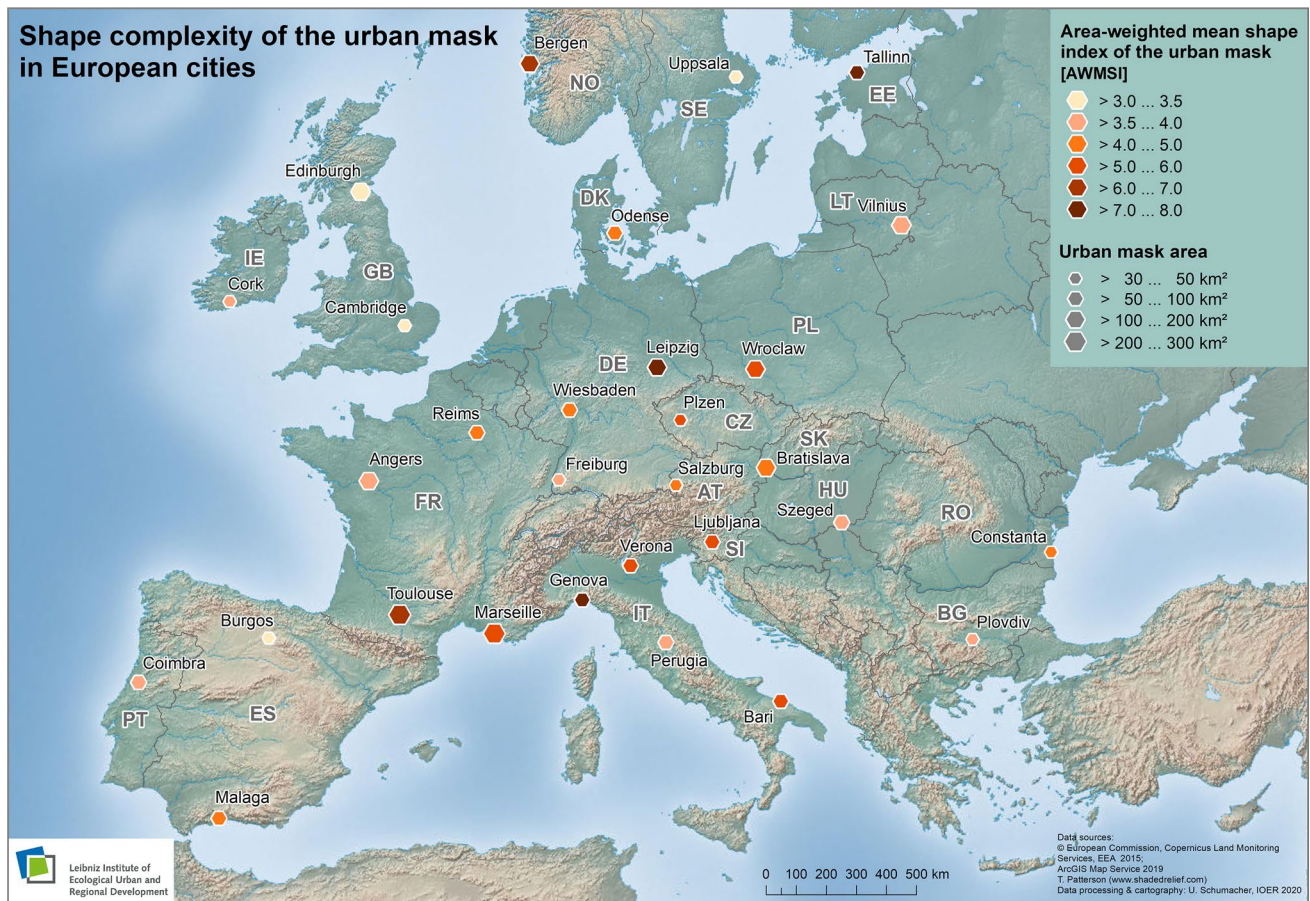


Fig. 3 Overview map of the shape complexity of the urban mask in selected European cities

the Urban Atlas classifies the riverside forest, watercourses and the dump site in this map section as green urban areas and thus assigns them to the urban mask. This classification is based on the ancillary data (thematic data, satellite images, aerial photos, city maps) taken from www.hot-map.com/de/leipzig (European Commission 2016). However, this additional map source does not appear to be a suitable reference, as green areas are not further distinguished and no legend is available. The different classification of green areas as either urban or non-urban can sometimes hinder the delineation of the urban mask.

Land use in the north-east section of the map of Leipzig is structured in many different ways. Although there are minor differences in the delineation of the urban mask in comparison to the ATKIS urban site, these are essentially balanced out in the total area. In this context, it should be noted that there is always a time lag in the mapping of land use changes, especially at the dynamically developing periphery of cities. For this reason, map comparisons based on the different geodata sources are always subject to uncertainties.

2.3 Case Study Cities

In our comparison of cities, the aim was to ensure a contrast in urban structures with the broadest possible geographical distribution across Europe, i.e. from the member states of the European Environment Agency (EEA) with available data from the Urban Atlas 2012. Finally, 30 large cities from 20 countries were visually selected using the Copernicus overview map (Copernicus Land Monitoring Service 2018). A third of these are coastal cities, reflecting Europe's distinctive and well-developed coastal areas. For each city, a spatially contiguous administrative area was considered, i.e. without exclaves or islands. The urban mask of a city should be easily distinguishable from neighbouring municipalities, which is why megacities or large urban agglomerations with over one million inhabitants were not included here. A lower limit was set at 100,000 inhabitants according to the common definition of a large city. Some of the 30 cities had already been analysed in previous studies using Copernicus data (Schumacher and Deilmann 2019a, b). This set of sample cities was considered sufficient to demonstrate the derivation of an urban mask from the input data and its

suitability for analytical purposes in the context of urban planning. The spatial distribution of the case study cities in Europe is shown on the overview map of the shape complexity of the urban mask in Fig. 3.

3 Applications and Results

3.1 Urban Planning Aspects with Reference to the Urban Mask

In order to analyse settlement structures for compactness, efficiency and environmental quality on a city-wide scale, we require an urban mask as the basic geometry. To this end, Deilmann et al. 2017 examined 17 urban planning interdependencies for a selection of cities in Germany, whereby a *Siedlungskörper* (urban mask) was constructed for each city based on the ATKIS object type urban site.

Initial approaches have been made to study these urban planning interdependencies in the same or similar way for European cities with open geodata. Thus, Schumacher and Deilmann (2019a) investigated the parameter “Fragmentation of urban space by traffic routes” in contrasting European cities using the Urban Atlas. In another paper, they also studied the parameter “Microclimatic effect of green and water surfaces” — modified for urban trees and with reference to the potential natural vegetation — using the Street Tree Layer of the Urban Atlas (Schumacher and Deilmann 2019b). Further, the parameter “Infrastructure efficiency” has been investigated using the method of delineating a European urban mask presented in Sect. 2.1 (Schumacher and Schiller 2020). This latter study showed that the area of the urban mask is more suitable as a general reference value than the administrative area of a city.

3.2 Using the Urban Mask to Determine the Shape Complexity of Urban Space

The planning relevance of the shape of the urban space lies in the fact that compact urban structures are characterised by spatial proximity and a close interweaving of the functions living, working, supply and recreation (Deilmann et al. 2017, 95). The shape of the urban space is closely related to the spatial design of urban infrastructure and the possibility of bundling traffic flows. Some negative effects of a compact urban space are a reduction in the influx of fresh air as well as poor accessibility of recreational areas in open space. In this context, the boundary line of the urban mask in the transition to open space is already of use to urban planners. In the physiognomic analysis, urban space is considered in its planar shape in the sense of an urban mask. The geometric basis for the analysis of compactness and complexity is thus formed by the urbanised areas of a city, which encompass

the contiguous built-up area plus the transport, recreation, vegetation and water areas that are closely interlinked in terms of location and function.

Settlement and landscape structures can certainly be analysed physiognomically using similar methodological approaches. For the quantification of shape complexity, suitable measurement variables are available from landscape ecology (McGarigal and Marks 1995). The focus here is on the area-weighted mean shape index (AWMSI). This dimensionless measure is a modified ratio of edge length to area, whereby larger (settlement) polygons are taken into greater account than smaller ones due to the weighting per unit area. The more jagged the borderline and the more complex the structure, the higher the index value. A single circular polygon would give an ideal value of 1. When compared with fractal (logarithmic) parameters, the AWMSI gives a more precise range of values for diversely structured cities. Furthermore, this index is only weakly correlated to the size of the reference units — a favourable characteristic in contrast to other measures of shape (Schumacher and Thinh 2009).

The map in Fig. 3 gives an overview of the shape complexity of urban spaces in 30 European cities. Here the measure of complexity is the AWMSI of the urban mask as delineated from the Urban Atlas 2012. The index values range from 3.05 in Burgos to 7.85 in Genova, with an average value of 4.82. The relatively compact cities of Burgos, Cambridge and Uppsala thus offer the potentially best opportunities for spatially linking the basic functions of living, working, utilities and recreation, as well as the best intra-settlement accessibility on a city-wide scale. In contrast, the cities of Genova, Leipzig and Tallinn show the highest shape complexity of their overall urban spaces, offering improved accessibility of green areas in open space.

The two maps in Fig. 4 show in detail the shape complexity of the urban mask for the sample cities of Burgos and Genova, which have the minimum and maximum AWMSI values, respectively. The difference in the degree of jaggedness at the edges of the settlements in the two cities can be clearly seen by considering the equivalent circles (which represent the areas of the urban masks in both cities). While Burgos, with a relatively compact settlement structure, is situated on the plateau of the Meseta Central on the Iberian Peninsula, the widespread urban area of Genova stretches in a narrow band along the Ligurian coast on the steep and jagged mountain slopes of the Apennines.

3.3 Selected Results in City Comparison

Table 1 summarises the basic shape characteristics for all European case study cities in relation to statistics on population and density. Here we note considerable differences between the cities, e.g. the total population lies between 109,000 (Cambridge) and 851,000 (Marseille), while

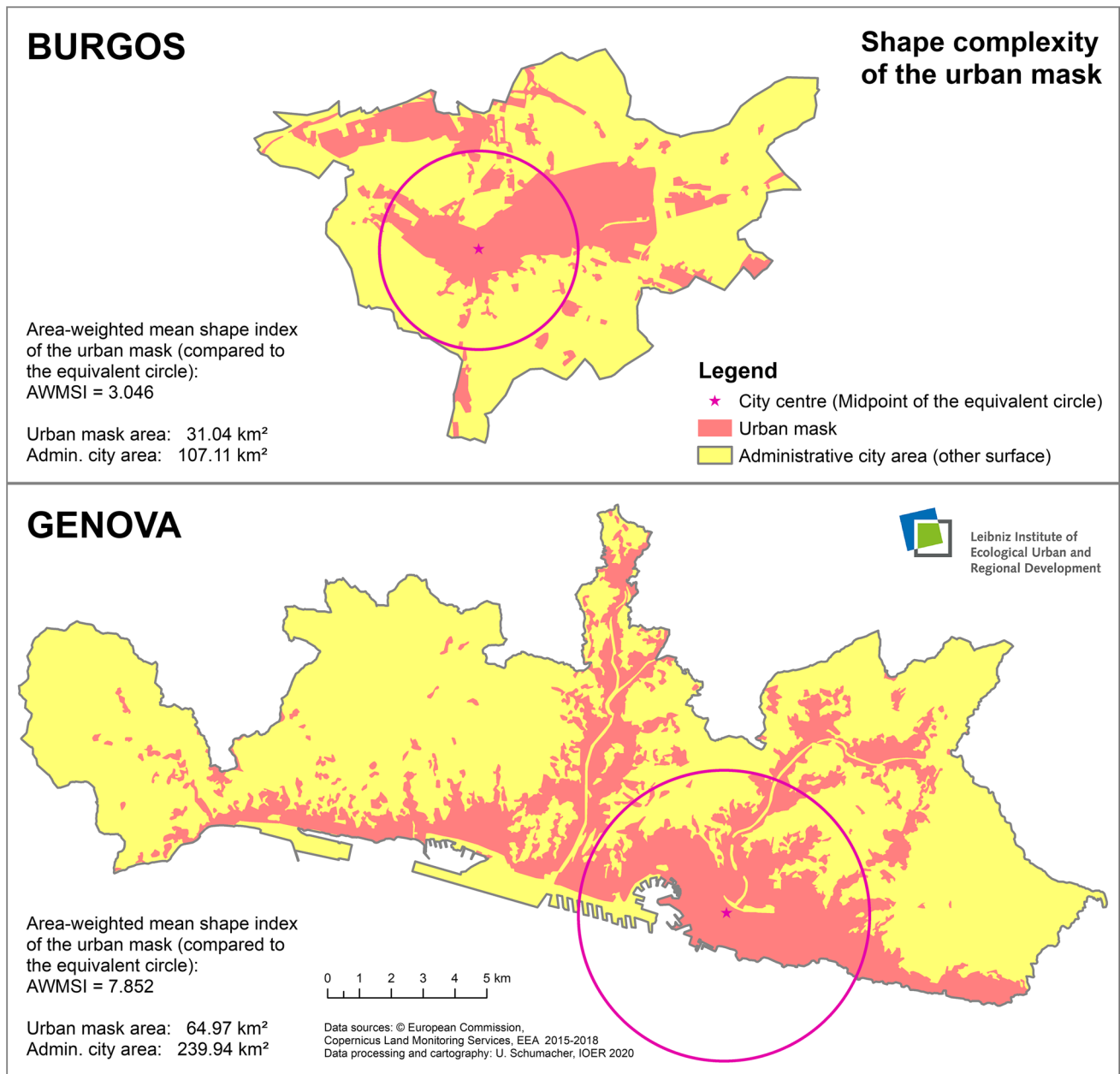


Fig. 4 Shape complexity of the urban mask as mapped for the cities of Burgos and Genova

the administrative area ranges from 39.62 km² (Cork) to 601 km² (Marseille). The urban mask is only weakly correlated with the administrative city area: The minimum and maximum values for the urban mask area are found in Burgos (31.04 km²) and Toulouse (249.34 km²). The AWMSI values in the last column indicate the shape complexity of the urban mask.

The graph in Fig. 5 illustrates some selected results of measured variables with reference to the urban mask of the case study cities. The values are standardised with $n(\max) = 1$. For each variable, the maximum value (n_{\max})

is determined and all other values (n_i) of the variable n are divided by this value. The sample cities are spread over the x -axis, arranged in ascending order of the values for “Area-weighted mean shape index [AWMSI] of urban mask”. As a result, the normalised value of this measure follows an ascending line. Both the absolute areas of the urban mask and the related settlement density (population per urban mask) show no recognisable correlation with the index AWMSI and therefore with the shape complexity of the urban mask. This highlights the diverse physiognomy

Table 1 Basic shape characteristics and population of selected European cities (min. and max. values in bold)

City	Administrative city area			Urban mask area					
	Area (km ²)	Population (1000 inh.)	Population density (1000 inh./km ²)	Area (km ²)	Settlement density (1000 inh./km ²)	Ratio to admin. city area (%)	No. of separate polygons	Area-weighted mean shape index (AWMSI)	
Angers	FR	518.77	276	0.53	129.49	2.13	25.0	424	3.904
Bari	IT	116.20	317	2.73	53.97	5.87	46.4	93	5.528
Bergen	NO	463.71	264	0.57	107.33	2.46	23.1	229	6.065
Bratislava	SK	367.55	413	1.12	106.23	3.89	28.9	87	4.936
Burgos	ES	107.11	180	1.68	31.04	5.80	29.0	53	3.046
Cambridge	GB	40.69	109	2.68	31.30	3.48	76.9	4	3.050
Coimbra	PT	319.44	143	0.45	64.59	2.21	20.2	260	3.721
Constanta	RO	126.09	284	2.25	43.63	6.51	34.6	39	4.633
Cork	IE	39.62	120	3.03	33.73	3.56	85.1	7	3.872
Edinburgh	GB	263.41	493	1.87	118.68	4.15	45.1	96	3.438
Freiburg	DE	154.32	214	1.39	44.22	4.84	28.7	48	3.718
Genova	IT	239.94	580	2.42	64.97	8.93	27.1	118	7.852
Leipzig	DE	297.98	510	1.71	159.26	3.20	53.4	73	7.635
Ljubljana	SI	275.05	288	1.05	68.82	4.18	25.0	161	5.765
Malaga	ES	394.34	567	1.44	68.24	8.31	17.3	175	4.941
Marseille	FR	601.00	851	1.42	217.87	3.91	36.3	141	5.584
Odense	DK	305.84	190	0.62	100.00	1.90	32.7	261	4.972
Perugia	IT	449.02	163	0.36	62.92	2.59	14.0	381	3.561
Plovdiv	BG	101.89	338	3.32	48.11	7.03	47.2	57	3.848
Plzen	CZ	137.68	167	1.21	48.36	3.45	35.1	66	5.033
Reims	FR	87.98	181	2.06	54.17	3.34	61.6	11	4.607
Salzburg	AT	65.64	149	2.27	35.28	4.22	53.7	35	4.935
Szeged	HU	281.01	170	0.60	57.08	2.98	20.3	76	3.856
Tallinn	EE	156.41	402	2.57	95.15	4.22	60.8	33	7.155
Toulouse	FR	461.21	725	1.57	249.34	2.91	54.1	249	6.710
Uppsala	SE	53.70	142	2.64	39.33	3.61	73.2	20	3.214
Verona	IT	198.99	255	1.28	67.33	3.79	33.8	274	5.383
Vilnius	LT	400.58	586	1.46	158.21	3.61	39.5	260	3.941
Wiesbaden	DE	203.77	271	1.33	69.13	3.92	33.9	79	4.309
Wroclaw	PL	292.79	631	2.16	137.79	4.58	47.1	101	5.545

Data sources: © European Commission, Copernicus Land Monitoring Services, EEA 2015–2018; Population from Eurostat, Urban Audit 2012 and Statistics Norway. Geodata processing: U. Schumacher, IOER 2020

of European cities, reflecting their hugely diverse natural conditions and anthropogenic development pathways.

4 Discussion

For urban planning on a city-wide scale, there is little doubt that the urban mask provides a suitable reference geometry to enable meaningful interpretations and support the identification of settlement-based influential factors. This follows from the simple fact that there is a direct physical link between the urban built environment and the settlement area, which is not the case for the administrative area. In

this respect, urban masks are applicable to all questions and related analysis and planning tasks in which the described physical relationship is relevant (Schumacher and Schiller 2020, 349).

The GIS-based method for generating an urban mask presented in this paper is reproducible and is generally suitable for medium-scale mapping applications and analyses. When comparing different cities with topographic maps or aerial photographs, we note that larger railway station complexes are not part of the urban masks. While this gap is not significant in relation to the total area of an urban mask, it is nevertheless unsatisfactory from a cartographic point of view. Indeed, there has been some debate on whether to

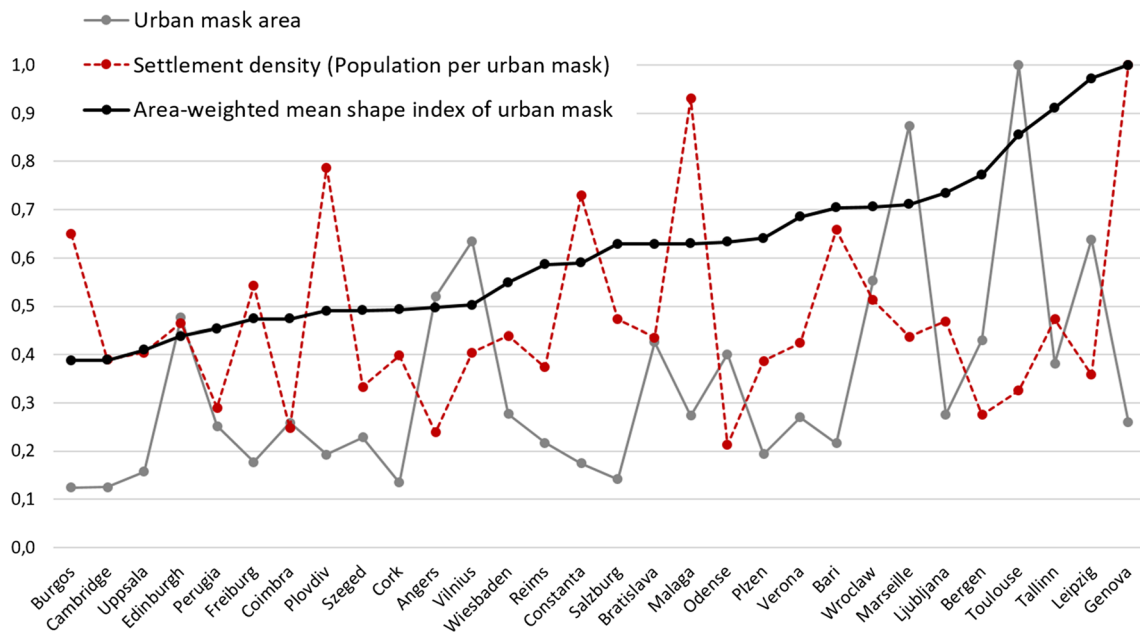


Fig. 5 Selected measures of the case study cities with reference to the urban mask, normalised with $n(\max)=1$ and arranged in ascending order on the x axis according to AWMSI value (Data sources: ©

European Commission, Copernicus Land Monitoring Services, EEA 2015–2018; Population from Eurostat, Urban Audit 2012 and Statistics Norway; Geodata processing: U. Schumacher, IOER 2020)

assign inner-city railway areas to the urban mask. It seems difficult to suitably extend the vector-based algorithm with the available Urban Atlas data, as there are no structural properties that can be generalised. In such cases it makes sense to interactively and manually modify the contours of the urban mask using spatial information from aerial photographs or city maps.

The mapping guideline of the Urban Atlas defines which green spaces (gardens, zoos, parks, castle parks, cemeteries) in which geometric constellation are to be mapped as green urban areas (EU 2016, 21). The classification of green spaces as either urban or non-urban can sometimes hinder the delineation of the urban mask, as explained in Sect. 2.2 in the case of Leipzig. This confirms that remote-sensing data is insufficient for the functional delineation of urban green from open space. Instead, reliable terrestrial mapping must be used as reference information for interactive editing.

5 Conclusions

The spatial aggregation and delineation of coherent settlement areas, in which the artificial elements are captured as a so-called “urban mask” (according to the German *Ortslage* or urban site), is a necessary prerequisite for numerous analyses in urban space. The method presented here for cartographic generalisation can be applied wherever Copernicus data from the European Urban Atlas is

available. For numerous urban planning tasks, the urban mask area is more suitable as a reference unit for the city as a whole than its administrative area.

In a city-wide perspective, the urban mask layer could support spatial planning in diverse applications, for example in the assessment of infill development potential, deficit analyses of urban green space or estimations of the conflict potential in the planning of wind farms. In addition, the urban mask forms a fragmentation element in the analysis and evaluation of landscape fragmentation.

In principle, it seems reasonable to relate urban metrics to an urban mask — both in the core city and in the surrounding functional urban area. The urban mask thus constitutes an important reference geometry for the definition and application of performance indicators relevant to spatial planning. For cross-border studies and reports in the context of the European Urban Audit or beyond, a comparable urban mask at European level would be desirable. The regular updating of the Urban Atlas data every 6 years within the framework of the Copernicus Land Monitoring Service opens up the possibility of integrating analyses based on the urban masks into the European Spatial Observation.

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Compliance with Ethical Standards

Conflict of Interest The author declares no conflict of interests.

Code Availability Software: ESRI ArcGIS 10.7.1.

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