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Un demi-siècle de suivi de la population des villes européennes (1961-2011) : la base TRADEVE

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AUTHOR'S NOTE

Link to TRADEVE data paper: https://journals.openedition.org/cybergeo/32077

Introduction

1 The following of European cities' population has received an increased interest in the last decades due to various major issues. A first subject of interest deals with the general evolution of urban systems, the analysis of historical cyclic urban development and the way these cycles are spreading differently among hierarchical levels and regions. In that respect, one of the main questions tackled has long been related to the interpretation of the major turnaround of growth slowdown in the 1970s and to the questioning of the counter-urbanization concept (Cattan et al., 1999; Champion, 2001). More recent works participating in the theoretical field of complex systems have focused on the relation between urban system dynamics and the diffusion of innovations, by articulating the urban hierarchy structures on macro-geographical scales and the trajectories of the cities themselves on micro-geographical level (Favaro and Pumain, 2011; Cottineau, 2014; Pumain et al., 2015; Raimbault, 2018). Beyond this theoretical framework there have been

for some years new investigations on the evolution of the rich heritage of small and medium-sized towns in Europe (Pumain, 1999), which comprises a worldwide concern for the shrinking cities issues (Martinez-Fernandez C. et al., 2016). The interest for this subject is related to major socio-demographic issues like the ageing process and slowing down of demographic growth (Bretagnolle et al., 2018; Rink et al., 2012). Along with this growing field of studies, the observation of more recent trends of a resurgence (regrowth after years of decline) has more recently made it necessary to consolidate comparative knowledge about the demographic future of cities (Rink et al., 2012, Wolff and Wiechmann, 2017).

2 Beyond their diversity, these issues have reinforced a common interest for the establishment of a longitudinal urban database in Europe. However, such databases are especially difficult to process since they raise at least three problems at the same time: the harmonization of urban definitions from one country to another, the availability of population data for each date at the level of local administrative units (LAU) and the geometrical and statistical sources for constructing urban delineations at each date. The challenging difficulties related to the statistical following of urban objects through time (Mathian and Sanders, 2016) are here exacerbated by the international context of comparison. Different choices have been made by researchers in order to support these studies. Some of these works have emphasized the length of time series while focusing on large cities (Van den Berg, 1982; Turok et al., 2007). Others have included small and medium sized cities for a shorter period between 1990 and 2010 (Wolff and Wiechmann, 2017). The Europolis programme (Chatel, 2012) allows following cities over a longer period (1850-2010, with evolving perimeter since 1990); however, the data are not available in open access.

3 This paper aims at discussing the interest of a new data model used in order to process a longitudinal and harmonized database of European cities, the TRADEVE[1] one, which provides delineations and populations of European urban areas, defined by taking into account continuous built-up areas and minimal population threshold from 1961 to 2011. It is based on two original sources, a harmonized database that allows studying small and medium sized urban areas in 2000 (Urban Morphological Zones - UMZ) and the Historical Population Database of European LAUs (from Gloersen et al., 2013). More than 3,900 urban areas (exactly 3,946) comprising over 10,000 inhabitants are considered in 2011 for 29 countries. Beyond the single issue of the construction of a new database, this paper makes an important contribution to implementing an open access database (European Commission, 2016; Kosmopoulos and Pumain, 2018), which is the first one for the evolution of European cities over 50 years[2].

4 First, we present the main conceptual models that are theoretically designed to integrate time into urban databases. Then we propose the data model used in order to provide evolving urban perimeters and which is based on the retropolation of UMZ 2000 back to 1961. Lastly, some insights into the resulting database are presented both at the macro level of countries and European regions (urbanization rate) and at the city level (population variation rates and clustering analysis of demographic trajectories).

Modelling the evolution of the population of cities: theoretical approaches

5 Many scholars have already stated that measuring cities' demographic change in the medium- and long-term sounds "misleadingly simple" (Bernt, 2015, quoting Wolff, 2011). Seemingly, population data are easily available, reliable and comparable in regards to social or employment statistics. However, several difficulties still represent important challenges to such measures.

6 Firstly, longitudinal data of local populations are often difficult to access. Even if the data in itself is easily available at each census, the monitoring over time of local population trends is complicated because LAUs (Local Administrative Units) have undergone many geometrical changes through time. Secondly, from a territorial perspective, cities are complex geographical objects that can be analyzed through different definitions and perimeters (Cottineau et al., 2017), from administrative to morphological and functional ones. The international harmonization of such delineations remains often a huge task, even though much progress has been registered in recent years for Europe (see a recent state of art in Bretagnolle et al. 2015). Thirdly, from a temporal perspective, cities are evolving objects and the following of urban objects through time is thus a complex issue (Bretagnolle, 2009), especially when the study extends over a relatively long period of 50 years.

7 This latter question about time integration has been rarely addressed in the literature on demographic changes of European cities, although it has considerable influence on the measure of urbanization. From an empirical perspective, some studies at a national scale have shown that the results of urban demographic trends largely depend on whether the delineation of cities is stable or evolving through time (Berry and Okulicz-Kozaryn, 2012; Bretagnolle et al., 2015; Pumain et al., 2015). The choice of a stable or evolving perimeter is especially critical from the 1960s due to the importance of the urban sprawl process itself. In France for instance, at the level of functional urban areas ("aires urbaines"), Paulus (2004) has demonstrated that more than 10 million inhabitants lived in municipalities that are currently comprised in functional urban areas' delineations in 1999, without being identified as urban following the same definition of functional urban areas in 1968. This is also the case for the morphological urban areas (MUA) ("unités urbaines") as urban settlements also develop in spatial continuity with the urban core: if less pronounced, the spatial extension of built-up areas has also been very significant and about 3.2 million inhabitants have been gained through updating urban area perimeters.

8 In light of these considerations, a previous work has formalized the identification of four different conceptual models that can be used for following urban areas through time (Bretagnolle et al., 2015) (Figure 1). This distinction depends on the richness of the statistical and geometrical data available at each date and on the partially or fully automated process of the database creation.

- In case A, there is a time series for urban objects, but it results from a process that recreates delineations from scratch at each date, without any link with the previous period. Urban areas are indeed independent from one year to another since there is no relation between them through time and no genealogy established through a common ID code. The result amounts to the production of "snapshots", which are quite simple to process. This is the case for the UMZ database, which is defined by CORINE Land Cover classes at three dates: 1990, 2000 and 2006 (and next, 2012). There has been an update for the delineation assessment of these zones; however, the database in itself does not allow us to follow the evolution of each UMZ since its identity is not conserved from one date to another. Even though such an approach is sufficient to provide general measures of urbanization (evolution of urbanization rates at different periods), it is not relevant for the analysis of urban trajectories.

- Case B corresponds to the most common case in longitudinal studies about population changes and is the easiest solution to implement. In this time series, the delineation of cities is the same for all dates. It presupposes choosing a reference year, which is generally fixed as the most recent date. It is, for instance, the approach adopted by Wolff and Wiechmann (2017) in their study about Europe's shrinking cities between 1990 and 2010.
- In case C, an evolving delineation is based on simple selection criteria applied to building blocks. The minimal distance between built-up areas is only assessed for one year (reference year), in general in the latest year. A retropolation method is then processed at each date by checking the urban nature of each building block (minimal threshold of population or density) and if they are spatially concentrated (contiguity of building blocks). For instance, a constant minimum density applied at different census periods enables following the urban sprawl of a city by aggregating the surrounding villages that exceed this threshold at each date. The perimeter can therefore be different at each date if the city has been expanding or retracting. That method has been chosen for the Geopolis database (Moriconi, 1994) until 1990. It is also the method chosen for the TRADEVE database. -Case D relies on an evolving delineation based on a reassessment (at each date, with a distinct reference year) of the continuous built-up criteria, in general a maximal 200 meters' distance between buildings or urban spots, based on aerial photographs or satellite images. This is the most rigorous method, but it remains costly and time consuming[3]. Only few countries use it to our knowledge (France, Sweden and Denmark).

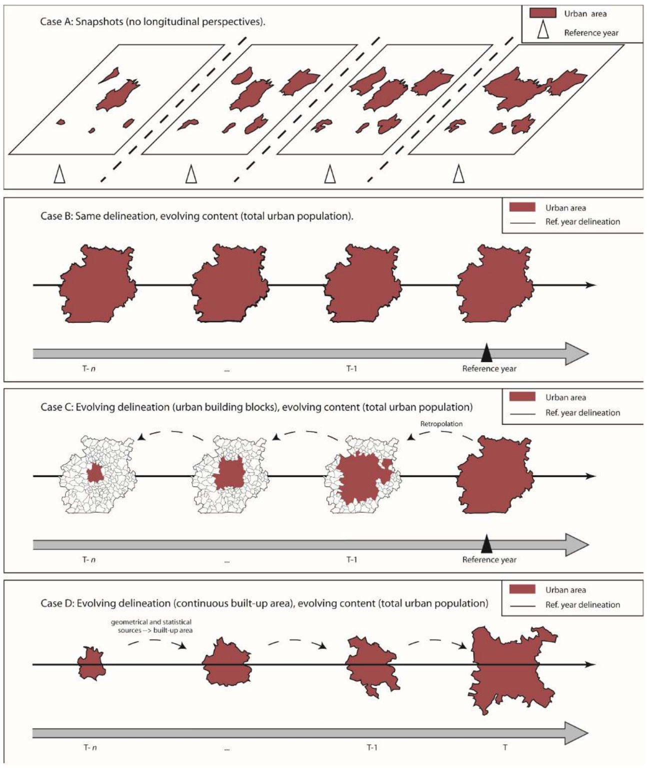
9 Consequently, it can be seen from the above that methodological and technical considerations explain to a large extent the choice of a database model rather than another. Evolving perimeters are not usually delivered by national statistical institutes. For instance, in France, INSEE (Institut National de la Statistique et des Etudes Economiques) provides the data about functional urban areas but only from 1990 to 2010. They have thus to be reconstructed by researchers. Furthermore, the longitudinal local data are not easy to obtain. It raises also the issue of the structure of the database itself, since evolving urban perimeters imply retracing a complex genealogy of objects (fusions, scissions, apparitions, disappearances) (Mathian and Sanders, 2016).

10 The preference for either of these models also depends on the temporal coverage under consideration. The need to choose evolving perimeters or definitions may actually be justified by a medium or a long-term period (for instance, 1960-2010), especially if the extension of cities has been considerable during this period, whereas fixed limits are often preferred for the 1990-2010 period. On long periods, the choice of a constant delineation excluding spatial growth would lead to overestimating the initial population and to underestimating demographic urban growth. For instance, Paulus (2004) has shown for France that updating the delineation of urban areas between 1968 and 1999 included about 1 more million urban inhabitants at each reference year, as compared to the results obtained with evolving delineation. As a result, the rhythm of urbanization is fairly different (1.4% for evolving limits, against 1.1% for constant ones), even though

global trends remain the same (a general slowdown of urban growth), apart from the latest period between 1990 and 1999 (a stabilization for evolving limits versus a slowdown trend for constant perimeter). Evolving perimeters appears thus preferable for longer periods, even though it supposes to tackle the sensitive issue of the fusions between cities.

11 For these reasons, cases C and D stand out as the most complex models to implement. However, it is worth considering them since on long periods, the measure of the urbanization rhythm is sensitive to the choice of one of these models.

Figure 1. Four conceptual models of time integration in urban areas' databases



Source: adapted from Bretagnolle et al., 2015

From theory to implementation: the TRADEVE database

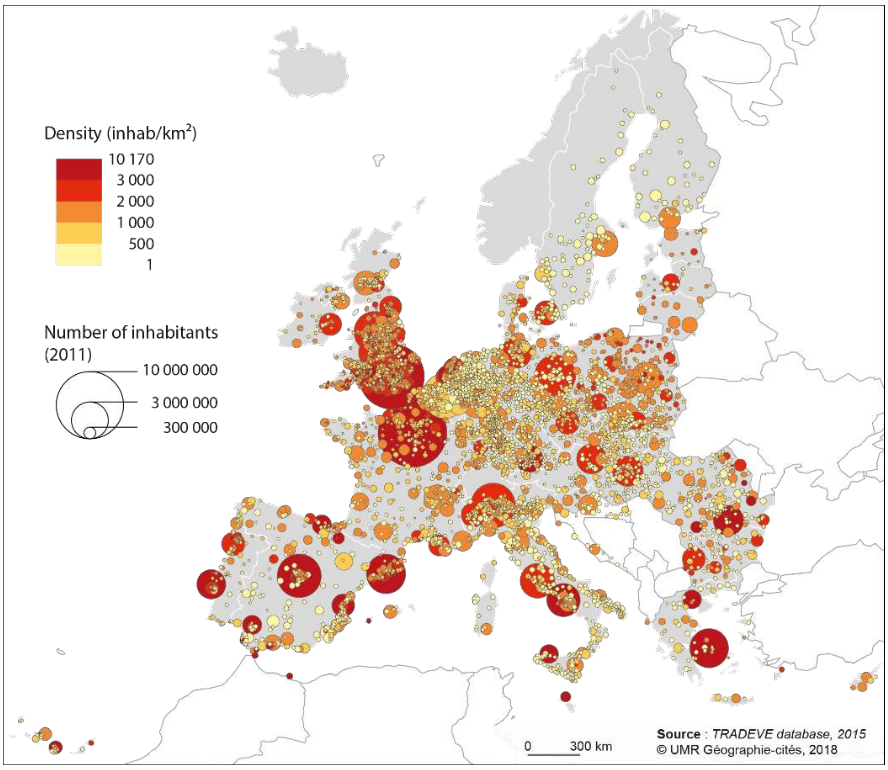
Geometrical and statistical sources

12 Considering the time period (50 years characterized by a strong urban spatial extension), the TRADEVE project relies on evolving perimeters (case C of Figure 1). This choice has been motivated by the recent availability of two original sources.

13 The first is a harmonized database of morphological urban areas in Europe. The UMZ database from the European Environment Agency offers a reference for the delineation of urban areas in 2000. Originally defined by the European Environment Agency from CORINE Land Cover images and continuous built-up areas criteria (Milego, 2007), UMZ were poorly used for urban studies until they were enriched in the ESPON Database by

other indicators, such as a name for each agglomeration and a correspondence dictionary with LAU2 (smallest Local Administrative Units) that allows joining other statistical datasets. A population density grid from the Joint Research Centre (Gallego, 2010) was used for attributing populations to these urban areas (Bretagnolle et al., 2016a and Map 1). This 100-metre resolution grid was constructed by using information from CORINE Land Cover in order to disaggregate LAU2 populations at a finer scale of observation (a weighting coefficient is attached to each category of land use and gives the share of the urban population to be reallocated). We also validated the use of the UMZ database by comparing urban populations or surfaces with those from national urban databases in Sweden, Denmark and France (Guérois et al., 2012).

Map 1: Population and density of European Urban Morphological Zones in 2011



14 The choice of a morphological definition is supported by the fact that it allows us to take into account the evolution of small and medium sized cities, even if it underestimates the growth of population in urban peripheries of the largest cities. Compared to other morphological databases, the UMZ database allows us to embrace a large range of city sizes (over 10,000 inhabitants) in a comparable way. The MUAs defined by C. Vandermotten et al. (1999) are much less numerous, as their minimal threshold is 20,000 inhabitants: we find 1,988 MUAs instead of 3,982 Tradeve-UMZ in 2000. The new Larger Urban Zones, delineated in a harmonized way by DG Regio, Urban Audit and OECD, are much fewer, using a minimal threshold of 50,000 inhabitants (Djijstra and Poelman, 2012). Turok and Mykhnenko (2007) started from Cheshire's database (1995) and tried to enlarge the timespan, but only for cities larger than 200,000 inhabitants. Wolff and Wiechmann (2017) used population, density and morphological criteria, but different definitions, of cities in Europe ("unités urbaines" were used for France) and a constant delineation.

15 The second important source is the local Historical Population Database, which has been constructed by E. Gloersen et al. (2013) as part of a DG Regio project. This longitudinal database contains the local population data for six dates (every decade from 1961 to 2011), in the limits of the 2012 administrative local units. It refers to LAU2, except for Greece, Portugal, Lithuania and Slovenia (at LAU1, the level just higher), and can be downloaded on the Eurostat website (http://ec.europa.eu/eurostat/web/nuts/local-administrative-units). We used an updated version after data checkings and adaptations of the LAU shapes[4] made for the TRADEVE project (Bretagnolle et al., 2016b).

Method and parameters

16 Despite the importance of such original sources, the definition of evolving perimeters for urban areas from 1960 to 2010 is far from evident. Indeed, National Statistical Institutes seldom provide evolving perimeters' databases. The most complete approach would assume to apply the same rules to the data at each date, with, for instance, a 200-metre criteria for delineating the built-up areas extension for urban areas. However, the availability of such data on a European scale is not guaranteed for each reference year.

17 An alternative approach comprises reconstructing past delineations in an indirect way, on the basis of present-day criteria (case C of Figure 1). This approach implies to set up rules in order to identify the administrative units that are part of an urban area at each date. On the basis of the most recent perimeter (UMZ 2000 delineation), it assumes it is possible to build urban areas' delineations at each date by selecting only the LAUs that are considered as urban and that are contiguous. In this regard, the most discussed step relies on the identification of what is an urban LAU at each date. Two criteria can be chosen in order to select urban building blocks at each date between 1961 and 2001: minimal density and minimal population[5].

18 We compared both methods and three different thresholds for each one, and finally chose the minimal population method and the 2,000-inhabitant threshold. The reconstruction of urban areas based on the most restrictive thresholds of population or density (10,000 inh. or 650 inh/km^2) leads to a strong fragmentation in the year 2000 as compared to the reference situation (UMZ 2000 perimeter). Consequently, choosing the 2,000 inhabitants or the 150 inh/km^2 seemed to be more appropriate (Table 1). Among those criteria, the density threshold introduced too much heterogeneity as it tends to reduce spatial coverage for countries characterized by large administrative units such as in Central and Eastern Europe, and conversely tends to improve spatial coverage for countries with small units.

Table 1: Total number of TRADEVE-UMZ per year according to different criteria and parameters (2001: reference year).

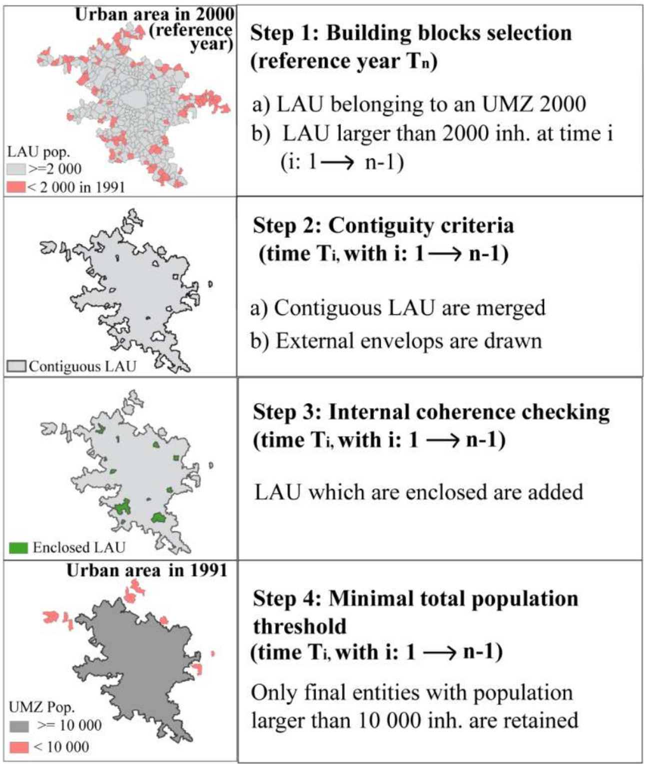
Population or density threshold	**2001**		**1991**	**1981**	**1971**	**1961**
	Abs.	**Rel.**				
2 000 inh	3 953	98,6%	3 877	3 775	3 548	3 248
5 000 inh	3 805	94,7%	3 699	3 571	3 345	3 044

10 000 inh	3 671	91,4%	3 593	3 491	3 284	2 995
150 inh /km²	3 691	91,9%	3 590	3 425	3 135	2 783
250 inh /km²	3 281	81,7%	3 135	2 946	2 648	2 265
450 inh /km²	2 521	62,8%	2 363	2 196	1 904	1 599
650 inh /km²	1 959	48,8%	1 837	1 708	1 480	1 200

Sources: TRADEVE Database 2015.

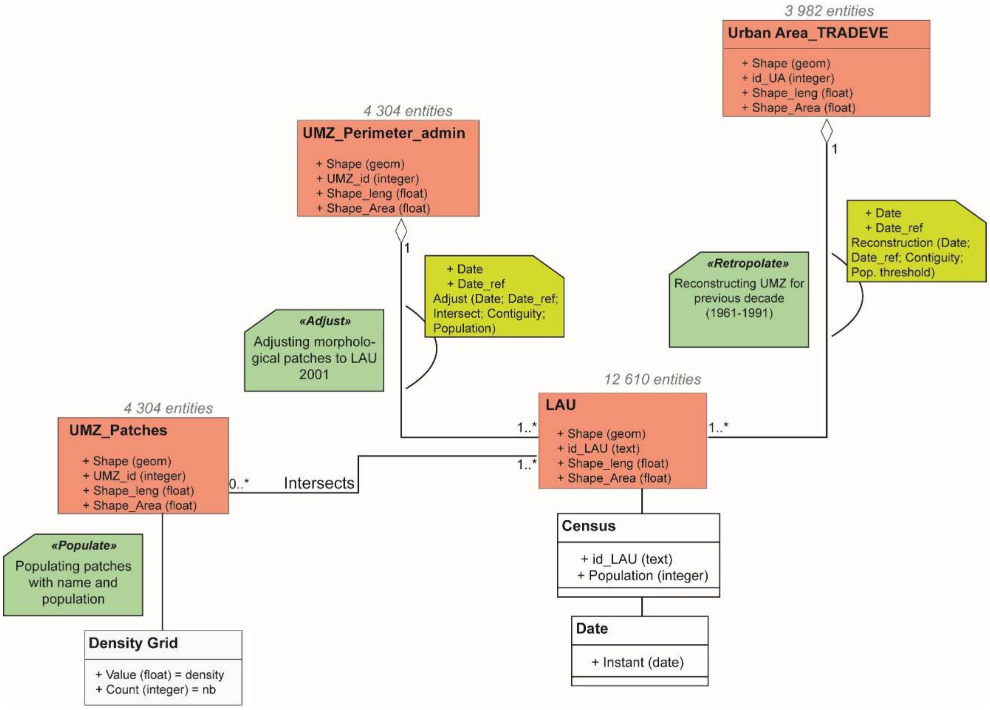
19 We thus applied the same definition of urban areas through time (continuous built-up area defined from CORINE Land Cover image and Urban Morphological Zones 2000), the same delineation (UMZ 2000) and an evolving content based on two different selection criteria applied to LAU-building blocks (contiguity and the 2,000-inhabitant threshold). This method has been applied from 1961 to 2001[6] (Figure 2). At this time, we used case B of Figure 1 (constant delineation with 2000 reference year) and the population change between 2001 and 2011 has been registered within the limits of UMZ 2000.

Figure 2: Four steps for constructing evolving delineations of TRADEVE urban areas



20 Figure 3 shows the data model that has been constructed to organize the different links between spatial entities (in red), statistical sources (in white) and functions (in green) and the way they are evolving through time.

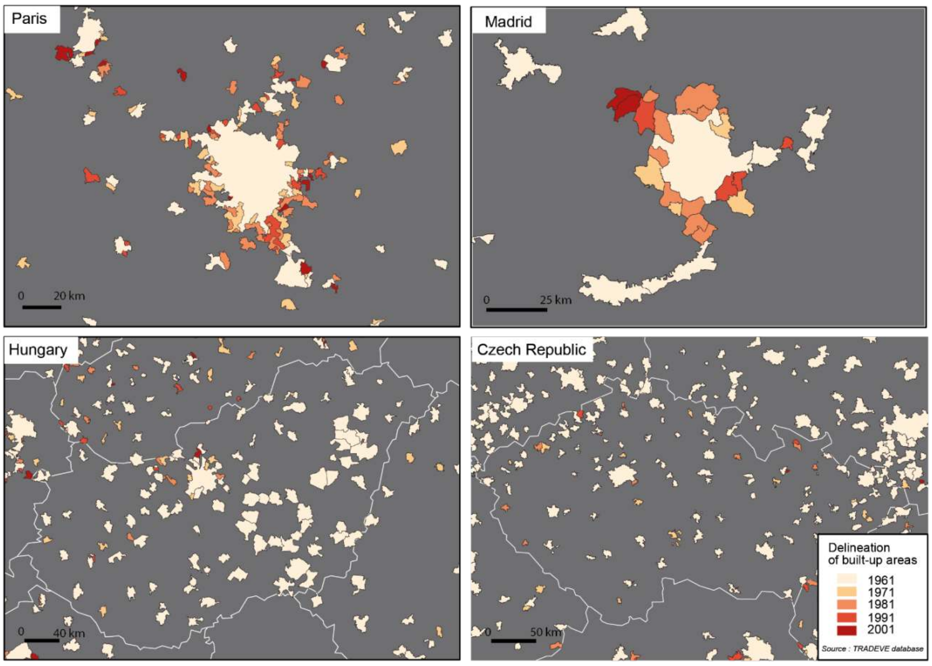
Figure 3: The TRADEVE data model for construction of evolving delineations of urban areas



Implementation and validation

21 The method has been implemented to construct 3,982 urban areas evolving from 1961 to 2011. In terms of urban spatial extension, the results are very different from one country to another, depending on the average size of the LAUs (see the differences between Paris and Madrid, Map 2) and inequality of LAU2 size between large and small cities in Central and Eastern Europe (see Budapest and Prague compared to other cities). Indeed, in this part of Europe, the urban sprawl that began at the end of the 19th century throughout the construction of suburban railways was followed by successive annexations of surrounding LAU2 by the central municipality. Consequently, the size of the eponymous LAU2 (for instance, Prague or Budapest) was progressively enlarged, absorbing the new suburbs. However, the TRADEVE database allows to follow the rise of some new urban areas, as illustrated, for instance, in the north and east of Czech Republic.

Map 2. An overview of the TRADEVE database results from four examples: Paris, Madrid, Hungary and the Czech Republic



22 In order to validate the results, we compared the TRADEVE urban areas and the French urban areas defined by INSEE and named "unités urbaines" larger than 10,000 inhabitants in 1999 (the same minimal threshold as for TRADEVE). Only two TRADEVE urban areas are not corresponding to a "unité urbaine" (Belleville, in the north of Lyon and Givet near the Belgium border). Conversely, 78 "unités urbaines" do not correspond to a TRADEVE urban area but are rather small (71 have a population lower than 15,000 inh. and 7 are between 15,000 and 25,000 inh.). This comparison shows that the TRADEVE urban areas are less fragmented than the "unités urbaines" (and consequently their total number is lower), which is easily understandable considering the method used by INSEE for constructing urban areas in France[7].

23 With the originality of the TRADEVE method being related to the evolving delineation of urban areas through time, it is worth assessing the consequences of this specific approach on the evolution of urban populations and delineations. An important concern lies in the measure of urban population from 1961 to 2001 and in the changes implied by the choice of an evolving perimeter rather than a constant one. When considered at a macro level (total urban population in Europe), differences seem to be very small (Table 2). Among the 3,217 cities present in the database at each date (without considering cases of appearance, fusion...), 15% of them show changing limits. This could be interpreted as a very limited result, but one has to consider the fact that the large majority of cities are small ones (urban areas from 10,000 to 50,000 inhabitants represent 70% to 90% of the total number of cities in each European country, (Bretagnolle et al., 2018)) and these small cities are generally composed of only one LAU.

Table 2. Total urban population, in thousands (1961-2001), with constant or evolving perimeter *

Year for perimeter Year for population	1961	1971	1981	1991	2001	*Absolute differences between constant/evolutive limits*
1961	217 771				219 067	*1 296*
1971		247 773			248 497	*724*
1981			265 105		265 499	*394*
1991				272 848	273 022	*174*
2001					277 458	-

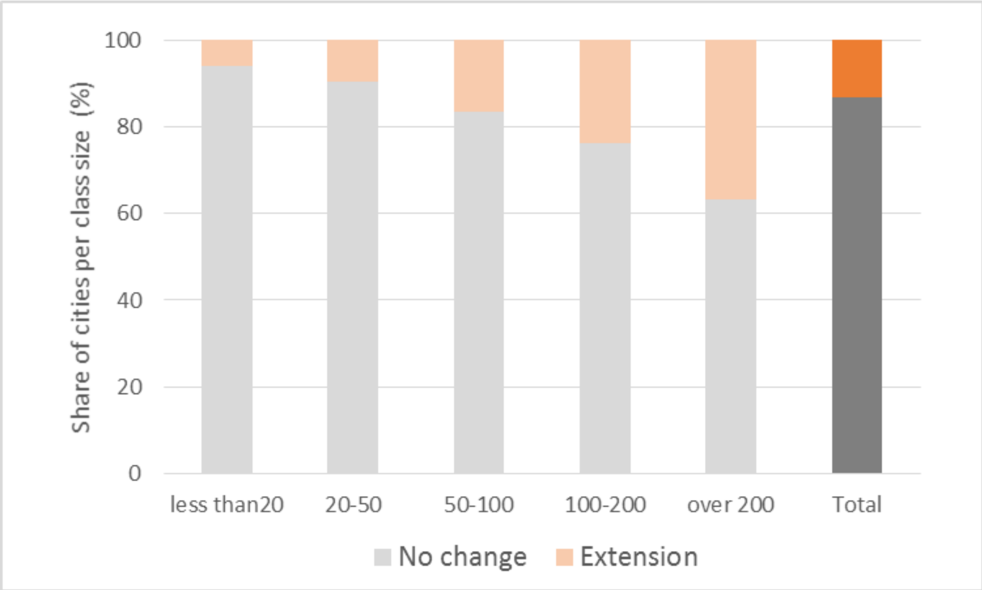
* Violet colors refer to evolving perimeters and green colors to constant ones. This analysis is based on the 3,213 UMZ that are included in the database from 1961 to 2001. It does not take into account apparition or disappearance of cities that are linked to the 10,000 inhabitants threshold.

Sources: TRADEVE Database 2015.

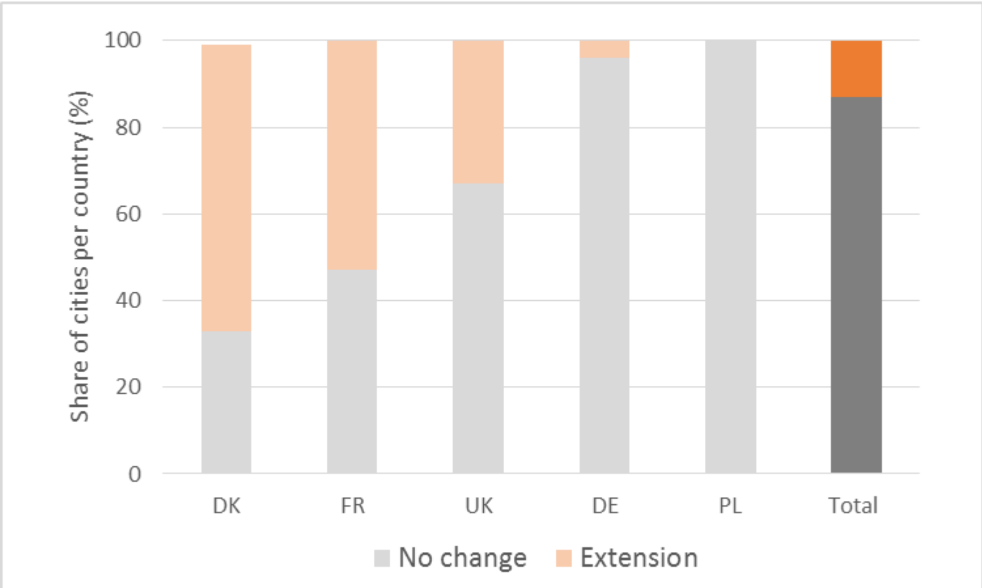
24 This ratio steadily increases with city size so that it reaches 37% of the cities of over 200,000 inhabitants (Figure 4). It also depends on the countries compared, as illustrated by the opposition between the cases of strong stability (in Poland, Hungary, Germany, but also the Netherlands or Sweden) and the cases where changes are much more frequent (in France, United Kingdom, Denmark...). This "changing rate" ranges from 0% (Poland) to 67% (Denmark). Some extreme values sometimes concern large cities, like the "new cities" of Milton Keynes (area multiplied by 4 during the half century) and Reading (multiplied by 3).

Figure 4. Percentage of TRADEVE urban areas with changing perimeters between 1961 and 2001

a. Per class size



b. Per country (examples)



Sources: TRADEVE Database 2015.

25 Some inherent limitations due to sources' availability or data geometries should therefore be taken into consideration. First, regarding the 2011 population results, it has not been possible to use more recent urban perimeters than those from UMZ 2000. The perimeters built from CORINE Land Cover 2012 are not available yet and there is still no update of the population density grid which was used to build the dictionary of correspondence with LAUs. As a consequence, the 2011 LAU populations have been attributed to the 2000 perimeter for now and we hope that it will be possible to update them later.

26 Furthermore, the model does not consider cases of spatial retraction: in the data model, when a building block is considered as urban at a particular date, it is conserved later on even if its population decreases under 2,000 inhabitants, for internal coherence reasons (see step 3 of Figure 2).

27 Lastly, the heterogeneity of LAU sizes partly impacts the measure of the spatial expansion or stability of urban areas in three different ways. First, one can assume that the measure of spatial expansion in time will be quite sensitive to the heterogeneity of LAU sizes between countries at the same date: small morphological variations are more easily registered/detected when the mesh is tight (like in France) than when it is quite loose (like in Nordic countries). For similar reasons, it is harder to register some spatial variations when territorial divisions have been adjusted to urban expansion: in Central and Eastern Europe, for instance, territorial divisions for cities are usually modified and adapted in order to better fit the spatial expansion of the built-up area. Lastly, the differing stability of LAUs that covers from one reference year to another might also influence the measure of urban growth or decline. That being said, this original method constitutes real progress as compared to former longitudinal studies.

Five decades of urban change in Europe in the light of the TRADEVE database: a multilevel insight

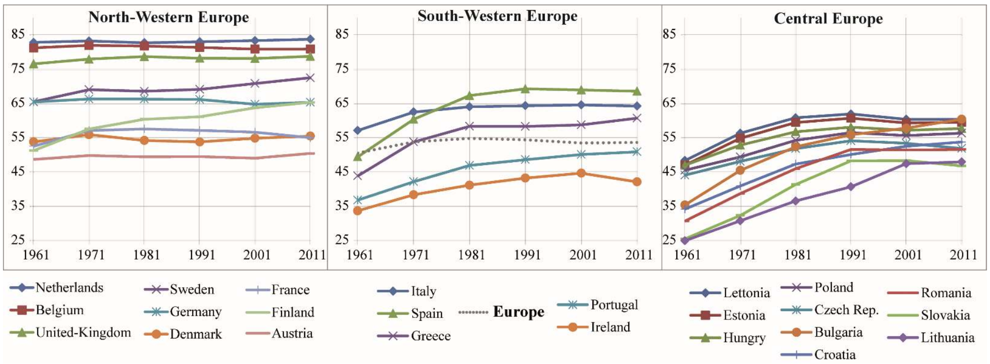
28 The harmonized database TRADEVE is a useful tool to carry out a comparative approach at the European level. Using the same morphological definition of urban areas allows us to perform some reliable multilevel insights. In this section, the first investigations of the TRADEVE database are presented on the basis of different core indicators about urbanization, first at the macro level of countries (urbanization rates) then at the level of the cities (average population variation). This last sub-section will focus primarily on population decreasing issues through a clustering analysis of demographic trajectories.

At the level of countries, urbanization rates

29 The European urbanization level (54% of the total population is living in cities in 2011) seems to be low, compared to the World Urbanization Prospect (WUP) 2014 (74% for UE28). This is because the WUP is a collection of national urban definitions that are not harmonized and most of the time not even representative of the definitions adopted by national statistical boards. Moreover, it is based on a minimum population size/density of urban areas much smaller than in the TRADEVE database[8]. Figure 5 displays the evolution of urbanization levels computed for 24 countries[9]. The curve representing the average (Europe) is characterized by a slight increase since 1991 (only 0.8%), which may be explained by the definition of cities adopted in the database: as we do not take into account functional urban areas, we do not include the rural areas located in the fringes of the largest cities and settled by commuters, a phenomenon that increased with the diffusion of automobiles and highways in the recent decades. Nevertheless, using a harmonized definition of urban areas reveals the intensity of the contrasts between highly urbanized countries (84% in the Netherlands, 81% in Belgium in 2011) and the less urbanized ones (47% in Slovakia, 48% in Lithuania in 2011). If we distinguish countries according to geographical criteria (North-Western Europe, Atlantic and Mediterranean periphery and Central and Eastern Europe), results clearly show that in North-Western

countries, urbanization has been more or less steady (with a slight increase in Sweden and Finland), whereas it has been increased mainly in the 1960s and 1970s in the Atlantic and Mediterranean periphery, and also in the 1980s in Central Europe. In these latter countries, stagnation occurs from 1991/2001, except for Bulgaria and Croatia (both show a total population decline).

Figure 5: Evolution of the urbanization level in Europe* (1961-2011)



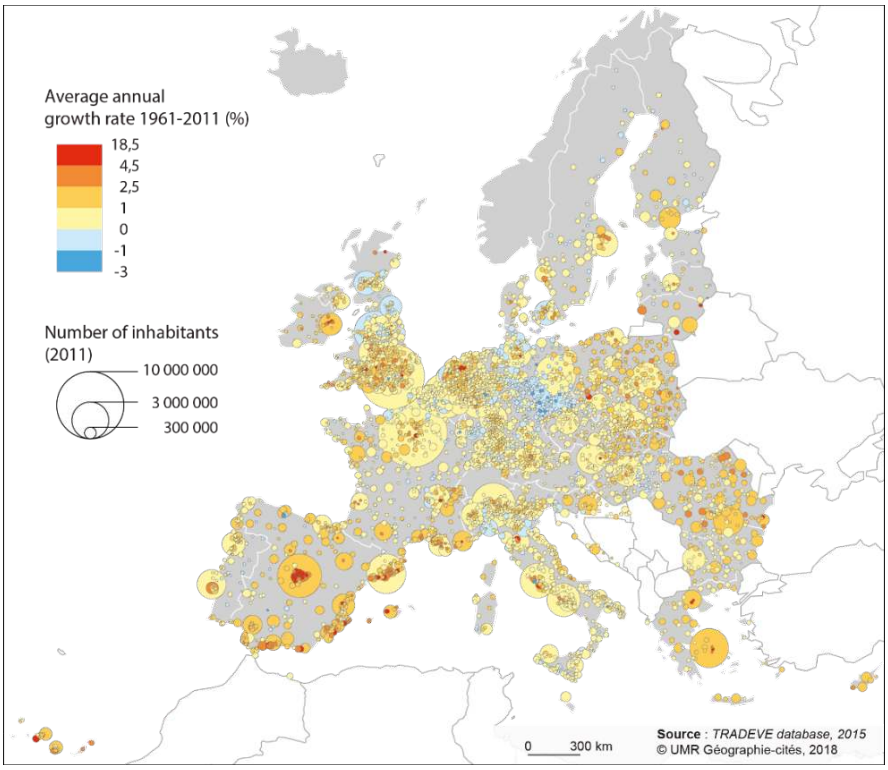
Europe*: 24 countries out of the 29 countries covered by the TRADEVE database (Cyprus, Lichtenstein, Luxembourg, Malta and Slovenia are not considered here due to their small size).

Sources: TRADEVE Database 2015.

At the level of cities, average annual growth

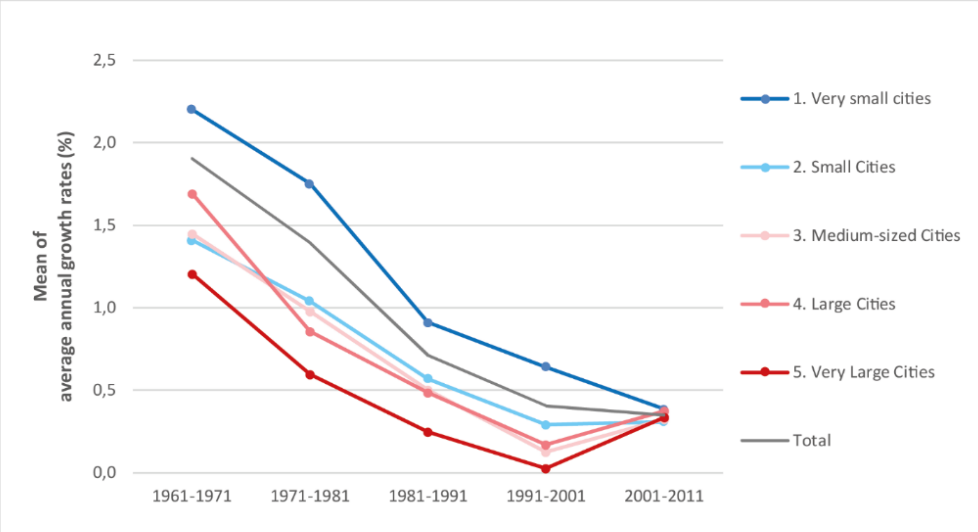
30 The map of average annual growth[10] between 1961 and 2011 (Map 3) reveals that the majority of European urban areas have experienced positive urban growth in the last 50 years (0,941% per year on average), with the exception of a large number of German urban areas in the West and the East of the country, in Northern Italy, Southern Hungary and Northern Great Britain (England and Scotland) but also of some small urban areas settled in different regions of France. Urban areas in Spain, Poland, Slovakia, Romania, Bulgaria and Greece have reached extremely highly annual growth rates (from 4.5% up to 88.5%) between 1961 and 2011. Medium sized and small urban areas have also experienced important annual growth rates as is the case of urban areas in some parts of France, in the Netherlands, in Southern England and Ireland.

Map 3. Average annual growth of European cities between 1961 and 2011



31 Taking a closer look inside ten-year periods, the average annual variation rate shows a progressive fall of growth between 1961 and 2011 (from 1.903%/year to 0,350%/year), even though the definition of a constant perimeter between 2001 and 2011 (see section 2.2) tends to underestimate population growth. Beyond this general trend towards slowing growth until 2011, differences are clearly displayed according to city size (Figure 6). The pace of growth decreases steadily according to city size, except for large cities (between 100,000 and 200,000 inhabitants), which grew more rapidly than small and medium-sized ones between 1961 and 1971. Progressively, there is a clear convergence towards lower rates, regardless of the size of the cities. The strong convergence observed during the last period is due to recovery of population growth for the largest cities (from medium-sized to very large cities) whereas population growth is still decelerating in small and over all very small cities.

Figure 6. Population growth between 1961 and 2011 according to city size



1. Very small: 10,000 to 25,000 inh., 2. Small: 25,000 to 50,000 inh., 3. Medium-sized: 50,000 to 100,000 inh., Large: 100,000 to 200,000 inh., Very large: over 200,000 inh.

NB: The cities characterized by exceptional rates (less than -15% and over 15% per year) have been removed from the corpus at each period. They concern mainly polders cities in Netherlands, new cities in United Kingdom or cities with large housing estates in Madrid suburbs. They are 30 between 1961 and 1971, 16 between 1971 and 1981, 8 between 1981 and 1991, 3 between 1991 and 2000.

Source: TRADEVE database 2015.

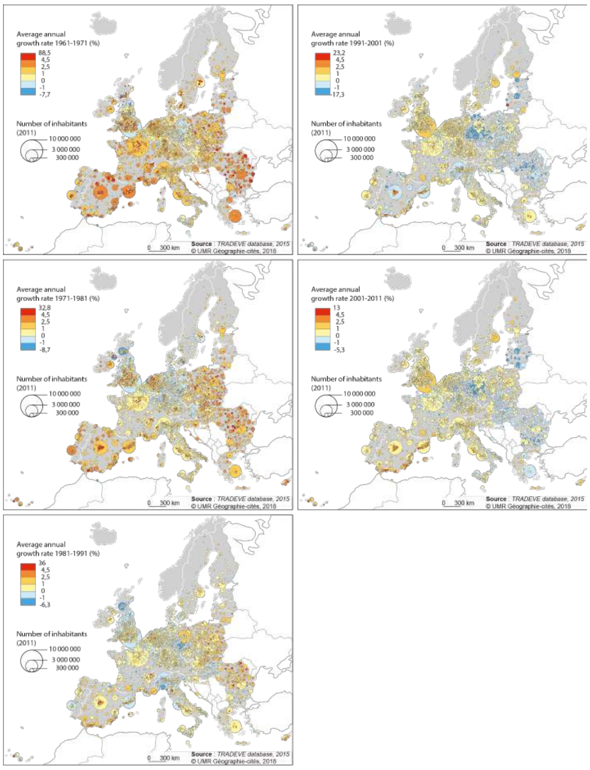
32 The mapping of this evolution displays the succession of two main periods. From 1961 to 1991, urban growth is especially strong in Southern and in Central and Eastern Europe, whereas decreasing situations are beginning to diffuse from the United Kingdom to other countries in Northern Europe:

- In the period 1961-1971 (Map 4-a), the urban annual growth of European urban areas has been mainly positive in the whole of Europe (around 1,8%). However, we can already point out at that time the decline of the population of urban areas in Northern Europe (for example, in large urban areas of the United Kingdom) and a higher urban growth comparing to other urban areas in Spain and Greece and especially in Romania and Bulgaria.
- In the 1971-1981 period (Map 4-b), the gap in terms of growth tendencies between Northern Europe and other European countries has started to deepen. Indeed, urban growth rates in the United Kingdom, the Netherlands, Germany or Denmark have fallen comparing to the previous period to less than -0.5%. At the same time, urban growth rates in Central and Eastern Europe and Spain have increased up to 4.5% or even more in the case of smaller urban areas of these regions.
- The decade between 1981 and 1991 (Map 4-c) reveals an increase of negative urban growth throughout France, Northern Italy up to Rome and in a few large urban areas in Spain and Portugal (Barcelona and Lisbon). In addition, a decrease has occurred in very small urban areas of Southern Hungary and in small sized urban areas in Bulgaria. Nevertheless, in other Central Eastern European urban areas, the average annual growth rates have remained highly positive (especially in Romania).

33 Since 1991 (Map 4-d), Europe has passed through an equilibration of urban growth rates and the regional tendencies have taken an opposite direction comparing to the previous period. Indeed, Central and Eastern European urban areas have experienced slightly

negative growth rates due to the spread of suburbanization, to the sharp decline in the birth rate related to the post-socialist transition and, for the smallest cities, to the collapse of small-town industrial plants that had been established in the centrally planned economy era (Pirisi and Trocsanyi, 2014; Zdanowska, 2016). The growth rates in Western Europe have switched to slightly above zero (between 0% and 1%, and between 1% and 2.5% in the case of London). Moreover, urban areas with the highest average urban growth rates have become exceptions (suburbs of Madrid, Barcelona, Paris, Athens, and Klaipeda in Lithuania). The beginning of the 21st century (Map 4-e) is marked by a certain recovery of urban growth in a few regions of Europe presenting average annual growth rates just above zero. This is the case of the whole United Kingdom, Central and Southern France, Belgium, the Netherlands, Denmark, Spain, Italy and Poland. Nevertheless, many urban areas in Germany, Hungary, Romania, Lithuania and Latvia have been still losing population as their annual growth rates were between -0.5% and -17.5%. An interesting point is that German central-eastern urban areas have never reached positive annual growth rates throughout the whole period 1961-2011, which confirms the results from Figure 6.

Map 4. Variations of population growth and decrease across Europe (1961-2011)



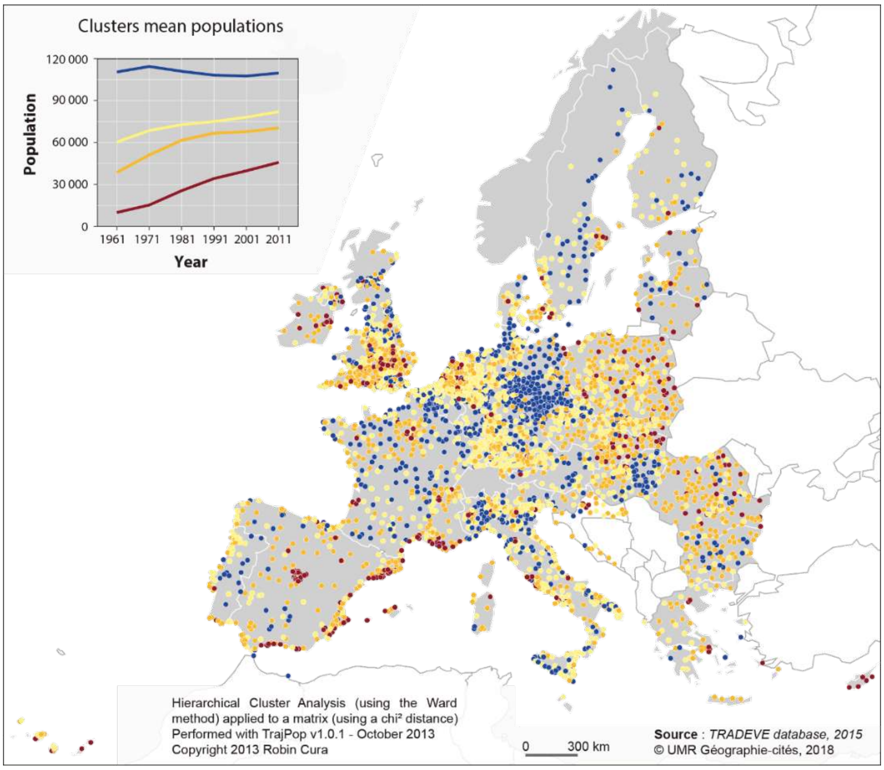
At the level of cities, a cluster analysis of population trajectories

34 These first outcomes can be completed by a hierarchical cluster analysis performed on demographic trajectories of 3,962 TRADEVE[11] urban areas. In order to conduct these data explorations, we applied the Ward method (which tends to minimize intra-class variance and to maximize inter-class variance) using Chi-2 distance on a matrix which resulted from a correspondence analysis on the temporal population table. This methodology is

convenient since it highlights the urban trajectory similarities and it understates stock effects[12].

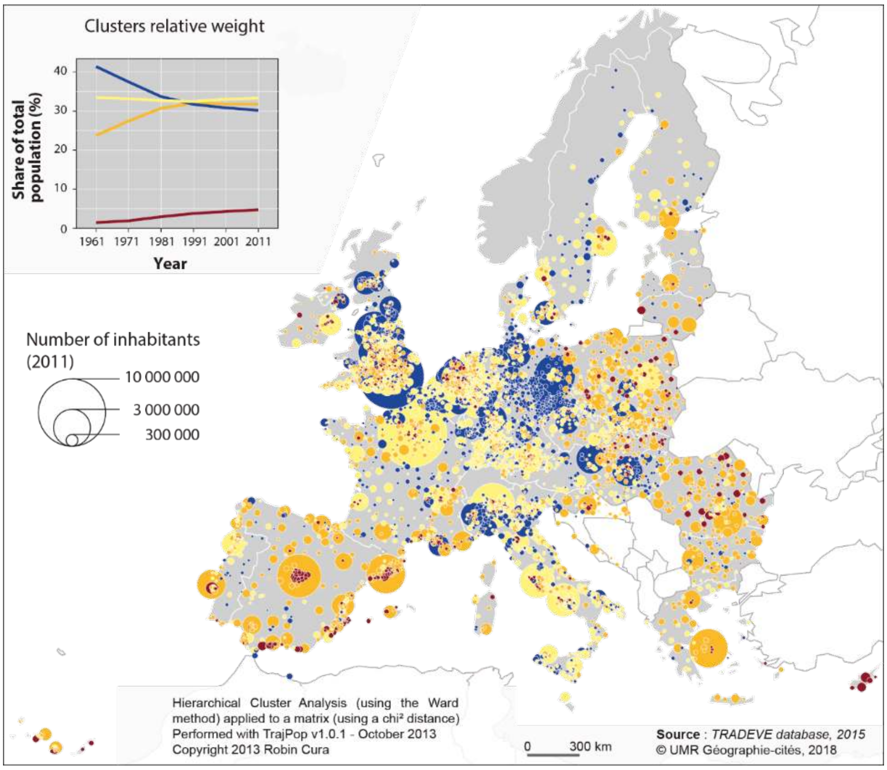
35 According to the intra-class and inter-class distances, a classification in four classes is the most adapted despite the number of cities analyzed. A first map (Map 5) displays those classes according to urban patterns, that means only considering the spatial distribution of cities, independently of populations. More than 60% of European urban areas belong to the clusters 1 (in orange) and 2 (in yellow), characterized by a certain growth of population during the whole period with a slight slowdown since 1991. They correspond in the majority to medium-sized and large cities settled in North-Western Europe (slight growth, in yellow) or Southern and Eastern peripheral countries (in orange).

Map 5. Four main demographic trajectories of European urban areas (1961-2011), mapped according to the spatial distribution of cities



36 The cluster 4 (in red) is the smaller one (only 330 urban areas) and it shows a strong population growth profile. It is a very specific profile, concerning an important share of small and medium sized urban areas; for instance, those which are settled at the fringe of large cities and which benefit from urban sprawl (see around Madrid, London, Paris, Stockholm, etc.) or which are located on the sunny coastal areas (Spain, France, Italy, etc.). These small and medium sized cities are more apparent in Map 6, representing urban populations instead of urban patterns.

Map 6: Four main demographic trajectories of European urban areas (1961-2011), mapped according to urban populations in 2011



37 Finally, the cluster 3 (in blue) aggregates stagnation and decay profiles and includes some large urban areas in Germany, central Great Britain and Northern Italy, also a large number of small cities in these latter countries, but also in France, Portugal, Scandinavia, Baltic countries, Hungary, Austria, Romania, etc. It concerns 870 urban areas, representing 22% of all the European cities, two thirds of which are located in only three countries (Germany, Italy and France) (Table 3). These results sound very similar to those obtained by Wolff and Wiechmann (2017), who conclude after an in-depth study of growth rates that 20% of urban areas were decreasing in Europe during the period 1990-2010.

Table 3. A focus on urban areas with decay trends, by country (1961-2011)

Countries where the proportion of cities with declining trajectory is over European average	Total number of cities with declining trajectory	Proportion of cities with declining trajectory as compared to the total number of cities in the country (%)
Germany	287	37
Hungary	37	37
Sweden	29	35
Austria	18	35

France	114	31
Belgium	14	30
Baltic states	12	26
Italy	131	25
Denmark	11	23

Sources: TRADEVE Database 2015.

Conclusion

38 The TRADEVE database presented in this paper is part of a larger research field focused on the investigation of urban systems over several decades and on the necessary spatiotemporal harmonization of urban objects. The originality of this work lies in four main contributions: the data extend over a long period (from 1961 to 2011), they allow specific studies on small and medium sized cities (Bretagnolle et al., 2019, Gourdon et al., 2019), they take into account the spatial expansion of cities and bring new discussions about the interest of a retropolation method, and finally they aim at the operational objective to be an open database, fully documented with metadata. Even though functional delineations would be important to consider in order to take into account suburban transformations, this is still impossible at this macro-regional scale and for that period of time. In turn, it is essential to recall the importance and interest of urban areas databases that allow to work on small entities: if the majority of European inhabitants live in urban areas (58%, according to the TRADEVE-UMZ database in 2001), nearly half live in small size ones populated by less than 50,000 inhabitants.

39 First thematic insights of the TRADEVE database allow following the hierarchical and regional expressions of urban growth slowing down during this period. In North-Western countries, urbanization has been more or less steady between 1961 and 2011, whereas it has been increased mainly in the 1960s and 1970s in the Atlantic and Mediterranean periphery, and between the 1960s and the 1980s in Central Europe. In these latter countries, stagnation generally occurs from 1991/2001. The average annual variation rate shows a progressive fall of growth between 1971 and 2011. Beyond this general trend, the pace of growth decreases steadily according to city size, apart from large cities (between 100,000 and 200,000 inhabitants), which grew more rapidly than small and medium-sized ones between 1961 and 1971. Progressively, there is a clear convergence towards lower rates, regardless of the size of the cities. Finally, a cluster analysis performed on the demographic trajectories of cities shows that 60% of European urban areas are characterized by a certain growth of population during the whole period, with a slight slowdown since 1991. They correspond in the majority to medium-sized and large cities settled in North-Western Europe or Southern and Eastern peripheral countries. Around 18% of European urban areas are characterized by a strong population growth profile and correspond in majority to small and medium sized urban areas settled at the fringe of large cities and which benefit from urban sprawl or located on the sunny coastal areas. Lastly, 22% of European areas are decreasing, i.e. 870 out of the 3,930 considered in the

database. Among them, one third is located in three countries, Germany (287 urban areas), Italy (131) and France (114). It remains to be analyzed whether these cities belong to metropolitan areas or not.

40 Two main methodological prospects are raised by this work. A first issue relates to the follow-up of the TRADEVE database in the short and medium term. For the 1961-2011 period, the increased concern about small towns justifies the interest for including urban areas between 5,000 and 10,000 inhabitants. Even though manual validation and expertise are still partly necessary, this upgrade should be greatly eased by the implementation of the process automation for naming UMZ and for constructing longitudinal urban objects. Similarly, there is still work to be done in shifting the year of reference for UMZ delineation, from the 2000 to the 2006 version, in order to better adjust the 2011 results to the actual extension of urban areas. Another matter of concern tackles the updating of the TRADEVE database in future periods and raises distinct challenges, where uncertainty prevails as far as the following up of the UMZ database seems gradually replaced by the European settlement data implemented as part of the Copernicus system (https://land.copernicus.eu/pan-european/GHSL/european-settlement-map/view). Beyond these considerations related to the TRADEVE database upgrade and update, a second major issue lies in the potential explorations of the existing database. We provided here some first insights into classical views of urban population variations from 1961 to 2011; however, other promising focus on decay and stagnation trends requires more in-depth analysis in order to test alternative methods such as, for instance, temporal sequence analysis (Gourdon et al. 2019).

BIBLIOGRAPHY

Bernt M., 2015, "The limits of shrinkage: conceptual pitfalls and alternatives in the discussion on Urban population loss", *International Journal of Urban and Regional Research*, doi:10.1111/1468-2427.12289, https://ideas.repec.org/a/bla/ijurrs/v40y2016i2p441-450.html [Online].

Berry, B. and Okulicz-Kozaryn, A., 2012, The city-size distribution debate: resolution for US urban regions and megalopolitan areas. *Cities*, Vol.29, 17-23.

Bretagnolle, A., 2009, Villes et réseaux de transport : des interactions dans la longue durée (France, Europe, Etats-Unis). PhD thesis, Université Panthéon-Sorbonne-Paris I.

Bretagnolle A., Paulus F., Pumain D., 2002, "Time and space scales for measuring urban growth », in *Cybergeo* [online journal], 219, 12 p.

Bretagnolle A., Delisle F., Mathian H., Vatin G., 2015, "Urbanization of the United States over two centuries: an approach based on a long-term database (1790-2010)", *International Journal of Geographical Information Science*, Vol.29, No.5, 850-867.

Bretagnolle A., Guérois M., Le Nechet F., Mathian H., Pavard A., 2016a, "La ville à l'échelle de l'Europe : Apports du couplage et de l'expertise de bases de données issues de l'imagerie satellitale", *Revue Internationale de Géomatique*, 26-1, 55-78.

Bretagnolle A., Guérois M., Pavard A., Gourdon P., Zdanowska N. et al., 2016b, *Demographical Trajectories of European urban areas (1961-2011) (TRADEVE).* [Research Report] Université Paris 1 Panthéon-Sorbonne, https://halshs.archives-ouvertes.fr/halshs-01311420

Bretagnolle, A., Guérois, M., Pavard, 2019, "European small cities and towns: a territorial contextualization of vulnerable demographic situations (1981-2011)", *Revue d'Economie Régionale et Urbaine, Vol.3, to be published.*

Cattan N., Pumain D., Rozenblat C., Saint-Julien T., 1999, *Le système des villes européennes*, Paris: Anthropos coll. villes, 2e édition.

Champion T., 2001, "Urbanization, Suburbanization, Counter-Urbanization and Re-Urbanization", in R. Paddison (ed.), *Handbook of Urban Studies*, London, SAGE Publications Ltd, 143-160.

Chatel C., 2012, *Dynamiques de peuplement et transformations institutionnelles. Une mesure de l'urbanisation en Europe de 1800 à 2010*, Thèse de doctorat, Université Paris Diderot-Paris 7.

Claramunt, C., Thériault, M., 1995, "Managing time in GIS: An event oriented approach", in Clifford J. and Tuzhilin A. (eds.), *Recent Advances on Temporal Databases*, Springer Verlag, Zurich, Suisse, 23- 42.

Cottineau, C., 2014) *L'évolution des villes dans l'espace post-soviétique. Observation et modélisations.* PhD thesis, Université Paris 1 Panthéon-Sorbonne.

Cottineau, C., Hatna, E., Arcaute, E., and Batty, M. (2017). Diverse cities or the systematic paradox of urban scaling laws. Computers, environment and urban systems, Vol.63, 80–94.

Cura R., Cottineau C., Swerts E., Ignazzi C., Bretagnolle A., Vacchiani-Marcuzzo C., Pumain D., 2017, "The old and the new. Qualifying city systems in the world with classical models and new data", *Geographical Analysis*, Vol.49, No.4, 363-386.

Davezies L., 2008, *La République et ses territoires. La circulation invisible des richesses*, Paris : Seuil.

Dijkstra L., Poelman H., 2012, *Cities in Europe. The new OECD-EC definition.* Regional Focus, RF 01/2012, Regional and Urban Policy, 15 pages.

European Commission, Directorate-General for Research and Innovation, 2016, *Open innovation, open science, open to the world: a vision for Europe.* Luxembourg, Publications Office. http://bookshop.europa.eu/uri?target=EUB:NOTICE:KI0416263:EN:HTML

Favaro, J.-M. and Pumain, D., 2011, "Gibrat revisited: An urban growth model incorporating spatial interaction and innovation cycles", *Geographical Analysis*, Vol.43, No.3, 261–286.

Gallego F. J., 2010, "A Population density grid of the European Union", *Population and Environment*, Vol.31, No.6, 460-473.

Gourdon P., Bretagnolle A., Guérois M., Pavard A., 2019, "Des petites villes davantage touchées par la décroissance ? Comparaison des trajectoires démographiques à l'échelle européenne » (1961-2011) », *Belgéo-Revue Belge de Géographie*, to be published.

Guérois M., Bretagnolle A., Giraud T., Mathian H., 2012, "A new database for the cities of Europe? Urban Morphological Zones (CLC2000) confronted to three national databases of urban agglomerations (Denmark, France, Sweden)", *Environment and Planning B*, Vol.39 (3), 439-458.

Kosmopoulos C., Pumain D., 2018, "Humanities and Social Sciences (HSS) at the head of Open Access as demonstrated from Cybergeo's experience », *Cybergeo : European Journal of Geography* [En ligne], Science et Toile, article No.861, URL : http://journals.openedition.org/cybergeo/29251 ; DOI : 10.4000/cybergeo.29251

Martinez-Fernandez C., Weyman T., Fol S., Audirac I., Cunningham-Sabot E., Wiechmann T., Yahagi H., "Shrinking cities in Australia, Japan, Europe and the USA: From a global process to local policy responses", *Progress in Planning,* Vol.105, April 2016, 1-48.

Mathian H., Sanders L., 2014, *Spatio-temporal approaches: Geographic Objects and Change Process*, Wiley-ISTE, 176 p.

Milego R., 2007, *Urban Morphological Zones, Definition and Procedural Steps*, Report, Copenhagen: European Environment Agency, European Topic Centre Terrestrial Environment, 9 p.

Moriconi-Ebrard F., 1994, *Géopolis. Pour comparer les villes du monde*, Paris, Anthropos, Economica, Collection Villes.

Paulus F., 2004, *Coévolution dans les systèmes de villes : croissance et spécialisation des aires urbaines françaises de 1950 à 2000*, thèse de doctorat de l'université Paris 1 Panthéon-Sorbonne.

Pirisi G., Trocsanyi A., 2014, "Shrinking small towns in Hungary: the factors behind the urban decline in small scale", *Acta Geographica Universitatis Comenianae*, Vol.58, No.2, 131-147.

Pumain D., 1999, "Quel rôle pour les villes petites et moyennes des régions périphériques ?", *Revue de Géographie Alpine*, Vol.87, No.2, 167-184.

Pumain D., Swerts E., Cottineau C., Vacchiani-Marcuzzo C., Ignazzi A., Bretagnolle A., Delisle F., Cura R., Lizzi L., Baffi S., 2015, "Multilevel comparison of large urban systems", *Cybergeo: European Journal of Geography* [Online], article No.706.

Raimbault, J. (2018), "Indirect evidence of network effects in a system of cities", *Environment and Planning B: Urban Analytics and City Science*, https://doi.org/10.1177/2399808318774335

Rink D., Haase A., Grossmann K., Couch C., Cocks M., 2012, "From long-term shrinkage to re-growth? The urban development trajectories of Liverpool and Leipzig", *Built Environment*, Vol.38, No.2, 162-178.

Turok I., Mykhnenko V., 2007, "The trajectories of European Cities, 1960-2005", *Cities*, Vol.24, No.3, 165-182.

Vandermotten C., Vermoesen F., De Lannoy W., De Corte S., 1999, *Villes d'Europe. Cartographie comparative*. Bulletin du Crédit Communal, Trimestriel, 53ème année, No.207-208, 407 pages.

Wiechmann T., Wolff M., 2013, *Urban shrinkage in a spatial perspective*. AESOP-ACSP Congress Dublin [Online].

Wolff M., Wiechmann T., 2017, "Urban growth and decline: Europe's shrinking cities in a comparative perspective 1990-2010", *European Urban and Regional Studies*, 1-18, DOI: 10.1177/0969776417694680.

Zdanowska, N., 2016, "Métropolisation et système de villes en Pologne depuis 1960", *Revue Géographique de l'Est*, Vol.56, No.3-4.

NOTES

1. This database results from the TRADEVE project « Demographical trajectories of European urban areas » (TRAjectoires DEmographiques des Villes Européennes).
2. See the corresponding Data paper in Cybergeo.
3. This procedure usually required a large expertise by hand for the previous census. It seems now to be processed automatically in France in support of INSEE BD Topo (see chapter 1 in https://www.insee.fr/fr/information/2571258).

4. In the United Kingdom and Ireland, for instance, the LAU2 are built from the electoral districts. The result is very fine units, sometimes sparsely populated. On the other hand, the higher administrative level (LAU1) has units that are too broad to analyze urban objects. An intermediate level has been rebuilt to allow these two countries to be treated with the same approach (Bretagnolle et al., 2016b).

5. Both have already been used: the MUAs (Vandermotten et al., 1999) are based on a 650 inh/km^2 density threshold whereas the Geopolis database (Moriconi, 1994) is based on a 200m distance and a minimal population threshold (10,000 inh. for the building blocks).

6. R and Postgis were used in order to implement these methods (see Cybergeo data paper).

7. This method is described in : « Composition communale des unités urbaines, Population et délimitation 1999, Nomenclatures et codes », INSEE, mars 1999. This is a method adapted to the fine scale of French LAU2. Morphological patches are first defined using the continuous built-up areas' definitions (from photo-interpretation and field), with a maximum distance between buildings of 200 metres ("zones bâties"). Then only LAU2 with more than 50% of their population laying in these "zones bâties" are retained in the urban area. Consequently, some of these building blocks may be very small, with a total population much lower than 2,000 inhabitants.

8. For instance, according to WUP data sources (https://esa.un.org/unpd/wup/DataSources/), these urban areas are represented by LAU2 larger than 5,000 inhabitants in Belgium (which gives an urbanization level of 98% instead of 81% in TRADEVE), larger than 200 inhabitants in Denmark (urbanization level of 88% instead of 56% in TRADEVE) and denser than 150 inh/km^2 in Germany (urbanization level of 75% instead of 65% in TRADEVE). The large differences between a harmonized approach and the heterogeneous definitions chosen by the United Nations leads us to question the assertion according to which the world population has been urban in the majority since 2003, an assertion which has been, however, cited by many researchers and political actors.

9. Luxembourg, Slovenia, Cyprus, Malta and Lichtenstein were removed, due to the weak surface of the country (less than 600 km^2).

10. The Annual Average Growth Rate (AAGR) is calculated as follows:

$$AAGR_{(t-1,t)} = \left(\sqrt[n]{P_t / P_{t-1}} - 1 \right) * 100$$

where *P* is the population of the urban area and *n* is the number of years in the study period *(t-1, t)*.

11. In order to avoid blanks in the database, 20 small UMZ that had merged into larger agglomerations during the period 1961-2011 have been removed from the hierarchical cluster analysis.

12. This step was processed by using the *Trajpop* application, which was built by Robin Cura (UMR Géographie-cités). For methodological details and access to R code: Cura R., (2013). TrajPop (1.0 web version) [Web application]. Retrieved from http://trajpop.parisgeo.cnrs.fr. And for another method example, see Pumain et al. (2015).

ABSTRACTS

In this paper we present the methodological issues and choices related to the construction of the TRADEVE database, which allows following the population of European urban areas since 1961. Whereas most of the recent academic works related to this issue focus either on time depth (for larger cities) or on the large coverage of urban hierarchy (for a shorter period), one of the main interests of the TRADEVE database is to extend over a relatively long period (from 1961 to 2011) and to cover small and medium sized cities at the same time. But, above all, it distinguishes by taking into account the spatial expansion of urban areas during a period characterized by a pronounced sprawling process. First insights are provided that allow studying the hierarchical and regional expressions of urban growth slowing down during this period. A cluster analysis performed on the demographic trajectories of cities shows that 22% are decreasing, i.e. 870 out of the 3,930 considered in the database. Along with the paper, the TRADEVE database fully documented with metadata is available online in open access.

Cet article présente les enjeux et les fondements méthodologiques de la base de données TRADEVE qui permet de suivre l'évolution de la population des agglomérations européennes depuis 1961. Alors que la plupart des travaux récents sur ces questions privilégient soit une grande profondeur temporelle tout en se focalisant sur les plus grandes villes, soit une large couverture de la hiérarchie urbaine sur une période plus courte, l'un des intérêts de cette base inédite est d'intégrer les villes petites et moyennes au corpus sur une période relativement longue (de 1961 à 2011). De plus, elle se distingue par le caractère évolutif des périmètres urbains identifiés, qui témoigne de la volonté de prendre en compte l'extension spatiale des agglomérations au cours d'une période caractérisée par un processus d'étalement prononcé. Les premiers résultats issus de l'exploitation de cette base permettent d'observer les expressions hiérarchiques et régionales du ralentissement de la croissance démographique des villes au cours de cette période. D'après une Classification Ascendante Hiérarchique effectuée sur les trajectoires démographiques des villes entre 1961 et 2011, il apparaît que 22% des villes ont connu des trajectoires de décroissance relative, soit 870 sur les 3930 considérées. L'article s'accompagne de la mise en ligne en accès libre de la base TRADEVE et de la documentation qui en détaille la conception.

INDEX

Mots-clés: agglomération, population, analyse spatio-temporelle, base de données en accès libre, données ouvertes
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