2.
TOPOI – A Scientific Approach for Understanding Urban-Rural Linkages

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2.1. Introduction

In recent years, urbanization research has largely focused on the development of large cities, urban agglomerations, and fast-growing megacity regions, and thus have concepts for a more sustainable development. Less attention has been paid to understanding the development of medium-sized cities, small towns, villages, or rural areas. However, looking at aspects such as transport, food production and consumption, or ecosystem services, one has to assume that there are numerous interrelations and spatial linkages between urban and rural areas.

Can a new perspective on urban and rural settlements and the understanding of their interlinkages lead to new approaches and solutions for a more sustainable development? With "TOPOI" (Carlow et al. 2022), we, a team of architects and planners together with geo ecologists, provide a new method for the integrated analysis and description of settlement units of different sizes, functions, and morphological characteristics in their urban-rural setting. The TOPOI method describes classes of settlements with similar characteristics and their interrelations, complementing classical broad definitions, such as "city", "town" and "village". Based on the building footprints, not their administrative borders, settlement units are identified as cohesively built-up areas. These settlement units are analyzed with a view to eleven characteristics of form, function, and linkages with others. Therefore, geospatial data are combined with additional publicly available data, e.g., public transport data. Subsequently, using a statistical method of affinity propagation, the settlement units are clustered according to their characteristics (Carlow et al. 2022).

As a result, a more detailed classification of urban and rural settlement types is achieved, complementing the classic divisions of City (independent), Urban County, Rural County with Densification Tendencies, and Sparsely Populated Rural County (BBSR 2017).

Looking beyond the limitations of those inherited categories is important at a time when the functional and physical differences between "cities" and "countryside" have been vanishing more and more (Steinführer 2016; Akkoyunlu 2015; Tacoli 2006). Accordingly, the understanding of what is *urban* and what is *rural* has changed, too. Well-known concepts describing the physical built environment, such as *Metapolis* (Ascher 1995), *Zwischenstadt* (Sieverts 1997), *Netzstadt* (Baccini and Oswald 1998), or *Metacity* (McGrath and Pickett 2011), reflect the complexity and fuzziness of the built environment. While Sieverts (1997) emphasized the historic relevance of central places, he showed that the urban system is evolving towards a polycentric network with different and complementary functions. Baccini and Oswald (1998) described the urban system of Switzerland as an interconnected network of nodes, edges, and flows, in which people, goods, and information move as flows on the edges between the nodes. Ascher (1995) has conceptualized the Greater Paris Region as a "metapolis" – a region with a distinct urban core and a more rural hinterland.

However, in formal planning in Germany and many other European countries to date, rather restrictive traditional categories such as "urban" or "rural" are still imposed. In Germany, the definition of a municipality as urban or rural has an impact on public expenditure and investments, which in turn has implications for the allocation of certain (public) functions and the supply of public services (BBSR 2000; Greiving, Flex, and Terfrüchte 2015). The population size within an administrative boundary is thereby considered the main indicator for categorizing a municipality as urban or rural (BBSR 2017), largely disregarding other important aspects such as the morphology of settlement units or parts thereof, their connectivity or linkages to other settlements. Accordingly, municipalities considered urban usually have a larger population size and are well connected, whereas rural municipalities are those that have a lower population density per area unit and are more remote. However, these distinctions do not take into account the interrelations and linkages that are characteristic for urban-rural systems today – with severe consequences, not only fiscal ones, for all municipalities.

2.2. Lower Saxony Metapolis

In Lower Saxony, only 20 % of the population lives in large cities with more than 100,000 inhabitants. The two largest cities are Hannover, the capital of the federal state with a population of around 535,000, and Braunschweig with about 250,000 inhabitants. There are another six "large cities" with more than 100,000 inhabitants (Oldenburg, Osnabrück, Wolfsburg, Göttingen, Salzgitter, and Hildesheim) (LSN 2019). Nine percent of Lower Saxony's population lives in medium-sized towns with 50,000 to 100,000 inhabitants, while the majority of people (71%) lives in small towns with less than 50,000 inhabitants, suburban and rural areas (LSN 2019). Regions in Lower Saxony show very diverse development patterns. Simultaneous shrinkage and growth in close geographic

proximity with often unsustainable effects, such as a high rate of land take and dense commuting patterns, have been characteristic of recent and current developments (MSGG 2013; Mühlbach et al. 2021).

Figure 2.1 shows Lower Saxon settlements in relation to different landscape types based on the classification of the Lower Saxony State Office for Mining, Energy and Geology (LBEG 1995). This map includes the two large cities of Hamburg and Bremen, which are two independent city states within the German federal system and surrounded by Lower Saxon territory. Depending on the landscape type, Lower Saxon settlements show different sizes and distribution patterns. The larger cities are situated along the river bodies and on the foothills with fertile soils, whereas in the heathland, on the coast, and in the hilly areas of the Harz Mountains, settlement units are considerably smaller and more scattered.

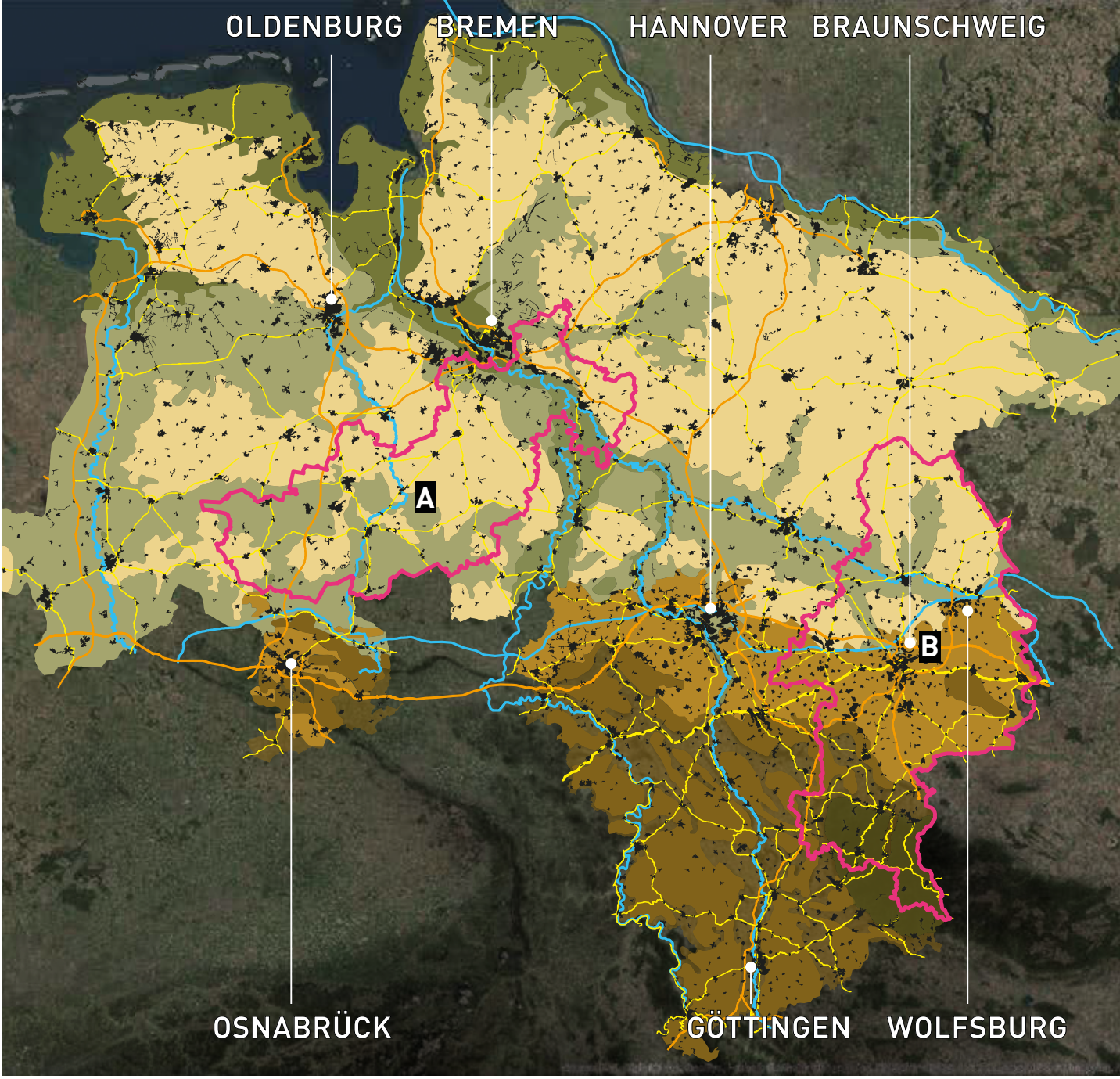
For the development and testing of our TOPOI method, we selected two study regions on the basis of their distinct development history, urbanization, and landscape patterns. Both study regions include municipalities from our partner network. The western study region *Vechta-Diepholz-Verden* (A, Figure 2.1) is characterized by a large number of evenly distributed, mainly prospering small to medium-sized towns and many villages in a sandy soil or heath landscape (Geest). Founded on rather infertile soils, today the region is characterized by intensive livestock husbandry and agriculture (Tamásy 2013). The study region of the larger Braunschweig area (B, Figure 2.1) includes both thriving cities and declining municipalities in immediate vicinity. The landscape of foothills is characterized by very fertile loess soils (Börde), which led to an early and relatively dense formation of settlements in the region.

2.3. The TOPOI Method

With the data-based TOPOI method, we analyzed the settlement structures based on eleven planning parameters of form (area, compactness, building density, open space ratio), function (functional variety, population density, retail and services ratio, agricultural building ratio) and spatial linkages (settlement density, public transport connectivity, proximity to regional train stations) (see Table 2.1).

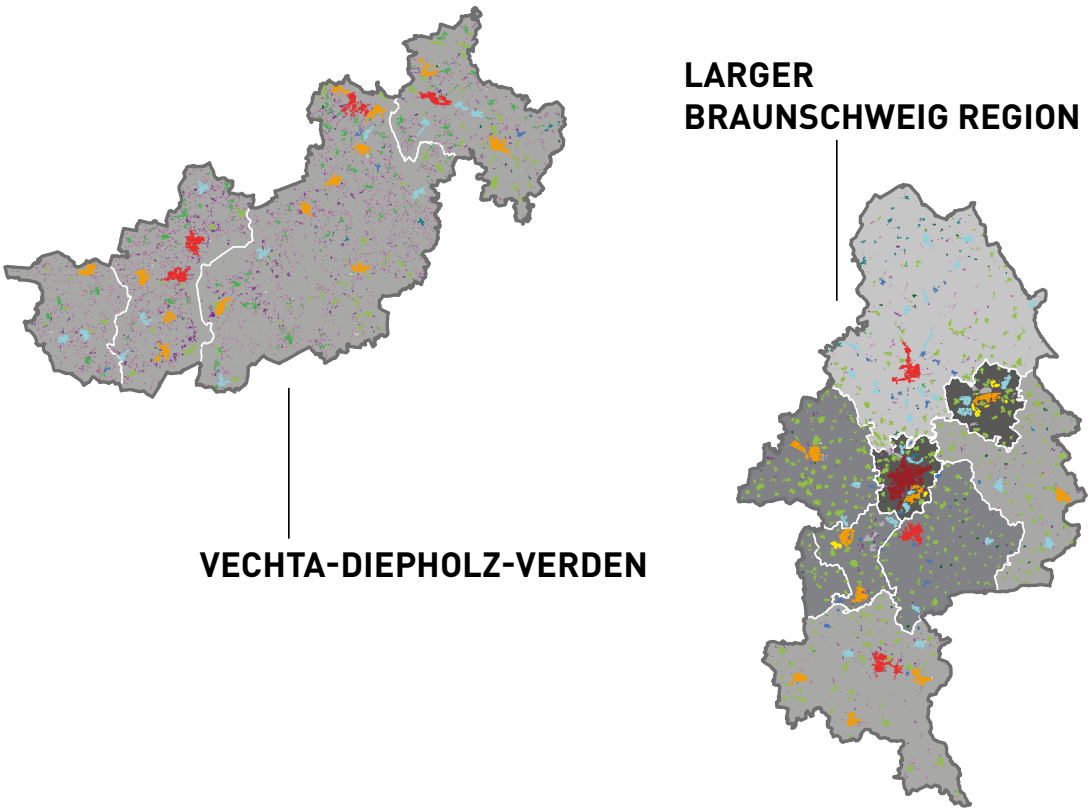
While our method can be studied in detail in several scientific articles (Carlow et al. 2021; Mühlbach et al. 2021; Carlow et al. 2022; Mumm et al. 2022; Zhu et al. 2022), in this book, we do not want to focus on the technicalities of the method but rather on some of the findings obtained by its application. The first results concern the definition of settlement units. While the traditional classification method of the Federal Office for Building and Regional Planning – BBSR (Figure 2.2) differentiates four main settlement categories, namely City (independent), Urban County, Rural County with Densification Tendencies, and Sparsely Populated Rural County, our TOPOI approach provides a more detailed and fine-grained understanding of the diversity of settlement units and their characteristics due to the defined eleven indicators.

Other findings concern the unequal access to public transport options, which the TOPOI method helped us reveal. We found out that roughly 60 % of the area in our two study regions had a densification potential based on public transport provision in relation to population density. On the other hand, approximately 50,000 people have no or only limited access to public transport (Carlow et al. 2021).



2.1 Built-up Areas and Landscape Types
of Lower Saxony and the two METAPOLIS study regions: (A) Vechta-Diepholz-Verden and (B) Larger Braunschweig region. Source: Carlow et al. 2022; Data: BKG 2012a,b; ESRI 2018; LBEG 1995.

2.2 Superimposition
of two classification methods: counties of the Spatial Development Report 2017 (BBSR 2017) and TOPOI classification of the settlement units in both study regions; Source: Carlow et al. 2022.



Legend

- Node City
- Node Town
- Periurban Town
- Exo Satellite Town
- Periurban Village
- Small Periurban Village
- Exo Village
- Small Exo Village
- Disseminated Village
- Agri Village
- Disseminated Hamlet
- Disseminated Living
- Agri Hamlet
- Exo Industrial Zone
- City (County free)
- Urban County
- Rural County with Densification Tendencies
- Sparsely Populated Rural County
- Study Region

25 km

Another example is the assessment of the global warming potential on the basis of the TOPOI classes and aspects such as mobility, which enable interdisciplinary recommendations e.g., on decarbonization (Mühlbach et al. 2021). The same study also showed that the overall land take has been larger for the sum of all smaller rural and urbanizing counties than for the cities over the past 70 years.

In order to identify and analyze the urban-rural settlement patterns, we started from the building scale instead of administrative boundaries. First, we identified cohesively built-up settlement units on the basis of building shapes and built-up areas, regardless of their administrative boundaries. A single settlement unit was thereby defined as a cohesively built group of buildings, as opposed to e.g., single buildings or splinter settlements as described in the German Building Code (§ 35 (3) 1.7 BauGB (BfJ 2017)). Our TOPOI settlement units were defined on the basis of two parameters: a) the maximum distance between buildings corresponding to the clearance requirements and b) the cohesiveness of a built-up area, with a minimum of eight buildings such a cohesively built-up area comprises.

In a next step, we analyzed the functional properties of these settlement units by integrating additional geo-spatial data. A set of properties was calculated for each settlement unit. The relative area that each of these functions occupies was determined for each settlement unit. Additionally, the number of functions within one settlement unit was used as an indicator for functional variety (Ritsema van Eck and Koomen 2008).

The spatial and functional interrelations between the different settlement units was also of great interest to us, since they depict urban-rural linkages. Accessibility is considered an important indicator for connectivity and thus of daily routines. In our understanding of accessibility, not only the geographic distance between settlement units or certain functions plays a role but also the modality by which settlement units are connected. Other indicators for spatial linkages are the location of the settlement units within the urban-rural fabric and their spatial distribution throughout the region. Two analyses were carried out on the accessibility and connectivity of each settlement unit. In a first step, we determined the shortest distance between existing regional train stations and the center of each settlement unit along the street network. In a second step, the quality of the local public transport network was assessed, based on the accessibility of each settlement unit e.g., by bus or tram, without changing transport (Carlow et al. 2022).

Subsequently, we defined the position of a settlement unit in the network as the result of a location analysis, which determined the number of settlement units within a 3 km radius coinciding with an area where daily goods and services should be easily accessible (Christaller 1933). The result shows the density of settlement units within a certain area. We considered the corresponding degree of proximity or dispersion relevant for a differentiated description of the urban-rural gradient.

In the fourth and concluding analysis step, we described the settlement units with regard to the eleven properties of form, function, and spatial linkages. Our analysis yielded a set of 13 TOPOI settlement units with similar characteristics. The TOPOI analysis shows that the urban-rural gradient can be

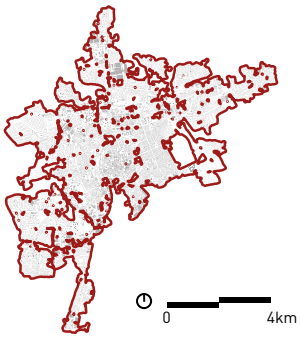
		INDICATORS										
		Form				Function				Linkages		
	Total count of TOPOI	Area [ha]	Compactness [%]	Building Density [buildings/ha]	Open Space Ratio [%]	Functional Richness	Population Density [inhabitants/ha]	Retail and Services Ratio [%]	Agricultural Facilities Ratio [%]	Settlement Units Density	Public Transport Connectivity	Proximity to Regional Train Station [km]
Definitions		Area of settlement unit [ha]	Ratio of area to perimeter: C = (2√πA)/P*100 with A=Area and P=perimeter of settlement unit (Bogaert et al. 2000) [%]	Ratio of the number of buildings to the area of the settlement unit [buildings/ha]	Ratio of the non-built-up area to total area of a settlement unit [%]	Number of functions in a settlement unit ranging from 1 to 8 (residential area; retail and services; public facilities; industrial and commercial area; agricultural facilities; supply facilities; disposal facilities; parks, sport and recreation facilities)	Ratio of the number inhabitants (inh.) to the area of the settlement unit [inh./ha]	Share of area occupied by retail and services of the total area of the settlement unit [%]	Share of area occupied by agricultural facilities to the total area of the settlement unit [%]	Number of settlement units within a radius of 3 km, computed on the basis of the Euclidean distance between the settlement units' centroids	Number of settlement units directly connected by public transport to the focused settlement unit; PTC=ΣL(L1+L2+Ln) with L=number of unique settlement units reached by the respective public transport line	Shortest distance between the nearest regional railway station and the centroid of the settlement unit, along the road network [km]
Node City	1	3,662	14%	13.9	80.0%	8	43.5	8.9%	0.3%	4	68	2.7
Node Town	7	1,153	22%	15.5	81.9%	8	22.5	5.8%	1.6%	18	31	1.7
Periurban Town	24	526	29%	14.4	82.9%	8	21.4	5.8%	1.0%	23	23	1.4
Exo Satellite Town	9	82	61%	10.9	82.9%	7	48.2	2.3%	0.1%	13	3	4.5
Periurban Village	42	224	38%	15.2	84.5%	8	19.7	4.8%	2.3%	13	21	1.7
Small Periurban Village	37	53	60%	15.1	86.7%	7	17.2	1.7%	5.0%	13	18	3.7
Exo Village	524	43	63%	13.1	86.8%	7	14.0	1.4%	7.3%	10	5	6.6
Small Exo Village	73	14	76%	11.3	88.6%	4	11.0	0.0%	13.4%	11	6	6.2
Disseminated Village	160	27	53%	8.0	90.2%	6	7.2	2.1%	8.6%	44	10	8.9
Agri Village	35	20	58%	7.7	89.7%	5	5.2	1.4%	14.1%	12	23	11.7
Disseminated Hamlet	1,071	5	81%	4.5	91.4%	3	2.8	0.0%	0.0%	34	0	7.0
Disseminated Living Agri Hamlet	4,283	3	89%	4.7	92.7%	2	2.6	0.0%	23.9%	38	0	8.1
Exo Industrial Zone	35	18	69%	1.9	68.6%	3	0.8	0.0%	0.0%	15	0	3.8

Table 2.1 The TOPOI Types
for the two study regions in Lower Saxony (Germany) and the median per indicator derived for a range of 11 indicators of form, function, and spatial linkages used in the affinity propagation clustering for classifying settlement types according to the TOPOI method; Source: Carlow et al. 2022; Data: Carlow et al. 2020.

described in much greater detail than the classical distinction between city or county allows. The location in space and the connection between each settlement unit allows a differentiation between urban-rural categories – such as EXO (isolated patterns), DISSEMINATED (disperse patterns), PERIURBAN (urban fringe), NODE (urban core) – and shows that the urban-rural gradient can take very different forms far beyond an urban-rural dichotomy.

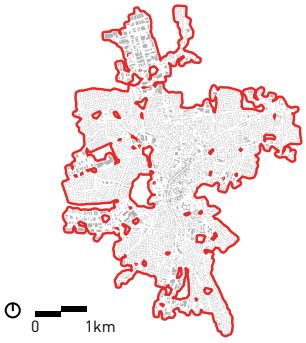
2.4. The TOPOI Types of Lower Saxony

The TOPOI classes were sorted according to their typical features and size. They include: Node City, Node Town, Periurban Town, Exo Satellite Town, Periurban Village, Small Periurban Village, Exo Village, Small Exo Village, Disseminated Village, Agri Village, Disseminated Hamlet, Disseminated Living Agri Hamlet, and Exo Industrial Zone.



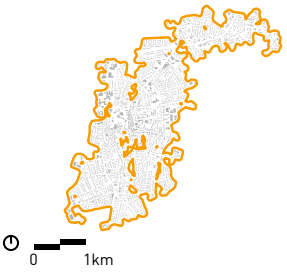
2.3

The ***Node City*** features the characteristics of an urban core. It has a relatively low compactness, which can be explained by the presence of large open spaces such as parks, water bodies, or infrastructural corridors like railway areas or highways. Node Cities show the highest diversity of urban functions, have a high population density, and a high connectivity to other settlement units. In our two study regions, there was one Node City, namely the center of Braunschweig.



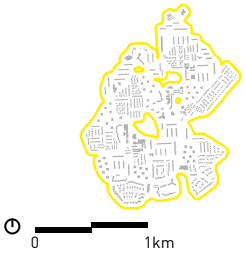
2.4

Node Towns show similar features but have a lower population density. In Node Towns, the relatively low population density coincides with a high functional variety and connectivity. In our study region, we found seven Node Towns.



2.5

Periurban Towns are typically found at the fringe of Node Cities or Node Towns, to which they are well connected. Otherwise, they have a medium population density and connectivity. We identified 24 Periurban Towns in our study areas.



2.6

Exo Satellite Towns, too, can be found at the urban fringes. As typical large housing estates from the 1950s, 60s or 70s, they have a high functional variety, high population density, but a low public transport connectivity. There are nine Exo Satellite Towns in our study regions.

2.7

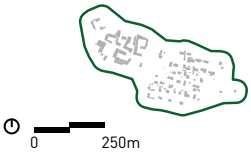
Periurban Villages are also located at the urban fringes. They are typically smaller than Periurban Towns or Exo Satellite Towns. Nevertheless, they usually have a medium to high functional diversity and a medium population density. A special characteristic is that they are located close to or have their own regional train stations. There are 42 settlement units of this kind.

2.8

The 37 ***Small Periurban Villages*** we identified usually have a smaller footprint than the Periurban Villages but nevertheless a high functional diversity. However, their connectivity is relatively low.

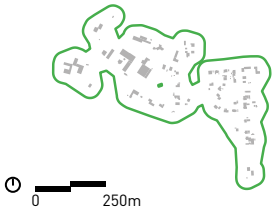
2.9

Exo Villages, of which we found 524 in our study regions, are rather isolated. Nevertheless, they show a medium to high functional diversity. They usually have a medium population density and low connectivity.



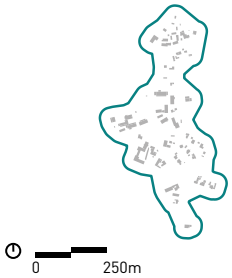
2.10

Small Exo Villages are also isolated. The 73 we identified show a high number of buildings with agricultural use. They are characterized by a large distance to the next train station and a low connectivity in general.



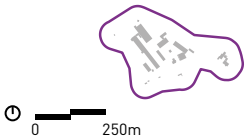
2.11

Disseminated Villages also include agricultural buildings but at a lower proportion than Small Exo Villages. They are dispersed throughout the territory, are located at a large distance from train stations, and have a generally low connectivity.



2.12

Agri Villages have a large proportion of agricultural buildings and at the same time a high building density. Like many of the other village types, they are rather scattered and have a low connectivity. There are 35 of them in our study regions.

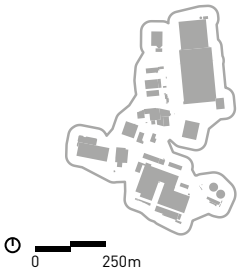


2.13

Disseminated Hamlets, of which we made out 1,071, were the second most common settlement type. They are dispersed throughout the territory, show a high building density, a large distance from the nearest train station, and a very low connectivity.

2.14

Disseminated Living Agri Hamlets are the most common TOPOI in our two study regions, where 4,283 could be identified. This is the smallest settlement type that is distinguished by a very low connectivity and a high building density with a large share of agricultural buildings.



2.15

The ***Exo Industrial Zone*** is a very special TOPOS. As a typical industrial area outside of cities and towns, it usually contains a small number of functions, has no population, a high open space ratio, low building density, and very low public transport connectivity.

2.5. Conclusion

These TOPOI allow the depiction of the urban-rural gradient in greater detail. Of the thirteen, four TOPOI (Node City, Node Town, Periurban Town, Exo Satellite Town) come under the two "urban" categories (City (independent), Urban County) of the traditional classification system. Whereas the traditional classification system differentiates only two "rural" types (Rural County with Densification Tendencies and Sparsely Populated Rural County), the TOPOI method identifies eight "rural" types instead (Periurban Village, Small Periurban Village, Exo Village, Disseminated Village, Agri Village, Small Exo Village, Disseminated Hamlet, Disseminated Living Agri Hamlet). Additionally, with the Exo Industrial Zone, the TOPOI method even detects an entirely new settlement type that can neither be exclusively assigned to "urban" nor "rural" categories. In Figure 2.2 we superimposed the results of the two classification methods – the traditional one by BBSR and our TOPOI method. It is visually apparent that our method provides a more differentiated picture. Even though they are identified as "rural" by the traditional classification system, we can find urban settlement types with a comparatively high population density such as Node Towns, Periurban Towns, and Exo Satellite Towns. An example of this is the town of Gifhorn, which is classified as the TOPOS type Node Town but is located in the BBSR category of Sparsely Populated Rural County. Taking the administrative area of Wolfsburg, for example, which is classified as a City in the BBSR classification system (BBSR 2017), the opposite can also be observed: Exo Villages, Disseminated Hamlets, and Disseminated Living Agri Hamlets identified in the area are TOPOI with rural characteristics.

Looking at the distribution of the different TOPOI classes, it becomes clear that the existence of the Exo Village shows that a high number of unconnected settlement units can be found in the vicinity of Node Towns. In contrast, the example of Periurban Towns shows that the "urban" is expanding geographically with settlements that are well connected and accessible. The Disseminated Living Agri Hamlets indicate the urbanization of the countryside with finely dispersed and evenly spread settlements.

This illustrates that TOPOI is a profound method for integrating diverse perspectives and data for a better understanding of urban-rural interrelations, thus opening up new solutions and approaches to a more sustainable development.

Building on our analysis, we have defined "prototypes" for each TOPOI class, on the basis of which we continued to explore and devise strategies for their more sustainable development. These prototypes can be understood as average or prototypical for their settlement type. From three of the TOPOI classes, we identified a specific settlement unit each for in-depth analysis: Eydelstedt, a Disseminated Hamlet; Detmerode, an Exo Satellite Town; and Schöppenstedt, a Periurban Village. Applying an innovative scenario building process (see Chapter 3), we have designed different possible futures for these three settlement units, which are described in detail in Chapters 4, 5, and 6. How scenario building can support municipalities in reaching their sustainability goals vis-á-vis their citizens, has been discussed with representatives of these three municipalities. The results are presented in Chapter 7.

The challenges we face, e.g., in the area of climate change mitigation and adaptation, require new methods that enable cooperation but also the analysis of the effects of local decisions on a larger scale. Since the TOPOI classes group settlement units of the same characteristics, the exemplary interventions and strategies developed for the three settlements (Chapters 4–6) can be transferred to other settlement units of the same TOPOI class. This is discussed in Chapter 9. Ultimately, this will enable an integrated regional assessment and evaluation of local sustainability measures and their impacts on the larger urban-rural context.