

**“The variability of urbanization in Lower Silesian Voivodeship,
Poland”**

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Table of Contents

Introduction.....	1
Literature Review.....	8
Urban Life Cycle Model	8
Urbanization Studies	11
Background.....	14
Administrative System	14
Study Site	15
Methodology.....	22
Data Acquisition and Preparation	22
Administrative Boundaries	22
Demographic Data.....	23
Land-Cover Data	24
Data Analysis	25
Voivodeship Level.....	26
District Level	27
Commune Level	28
Results.....	32
Urbanization at the Voivodeship Level.....	32
Urbanization at the District Level	37
Urbanization at the Commune Level	43
Discussion.....	59
Conclusion	65
Bibliography	68

List of Figures and Tables

Figure 1. Variations in the urbanization levels of the world's regions.....	2
Figure 2. The percentage of urban population in the voivodeships of Poland in 2010.	4
Figure 3. The percentage of urban population in the districts of Lower Silesia in 2010. ..	5
Figure 4. Urban life cycle model based on the changes in population.	8
Figure 5. The towns and communes of Lower Silesian Voivodeship.	17
Figure 6. Changes in total population and urbanization level in LSV 1995-2010.....	33
Figure 7. Changes in rural and urban populations of LSV 1995-2010.....	34
Figure 8. Changes in major land-cover classes in Lower Silesia.....	35
Figure 9. CORINE Land Cover Change between 2000 and 2006.	36
Figure 10. Percentage of total population change by districts.	38
Figure 11. Difference in the percentage of urban population by district.	39
Figure 12. Percentage of artificial land cover by districts in 1990 and 2006.	41
Figure 13. Percentage of artificial land cover change by districts.	42
Figure 14. Percentage of total population change by communes.	44
Figure 15. Clusters and spatial outliers in the population change.	46
Figure 16. Population change clusters by commune type.....	47
Figure 17. Population change trajectories by commune type	49
Figure 18. Summary of urbanization stages by commune type.....	51
Figure 19. Change in the artificial land cover by commune.....	53
Figure 20. Clusters and spatial outliers in the artificial LC change.	55
Figure 21. Artificial land-cover change clusters by commune type.	56
Table 1. Population change in Lower Silesian Voivodeship.	33
Table 2. CORINE Land Cover change in Lower Silesian Voivodeship.....	35
Table 3. Changes in the artificial land cover type.....	37
Table 4. Population change by commune type	43
Table 5. Results of global Moran's I analysis.	45
Table 6. CORINE Land Cover change by commune type.	52
Table 7. Cross tabulation of urban commune type clusters	58
Table 8. Cross tabulation of rural commune type clusters.....	58
Table 9. Cross tabulation of urban-rural commune type clusters.	58

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Introduction

In 2008, the world's population reached a new milestone – for the first time half of more than 6.7 billion people were living in urban areas around the world (UN, 2010). Urbanization is a complex process that is often thought of in terms of development of cities and increasing urban population, however it also encompasses social and economic systems as well as land use and function of the urban areas (Regulski, 1980). In general, it is “a process of population concentration” (Champion, 2001). Most commonly, the degree of urbanization is measured by the share of urban population in relation to the total population, which is how the urbanization statistics are reported by agencies like United Nations (Champion, 2001). Although the rate of global urbanization has declined in the recent decades, the percentage of urban dwellers on the planet is expected to reach 70% by 2050 (UN, 2010).

The spatial variability of urbanization percentages is apparent on the global, continental, regional, and national scale (Figure 1). South America is currently the most urbanized continent in the world with a rate of almost 84%, which is estimated to increase to over 91% by 2050. Among the least urbanized regions are Africa and Asia, although both are projected to experience high rates of urban growth by 2050. Europe is also a highly urbanized continent, although it is less urbanized than North America. More importantly Europe exhibits a high degree of spatial variability in urbanization percentages (Figure 1). While Europe as a whole was approximately 73% urban as of 2010, the northern and western parts of the continent had urbanization levels above the continental level (84% and 77% respectively) and the eastern and southern portions had levels below the continental

percentage (69% and 67%). All regions of the world are expected to increase in their urban percentages by 2050 although at varying degrees (UN, 2010). However this measurement of urbanization process is highly dependent on the definition of urban population and delineation of urban areas, which often vary depending on the country considered and its political and social systems (Antrop, 2004; LeGates, 2006). It is inherently tied to the enumeration units of the administrative system of each of the countries.

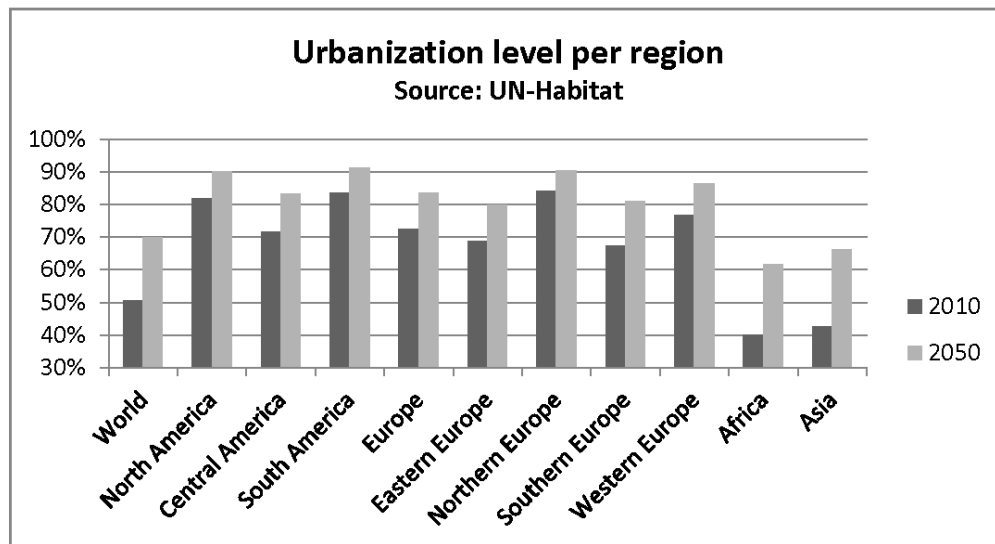


Figure 1. Variations in the urbanization levels of the world's regions.

Urbanization is a 'global process' that has highly individual characteristics in each country (Parysek, 2005), but can be generalized using the urban life cycle model. The urban life cycle model is a descriptive model that demonstrates the cyclical relationship between the populations of two urban locations – the core and the periphery (Capello & Faggian, 2002). This relationship gives rise to the four generalized stages of the cycle – urbanization, suburbanization, de-urbanization, and re-urbanization. A country's stage in the cycle is closely associated with its economic development stage (UN, 2010) and in general, countries

with higher per capita incomes tend to be more urbanized, and in most cases, have cities in the later stages of the urban life cycle (i.e., suburbanization and de-urbanization). Less developed countries with lower incomes, on the other hand, tend to be less urbanized, with cities experiencing the early stages of urbanization (i.e., rapid urban expansion; UN, 2010).

Measuring urbanization in terms of the share of urban population, however, is only one way to study urbanization processes; although it is often the only method used in describing the stages of the urban life cycle model. It could be supplemented or substituted with another method that is not inherently dependent on the arbitrary administrative units in order to more comprehensively examine the urban patterns and identify the stage of the urban life cycle model. One such method is measuring changing urban growth patterns using time-series classified imagery (i.e., examining changing patterns of urban land-cover in a land change analysis). In the context of a land change analysis, urbanization process can be defined as “the general process of city growth,” where native land-cover such as agricultural, pasture or forest land is replaced by artificial land-cover for uses connected to human activity (Jenerette & Wu, 2001). Land cover is not tied to enumeration units, but rather is a continuous coverage dependent on the resolution of the remotely sensed images. It can be aggregated to the enumeration units for comparison with demographic change, enabling a more thorough representation of urban change. This twofold methodology to studying the urban life cycle model can provide important insights into spatial variation of urban change at a smaller scale; however this approach is limited in urbanization literature.

Poland, located in Eastern Europe, had an urbanization level of 60.9% in 2010 (i.e., 60.9% of its population was located in urban areas), which is below the average for Eastern Europe (68.8%). Spatial variation in urban percentages exist within the country. In general, urbanization percentage tends to increase from east to west in Poland (Banski, 2003; Korcelli, 2005) as the urban network becomes more developed (Figure 2). Urbanization percentages, as measured by voivodeships, the largest administrative units in Poland that are roughly equivalent to the historic provinces, range from 78% in the highly industrial Silesian Voivodeship to 41% in the largely rural and mountains Subcarpathian Voivodeship (CSO, 2010). Four of the voivodeships were below the 50% urbanization level in 2010, although all four were at least 40% urbanized (CSO, 2010). In addition, a large degree of spatial variability is also observed within the voivodeships. The study site for this research, Lower Silesian Voivodeship, is a great example of inter-voivodeship spatial variation in urban

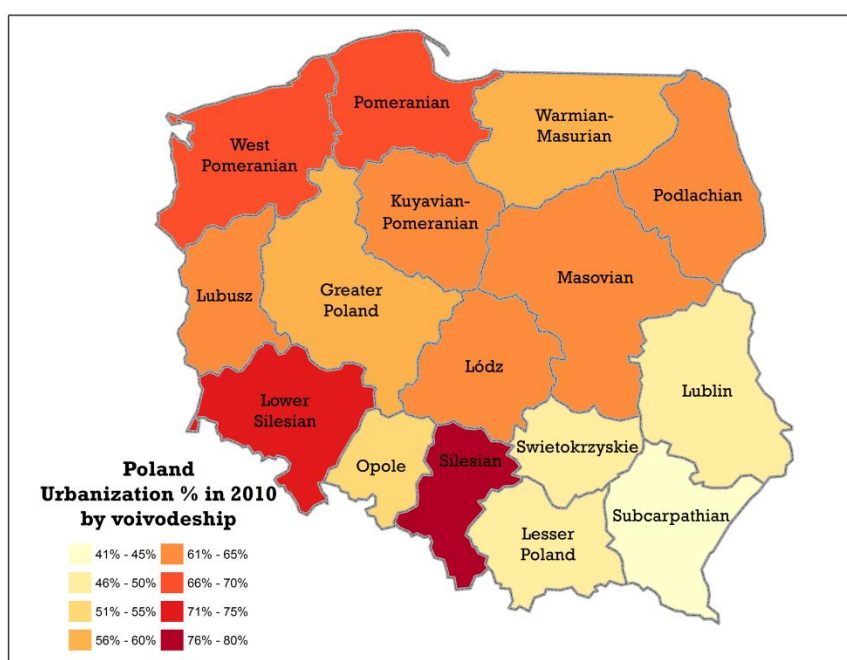


Figure 2. The percentage of urban population in the voivodeships of Poland in 2010.

percentages. Lower Silesia is the second most urbanized voivodeship in Poland, with an urban population consisting of 70.1% of the total population of the region (CSO, 2010). Within the voivodeship, seven out of its 29 districts that compose the voivodeship exceeded the average for Lower Silesia (Figure 3), including three urban districts that are 100% urban. These three urban districts are home to 40% of the urban population of Lower Silesian Voivodeship. Ten out of 29 districts in the province are less than 50% urbanized.

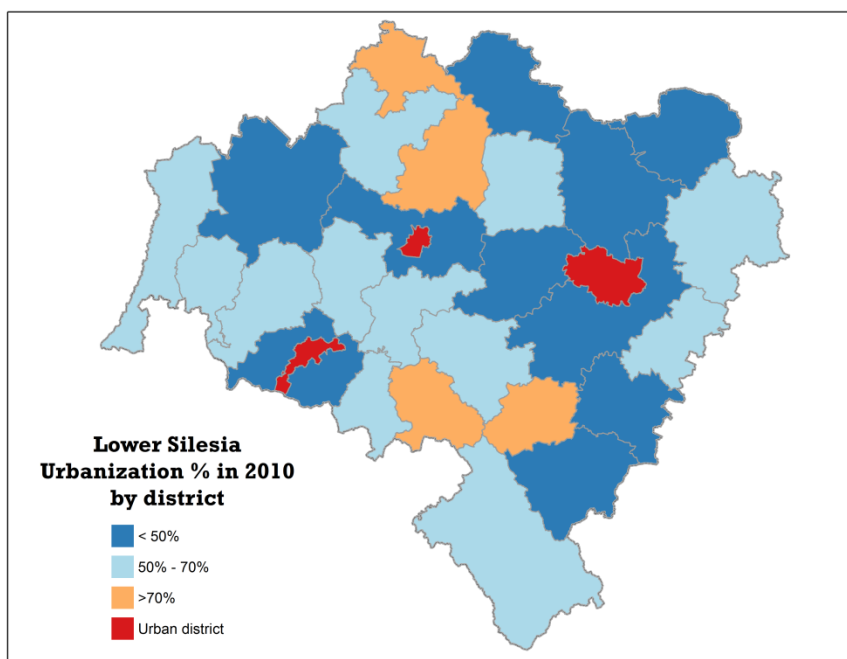


Figure 3. The percentage of urban population in the districts of Lower Silesia in 2010.

As mentioned before, urbanization measurements are inherently tied to the enumeration units defined by a country's administrative system. Poland illustrates this dependency as the definition of urban and rural populations is directly tied to the urban or rural designation of the smallest administrative unit called a commune. Specifically, the country is divided into 2,479 communes that are categorized as urban, rural or urban-rural.

This means that urban communes are 100% urbanized, rural communes are 0% urban, and the urban-rural communes have an urbanization percentage somewhere in between. While this allows for a clear distinction between urban and rural populations, it is not useful for studying urban change patterns in the province as the urbanization percentages for the urban and rural communes never change. This limits the effectiveness of applying the urban life cycle model at the commune level using urbanization percentages alone. A new methodology is necessary to apply the model when examining the urbanization patterns at the level of communes.

Most research studies examining Polish urban patterns at the national scale consider only one approach to quantify changes in the urbanization levels: measurement based on demographic data (Francis, 1971; Korcelli, 1990; Kupiszewski, Durham & Rees, 1998; Deichmann & Henderson, 2000, Szymanska & Matczak, 2002) or measurement based on land-cover (Bielecka & Ciolkosz, 2004; Ciolkosz & Bielecka, 2005). With few exceptions (Lowicki, 2008), research on urbanization process utilizing multiple datasets in the individual voivodeships is limited. By applying the urban life cycle model using both demographic data, measured using enumeration units derived from Poland's administrative system, and land-cover data, derived from satellite imagery, this research can have a unique contribution to the Polish urbanization literature. Furthermore, the results of this work also have potential implications for urban planning and management at the provincial level by providing a more comprehensive approach to studying the spatial variation of the urban patterns of communes in a voivodeship.

The goal of this research is to characterize the urbanization level of Lower Silesian Voivodeship between 1990 and 2010 using both demographic and land-cover data and apply

the urban life cycle model to describe urban change within the province. My hypothesis is that a better understanding of urbanization patterns and trends in the province will result by examining urban change at multiple spatial scales and with multiple data sets. Specifically, I addressed the following research questions to evaluate my hypothesis: 1) what are the patterns and trends of urban change in Lower Silesia at each of the three administrative levels; 2) what is the potential spatial, temporal and typological variability in urbanization patterns within the region based on the two datasets; and 3) how does the inclusion of land-cover information better inform the identification of the stage of the urban life cycle model.

This paper is organized into six sections: Literature Review, Background, Methodology, Results, Discussion and Conclusion. The Literature Review explores the existing literature on the topic of urban change. Specifically, the urban life cycle model used to categorize the urban development is discussed, and previous urbanization studies in the context of population change as well as land-cover change are reviewed. The Background section introduces the Polish administrative system, which varies considerably from the system in the United States, and describes the study site of Lower Silesian Voivodeship. The Methodology section discusses the analyses needed to address each research question. Specifically, the datasets used in the research are discussed in detail, along with the methods used to quantify urban patterns. The Results of the analysis are then presented. The Discussion section synthesizes the results in order to assess variability of urban change in Lower Silesian Voivodeship at multiple scales and to evaluate the inclusion of land-cover information in the urban life cycle model. Finally, the Conclusion section highlights the major findings of the work.

Literature Review

Urban Life Cycle Model

The urban life cycle model is a simple descriptive model that portrays the cyclical relationship between the relative change in populations of two urban locations – the urban center or core and the fringe or periphery (Champion, 2001; Capello & Faggian, 2002; Antrop, 2004). This relationship allows for the identification of four generalized stages of the urbanization process – urbanization, suburbanization, de-urbanization, and re-urbanization (Figure 4). The idea underlying the model is as follows: “the city has a life cycle which takes it from a ‘youthful’ growing phase through to an ‘older’ phase of stability or decline” (Champion, 2001). The model was first suggested by Hall (1971), who introduced the idea of three stages of urban development. It was later amended by Klaassen *et al.* (1981), who added the fourth stage to the model as part of a recurring cycle, in which after a period of overall urban decline the second cycle begins with renewed urban growth (Champion, 2001).

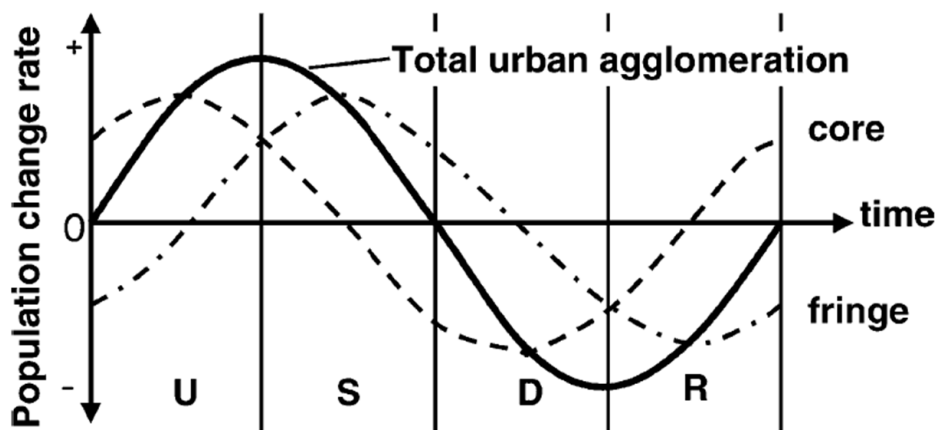


Figure 4. Urban life cycle model based on the changes in population: U, urbanization; S, Suburbanization; D, deurbanization; R, reurbanization phase (from Antrop, 2004).

The urbanization stage of the urban life cycle model is characterized by the demographic shift from rural to urban, with growth in the urban population as the population moves from the fringes of urban areas to the urban center. This stage is best exemplified by urban growth following the Industrial Revolution in Europe and North America. In general, with the dawn of the Industrial Revolution, the quickly industrializing cities of the more developed countries were attracting people with a promise of better paying jobs and improved access to services such as transportation, education, and health care, while the countryside was struggling with poverty, unemployment, lack of infrastructure and services (Banski, 2003). The benefits however, did not always outweigh the costs - pollution, overcrowding, noise, high land prices, crime and social problems eventually started to drive people away from the urban centers and to the periphery – the suburbs (Jacobs, 1993; Glaeser, 1998; Kupiszewski, Durham & Rees, 1998; Parysek, 2005, Levy, 2006). As transportation networks developed, many of those who could afford it left the inner cities and moved to the outskirts of urban areas where land was cheaper and plentiful, air was cleaner, and costs of living were much lower. This process leads to the second phase of the urban life cycle model – suburbanization.

In the suburbanization stage, the periphery is gaining urban population at the cost of the urban core (Antrop, 2004). This stage is typified by the American suburbs, and is often referred to as “urban sprawl”, “horizontal spreading”, or “dispersed urbanization” (UN, 2010). The communities close to a city tend to increase in population while the urban core loses population, resulting in suburban growth (Markowski, 1997; Kupiszewski, Durham & Rees, 1998; Deichman & Henderson, 2000; Banski, 2003; Parysek, 2005). Eventually even

the suburbs become overcrowded and begin to lose population to locations even further removed from the urban core. This leads to the third stage in the urban life cycle model - de-urbanization, which is characterized by the decrease of urban population in both the core and the periphery (Antrop, 2004). The fourth stage is re-urbanization, where cities now with smaller populations once again become attractive, the urban population recovers and the cycle begins again.

The urban life cycle model can be compared to the typical demand and supply model and the Lotka-Volterra ecological prey-predator model (Capello & Faggian, 2002). Despite the criticism of being a simple descriptive model that lacks economic variables, the urban life cycle model is useful in setting the stage for urbanization research and understanding the general process of urban change. The cycle uses changes in population rather than simple urban percentages to examine the stage of the urbanization process. By utilizing population measurements from both the urban core and periphery the urban life cycle model provides a simple, yet comprehensive understanding of the current urban trends for a region. However, the model relies on the definition of urban and rural populations which are often arbitrary and depend on the administrative system of the studied region. Therefore, the inclusion of land-cover information in the urban life cycle model can add to a better understanding of the urban patterns as it is not tied to the enumeration units especially at the smallest administrative level. The process of conversion from artificial land cover to another category is rare, therefore artificial land cover is only expected to increase. However, the change in the rate of increase can be an important indicator of urban change. A high increase in artificial land-cover in the rural areas surrounding a city suggests a suburbanization stage of the urban life

cycle model. A small increase in artificial land-cover in both urban and rural areas indicates a deurbanization stage, while a large increase in artificial land-cover in the urban areas points to urbanization or reurbanization stage of the model.

Urbanization Studies

Demographic data is most commonly used data source for studying the urban life cycle model and the process of urbanization (Champion, 2001). The application of the model requires a calculation of the urban and rural population change for an area of interest. Additionally, the urban percentage can be calculated to track the overall urbanization of the region. Most research efforts have quantified this measure using demographic data by determining the share of urban population in relation to the total population of a particular place. This seemingly simple urban measure can describe the state of urbanization of any continent, country, region, state or metropolitan area and is widely utilized in urbanization research (e.g., Champion, 2001; Antrop, 2004; UN, 2010).

The demographic data however is not without its shortcomings which stem from the inherent ties to the enumeration units such as country borders or city limits and the often arbitrary delineation of urban and rural areas (Champion, 2001 Antrop, 2004). As the borders change, so does the urbanization percentage. In addition, the definition of the urban population itself can be ambiguous depending on how such data is collected and categorized (LeGates, 2006). Mykhnenko & Turok (2007) discussed the issue of inconsistent city boundary definitions in their study of population trajectories of East European cities.

“The relevant concept of the city is the commonsense idea of a continuous built-up area larger than a certain population size. This is a physical and function definition (the de facto city) rather than an administrative or legal one (the de jure city)” (Mykhnenko & Turok, 2007).

The physical or functional extent of a city varies from the administrative extent and therefore the measured urban population can vary as well. The urbanization percentage as measured by the share of urban population can vary depending on the definition of the urban population, delineation of urban areas, and the administrative system of the area of interest.

Another method of studying urban change is to track change in urban land use over time by applying a land change analysis based on remotely-sensed data. Remotely-sensed data is a rich source of information capturing changes in landscape condition (Lillesand, Kiefer, & Chipman, 2007) and has been applied in variety of fields, from agricultural and environmental research (Jenerette & Wu, 2001), regional planning, resource management (Bielecka & Ciolkosz, 2000), to urban modeling and population density mapping (Yuan, Smith & Limp, 1997; Chen, 2000; Mesev, 2003; Briggs, Gulliver, Fecht & Vienneau, 2007; Gallego, 2010). Many of the studies exploring the use of remotely-sensed data in urban modeling have focused on the impacts of urban change on the surrounding landscape and environment (Carlson & Traci, 2000; Jenerette & Wu, 2001; Xiao, *et al.*, 2006).

Land cover represents the physical material that exists on the surface of the earth such as forests, fields or water (Lillesand, Kiefer, & Chipman, 2007). Land-cover urbanization, as measured through classified remotely-sensed imagery, is traditionally defined as “the general process of city growth” where “native land-cover is appropriated for industrial, commercial, residential, and other land uses associated with human demands” (Jenerette & Wu, 2001).

The native land-cover types such as wetlands, forests, or fields are replaced by artificial or urban land-cover that represents human land uses. The land-cover change analysis examines the amount and spatial location of this type of change by quantifying the number of pixels that became part of the artificial/urban land-cover category. Land-cover data is not tied to enumeration units like the demographic data, but rather it is a continuous coverage dependent on the resolution of the dataset derived from remotely-sensed images. It can be aggregated to enumeration units to serve as a supplement to measured demographic change, enabling a more thorough representation of urban change.

The complex process of urbanization can be best explored by integrating these two types of datasets – socioeconomic census data and physiogeographic land-cover data (Martin & Bracken, 1993) – to more holistically describe the patterns and trends. This is particularly true for urbanization studies focused on Poland. Despite the clear distinction between urban and rural areas in Polish administrative terms the reality on the ground is not as clear cut. The communes closest to the city tend to fill the role of suburbs (Markowski, 1997), but are officially considered rural. Because the delineation of cities on the fringes is ambiguous and often arbitrary (Mesev, 2003; Antrop, 2004), land-cover data can improve our understanding of the urbanization process in areas surrounding the cities by describing change in land-cover classes associated with urban land uses (i.e., artificial land-cover class). Spatially continuous land-cover data is a great supplement to the spatially explicit and purely statistical demographic data. Therefore, my research will couple population dynamics as described by demographic data with a land-cover analysis based on remotely-sensed data in order to provide a more comprehensive understanding of urban change within the province of Lower

Silesia. This twofold methodology has potential to add value to the urbanization research community by providing a more comprehensive approach to studying variations in urbanization patterns at multiple scales in Poland.

Background

Administrative System

The current administrative system of Poland was established on January 1st, 1999 and divided the country into 16 voivodeships (provinces) that are largely equivalent to the historical regions of Poland. Voivodeships are governed by a voivod (governor) and are further subdivided into powiats (equivalent to counties or districts). Prior to 1999, Poland was divided into 49 smaller voivodeships and further subdivided into basic territorial units called gminas (communes). The districts as administrative units were created in 1999 and currently there are 379 districts in Poland, with areas ranging from 13 km² to almost 3,000 km². On average, each voivodeship has 24 districts; although the number of districts comprising a voivodeship can range from 13 to 42. Districts are further subdivided into communes, of which there are 2479 in Poland. Communes range in their population and area dramatically depending on the voivodeship. The largest number of communes in a district is 19, while the most communes in a voivodeship is 314 (CSO, 2010). Commune populations can range from less than 400 people to almost 1.7 million. Communes are classified as either “urban” if they consist of just the city, “rural” if they consist of only villages and countryside but no city, or “urban-rural” if they encompass a city as well as the surrounding villages and

countryside (Central Statistical Office, 2010). In 2011, there were 306 urban communes in Poland, 1,571 rural communes, and 602 communes classified as urban-rural.

The Central Statistical Office of Poland defines an urban area as a place that has official municipal rights, thereby having status of a city. A rural area is defined as “any land that lies beyond the administrative limits” of a city (Banski, 2003). Due to this well-defined designation, the distinction between urban and rural areas, or cities and villages, as well as their populations, is very clear in Polish administrative terms. In addition, the assumption that “the coincidence between the settlement system and administrative boundaries” is largely justified in the Polish administrative system (Kupiszewski, Durham, & Rees, 1998), meaning that the political boundaries of city or village are generally equivalent to its actual extent. However, in practice it is hard to achieve a perfect delineation between the urban and non-urban areas as cities and their populations often expand past the administrative boundaries during the suburbanization stage of the urbanization process. Arbitrary political boundaries, therefore, cannot always accurately capture the gradient between the urban core and the rural periphery. This limitation advocates for additional methodology to more precisely study and measure the growth of the 908 urban areas in Poland, including 91 Lower Silesian cities.

Study Site

Lower Silesia Voivodeship is located in the southwest corner of Poland and has a population of over 2.88 million inhabitants (Central Statistical Office, 2010) residing in an area of more than 7,700 square miles (19,946 km²). With regard to population, the voivodeship is similar in size to Kansas. When considering the size of Lower Silesia, it is larger than Connecticut but smaller than New Jersey. Lower Silesia borders Germany to the

west, Czech Republic to the south, Lubusz and Greater Poland Voivodeships to the north and Opole Voivodeship to the east (Figure 5). The physical landscape varies from mostly plains and lowlands in the northern part of the province to rolling hills and Sudety Mountains in the south.

Lower Silesia is fifth largest province in the country in terms of population (7.5% of total population) and seventh largest in terms of size (6.4% of total area of Poland). Additionally, the voivodeship has the second highest urban percentage in Poland – 70.1% of the population of Lower Silesia lived in the 91 cities of the province in 2010. The city of Wrocław is the capital of Lower Silesia and largest city in the province with over 600,000 people. Lower Silesian Voivodeship is composed of 29 districts, which includes three cities with district rights (i.e., entire district is within the city limits), and 169 communes. Based on the national division into three commune types, Lower Silesia had 36 urban communes, 78 rural communes, and 55 urban-rural communes (Figure 5). This division provides a variety of urbanization levels in the province and lends itself very well to the study of urbanization process using the methodology proposed in this research. Lower Silesia has a mixture of highly urbanized and rural agricultural areas, which are reflected by the land-cover types. There are 91 cities in Lower Silesia with populations that vary from almost 640,000 to barely 2,000 inhabitants (Figure 5). Three new cities have been established within the province since 1995. The smallest commune in the province is 5 km² in size, while the largest is 438 km².

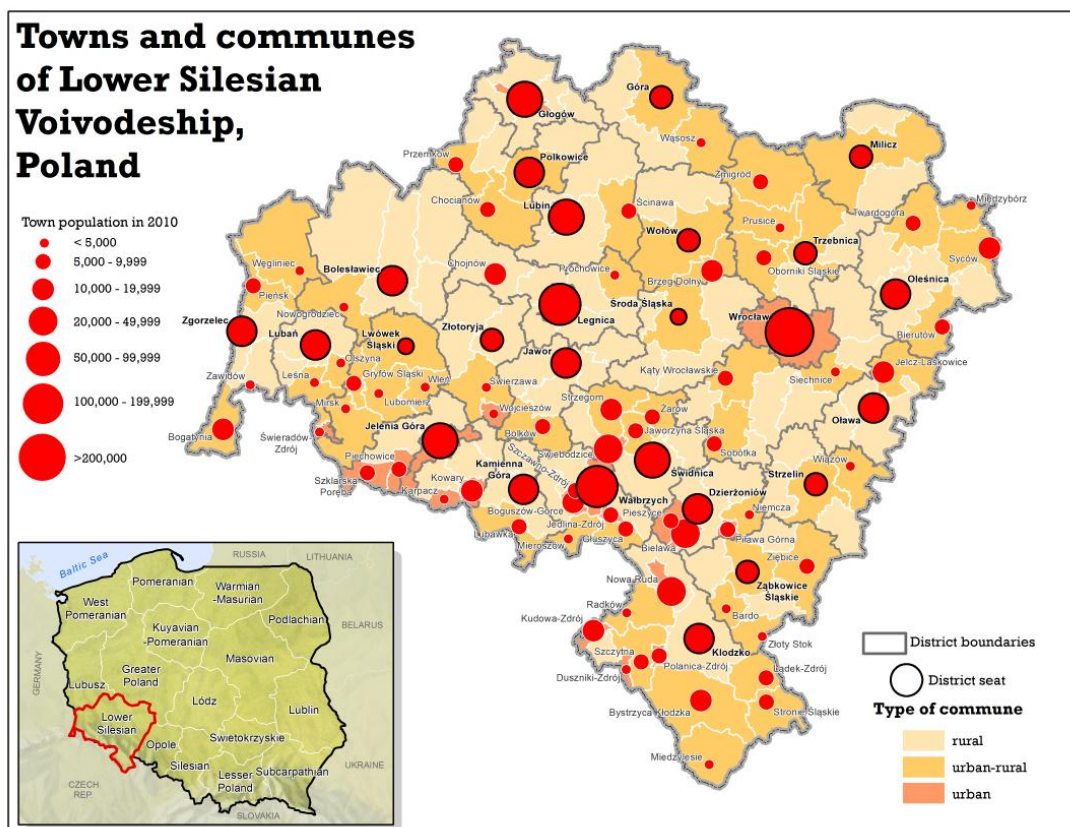


Figure 5. The towns and communes of Lower Silesian Voivodeship.

The province was chosen as the study site due to its high urbanization percentage, combination of urban and rural communes, and its historic urban significance. Lower Silesia is considered the birthplace of the Polish cities where the German settlers first introduced the idea of town charters in Poland (Koter & Kulesza, 1999). Charters were given by the feudal lords and outlined the duties and rights of the town people (Ostrowski, 1966). The first town charters, based on the German Magdeburg law, were granted in Lower Silesia at the beginning of 13th century (Pudelko, 1967). The region was one of the richest in the country, and due to its borderland geographic location, it was influenced by “west European innovations” (Koter & Kulesza, 1999). Lower Silesian Voivodeship remains an important region of the country economically as well as politically and socially.

Historically, the voivodeship was always more urbanized than most of the country (Nowakowski, 1988). In 1946, 40.9% of population lived in the cities of the province compared to the 34.02% that lived in all Polish cities (Kapusta, 1980). This higher urbanization level stems from the fact that Lower Silesia has always been a very industrialized region and is part of one of the major industrial belts of Europe (Regulski, 1980). Lower Silesia reached its 50% urbanization level in 1950, 17 years ahead of the national average, and experienced a much higher rural to urban migration rate than the national average (Kapusta, 1980). Urban populations in Poland and Lower Silesia increased during this time period not only due to high rates of rural to urban migration, but also as a result of the establishment of new cities, an expansion of the administrative boundaries of already existing cities, and high rates of natural population increase in cities (Nowakowski, 1988).

The socio-economic crisis in the 1980s led to the collapse of socialism in Poland at the end of the decade and dampened the previously intense urbanization stage of the urban life cycle model (Korcelli, 1990; Wrobel, 1992; Lorens, 2006). After the fall of communism in 1989, the country experienced a “fundamental social, political and economic revolution” that has dramatically changed population and migration patterns (Kupiszewski, Durham & Rees, 1998). The character of the urbanization processes changed after 1989 (Lorens, 2006; Szymanska, Grzelak-Kostulska, & Holowiecka, 2009) and researchers began to notice the beginnings of the suburbanization stage in Poland in the 1990s – a similar phenomenon that has been previously observed in the countries of Western Europe (Markowski, 1997;

Kupiszewski, Durham & Rees, 1998; Szymanska & Matczak, 2002; Banski, 2003, Parysek, 2005).

Several studies have examined urban growth and population change in Poland using demographic data as a main source of information in describing urbanization processes in the country (Francis, 1971; Eberhardt, 1989; Korecelli, 1990; Markowski, 1997; Kupiszewski, Durham & Rees, 1998; Deichmann & Henderson, 2000; Banski, 2003; Parysek, 2005; Szymanska, Grzelak-Kostulska, & Holowiecka, 2009). Francis (1971) focused on the “dynamism of urbanization process in Poland” between 1957 and 1968 and how it affected the population of the 23 largest cities he studied. Instead of discussing regions gaining population, Eberhardt (1989) brought attention to the areas of Poland that were depopulating. Korcelli (1990) documented urban change in Poland in the 1970s and 1980s and noted the beginning of suburbanization; however he thought that this trend would only be temporary due to the socio-economic crisis of the 1980s. Markowski (1997) presented the current level of development in Poland after the transformation to a market economy and discussed the problems facing urban planning due to the transition. Kupiszewski *et al.* (1998) carried out a population change study for the entire country at the commune level for years between 1984 and 1994 and found “profound change of population redistribution patterns in Poland” after the fall of communism in 1989. They noted that people were becoming more mobile leading to suburbanization that started after 1990, but noted that there are spatial variations in the urbanization process. Deichmann *et al.* (2000) investigated changes in demographic patterns, urban agglomeration and population mobility. By examining changes in the migration patterns they also found evidence of suburbanization in Poland. Banski (2003), focusing on

rural areas, observed the deconcentration of population that characterizes the suburbanization stage of the urban life cycle model. Parysek (2005) analyzed the development of 883 Polish cities between 1992 and 2002. He categorized the cities based on their population size and examined differences between the groups for a more detailed look at urbanization processes. Szymanska *et al.* (2009) discussed spatial and population density changes in Polish cities between 1960 and 2003 also utilizing similar population size categories to study the changes in cities of different sizes. They explained the role of industrialization in the urbanization processes of Poland and how the transition to a market economy influenced Polish towns in terms of their population density and area.

All of the studies mentioned above focused on the country of Poland as a whole, with limited consideration of specific voivodeships. Only a few studies have focused on the Lower Silesia region. Kapusta (1980) provided a very detailed description of the socio-economic changes in the villages of Lower Silesia between 1945 and 1976. He identified 1950 as the start of urbanization stage in the region, as the percentage of urban population started to increase and surpassed the 50% mark. Kapusta also noted that Lower Silesia was urbanizing faster than the country as a whole, although variations in urban percentages were observed among the districts comprising the voivodeship. Breitkopf's 1948 research, while rather outdated, provides a historic view of urban trends in Lower Silesia and includes a description of urbanization levels post-WWII. There is a lack, however, of demographic studies concentrating on recent urbanization trends in Lower Silesia. This lack of studies also applies to land-cover change in the voivodeship.

Of the few reviewed studies focused on land-cover change in Poland (Bielecka & Ciolkosz, 2004; Bielecka, 2005; Lowicki, 2008), none examined study areas that overlapped with Lower Silesian Voivodeship. Bielecka & Ciolkosz (2004) conducted a land-cover change analysis using the CORINE dataset to assess changes in land cover between 1990 and 2000. Although this study was not focused on urban change, the study reported evidence of increasing urbanization within the country, measured by an increase in artificial land-cover especially surrounding larger cities such as Warsaw and Wrocław. Bielecka (2005) used landscape metrics to map the landscape diversity in Poland between 1990 and 2000 and found that artificial areas are becoming more fragmented due to urbanization and industrialization, while the agricultural and forest areas are actually becoming less fragmented due to conversion of grassland to arable lands and reforestation. The development of new highways, especially A4 (major highway connecting the eastern and western borders) had and continues to have a major impact on the landscape of Poland (Bielecka, 2005).

Łowicki (2008) used the case study of Wielkopolska Voivodeship to analyze land-use changes in Poland after the fall of communism in 1989. He argued that the political, economic and social transformation that has occurred in Poland had an impact on the rates and pattern of land-cover change at both local and regional levels. Using land cadaster, a legal registry of parcels, as a source of information about land use, Łowicki found an increase in settlement areas, especially in communes closest to larger urban centers, as well as a decrease in agricultural areas as a result of urban growth and reforestation. Wasilewski & Krukowski (2002) noted a similar observation – the conversion of agricultural lands into

housing in the areas surrounding large cities as a result of the urbanization of Poland after 1989.

Methodology

The methodology section is divided into two main topics. Data acquisition/preparation describes the demographic and land-cover datasets, including acquisition and pre-processing procedures. It also includes a description of the administrative boundaries spatial layer. Data analysis contains the methodology pertinent to addressing the research questions. The methodologies presented are subdivided by the three administrative levels as a way to provide structure to the analysis.

Data Acquisition and Preparation

Administrative Boundaries

The spatial dataset of the administrative boundaries for Lower Silesian Voivodeship as of January 1st, 2011 was purchased from Central Documentation Centre of Geodesy and Cartography in Warsaw (<http://www.codgik.gov.pl/>), part of the State Register of Borders and Area of Units of Administrative Division. The dataset consisted of vector GIS polygon shapefiles identifying the boundaries for the three administrative levels: voivodeship, districts and communes. The commune shapefile included a unique identification number, as well as the commune type. The urban-rural communes were further divided into urban and rural areas. The shapefiles were re-projected from their original coordinate system, WGS

1984, to the coordinate system of the research project, UTM Zone 33N based on WGS 1984, and then converted into feature classes compiled in one geodatabase.

Demographic Data

The source of the demographic data is the Central Statistical Office of Poland (CSO). CSO is a main source of statistical information on the population, economy, and environment of Poland. CSO's online database, Local Data Bank, contains a wide variety of public and freely available data for each of the Polish administrative levels - voivodeships, districts, and communes. The data is collected at the commune level and then aggregated for the district and the voivodeship levels. Temporal limitations to the database exist however, as the database only includes data for each year from 1995 to 2011. Microsoft Excel spreadsheets were downloaded from Local Data Bank containing the demographic data, total population and urban population, for each year between 1995 and 2010 at the voivodeship level, and for the years 1995, 2000, 2005, and 2010 at the district and commune levels. The data acquisition for the districts and communes was limited to four years in order to make the analysis more manageable at these levels. For the voivodeship and districts the demographic urbanization percentage was determined by dividing the urban population by the total population for each time stamp. The urbanization percentages for the communes however, have limited practical utility due to the definition of urban population in administrative terms. All urban communes, by definition, are 100% urbanized and all rural communes lack any urban population. Urbanization changes were therefore measured by the change in the total population of each commune, regardless of type, rather than the share of urban population in the total population. The percentage of total population change was calculated for each time

period for each commune. Additionally, total population change was also calculated for each district as well as the whole voivodeship. The tabular data was joined to the district and commune layers of the administrative boundaries to create a spatial database of the demographic data that was later mapped and spatially analyzed.

Land-Cover Data

The source of land-cover data for Lower Silesian Voivodeship is the CORINE Land Cover dataset developed by The European Environment Agency. The dataset is freely available and covers twelve European countries with an area of 2.3 million km² for years 1990, 2000, and 2006 (European Environment Agency, 2011). It was created through “computer-assisted visual interpretation” of Landsat and SPOT satellite imagery, “with the simultaneous application of ancillary data” such as topographic maps, thematic maps, statistical info, and aerial photographs to improve the accuracy and quality of the land-cover classification (Bielecka, 2005). The geometric accuracy requirement for CORINE is 100m and the thematic accuracy of the datasets is at least 85%. The mapping scale of CORINE is 1:100,000 with the smallest cartographic unit of 25ha, which reflect budgetary and time constraints due to its large spatial extent (CORINE Land Cover Manual). CORINE is available at both 100 meter and 250 meter resolution. Despite this relatively coarse spatial resolution, this dataset is adequate for “general urban delineation” (Mesev, 2003) and can be used in general urbanization studies such as this research.

The land-cover classification scheme used by CORINE is composed of three levels. The first level assigns one of five major land-cover categories to each pixel: 1) artificial surfaces; 2) agricultural areas; 3) forests and semi-natural areas; 4) wetlands; and 5) water

bodies. Levels two and three further refine these coarse categories and consist of 15 and 44 categories, respectively. The artificial land-cover category contains four classes at the second level: 1) urban fabric; 2) industrial, commercial, and transport; 3) mine, dump and construction sites; and 4) artificial, non-agricultural vegetated areas. Although the artificial surfaces are separated into more detailed classes at the second and then third level, they all represent human uses and can be associated with the change in the urban development. Therefore, only Level I was used in this research to simplify the land change analysis.

Raster data format of CORINE was downloaded at 100m spatial resolution for the three available years – 1990, 2000 and 2006. Using the administrative boundary of Lower Silesian Voivodeship, the land-cover data for the province was extracted from the entire European dataset. The extracted rasters were then reclassified to only contain the first level of the CORINE nomenclature as described above.

Data Analysis

The data analysis examined three major aspects of possible variation in the characterization of urbanization stages throughout the study region as identified by the urban life cycle model - spatial, temporal and typological. Spatial variability was assessed through mapping and spatial cluster analysis. Temporal variability was evaluated by analyzing three 5-year time periods. Finally, typological variability was examined by measuring urbanization levels using the three administrative levels – voivodeship, districts and communes (including the three types of communes). The data analysis, described below, is divided by the administrative unit to demonstrate the impact of scale on the variability of the urbanization processes in the province. The aspatial analysis of the demographic and land-cover datasets

was conducted using statistical software SPSS and Minitab, while ArcGIS 10 (ESRI) was used to conduct the spatial analysis.

Voivodeship Level

As a first step to understanding urbanization patterns and trends in Lower Silesian Voivodeship, total population, rural and urban population, and urban percentage were graphed to illustrate demographic change across the 15-year study period. The resulting graph served as the basis for applying the urban life cycle model and classifying the current state of the voivodeship (i.e., stage of urbanization).

To determine changes in the urbanization level of the voivodeship as measured using land-cover data, the three land-cover maps were overlaid in a land change analysis to identify the type and location of land-cover change throughout the study region. All five of the major land-cover classes were examined; however only changes in the artificial land-cover class are presented given the focus of this research. The urbanization percentage, as measured by the land-cover data, is the share of the artificial land-cover in the landscape. The percentage was calculated for the voivodeship and its urban and rural areas as defined by the administrative boundaries of communes and cities boundaries within the urban-rural communes. Changes in the artificial land-cover were calculated for the time periods 1990 to 2000 and 2000 to 2006, as well as overall period 1990 to 2006 and then mapped to examine the spatial variability of urbanization-driven land-cover change throughout the province. Change in artificial land-cover composition was graphed to examine the relationship between change in land-cover and change in population in relation to the urban life cycle model.

District Level

At the district level, total population change and urban population change were calculated and mapped for each 5-year time period (e.g., 1995-2000) as well as the overall time period under study (i.e., 1995 to 2010) to examine changing urbanization levels over both space and time. The urbanization percentage, as measured by the share of urban population in the total population was calculated for each district. Three of 29 districts are designated as cities with district rights, meaning that the district is composed of only urban communes. Urbanization percentages were then mapped by district to visually explore the spatial differences in the percentages. The population changes and the urbanization percentages at the district level were used to preliminarily assess the spatial variations in the urban life cycle model.

The percentages of artificial land-cover in 1990 and 2006, as well as the percentage of change in the artificial land-cover, were determined and mapped for each district to assess possible spatial variability in the rates of artificial land-cover change within the voivodeship. The land change analysis examined only the overall study period for land-cover dataset (i.e., 1990 to 2006) because I was interested in overall changes in land cover and splitting the analysis into two time periods (i.e., 1990 to 2000 and 2000 to 2006) created uneven time periods. Although the temporal data availability for the two datasets differed, the overall changes in population and artificial land-cover can be compared. Artificial land-cover changes and urbanization percentages as measured using the land-cover data were also used to examine spatial variations in the urban life cycle model. Differences in artificial land-cover change rates were compared to differences in population change rates across districts

to assess possible complimentary or contradictory relationships in urban trends when comparing the demographic and land-cover data.

Commune Level

At the commune level, the total population data for each commune were analyzed by calculating population change percentage for each of the three 5-year time periods as well as the overall time period (e.g., 1995 to 2010). The percentage of artificial land-cover in 1990 and 2006, as well as the percentage of change in the artificial land-cover between 1990 and 2006 were also determined for each commune. As an initial exploration of possible spatial and temporal variability in urbanization trends across the region, population change and artificial land-cover change were mapped by commune for each time period considered (i.e., 5-year time periods for population data and 1990 to 2006 time period for land-cover data).

A simple classification scheme was applied to improve the visualization of population change at the commune level. The calculated population change percentages were classified into two classes – loss or gain – by assigning a ‘-’ or ‘+’ sign for each time period based on either loss or gain in population. The combination and ordering of the classes (e.g., -|-| versus +|+|) defined the level of brightness and saturation when mapping changes in population across each five-year time period. In addition, the categories for each commune type (e.g., urban, rural, urban-rural) were assigned a different hue to allow commune types to be easily distinguished on the resulting map. Urban-rural communes were assigned two similar hues due to the larger number of classes. This visualization approach allows the map reader to visualize both spatial and typological variability in urbanization process across the voivodeship, while also examining trends in the population change across time.

In addition, population changes and artificial land-cover changes were grouped based on commune type – urban, rural, and urban-rural – as well as simpler urban/rural classification, in order to examine variability in the rates of population change and artificial land-cover change based on commune typology. In other words, I was able to assess whether the change in population and the change in the artificial land-cover for a commune (increase or decrease in population/artificial land-cover over time) was associated with its assigned commune classification; for example, were consistent losses in population over time associated with the commune type urban or were consistent gains in artificial land-cover over time associated with the commune type rural or urban-rural. When defining communes with respect to the simpler urban / rural classification, urban areas included all urban communes and the urban parts of the urban-rural communes as defined by the administrative boundaries obtained from the Central Documentation Centre of Geodesy and Cartography. Rural areas, on the other hand, included rural communes and the rural parts of the urban-rural communes.

Descriptive statistics such as the mean, median, standard deviation and range of the percentage of population change and amount of artificial land-cover change summarized variability in urbanization trends within each commune type. The descriptive statistics help to assess the typological variability of urbanization patterns within the region based on the two datasets. An analysis of variance (ANOVA) was conducted to determine if there was a significant difference in population change between the three commune types for all three time periods and the overall study period. The artificial land-cover change between 1990 and 2006 was also assessed using ANOVA for the commune types. Independent-samples *t* test was used to compare the urban and rural areas with regard to differences in both types of change.

To explore possible spatial autocorrelation in population change trends across the voivodeship more formally, global Moran's I values were calculated for each change time period (e.g., 1995-2000). In addition, Moran's I values were also calculated for the artificial land-cover change between 1990 and 2006. Given the set of communes and their associated population change or artificial land-cover change, Moran's I determined whether the pattern of population change and artificial land-cover change in Lower Silesian Voivodeship was clustered, dispersed, or random. In other words, a positive Moran's I value would indicate that the values are clustered, while a negative Moran's I value would indicate that they are dispersed. The significance of the global Moran's I value was also determined and assessed the null hypothesis that the urban change was randomly distributed across communes (i.e., no significant pattern to population change/artificial land-cover change). To identify statistically significant clusters or outliers, local Moran's I values were calculated for each commune. The resulting z-scores and p-values corresponding to each commune allowed me to identify 'hot spots' or local clusters; e.g., regions where adjacent communes have similar values and spatial outliers, e.g., communes with significantly different values as compared to their neighbors. The statistically significant clusters and outliers were then identified, mapped and compared for each time period. The mapped clusters and outliers of population change were compared to the clusters and outliers of artificial land-cover and artificial land-cover change.

To summarize spatial variability across time-periods and/or dataset (i.e., demographic and land-cover data), a series of statistical cluster analyses were performed. Specifically, the Cluster Observations method was used to group communes based on: 1) changes in population over time; and 2) changes in artificial land-cover over time. This technique is appropriate for smaller datasets (i.e., < 200-250). Conducting a cluster analysis requires the

specification of several parameters, namely the calculation of distances between clusters, the linkage method, which defines the start and end points of clusters, and the number of target clusters. These parameters are needed to make sense of the data being grouped and link them into clusters accordingly. For this research, single linkage and Euclidean distance were selected, which meant the distance between the two clusters was computed as the straight-line distance between two closest communes. In addition, all variables were standardized which differences in the range of values for each variable would be accounted for in all calculations.

Cluster Observations is an agglomerative hierarchical method, which means that at first all communes are separate clusters. After each step, communes that are most similar to each other with regard to their measured values (e.g., changes in population for each of the three change time periods) are joined. The process continues to join communes or clusters of communes until either the target number of clusters is met or a single cluster containing all communes is reached. Achieving a single cluster is not the goal of the clustering analysis. Instead, the focus of the analysis is examining changes in the similarity level of the newly joined communes or clusters of communes at each step; i.e., after selecting two communes or clusters of communes to join the cluster analysis measures the similarity of the joined clusters. The similarity level quantifies how alike communes are with regard to their variable values in the joined cluster. When two communes with different population change or artificial land-cover change values are combined, the similarity level of the cluster analysis will decline. While the joining together of communes will always result in a decline in the similarity level, the change in similarity levels after each step is the key to identifying significant groupings of communes. To determine the number of significant clusters, I used

the relative decline in similarity levels, i.e., current decline in similarity level compared to previous declines. The cluster analysis was conducted twice for each of the commune types. The first analysis involved population change percentage for each of the three 5-year time periods, and the second involved artificial land cover change percentage along with the difference in percentage points between artificial land-cover levels in 1990 and 2006.

The communes belonging to each significant cluster, as defined above, were mapped to examine the spatial variability in population change and the spatial variability in land-cover change over time. The cluster analysis also allowed me to identify communes with significantly different trends in urbanization levels; communes that are discernibly different from the majority. In other words, I was able to identify communes and/or regions displaying distinct urbanization patterns from the trends observed across the voivodeship. The map of the population change clusters and the map of the artificial land-cover change clusters were compared to identify any common urbanization patterns and trends as measured by the two datasets.

Results

Urbanization at the Voivodeship Level

Lower Silesian Voivodeship lost 3.7% of its total population between 1995 and 2010, with the largest decline happening in 1999 (Figure 6). The population of the province seems to have stabilized since 2007 at slightly below 2.88 million inhabitants. The trends in the total population change do not however illustrate the urbanization story of Lower Silesia. In 1995 71.6% of almost 3 million residents of Lower Silesian Voivodeship lived in the cities of

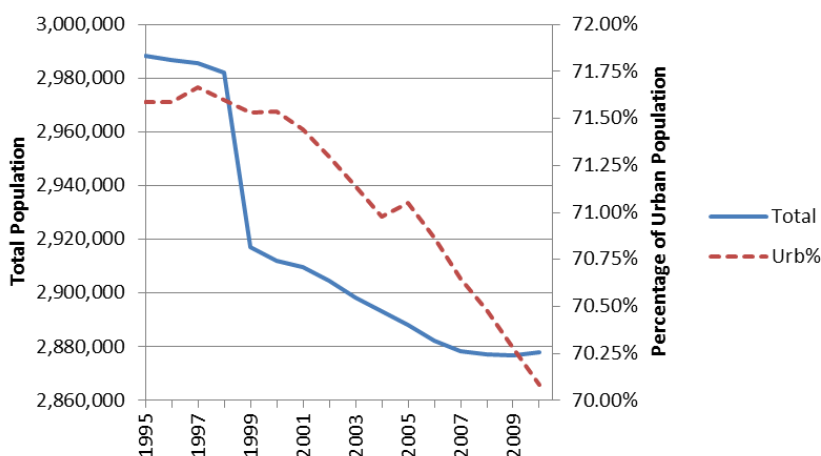


Figure 6. Changes in total population and urbanization level in LSV 1995-2010.

the province, making it the second most urbanized voivodeship in the country. This percentage declined to 70.1% in 2010 (Table 1) as cities lost 5.7% of their population, rural areas gained an additional 1.4% and over 110,000 people left the province altogether.

Table 1. Population change in Lower Silesian Voivodeship.

		TOTAL	Urban	Rural
1995	total population	2,988,278	2,139,147	849,131
	% of total population	100.0%	71.6%	28.4%
	1995-2000 change	-2.5%	-2.6%	-2.4%
2000	total population	2,912,195	2,083,253	828,942
	% of total population	100.0%	71.5%	28.5%
	2000-2005 change	-0.8%	-1.5%	0.9%
2005	total population	2,888,232	2,052,094	836,138
	% of total population	100.0%	71.1%	28.9%
	2005-2010 change	-0.4%	-1.7%	3.0%
2010	total population	2,877,840	2,016,830	861,010
	% of total population	100.0%	70.1%	29.9%
	1995-2010 change	-3.7%	-5.7%	1.4%

Urban and rural populations also exhibited different trends across the study period. Both urban and rural populations declined between 1995 and 2000, less than a decade after the fall of communism in Poland. However during the first ten years of the 21st century, cities within the province lost 3.2% of inhabitants while the rural areas gained 3.9% of population. Applying the urban life cycle model, these changes in the urban and rural populations

suggest that Lower Silesian Voivodeship is currently undergoing suburbanization; i.e., urban areas are losing population while the surrounding rural areas are gaining inhabitants (Figure 7). The demographic data suggest that the urbanization level of the province has decreased during the 15 years examined in this analysis due to the suburbanization stage of the urban life cycle model.

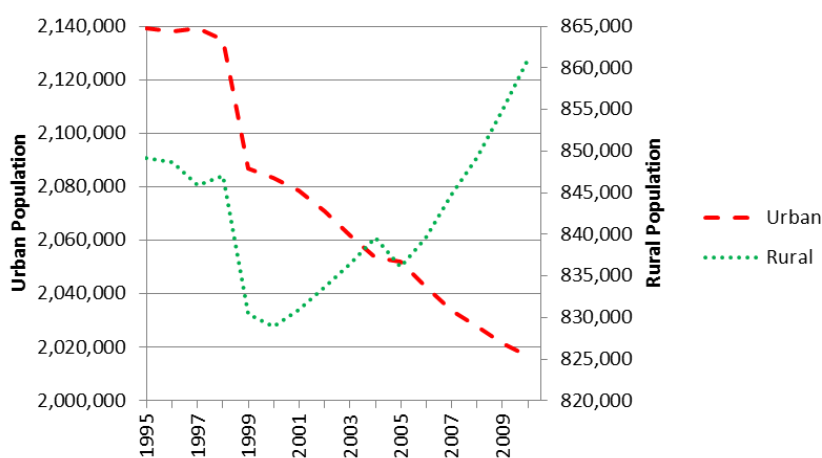


Figure 7. Changes in rural and urban populations of LSV 1995-2010.

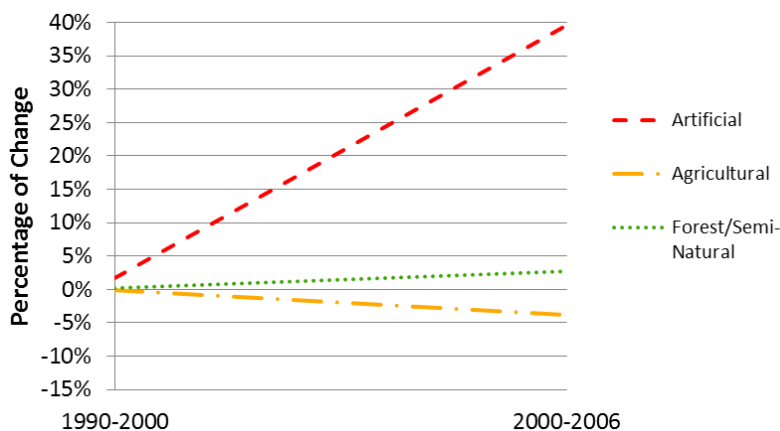
In terms of artificial land-cover, the urban percentage increased from 4% in 1990 to 5.7% in 2006 which represents an increase of 42% or 338 km² in the artificial land-cover in the province (Table 2). In the same time period agricultural land-cover has decreased by 4.1% from 64.3% of the total area to 61.7%. There was very little land-cover change between 1990 and 2000 and only slight increases in artificial land-cover. Only 0.2% of the total area of Lower Silesia underwent any type of land-cover change during this time period. The most numerous change was the conversion of agricultural land to artificial land cover, while the

Table 2. CORINE Land Cover change in Lower Silesian Voivodeship.

Land Cover Type	1990		1990-2000 change		2000		2000-2006 change		2006		1990-2006 change	
	area (sq km)	% of total area	area (sq km)	% of change	area (sq km)	% of total area	area (sq km)	% of change	area (sq km)	% of total area	area (sq km)	% of change
Artificial Areas	805.9	4.0%	13.2	1.6%	819.1	4.1%	325.1	39.7%	1144.1	5.7%	338.3	42.0%
Agricultural Areas	12822.7	64.3%	-21.9	-0.2%	12800.8	64.2%	-498.5	-3.9%	12302.3	61.7%	-520.4	-4.1%
Forest/Semi-Natural Areas	6122.9	30.7%	8.4	0.1%	6131.4	30.7%	164.4	2.7%	6295.8	31.6%	172.8	2.8%
Wetlands	32.8	0.2%	-4.5	-13.8%	28.3	0.1%	-0.2	-0.6%	28.1	0.1%	-4.7	-14.3%
Water Bodies	162.5	0.8%	4.8	3.0%	167.3	0.8%	9.2	5.5%	176.5	0.9%	14.0	8.6%

conversion of agricultural land and wetlands to forest and semi-natural areas was also prevalent.

Between 2000 and 2006, 3.2% of the total area of the voivodeship underwent a change in land-cover with more than half of these changes attributed to the conversion of agricultural to artificial land-cover. Of the remaining changes, the conversion of agriculture to forests and semi-natural land-cover occurred in the highest amount. Overall, the trend in land-cover over time was an expansion of artificial areas, a decline in agricultural land, and an increase in forested and semi-natural areas (Figure 8). Figure 9 illustrates the locations of changes in land cover between 2000 and 2006. Changes to artificial land-cover were concentrated around the city of Wrocław and along roadways as indicated by the linear

**Figure 8. Changes in major land-cover classes in Lower Silesia.**

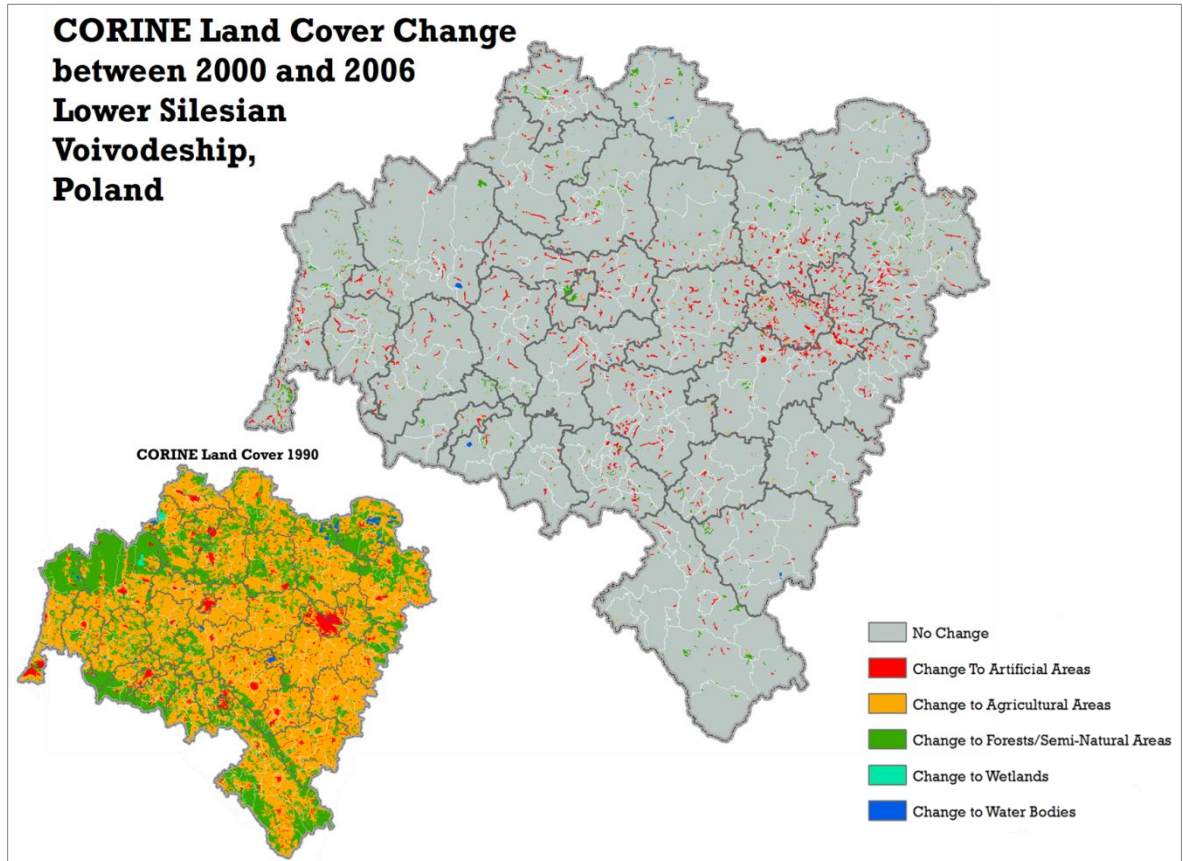


Figure 9. CORINE Land Cover Change between 2000 and 2006.

nature of many of the land change patches (i.e., pattern suggests development along roadways).

Based on the administrative divisions, urban areas account for 11% of the total area of the voivodeship and rural areas account for 89%. Over the time period examined, urban and rural areas differed with respect to changes in artificial land cover. In 1990, 22.3% of the urban areas and 1.8% of rural areas were classified as artificial land-cover, percentages that did not change greatly between 1990 and 2000 (Table 3). However, between 2000 to 2006 artificial land cover in the urban areas increased to 25.9%, while artificial land-cover increased to 3.2% in the rural areas. Overall, the urban areas gained 91.4 km² (35.3 mi²) of

Table 3. Changes in the artificial land cover type.

	1990 % of total area	2000 % of total area	2006 % of total area	% of change 1990-2006
Urban Areas	22.3%	22.4%	25.9%	19.0%
Rural Areas	1.8%	1.9%	3.2%	75.7%

artificial land-cover, equivalent to a 19% increase. The rural areas gained 246.8 km² (95.3 mi²), for an increase of over 75%. Of the 338.1 km² (130.6 mi²) of new artificial land-cover gained in Lower Silesian between 1990 and 2006, 73% of the increase occurred in rural areas. This supports the results observed in the demographic data – the voivodeship appears to be in the suburbanization stage of the urban life cycle model. The population declines from 1995 to 2000 were mirrored by a slow rate of artificial increase between 1990 and 2000. In the first decade of 21st century, the rural areas experienced an increase in population as well as larger increases in artificial land-cover. Although the two datasets are slightly different, they do show similarity in general trends at the voivodeship level.

Urbanization at the District Level

The changes in population were not uniform across the voivodeship (Figure 10). Overall, all districts in the southern part of the province experienced a decrease in total population over the time period examined (1995-2010). Six out of seven districts that increased in population are surrounding the city of Wroclaw although the city itself lost population. This part of the province saw a consistent increase in population since 1995. This indicates that the suburbanization of the region surrounding Wroclaw was already occurring at the end of the 20th century, and as the first decade of 21st century progressed the suburbanization of this part of the province became more widespread. The northern part of the province shifted from losing to gaining population, while most of the southern districts

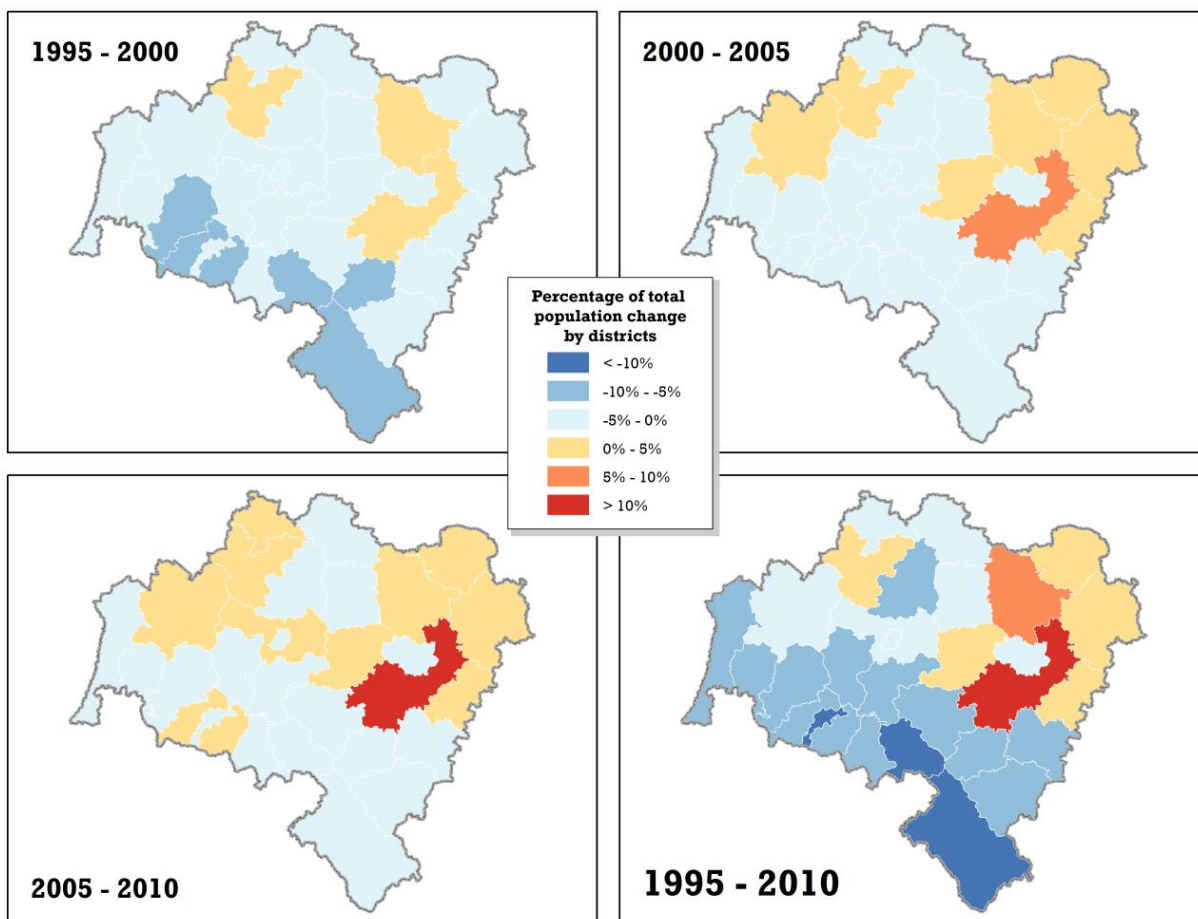


Figure 10. Percentage of total population change by districts.

have been consistently losing population. The largest increase was the Wroclawski district at 13.2%. The other two city districts – Legnica, and Jelenia Gora – lost population for each 5-year time period, while the districts surrounding these cities gained population during the last five years of the study period, suggesting beginning of the suburbanization stage of the urban life cycle model in these areas. The variations in the population changes by district are the first signs of spatial variability in the urbanization process within the province. The average percentage of total population change between 1995 and 2010 by district was -3.44% with a standard deviation of 6.97%. The average percentage of urban population change in the same time period was -4.14% with a standard deviation of 11%. This suggests a greater variability

in urban population change across the region as compared to total population change. In addition the urban population decreased at a faster rate than total population.

Changes in urban percentages between 1995 and 2010 were mapped to examine variability in urbanization trends within the voivodeship (Figure 11). The three districts representing city districts had urbanization levels of 100%, which by definition remained constant over time. The patterns and trends of urbanization observed at the district level confirm the results observed for total population change – the province is experiencing suburbanization as most of the districts become less urbanized. However, variation to this general trend do exist. The districts surrounding the capital city of Wroclaw are gaining total population and increasing in their urban percentage, meaning that the smaller cities

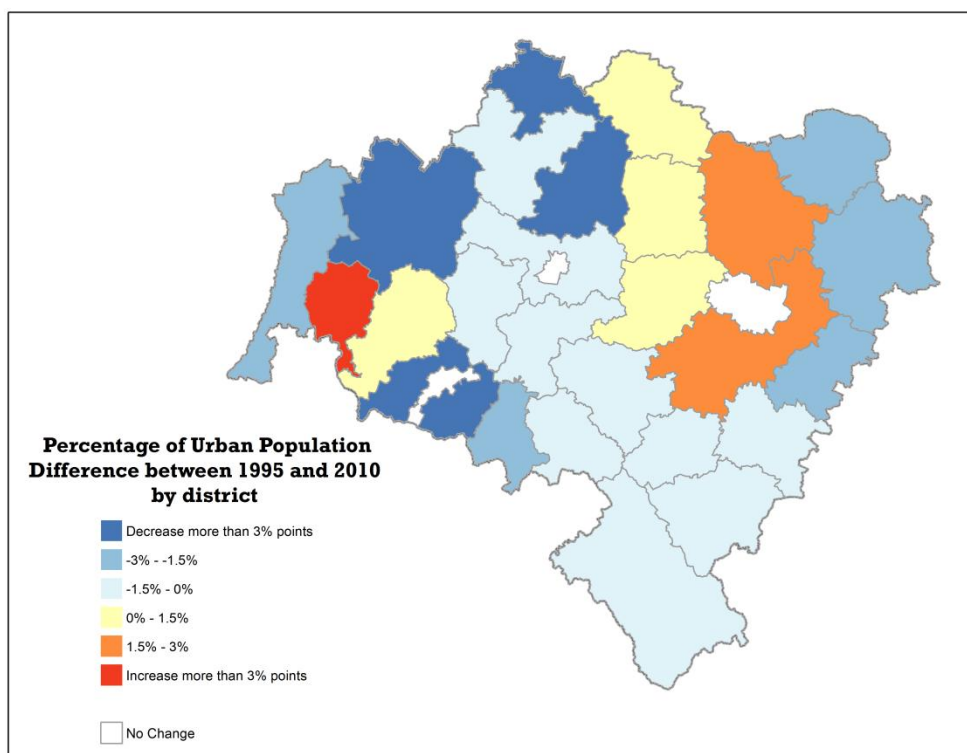


Figure 11. Difference in the percentage of urban population by district.

surrounding Wroclaw are gaining population. This increase in the urban population in the districts around Wroclaw suggests an urbanization stage of the urban life cycle model in this region as opposed to the suburbanization stage concluded from the population change results. Lubanski district in the western part of the voivodeship, also seems to have different patterns of urban change than the voivodeship in general. Despite losing more than 7% of its total population between 1995 and 2010, the district increased from 57% to 63% urban due to a high increase in urban population between 2000 and 2005, and decrease in rural population.

In general, the patterns of total population change and changes in the urbanization levels support the conclusion of suburbanization stage from the results at the voivodeship level, however not all sub-regions show this pattern. In order to better understand the urbanization process in Lower Silesia and reveal more complex pattern of spatial variability of urban change an increasing level of spatial detail was needed. The urban life cycle model was not utilized to its full potential in exploring the urbanization process in the region due to the coarse resolution of the demographic data that resulted in the contradicting identification of the stages of the model for the districts surrounding Wroclaw.

Districts varied with respect to the percentage of artificial land-cover (Figure 12), and as anticipated the three city districts had the highest percentage of artificial land-cover in both years. The district of Wroclaw had the highest percentage of artificial land-cover in 2006 at 50.6%. Legnica city district has 49.9% of artificial land-cover in 2006, while Jelenia Gora had only 19%. Although all three city districts are considered 100% urban as measured by the demographic data, the variations in the amount of artificial land-cover suggest that the administrative boundaries do not necessarily correspond to the extent of the urban areas. The

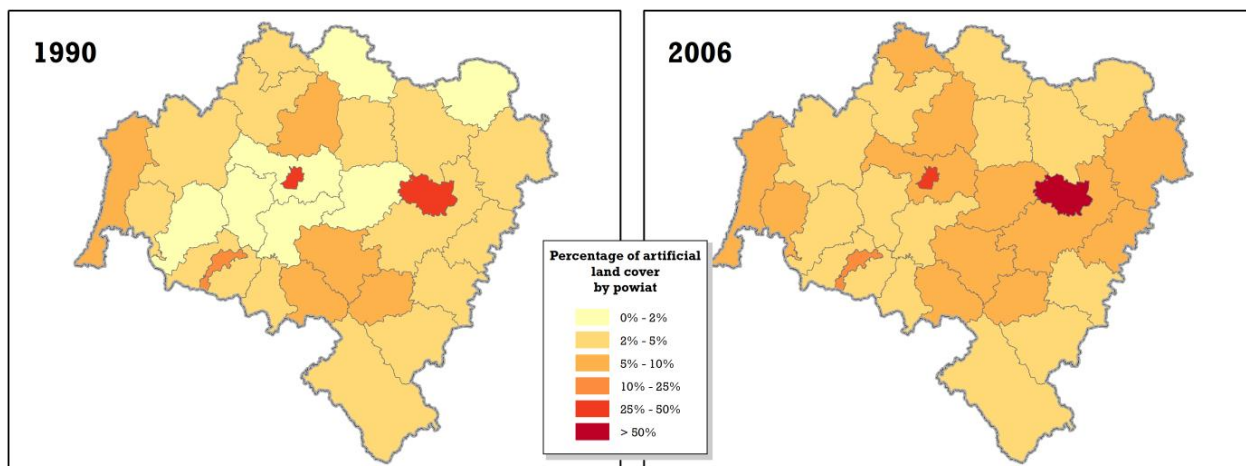


Figure 12. Percentage of artificial land cover by districts in 1990 and 2006.

analysis of the artificial land-cover revealed variability in the urbanization patterns that were lacking in the demographic data. All other 26 districts had less than 10% of their total area in the artificial land-cover class, ranging from 2% to 9% in 2006 as an example. Lower Silesia is generally very rural.

The greatest increases in artificial land-cover were clustered in the center of the province along an east-west axis (Figure 13). All 29 districts experienced increases in artificial land between 1990 and 2006, with seven out of 29 districts experiencing increases of more than 100% of their 1990 artificial land-cover levels. These districts increased from 1% to 3% of artificial land-cover an urbanization percentage between 2.5% to 7%. Overall, the changes in the artificial land-cover show the variability of urban growth in the province. However, three of the seven districts with highest growth in the artificial land-cover experienced a decrease in the urbanization percentages as measured by the demographic data. In general, at the district level, the demographic and land-cover data differ although the districts surrounding the cities of Wrocław and Luban are consistent between the two

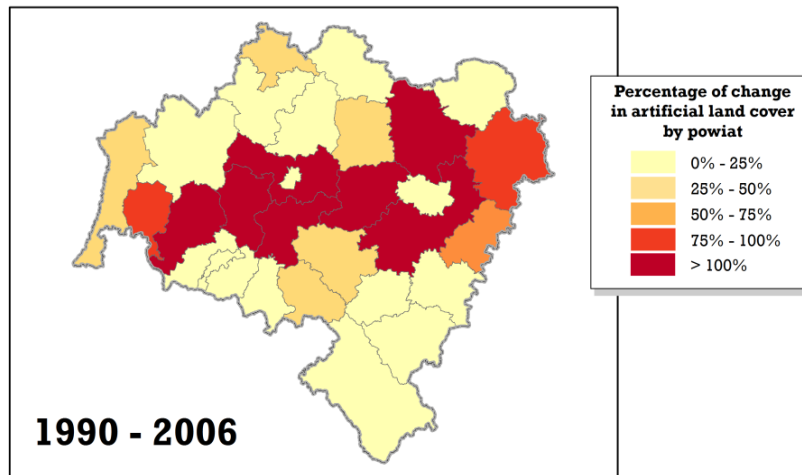


Figure 13. Percentage of artificial land cover change by districts.

datasets. Because of the different patterns exhibited by the two datasets at the district level, both demographic data and land-cover data are needed to better understand the urbanization patterns in the province and categorize them using the urban life cycle model.

As measured by the demographic data, the urbanization percentage increased in the districts surrounding Wrocław and few other smaller cities in the region while the rest of the districts became less urbanized suggesting overall suburbanization of the province. As measured by the land-cover data, the urbanization percentage increased for every district but concentrated in the east-west axis in the center of Lower Silesia. At the district level, it is difficult to conclusively determine the stage of the urban life cycle model by examining the changes in the artificial land-cover due to lack of urban and rural divisions. Potential examples of suburbanization exist in the areas around Wrocław and Legnica with the surrounding districts more than doubling the amount of artificial land-cover during the study period (i.e., 1990-2006).

Urbanization at the Commune Level

Spatial and temporal variability of population change at the commune level was observed in the population change maps for each 5-year time period (Figure 14). In general, between 1995 and 2000, the communes of Lower Silesia experienced a loss of population, however spatial variations exist. 26 communes gained population and most surround cities that lost urban population (Wrocław, Lubin, Bolesławiec, Głogów, Kamienna Góra, Oława, and Oleśnica). Examining population change across commune type, both urban and rural communes lost population, 3.1% and 4.5% respectively (Table 4), while urban-rural communes grew slightly. Additionally, differences in population change were observed within the urban-rural communes as the rural areas of these communes gained population, on average, while the urban areas lost population.

Table 4. Population change by commune type

		Commune type				
		urban	urban-rural			rural
			total	towns	villages	
1995	total population	1,738,359	714,151	400,788	313,363	535,768
	% of total population	58.2%	23.9%	13.4%	10.5%	17.9%
	1995-2000 change	-3.1%	0.2%	-0.6%	1.2%	-4.5%
2000	total population	1,684,970	715,393	398,283	317,110	511,832
	% of total population	57.9%	24.6%	13.7%	10.9%	17.6%
	2000-2005 change	-1.8%	0.5%	-0.2%	1.3%	0.6%
2005	total population	1,654,417	718,785	397,677	321,108	515,030
	% of total population	57.3%	24.9%	13.8%	11.1%	17.8%
	2005-2010 change	-1.8%	0.1%	-1.2%	1.7%	3.8%
2010	total population	1,623,926	719,556	392,904	326,652	534,358
	% of total population	56.4%	25.0%	13.7%	11.4%	18.6%
	1995-2010 change	-6.6%	0.8%	-2.0%	4.2%	-0.3%

Between 2000 and 2005, the rate of population decline slowed down and more rural and urban-rural communes began to experience an increase in population. Once again all urban communes lost population, although at a smaller percentage (1.8% versus 3.1%). The largest increase in population was concentrated around the city of Wrocław similar to 1995-

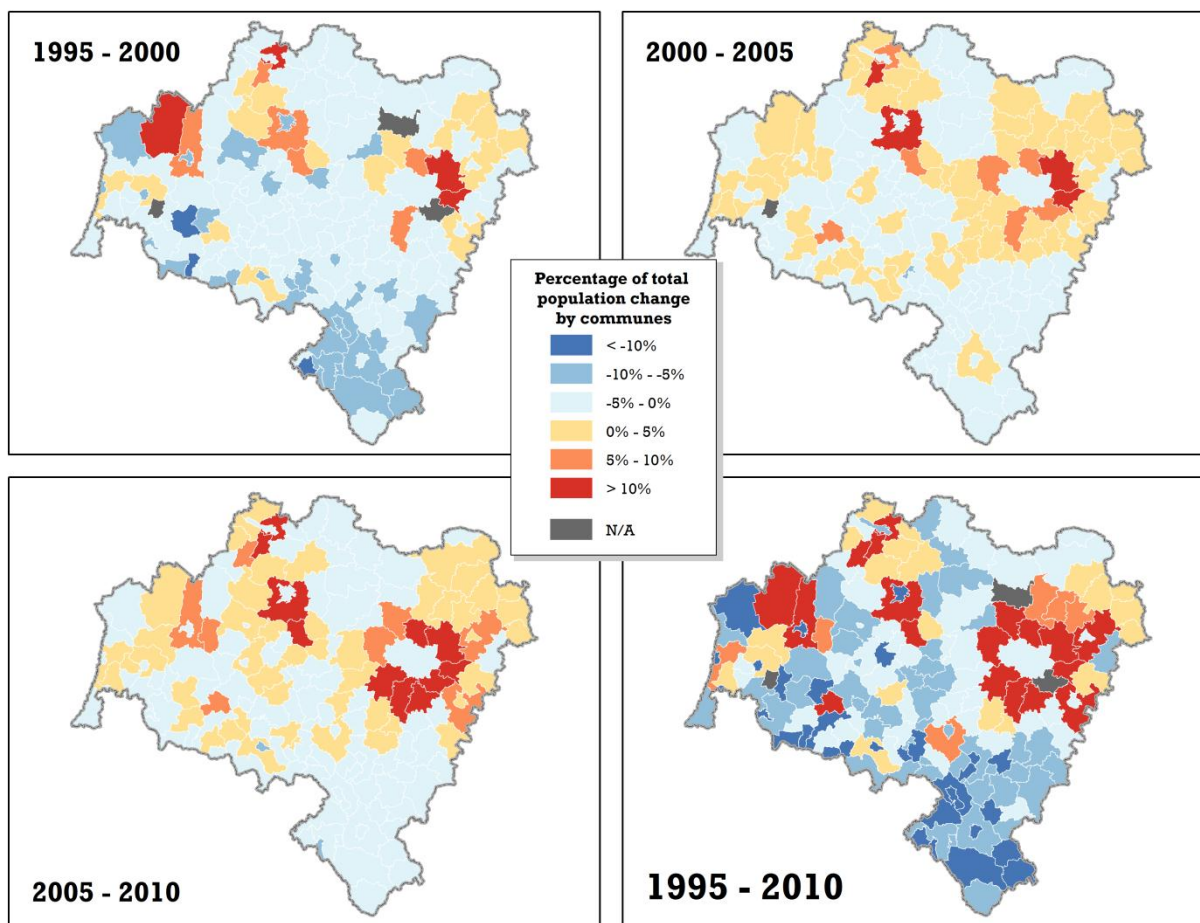


Figure 14. Percentage of total population change by communes.

2000 time period. This trend of population gain in areas adjacent to declining cities was observed for the rural communes of Lubin, Głogów, Bolesławiec and Klodzko as well. A clear relationship existed when comparing population change in urban versus rural land areas between 2000 and 2005: urban communes and the towns of the urban-rural communes lost population, 1.8% and 0.2% respectively, while rural communes and the villages of the urban-rural communes gained population, 0.6% and 1.3% respectively. A similar pattern of population change was also observed for the next five-year period (2005 to 2010). In general, communes surrounding major cities gained population while communes both farther from major cities and those that were major cities themselves tended to lose a small percentage of

their population. This was the only time period during which urban communes gained population. Rural communes saw the greatest increases in population in this time period while urban communes experienced another decline.

Results from the Moran's I analysis revealed that population change at the commune level exhibited spatial autocorrelation and that high rates of population loss/gain are clustered within the voivodeship (Figure 15 and Table 5). Additionally, these results were observed across all three change time periods. The same cluster of statistically significant high population increase, as identified using the local Moran's I statistic, was identified across the time period under study. This suggests a temporal consistency in population change. This cluster of high population increase is composed of communes neighboring Wroclaw. The remaining high population increase clusters are located in the northwestern part of the province surrounding the cities of Glogow and Boleslawiec. The location of the high population increase clusters further supports the idea of suburbanization in the province, especially around Wroclaw. Less consistency was observed in the locations of communes identified as members of significant local clusters of population decline. For the time period of 1995 to 2000, three clusters were identified in the southern part of the Lower Silesia however they were not identified for any of the remaining time periods. For 2000-2005, there was a different cluster of population decrease, while for 2005-2010 time period there were none. This suggests that high population decrease was only experienced in the first five years of analysis, which is consistent with the

Table 5. Results of global Moran's I analysis.

	Moran's I	z-score	p-value
1995-2000	0.236	3.910	0.00009
2000-2005	0.221	3.672	0.00024
2005-2010	0.232	3.895	0.00010
1995-2010	0.255	4.256	0.00002

with the population change maps – the rate of population decrease was smaller in the first ten years of 21st century. Additionally, the results revealed two spatial outliers that were consistent over time. The city of Lubin and its surrounding rural commune were identified as spatial outliers. The city with a high population decrease is surrounded by a commune with high population increase which points to the suburbanization stage of the urban life cycle model.

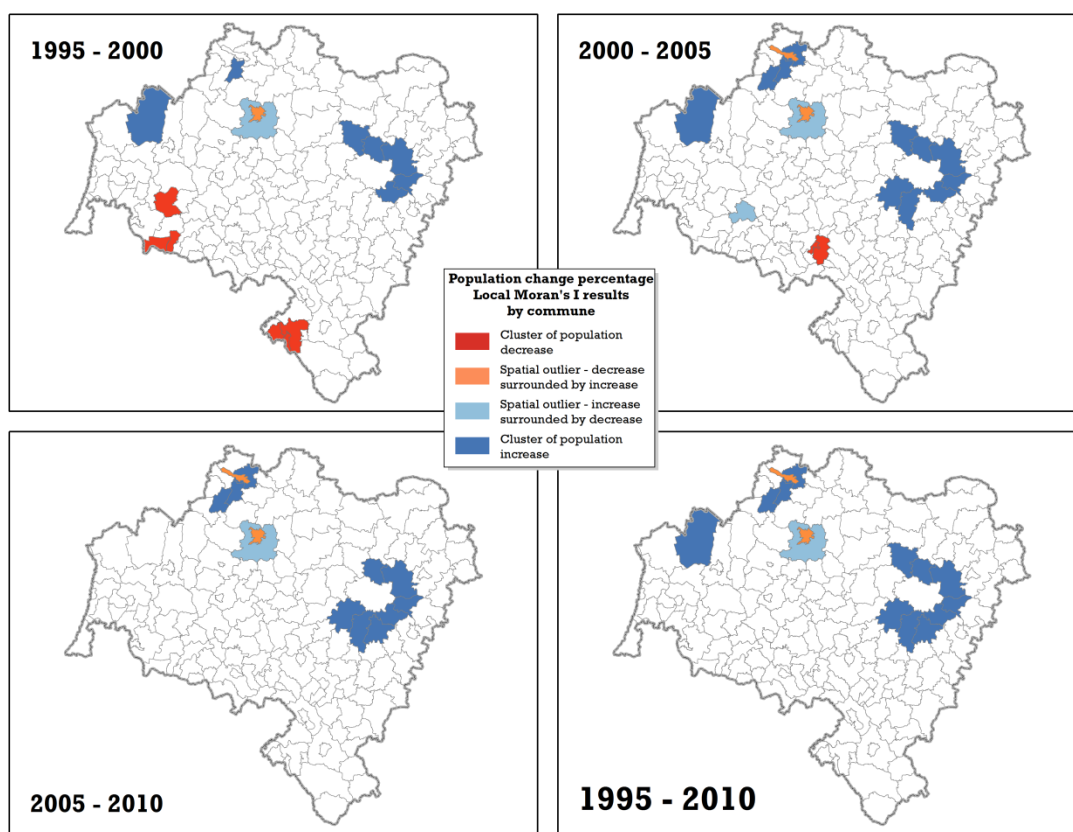


Figure 15. Statistically significant clusters and spatial outliers in the population change.

Statistical cluster analysis allowed for the identification of communes that were discernibly different from the majority, meaning they exhibited distinct urbanization patterns. The analysis was aspatial, i.e., the location of the communes did not influence the clustering

such as is the case in the spatial autocorrelation analysis. However, once the clusters were mapped, spatial variability was examined. Several of the communes identified by the statistical cluster analysis were also the communes that were recognized as clusters or outliers in the spatial autocorrelation analysis. The clusters for each commune type were combined in a single map to examine the spatial relationships between clusters identified in the analyses (Figure 16). The cluster analysis for the urban communes resulted in the identification of five distinct clusters. The differences between these clusters mainly result from differences in their population change values for the period 1995-2000. The cities of Piechowice and Szklarska Poreba in the southwestern part of the province (clusters 5 and 3, respectively) had the largest population loss, while the two district cities of Wroclaw and

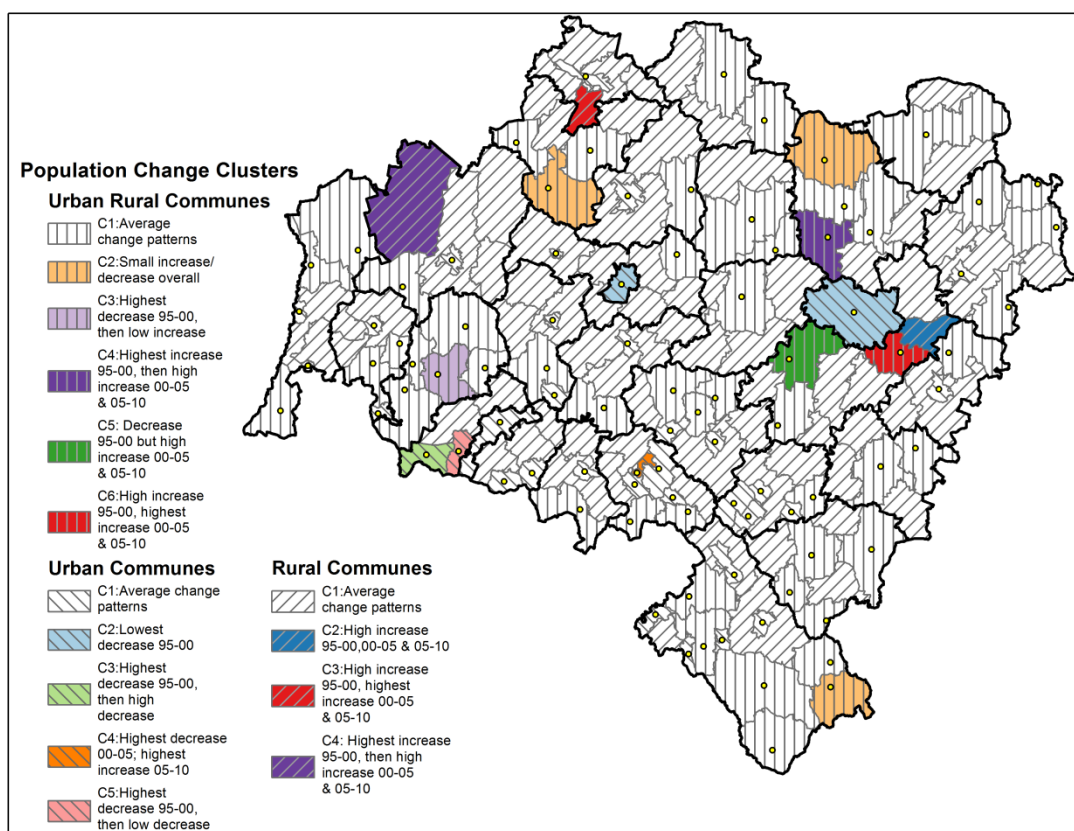


Figure 16. Population change clusters by commune type.

Legnica (cluster 2) had the smallest population loss in the same time period. The city of Szczawno Zdroj (cluster 4) had the largest population loss for 2000 to 2005 time period, however it had the largest population increase between 2005 and 2010. It was also one of the only three urban communes that gained population in that period. This implies that although overall the urban communes show a similar pattern of population loss, there are communes that have different population trends and therefore appear to be in different stages of the urban life cycle model.

All three urban-rural communes that surround the capital city of Wroclaw were identified through the statistical clustering. The communes of Siechnice, Katy Wroclawskie and Oborniki Slaskie (clusters 6, 5, and 4 respectively) are the top three urban-rural communes that gained population between 2000-2005 and 2005-2010 periods which further points to the suburbanization of Wroclaw. All three were also identified as high population increase clusters in the spatial autocorrelation analysis, suggesting strong patterns of urban change in this region, specifically suburbanization stage of the urban life cycle model. The commune of Lubomierz in the southwest (cluster 3) is dissimilar from other urban-rural communes due to its largest population decrease between 1995 and 2000 when it lost 10% of its population. Since 2000 the commune gained only a very small percentage of population (0.1% and 0.3%). The cluster analysis showed that although most urban-rural communes have similar urbanization patterns, there are exceptions.

The three rural communes that were identified as dissimilar from others had high population increases for all three time periods. In addition, all three communes were also identified as clusters in the spatial autocorrelation analysis. Rural commune of Osiecznica (cluster 4) in the western portion of the province experienced 16% increase in population in

1995-2000 for a total population increase of 22% between 1995 and 2010. The commune of Jerzmanowa (cluster 3) that lies just south of the city of Glogow in the north part of the voivodeship had the largest population increases in 2005 and 2010, 13.5% and 26% respectively, for a total increase of almost 50% between 1995 and 2010. The commune neighboring the city of Wroclaw, Czernica (cluster 2), was the second most gaining rural commune for each time period, accumulating to the highest population increase of 56%. The results of the statistical clustering for the rural communes suggest that most rural communes have similar urbanization patterns but the three identified clusters are significantly different patterns – they experienced some of the highest population increase and their location around the cities suggest a strong level of suburbanization.

The typological variability of the urbanization patterns was revealed at the commune level. The urban communes experienced a population decrease during all three 5-year time periods while the rural areas increased in population in the 2000s (Figure 17). While urban-rural communes gained population, this overall trend masks an important spatial relationship:

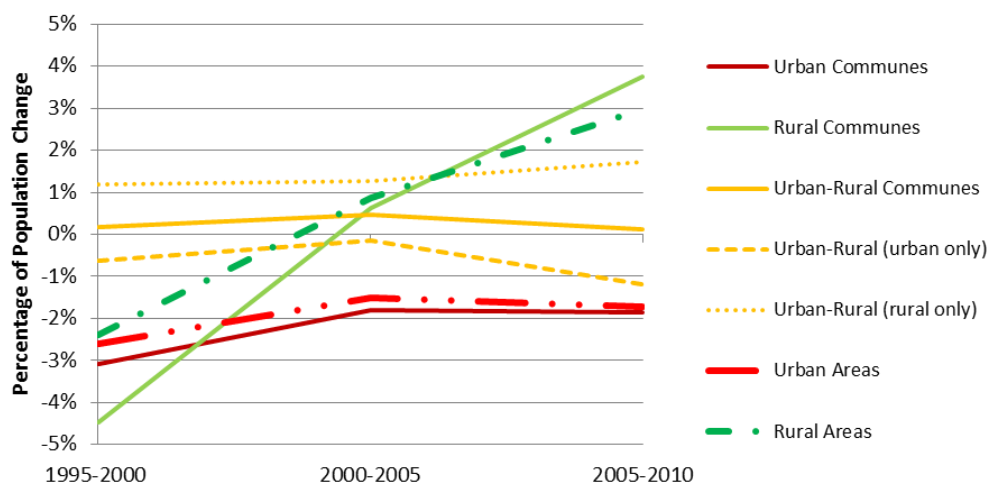


Figure 17. Population change trajectories by commune type

urban areas within the communes lost population while rural areas gained population. The results of the analysis of variance confirmed trends observed in Figure 18 – a statistically significant difference in the percentage of population change existed between the commune types for each of the three change time periods. The results of the independent-samples t test also showed a statistically significant difference between the two commune aggregates – urban and rural areas.

In general, the urban areas of the province (urban communes and urban parts of the urban-rural communes) experienced a loss in population while the rural areas (rural communes and rural parts of the urban-rural communes) increased in population. This suggests an overall suburbanization pattern in Lower Silesia, which is the same result as from voivodeship- and district-level analysis. However, the local trends in the urbanization patterns in the province can only be revealed at the commune level. Applying the urban life cycle model at the commune level, each of the four stages of the urban life cycle model can be found in Lower Silesian Voivodeship (Figure 18).

The stages of urban life cycle model are identified on the basis of the changes in population between the urban core and its periphery, and are not identified by examining individual communes. The map in Figure 18 allows one to examine change in population across each of the three commune types and more easily identify the stages of urban life cycle model based on the trends observed in neighboring communes. The most common stage of cycle observed across the province is suburbanization, and the best example is the communes surrounding Wrocław as the city itself declined while the rural and urban-rural communes around it experienced a significant increase in population. Urbanization stage is

pronounced at the commune level. The stage of the urban life cycle model differs across landscape when smaller spatial units are used (province is defined into small regional units [i.e., communes]) as seen in Figure 18.

The spatial variability of the urbanization patterns at the commune level was also observed in the land-cover change analysis. Similar to the voivodeship- and district- level land change analysis, the communes of the province experienced an increase in the amount of artificial land-cover (Table 6). Overall, the urban areas of the province saw an increase of 19% in the artificial land cover between 1990 and 2006 while the rural areas increased by

Table 6. CORINE Land Cover change by commune type.

Territorial unit	Artificial Land Cover			Agricultural Land Cover			Forest and Semi-Natural Land Cover		
	1990 % of total area	2006 % of total area	% of land cover change	1990 % of total area	2006 % of total area	% of land cover change	1990 % of total area	2006 % of total area	% of land cover change
Lower Silesian Voivodship	4.0%	5.7%	42.0%	64.3%	61.7%	-4.1%	30.7%	31.6%	2.8%
urban communes	24.6%	28.9%	17.6%	45.7%	40.4%	-11.6%	29.0%	30.0%	3.4%
urban-rural communes	3.1%	4.5%	51.0%	61.0%	59.1%	0.5%	34.8%	35.2%	4.8%
town areas of urban-rural	17.8%	20.6%	22.5%	50.5%	47.0%	-1.1%	31.2%	32.1%	9.1%
village areas of urban-rural	1.6%	2.9%	80.5%	62.0%	60.3%	0.6%	35.2%	35.6%	4.4%
rural communes	2.0%	3.5%	72.7%	69.7%	67.0%	-6.7%	27.5%	28.5%	0.7%
towns	22.3%	25.9%	19.0%	47.5%	42.9%	-7.7%	29.7%	30.6%	5.4%
villages	1.8%	3.2%	75.7%	66.3%	64.0%	-3.7%	30.8%	31.7%	2.5%

75.7%. The rural communes experienced the largest increase along with the villages in the urban-rural unit communes which mirrors the results from the population change analysis and further supports the general trend of suburbanization in Lower Silesia. However, as it was the case with the population data, the land-cover analysis at the commune level also reveals local trends and illustrates the spatial and typological variability of the urbanization patterns in the province.

As expected, the urbanization percentage as measured by the share of artificial land-cover was the highest in the urban communes (Figure 19). However, the spatial variability of urban change in the province was exposed in mapping the changes in the artificial land-cover. Changes in the artificial land cover exhibited strong spatial patterning (Figure 19) that is similar to the pattern at the district level where the highest increase in the artificial land-cover was concentrated in the east-west axis in the central part of the province, although the smaller administrative units expose the trends at a more local level. The large increases in the artificial land-cover in the communes surrounding the major cities suggest suburbanization, especially around the city of Wrocław, which is consistent with the increase in population in

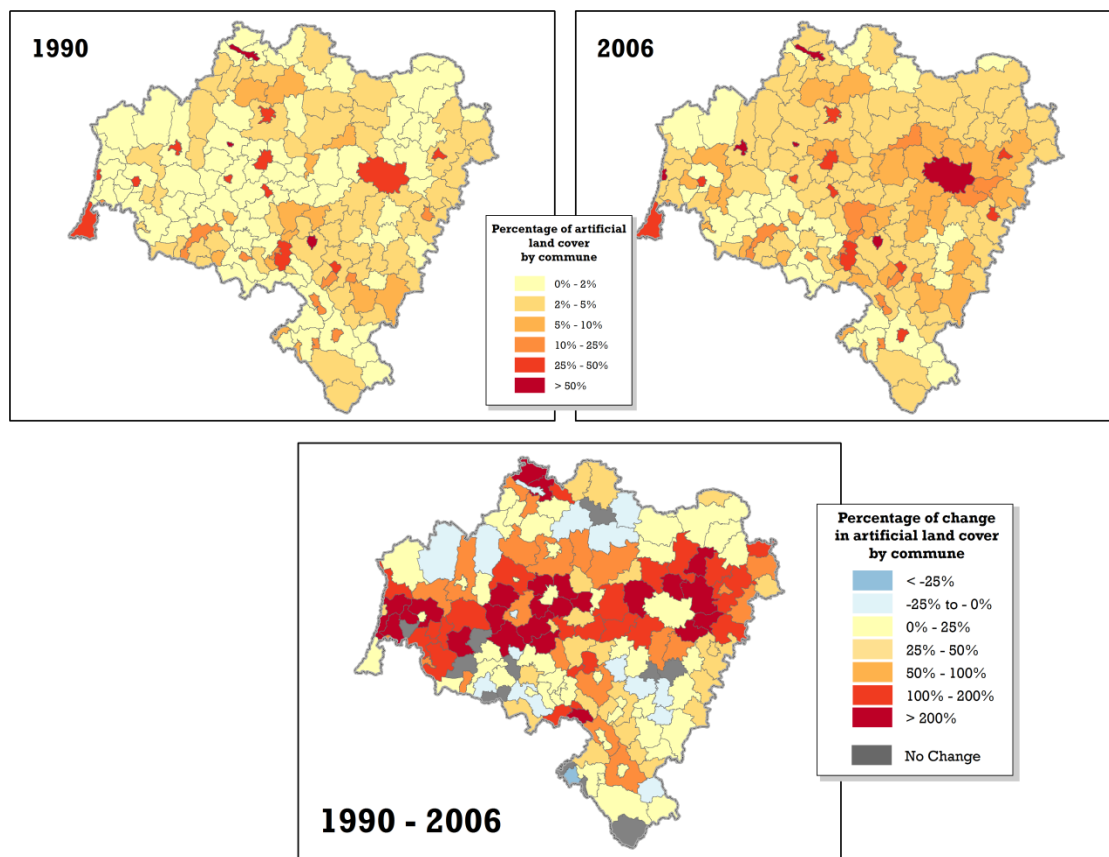


Figure 19. Change in the artificial land cover by commune.

these communes. Several communes observed to have lost artificial land cover over the study period. The artificial land-cover is a broad category that includes a variety of human-related surfaces such as residential, industrial, commercial areas as well as transportation network and construction/mining sites. The loss of artificial land cover can reflect a decrease in any or all of these sub-categories. The results of the analysis of variance for the artificial land-cover change percentage did not find a statistically significant difference among the commune types. In other words, changes in artificial land-cover are independent of the commune type. This was contrary to the result observed using demographic data, in which the population change was significantly different between the commune types.

While the overall spatial trends are similar for both datasets, there are communes that show different patterns of urban change depending on which measure is applied. For example, some of the communes in the east-west axis of artificial land-cover increase experienced a population decrease which points to a different urban change patterns. Although the demographic data might suggest deurbanization stage of the urban life cycle model, the land-cover data did not support that conclusion. The addition of the land-cover information in the urban life cycle model results in new insight when it does not mirror the trends and patterns seen in the demographic data.

A global Moran's I value of 0.104 was observed for the map of artificial land-cover change, with a p-value of 0.046, indicating that changes in the artificial land cover were spatially clustered. Calculations of Local Moran's values illustrated that five communes had statistically significant patterns (Figure 20). Four rural communes were identified as part of two clusters of high artificial land-cover change percentage, and a fifth rural commune was

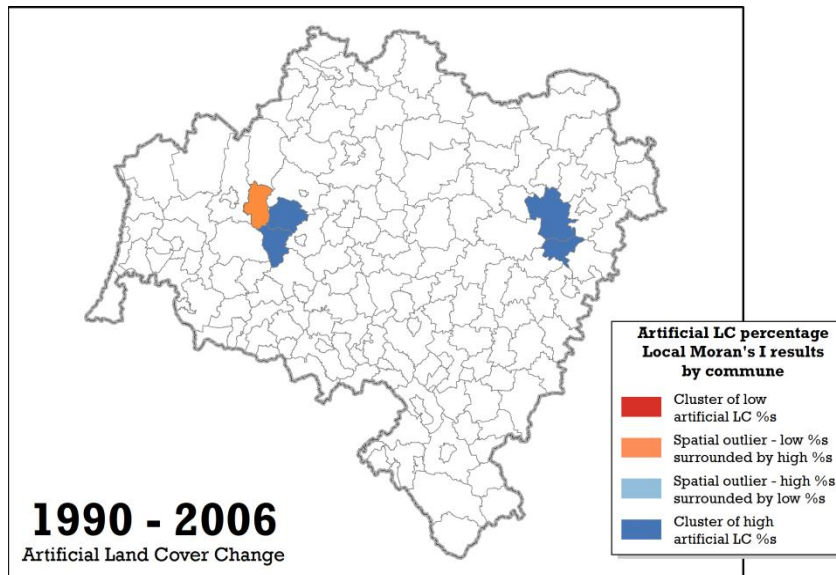


Figure 20. Statistically significant clusters and spatial outliers in the artificial land cover change.

identified as a spatial outlier – having a low percentage of change while surrounded by communes experiencing higher change percentages. One of the high value clusters neighbors the city of Wroclaw and was also a high value cluster for population change. This suggests the consistency between the two datasets for these two rural communes. The second cluster of high values along with the spatial outlier resulted because both communes that are part of the cluster did not have any artificial land-cover in 1990 and increased to 1.1% and 3.3% in 2006. These communes were not flagged as significant in the population change results.

The results of statistical clustering for each of commune types were illustrated on one map to examine their spatial location and relation to one another (Figure 21), similar to the results using population change data. Seven urban communes were identified through statistical clustering, and they all exhibited very high increases in the artificial land cover. Four of these communes experienced a loss of population during the study period, but still demonstrate different urbanization patterns in terms of land-cover change. The commune

Piechowice in the southwestern part of the province was also identified as a cluster in the statistical clustering of population change due to a high population loss between 1995 and 2000. The results show that although the urban communes lost population, especially in the first five years of the analysis, they can still increase in the urbanization percentage as measured by the share of artificial land-cover. Growth in the urban fabric continues as population decreases, possibly due to an increase in industrial or commercial activity.

Twelve rural communes were identified through statistical clustering due to their high artificial land-cover increases and all were surrounding major cities of Lower Silesia. Nine of these communes experienced population increase for at least one of the three 5-year time

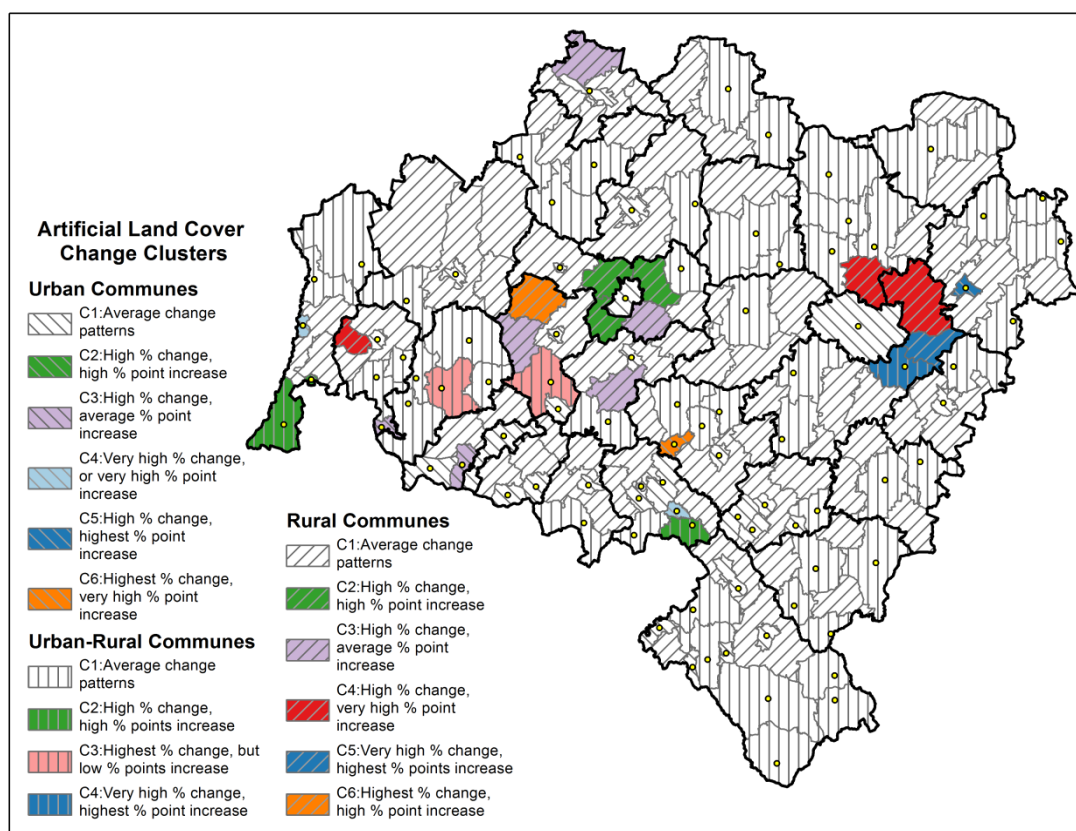


Figure 21. Artificial land-cover change clusters by commune type.

periods which further supports the overall suburbanization of the region. The commune of Czernica was recognized as a cluster of high increase in artificial land cover through spatial autocorrelation. In addition, it was also high population increase clusters for both analyses – spatial autocorrelation and statistical clustering of population change – which suggests a unique urbanization pattern for the commune.

Five urban-rural communes were recognized due to their very high increases in the artificial land-cover. Siechnice (neighbors Wroclaw) and Lubomierz (southwestern corner of Lower Silesia) were both identified through statistical clustering of population change, although they have starkly different urbanization patterns with Siechnice gaining population and Lubomierz experiencing a significant population loss in the first five year of analysis. This shows that although the demographic and land-cover data are generally in agreement, there are exceptions where two different urbanization patterns are presented based on the analyzed dataset.

Unique clusters tended to be spatially located near each other. For example, near the city of Wroclaw, there is a single-commune cluster for each commune type (urban, urban-rural, and rural). In other words, communes that have statistically different trends in artificial land cover change in three independent analyses based on commune type are all located in the same region which indicates a unique patterns of urbanization in that region. Population change clusters (Figure 16) and artificial land-cover change clusters (Figure 21) have a few similarities as previously mentioned, but also have some significant differences and do not necessarily point to the similar conclusions in terms of identifying the stage of urban life cycle model. The cross tabulation of the population change clusters and artificial land cover

change clusters for each of the commune types illustrates the similarities and differences between the clusters (Table 7,8, & 9). In general, most communes belong to the average change cluster for both type of clusters,

Table 7. Cross tabulation of urban commune type

Urban Communes		Population Change Clusters					Total
		1	2	3	4	5	
Artificial LC Change Clusters	1	25	2	1	1		29
	2	1					1
	3	1				1	2
	4	2					2
	5	1					1
	6	1					1
	Total	31	2	1	1	1	36

however the unique urbanization patterns as measured using the two datasets can be identified. For example, the urban commune of Piechowice has contradictory results from the analyses of both datasets. On one hand it had a high decrease in population, while on the other hand it experienced a high increase in artificial land cover. This suggests that urban growth is influenced by other factors in addition to population and that inclusion of the artificial land-cover category in the urbanization research can help in identifying areas where changes in population might not be a leading driver of urban change.

Table 8. Cross tabulation of rural commune type clusters.

Rural Communes		Population Change Clusters				Total
		1	2	3	4	
Artificial LC Change Clusters	1	64		1	1	66
	2	3				3
	3	4				4
	4	3				3
	5		1			1
	6	1				1
	Total	75	1	1	1	78

Table 9. Cross tabulation of urban-rural commune type clusters.

Urban-Rural Communes		Population Change Clusters						Total
		1	2	3	4	5	6	
Artificial LC Change Clusters	1	45	3		1	1		50
	2	2						2
	3	1	1					2
	4						1	1
	Total	48	4	0	1	1	1	55

Discussion

Urbanization is a ‘global process’ meaning that has highly individual characteristics for each continent, region and country (Parysek, 2005). The spatial, temporal and typological variability of the urbanization process in Lower Silesian Voivodeship was illustrated through an examination of two datasets (demographic and land cover) at multiple spatial scales as well as through an application of the urban life cycle model. The southern part of the province experienced greater losses in population and had less gain in land cover than the north, in general. The areas surrounding the capital city of Wroclaw experienced some of the highest population and artificial land-cover increases. Temporally, between 1995 to 2000 high population decreases across the province were observed. This trend changed after 2000, when the province displayed strong signs of the overall suburbanization of the province. However, the general trend of suburbanization at the voivodeship level masks significant local trends that were revealed at the smaller administrative levels. For example, the statistical clustering of communes based on population change and artificial land-cover change exposed some of the unique urban change patterns in the province.

The results of this research presented a story of urbanization process in Lower Silesian Voivodeship. The urban population of the province declined suggesting that the urbanization percentage decreased, while a larger percentage of the province was classified as having artificial land cover suggesting urban growth. Both datasets result in the same conclusion that, in general, the province is suburbanizing. However, the general trends at the voivodeship level do not reveal any spatial or typological variability in the urbanization process. At the district level, the spatial variability started to emerge as the southern part of

the province experienced a loss of population and lower increase in the artificial land-cover than the northern part. As the northern part of Lower Silesia, especially the region surrounding the city of Wrocław, is suburbanizing, a different trends are observed in the south. The general trends are similar for both datasets at the district level as well, although some spatial differences between clustering of population change and land-cover change emerged.

The standard measure of urbanization level is the urbanization percentage as measured by the share of urban population. One important challenge to this approach in Poland is that this measurement of urbanization can only be explored at the voivodeship and district levels and not at the commune level due to the definition of the urban population in terms of the Polish administrative system. At the commune level, the urbanization percentage as measured by the share of urban population is ineffective, and therefore a different metric, population change percentage, was needed to measure urban change. In addition, the application of the urban life cycle model to studying the variability in urbanization patterns also benefited from addition of the land cover information at the commune level. For example, there were urban communes that experienced a decrease in population but a significant increase in the artificial land cover which suggests that land-cover info can help identify areas with unique urbanization patterns.

The analysis of the population change by commune type revealed that indeed the urban population decreased between 1995 and 2010; however the rural areas surrounding the cities actually gained population. This phenomenon is the typical characteristic of the suburbanization stage of the urban life cycle model. Suburbanization is typified by American suburbs where the communities close to a city tend to increase in population while the urban

core is losing its population resulting in suburban growth. The best example is the city of Wrocław and its surrounding communes. While the city itself lost 1.4% of its 1995 population, the rural and urban-rural communes neighboring the city all gained a significant amount of population, anywhere from 12% to 56% increase compared to 1995. This pattern is only partially apparent in the urbanization percentage of the districts with the significant increase of the urban population in the districts surrounding Wrocław; however it is much stronger at the commune level. The suburbanization of this area is consistent between scales as well as between both datasets and their multiple analyses. There is no other region in the province that displayed such strong consistency.

Urbanization as measured using the second measure used in this research – the share of artificial land-cover – revealed an increase in the urban percentage of Lower Silesian as the amount of land dedicated to human uses grew significantly since 1990 from 4% to 5.7% of the total area. This increase was significant at the other two administrative levels as well – for districts and for communes alike. The rural areas of the province gained the highest percentage as compared to their 1990 level as most of the land-cover change was associated with conversion of the agricultural land into artificial one. The districts and communes with the lowest percentage of artificial land-cover were often the ones with the highest percentage increase. Granting, it is true that areas already had a high percentage of artificial land cover cannot experience high increases over time, therefore most of high rates of change is bound to happen in rural areas. The analysis of the land-cover data revealed characteristics such as high increases in the artificial land-cover surrounding the cities, which are typically seen in

the suburbanization stage of the urban life cycle model - just as the analysis of population change at the commune level did. However, the general similarity between the dataset

These differences between the datasets and the administrative level also revealed the importance and impact of scale on studying processes such as urbanization. The characterization of urbanization is highly dependent on the definition of urban population and delineation of urban areas which was illustrated through this research. For example, the urban and rural populations are tied to the definition of administrative units, i.e., urban communes have 100% of urban population, rural communes have 100% of rural population, while the urban-rural communes experienced a mixture of both. The population data was collected at the commune level and then aggregated to districts and voivodeships, therefore the commune is the finest scale for the demographic data. Land cover information is not inherently tied to the arbitrary administrative units, as it is collected at a 100m pixel level, therefore it allows for examination of patterns at finer scale. Land cover data serves as a great supplement to the urbanization research thus providing a more complete look at the process from a different perspective. Land-cover data can better represent change in urban growth as it illustrates the urban-rural gradient which demographic data lacks. This is especially important at the commune level since the demographic urbanization percentage is inefficient. However, land-cover is dependent on the resolution of the imagery and the geo-processing involved in creating the dataset. A larger spatial and/or categorical resolution equates to a coarser result of the land-cover change analysis.

A single measure alone cannot capture the complete story of an urbanization process, instead both the demographic and land-cover data should be used in combination. Both datasets complement each other to illustrate the complexity of the urbanization processes and

its spatial, temporal and typological variability. In the case of the Polish administrative system, the multi-scale two-fold methodology presented in this research proved successful in exploring the variability in the patterns and trends of urban change. The urban change was examined at each of the three administrative levels and the results revealed insights about the nature of change in the voivodeship and the variability associated with the urbanization processes. Specifically, the different spatial patterns of change as measured by the two datasets especially at the commune level, provide important insights on the complexity of urban change. For example, the combination of the two datasets revealed the areas that exhibit unique urban patterns, i.e., the communes that increase in population but decreased in artificial land cover, or the communes that decreased in population but increased in artificial land cover.

Korcelli (1990) noticed the changes in trends of population change and even started to cautiously hypothesize that they might represent the entrance of Poland into suburbanization stage of the urban life cycle model. He thought that this was only a temporary occurrence due to the socio-economic crisis in 1980s; however over the next decade, other scholars (Kupiszewski, Durham, & Rees, 1998; Deichmann & Henderson, 2000; Banski, 2003; Parysek, 2005; Szymanska, Grzelak-Kostulska, & Holowiecka, 2009), as well as the results of this research proved his original hypothesis correct. The urban life cycle continues as the suburbanization becomes a predominant, but not the only one, characteristic of Lower Silesian cities. The general statement of suburbanization fails to identify important local trends and acknowledge the variability of the urbanization process. Therefore, in addition the description of the average state of the province a more in-depth

examination at a smaller spatial scale is needed to better understand the urbanization patterns and trends in the province.

Despite the attention given to the research design process and the two-fold methodology, the results can still contain a certain amount of error. One of the major issues is the temporal correspondence of the two datasets. The demographic data was freely available starting with year 1995 at yearly increments, while the land-cover data was only available for 1990, 2000 and 2006. The two data sources were therefore offset by five years. Ideally, the demographic information should be accessible from Central Statistical Office of Poland starting in 1990 and a new CORINE dataset should be created by European Environmental Agency for year 2010. The limitations in data availability existed however, and could have an impact on the results of this research. For example, 2005-2010 time period experienced some of the largest population increases which might have led to more changes in the artificial land-cover, however these changes are not captured in current land-cover dataset. In addition, the categorical resolution of the data is another important aspect affecting the accuracy of the results. For example, how the results of the land change analysis would be affected if the sub-categories were used instead of the broad artificial land-cover class. The sub-categories would allow separating industrial and commercial development from residential development and therefore potentially better identify the nature of artificial land cover increases. How this greater level of categorical specification would impact the similarity observed between land-cover change patterns and population change patterns remains unanswered. A possible next step for this research would be to compare the impact of categorical resolution on the spatial variability of the urbanization patterns.

Nevertheless, the presented methodology provides a test case scenario and a proof-of-concept illustrating the need to explore more than one spatial scale and more than one measure in order to fully understand the patterns of urbanization. By applying the urban life cycle model using both demographic data and land-cover data, this research can have a unique contribution to the Polish urbanization literature. Furthermore, the results of this work also have potential implications for urban planning and management at the provincial level by providing a more comprehensive approach to studying the spatial variation of the urbanization patterns of communes in a voivodeship. With similar approach and combination of methods, any region of Poland or any other country could be analyzed for the urbanization patterns and its corresponding patterns of land-cover change in order to provide a better understanding of urbanization process.

Conclusion

“Urbanization is a complex process of change of rural lifestyles into urban ones” (Antrop, 2004) and as such a thorough examination at multiple scales and with multiple datasets is needed to better understand the patterns and trends of the urban change. This study has provided an assessment of the urbanization level of Lower Silesian Voivodeship at multiple scales and with multiple datasets by utilizing a twofold methodology and by applying the urban life cycle model to describe the urban change in the province. Overall, Lower Silesia is suburbanizing, however the analysis revealed that significant spatial, temporal and typological variability exists in the province and creates an intricate pattern of

urban change in the last two decades. This research has implications for the urban planning and management in Lower Silesia as it comprehensively studied the urban change after the fall of communism in 1989 and captured the effects of the social, political and administrative changes that resulted from the transition to the market economy.

Two definitions of urbanization level were utilized in this study. As measured by the demographic data, the urbanization percentage is the share of urban population in the total population and as measured by the land-cover data, it is the share of artificial land-cover in the total area. Each measure has its advantages and limitations, as discussed previously, however the combination of the two methodologies with some modifications allows for a more complete visualization of the patterns and trends of urbanization, although this approach is limited in literature. While overall there was a high degree of similarity between the patterns, important differences emerged, particularly with regard to communes identified as undergoing rapid urban change (either measured using population or land cover data). When one measure is inadequate for a particular level analysis, it is especially important to examine more than one source of data in order to glean important insights about the patterns and trends. This was the case in Lower Silesia, where the demographic urbanization percentage was not a useful measure of urbanization at the commune level. The population change data supplemented with changes in the artificial land-cover provided an approach to analyzing urbanization at the commune level.

It is widely recognized that urbanization is ubiquitous but highly variable phenomenon around the world (Parysek, 2005; UN, 2010). At any scale the variability in the urbanization patterns exists, and therefore the multiscale approach allowed for a closer look at the spatial, temporal and typological variability of urban change in Lower Silesia. The

application of the urban life cycle model allowed to describe the variability of urbanization process and categorize the changes in province into four stages: urbanization, suburbanization, de-urbanization and reurbanization. Although Lower Silesia is suburbanizing overall, the analysis of urban change at the commune level revealed an example of each stage of the urban life cycle model. This model can be applied to any region or country to illustrate the urban development. Coupled with the twofold methodology of this research, even the smallest administrative units can be examined for patterns and trends of urbanization.

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