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IDENTIFYING AND CLASSIFYING SMALL AND MEDIUM SIZED TOWNS IN EUROPE

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ABSTRACT

This paper provides a first attempt at the construction of a unified, homogeneous inventory of different classes of urban settlements in the European space, building on the approach of international institutions such as OECD and the EU in relation to larger urban areas and extending it to the specific challenge presented by smaller settlements. Its objective is twofold. The first is to address the fundamental empirical problem that was central to the development of the ESPON 2013 project 'Small and Medium sized Towns in their Functional Territorial Context' (TOWN), that is the proper geographic identification of different classes of urban settlements. The second is to introduce one basic classification of urban settlements, and two more refined typologies of small and medium sized towns (SMST). These typologies are used to provide a first impression of territorial structures of urbanisation throughout Europe, further elaborated in functional terms in the TOWN project.

Key words: urban areas, geomatic methods, urbanisation morphology, ESPON

INTRODUCTION

The main goals of this paper are, first, to present a method to identify small and medium-sized towns (SMST) in the European space; and, subsequently, to provide details of the steps and the problems faced in the development of a geodatabase which could be used for further analysis of the spatial distribution and roles of SMST, such as those presented in other contributions to this special issue. It then proceeds to provide a first impression of territorial structures of urbanisation throughout Europe. Our motivation in this sense is to fill the gaps in current classifications developed by the EU and OECD, which were remarkably functional to the development of a thorough classification and analysis of the inner diversity of functional urban areas and metropolitan systems. Preserving this conceptual and operational approach, we extend it to analyse the full range and diversity of urban settlement types.

Two main fundamental theoretical and empirical problems (which have been central to the development of the ESPON 'TOWN' project[1]) are thus addressed: first, the proper geographic identification of urban settlements; and second, the specification of a set of criteria for the classification of urban types, bringing to the fore the specific status of small and medium-sized towns. While the former is generally dealt with through geomatic methods (Guerois *et al* 2012), the latter has been mostly addressed through the identification of meaningful thresholds of population within a predefined jurisdictional unit (Bloom *et al.* 2010; Montgomery 2010). Critiques of such purely population-based approach can be traced back to the work of Wirth (1969, quoted by Brenner & Schmid 2014), whose theory of urbanism paid attention to spatial interdependencies and shifting territorial arrangements. Brenner and Schmid (2014) also criticise this approach for the subsumed reduction of territorial complexity to an urban-rural dichotomy, without any meaningful connotation of the rural territory except its residual role with respect to the urban dimension. Yet, in an increasingly globalised context, 'many rural areas have as many links to distant regions across Europe or the rest of the world as they do to adjacent urban areas.' (Copus *et al.* 2011, p. 11). This implies that the full complexity of the urban phenomenon and its territorial encasing can only be grasped looking at the multi-layered relationships between socio-spatial structures with involve links and flows that are not only physical and human in nature but extend to the immaterial, the virtual and even the symbolic realm.

The general approach of the ESPON 'TOWN' project, which is the main research programme from which this paper draws from, has been sensible to these critiques; indeed it aimed at analysing SMST in their 'functional territorial context', as the title of the project says. Thus, it developed various branches of research to analyse the functional relations of SMST within urban systems, their performance (as compared to that of larger urban areas), and their trajectories of evolution in terms of productive structures. This analysis has specifically focused on the 2000 decade, when long-term spatial trends have conjured with the 2007 financial slump in bringing forward exceptional conditions for smaller urban areas – either at great risk of 'disconnection' from urban cores or an altogether new 'field of opportunities' for new territorial cohesion strategies. In any case, the objectives of this research frame the methods and criteria used to identify and characterise its basic object, the urban areas; and this is a complex task which needed to take into due account the homogeneity of the sources used.

As to classifications based on a pure population criterion (generally, density), the sources typically refer to census data at the level of local administrative units. Considering that often a LAU contains portions of both rural and urban areas, some studies use smaller statistical units, such as blocks or census zones, in order to improve spatial accuracy. Unfortunately, these data are not available for most countries, and moreover data at this spatial scale are remarkably inhomogeneous across countries or even regions within the same country.

More sophisticated identification approaches reflect the broadening of the conceptual approaches to what is in fact 'urban'. Remotely sensed data are generally used to detect the physical structure and composition of urban areas – residential, commercial or mixed neighbourhoods; green spaces or other open spaces – and of the built environment, whether urban or not (including airports, ports, highways, etc.) (Netzband & Jürgens 2010). The combination of land cover and population density criteria has been introduced with the aim to integrate and enhance the previous approaches. Thus, Weeks (2010) developed an 'urban index' combining census data with remotely-sensed data identifying characteristics of the built environment, like the proportional abundance of impervious surface combined with shade, and an original landscape metrics involving the measurement of the spatial configuration of the patches comprising each land cover class. In recent works in this line, other criteria are added. Schneider *et al.* (2010) use the concept of urban eco-regions (a stratification based on climate, vegetation, and urban topology) and the level of economic development (per capita gross domestic product in purchasing power parity) to map urban areas across the globe. Wandl *et al.* (2014) apply criteria such as 'maximum population density', referring to stable resident and floating working population, and infrastructure land cover (from the Corine geodatabase) related to population density, to characterise 'intermediate' areas between the rural and the urban zones in two case studies (South Holland in the Netherlands and Tyrol in Austria). These more advanced methods thus recognise the importance of looking at the urban fabric in its functional, relational, environmental contexts. However, most of them rely on a process of elaboration and 'cleaning up' of spurious data sources which could be reasonably performed at case study level but hardly systematically in the whole European space.

In this sense, the adoption in this paper of a pure population-based method to identify urban areas has not only been a pragmatic choice, determined by the availability of population data from homogeneous sources. While this concern was obviously present, this approach is seen as the more apt to construct an European 'base' of finite urban extensions which are then analysed in their relational and functional dimensions in subsequent stages of the TOWN project. This method stands in contrast to a criterion based on formal legal jurisdictions, which could be used to examine institutional arrangements, but it is subject to large heterogeneity of scales, forms and functions across countries (and even regions within the same country) and hardly captures the dynamic reconfiguration of human settlements within wider systems. On the other hand, it stands in direct relation with an analysis based on relational patterns – for example daily flows and economic connections – which contribute a deeper understanding of the structure and functions of wider urban systems, but use a consistently delimited space as the basic spatial unit.

In this project we have used the GEOSTAT database, which allows a uniform application in the European space in order to develop a first broad outlook of the dimension of the small-sized urban phenomena across Europe. As will be explained below, other criteria or sources have been discarded either for lack of homogeneity or for inconsistency in the type of basic information associated to them which is seen as crucial in the context of the particular research project of which this exercise is an integral part.

Thus, the TOWN project set on to, first, pin-point what is really an 'urban area' in pure terms of population and built environment, which would lead to the identification of 'urban stains' contained in or stretching over formal borders; second, to classify them in relation to size and density; and third, to attribute to the so-derived spatial units the social and demographic values recalculating them from the underlying indicators generally available at municipal or regional level. Only then it was possible to rely on a properly defined database of urban areas which could be further analysed in functional terms. This method is consistent with recent approaches to the study of urban systems: not only the EC and OECD studies frequently quoted throughout this paper (which we have taken as an operational reference), but also some of the most inspiring ESPON projects, such as TRACC (Spiekermann *et al.* 2014) focusing on interurban accessibility, or GEOSPECS (Gloersen *et al.* 2013), focusing on processes of functional disconnection, have used 'morphological' spatial units as a base for further elaborations.

This paper illustrates the basic process of obtaining such European database of urban areas, the way the technical problems encountered have been dealt with, and the first insights from this construction. The material is so organised. The following section informs about the process and criteria followed to obtain a geo-base of urban settlements through aggregation of spatial grids of 1 km^2 into polygons throughout the European space. The third section introduces one basic and two advanced typologies of urban settlements and explores the results of such classifications and of the geographical structures so obtained, and the fourth section 4 concludes.

POINTS OF ENTRY AND DELIMITATION PROCEDURE OF SMST

The first fundamental step in the definition of urban settlements from a morphological point of view has been the conceptualisation of the distinction between built-up and open-space areas. In general, an urban settlement is considered to be an area in which buildings are not too sparse and contain a concentration of population that creates a sense of urban agglomeration. From this perspective, two parameters are most commonly used:

first, the distance between buildings must be inferior to a given threshold; second, the total population of the built-up area must exceed a certain level.

While the use of these parameters is commonly accepted in official definitions, there are significant differences between thresholds applied in each country. The United Nations recommends that for the identification of urban areas, a threshold of 200 metres as the maximum distance between houses should be used (Le Gléau *et al.* 1997), although in some European countries the official criteria shift this threshold from 50 metres, as in the cases of the UK and Norway, to 250 metres as in Belgium. In addition, there are different interpretations for areas used for public, commercial and industrial purposes. For the second parameter, the continuous built-up area can only be considered 'urban' if its aggregated population exceeds a certain threshold that also varies among different countries (e.g. 200 inhabitants in Belgium and the Nordic Countries), but other proxies are also used (e.g. 50 occupied dwellings is the threshold adopted in Ireland). Besides, when built up areas approximate administrative or statistical boundaries, the criterion adopted for the identification of the urban settlement is population density (as for instance in the Netherlands, which considers a threshold of 1,000 inhabitants per km^2).

The method used to build a geo-database of small and medium towns in the TOWN project has, of necessity, been constrained by data availability and harmonisation. It thus followed the procedure implemented by the EC Directorate for urban and Regional Policy in the document 'The New Degree of Urbanisation' (DEGURBA) (Dijkstra & Poelman 2014), which uses as a spatial base unit a database of more than 2,000,000 grid cells of 1 km^2 produced by GEOSTAT and the associated population data in year 2006. This methodology allows a greater accuracy of population estimation than others also employed by European Union agencies (Gallego & Peedell 2001), and minimises the problem related to the pycnophylactic interpolation (Tobler 1979), common in dasymetric mapping.

Elaborating data on population size and density in contiguous cells according to a method approved by the Eurostat Labour Market Working Group in 2011, the DEGURBA document has identified a number of urban settlement structures classified into three 'degrees of urbanisation'; in a similar fashion OECD has classified urban areas in its recent 'Redefining urban areas in OECD countries' report (Brezzi *et al.* 2012):

1. High-density urban clusters: settlements formed by a continuous agglomeration of grid cells of 1 km^2 with a population density of at least 1,500 inhabitants per km^2 and a minimum population of 50,000.
2. Urban clusters: clusters of contiguous grid cells of 1 km^2 with a density of at least 300 inhabitants per km^2 and a minimum population of 5,000.
3. Rural grid cells: grid cells outside urban clusters

On the basis of this classification, the DEGURBA document has generated a three-way classification of LAU2s as follows:

1. Densely populated area: (alternative name: cities or large urban area): At least 50 per cent lives in high-density clusters.
2. Intermediate density area (alternative name: towns and suburbs or small urban area): Less than 50 per cent of the population lives in rural grid cells and Less than 50 per cent lives in a high-density cluster.
3. Thinly populated area (alternative name: rural area): More than 50 per cent of the population lives in rural grid cells.

DEGURBA also looked into the inner structure of urban settlements, distinguishing 'cores' from 'peripheries' and sprawling urbanised areas within municipal delimitations. The approach of DEGURBA, as well as its validation procedures, has mainly focused on the structure of urbanisation for the larger European urban areas identified by cores that are 'high density urban clusters' and their functional regions. It did not develop the same methodology at the lower urban scale (smaller and/or less dense urban clusters). In the TOWN project, small and medium towns (SMST) have been identified according to a differential approach with respect to the DEGURBA document: hence, urban settlements which are neither 'high-density urban clusters', nor 'rural grid cells' according to Dijkstra and Poelman's (2014) classification.

The following procedure has therefore been implemented in order to identify urban clusters and SMST within them:

- selection of contiguous cells of at least 300 inh./km^2;
- creation of polygons by aggregation of the selected grid cells;[2]
- from the resulting polygons, high-density urban clusters (i.e., polygons having at least 1,500 inh./km^2 and a population size of more than 50,000) and other urban settlements (thus with a density of less than 300 inh/km^2 and a population of less than 5,000) have been separated out; and
- the remaining polygons, fitting the condition of a population size between 1,500 and 50,000 inhabitants (whatever their population density, provided it is greater than 300 inh./km^2) or a density between 300 and 1,500 inh./km^2 (whatever their population size, provided it is greater than 1,500) are identified as SMST.

Thus, our first basic morphological classification defines SMST as continuous urban clusters with a population above 5,000 and a density above 300 inh./km^2 that are not 'high density urban clusters' (HDUC) as according to the DEGURBA definition; therefore, these include:

- polygons with a total density (average density of all cells included) between 300 and 1,500 inh./km^2 and a population between 5,000 and 50,000 inhabitants;
- polygons with a total density of more than 1,500 inh./km^2 but a total population of less than 50,000; and
- polygons with a total population of more than 50,000 but a total density of less than 1,500 inh./km^2.

By elimination, we then identify another class of urban areas that are smaller than SMST. Our basic classification of urban settlements (TOWN Typology 1) thus includes also those settlements that are characterised by a population density superior to 300 inh./km^2 but a population lower than 5,000 and therefore insufficient to be considered SMST, hence classified as 'very small towns' (VST).

The remaining entities (urbanised areas of less than 300 inh./km^2) are classified, by exclusion, as 'other settlement types' and include unpopulated areas, sprawling urbanisations, or settlements that are too sparsely populated to be even considered VST and aggregated into polygons in our geodatabase. The legend of Figure 1 illustrates this classification, with nomenclatures and colours corresponding to the maps.

A first simple run of this procedure of geomatic manipulation of the grid-based dataset provided by Geostat and the classification of the resulting polygons, yielded the following structure:

- 846 urban settlements classified as HDUC;
- 8,350 urban settlements classified as SMST;
- 70,480 urban settlements classified as VST.

However, other intermediate steps have been necessary in order to obtain a sufficiently accurate representation of the morphological settlement structures in the European space. The main issue has been the revision of the geomatic procedure, which inevitably led to a number of errors in the coherent delimitation of urban areas. Such errors depended on the poor capacity of grid surfaces, albeit at the 1km^2 scale, to capture every type of continuity or gap in the urban fabric, and are inherent to any grid-based analysis (De Mers 2009). Areas that appear separated may be so 'by accident' mostly because of the imperfect superimposition of the grid geography with natural features; or, conversely, elements that the mere geomatic procedure has bundled together in one urban settlement, are in fact different 'entities' – for example, if separated by a watercourse, a national border, or other elements of discontinuity not captured at the 1km^2 scale – that should be kept separated for analytic purposes. A number of other 'accidents' of this type may occur, and systematic detection and revision – which could be carried out, for

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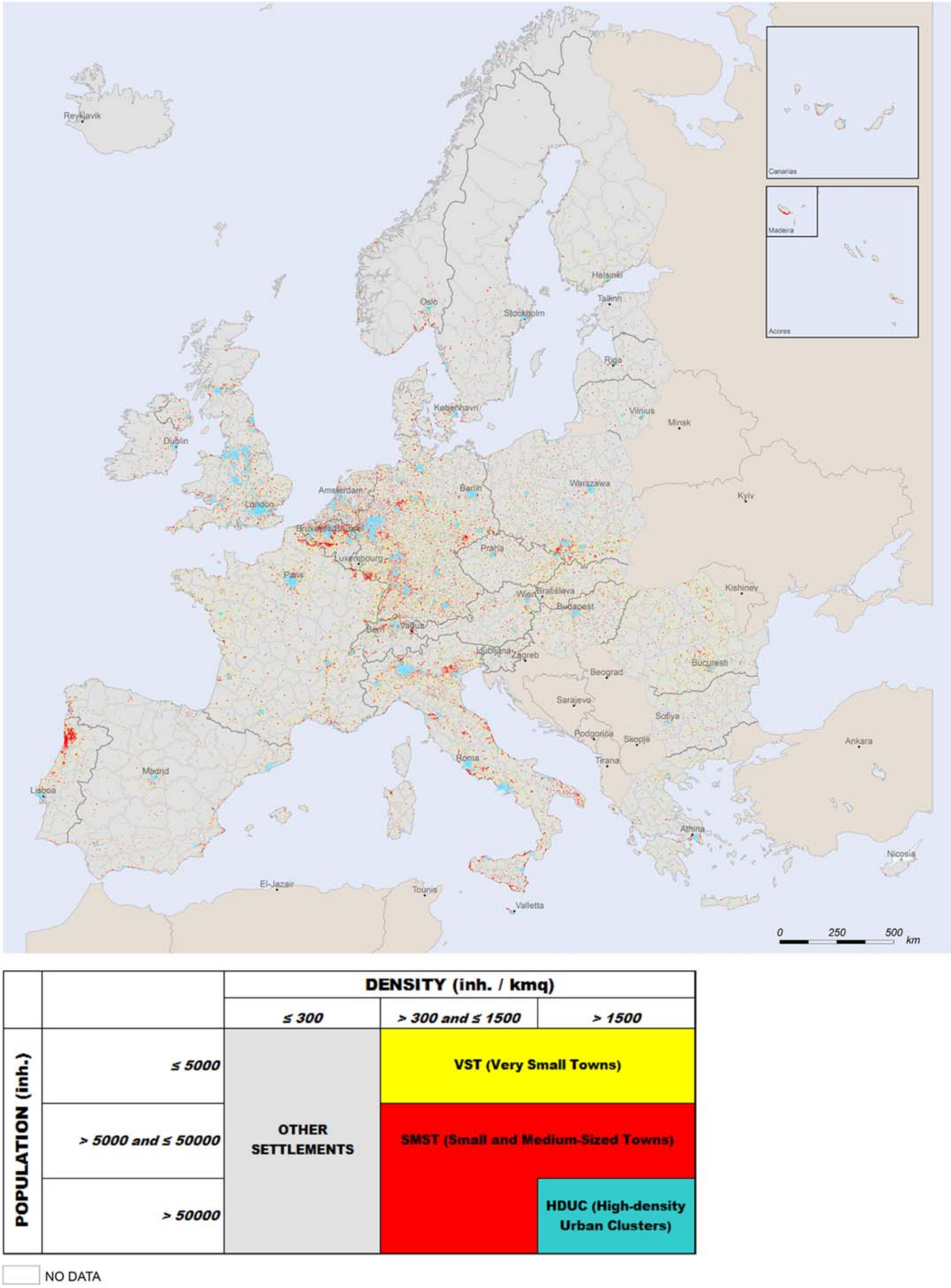

Figure 1. *Basic TOWN typology of urban settlements*. [Colour figure can be viewed at wileyonlinelibrary.com]

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instance, in the DEGURBA project because of the relatively limited number of high density urban clusters involved – becomes problematic in this project that deals with more than 79,000 urban settlements.

Thus, the project has revised the original procedure in 10 case study areas included in the TOWN project,[3] where the precision of this geography was critical to the accuracy of the analysis and thus the soundness of the scientific results from this project. In these areas, the morphological structure has been carefully and systematically revised on the basis of local knowledge, leading to the re-configuration and re-classification of urban settlements.

After implementing the 'acceptable' revisions as illustrated above and integrated the database with the spatial information in Cyprus,[4] the procedure of classification of urban settlement polygons was repeated, yielding the following results:

- 8,414 urban settlements classified as SMST;
- 850 urban settlements classified as HDUC;
- 69,043 urban settlements classified as VST.

In Figure 1, SMST are mapped out as red polygons, together with the HDUC in light blue and VST in yellow. At a first glance, SMST can barely be distinguished within the wider scale of the ESPON space; however the small detail reveals a richness of SMST on a sector that goes from the south of England throughout the Benelux and the West of Germany to Italy, with other 'clusters' in the industrial belt of South-Eastern Germany and Poland, and along the whole Western Mediterranean arc from Spain to Italy; moreover it illustrates the relative sparseness of SMST in the interior of France, north-eastern Spain, the Alpine arc, and the eastern side of the pentagon area.

This classification includes among SMST urban areas which would not normally be considered 'medium-sized' towns, as is the case of large sprawling conurbations in North-eastern Italy, Belgium, and the German-French border which can be easily spotted in the map. In part, this is the result of the method deployed, which does not allow for 'separations' within continuously built-up settlements, and it is problematic due to the fact that in most of the subsequent streams of analysis carried out in the TOWN project very large urban areas are pooled together with smaller and compacter settlements (and particularly so where the morphology of such areas is complex, as in the ribbon-shaped configuration of many Belgian and German settlements). Yet it does make some sense from the point of view of the 'morphological' interpretation, because this continuity also produces a certain commonness of urban issues and performances throughout these areas. This problem anyway has been dealt with through classifications of SMST (see next section), which single out specific dimensions of SMST, and in subsequent analytic stages of the TOWN project as the functional classification of urban centres.

Table 1 offers some key descriptors of the polygon classes in Typology 1, where it is shown how as much as 53.7 per cent does not live in metropolitan areas, and notably short than a quarter of the European population lives in SMST, which on average are nine times smaller than HDUC, but are 10 times as numerous. At country level, we can distinguish three main types of national urban settlement structures (the full table of results by country and classes of urban settlements is offered in Table A1 in the Appendix):

1. countries with a neat prevalence of urbanised population, clustered in high-density urban centres, as Belgium, Switzerland, Greece, the Netherlands, Spain, the UK, as well as smaller island states as Iceland and Malta;
2. countries with an overrepresentation of population living in smaller settlements, like Finland, France, Ireland, Lithuania, Luxembourg, Norway and Slovakia; and
3. all other countries have a more balanced repartition of population between classes of high-density urban clusters and small and medium towns.

To conclude this section, we stress that the method of obtaining a delimitation and classification of urban settlements, involving a sequence of elaborations on the original grid-based database and further manipulations as illustrated above, is not without limitations. We can point to three orders of problems in this sense.

Table 1. •••

Classes	Delimitation criteria	Count	Av. Pop	Av. Sq.km	Av. Density	Total pop. in this class	As % of ESPON space*
High-density Urban Clusters (HDUC)	Pop. > 50,000, AND Pop. Density > 1,500 inh/km^2	850	275,476.1	92.3	2,927.1	234,154,670	46.3%
Small and Medium-sized Towns (SMST)	Pop. > 5,000 AND Pop. Density > 300 inh/km^2	8,414	14,553.7	10.1	1,535.9	122,455,009	24.2%
Very Small Towns (VST)	Pop. < 5,000 AND Pop. Density > 300 inh./km^2	69,043	1,193.1	1.7	699.3	82,376,586	16.3%

The first is the sensitivity of the parametric specification adopted for the identification of the three basic classes of urban settlements. As the main concern of this study is the spatial distribution of urban settlement types, it is useful to test whether the spatial distribution of different classes would change substantially if other parameters would be adopted, looking at country level. To this aim we have considered six 'variations' on the original parametric scheme:

1. all population size thresholds lowered by 25 per cent;
2. all population size thresholds increased by 25 per cent;
3. all density thresholds lowered by 25 per cent;
4. all density thresholds increased by 25 per cent;
5. both population size and density thresholds lowered by 25 per cent; and
6. both population size and density thresholds increased by 25 per cent

The results are provided in Table A2 in the Appendix. Figure 2 represents graphically the percent change in the number of polygons obtained in relation to the original model for the three classes of urban settlements, country by country.

The sensitivity of the original model to changes in parameters is higher for models E and F (both population size and density respectively decreased and increased by 25 per cent over original thresholds) and for small countries in terms of population size as Malta, Finland, Norway and Estonia; a sharp decrease of VST count is also noted for the Netherlands. For the other countries both the count and distribution of urban settlements is relatively stable, with variations contained within the 50 per cent bounds for most countries, and a decreasing variance along the HDUC-SMST-VST scale. Table A2 shows the average percentage deviation over the original model of the six alternative models for the number of SMST polygons obtained, their surface, average population size and density. While variations on the population size and density are imposed by the parametric specifications, the variations of real interest regarding the

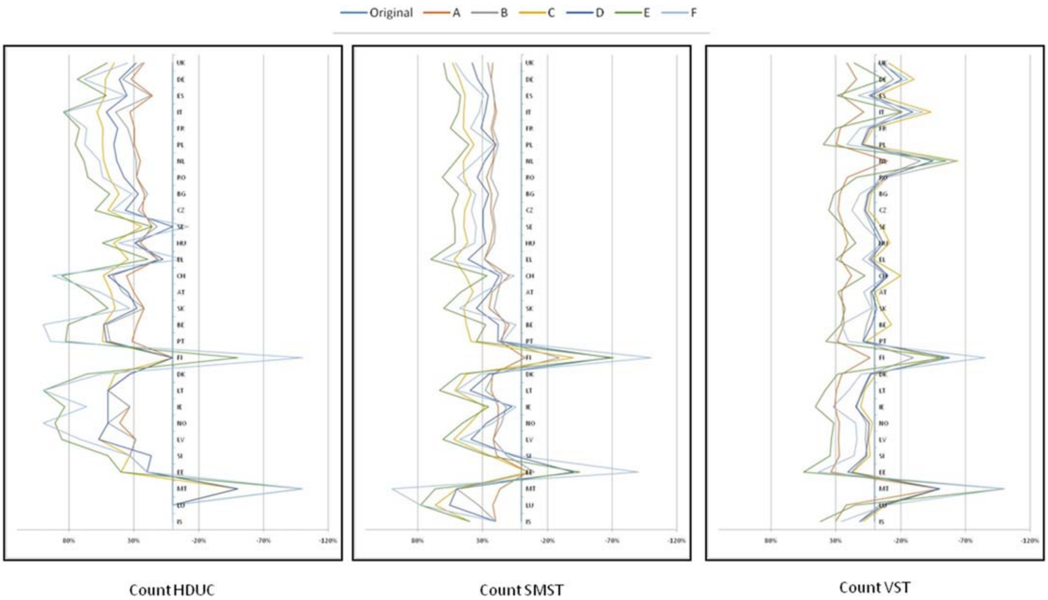

Figure 2. *Number of polygons classified as HDUC, SMST, VST in each country (percentage variation on original model of 6 alternative parametric schemes).* [Colour figure can be viewed at wileyonlinelibrary.com]

number and extension of the polygons obtained in the alternative schemes. As it is shown in Table A2, variations for small and medium sized towns are generally inferior to 50 per cent for the numbers of polygons while the average extension of the SMST polygons varies less than 10 per cent with some exceptions regarding generally smaller and more sparsely populated countries. The extreme variations which are observed for HDUC could be explained by the fact that this class of urban settlement is situated on the extreme of the distribution tails of the two indicators considered and is defined by elimination: thus the maximum count values will always account for a greater distance (in fact, the superior limit is open). Indeed, any attempt of delineation of urban types according to arbitrary thresholds will produce such variability of the 'extremes' reflecting only in part empirical reality. In any case we observe that variability is not overtly high for the urban types which are the main focus of this research, SMST (and VST), and generally holds within reasonable limits in the case of most European countries. At the same time the original scheme is functional to consistency with the basic identification criteria introduced by the DEGURBA document.

A second 'sensitivity' issue regards the method employed to create SMST polygons by aggregation of contiguous grid cells. First of all, it must be noted that our methods involves the aggregation of grid cells that are all superior to 300 inh./km^2, producing aggregate SMST densities that are in general well above the 300 inh./km^2 threshold. A more sophisticated method that generates clusters of contiguous grid cells whose aggregate density is superior to the 300 inh./km^2 threshold would return different results, specifically it would extend the number and morphology of urban settlements to include lower density grid cells generally at the fringes of urban areas. However, its application would be technically complex and subject to a certain degree of discretion in the delimitation of the resulting polygons. Moreover, it would be inconsistent with the method adopted by the EC and OECD, making our respective approaches incomparable.

An opposite problem comes up with the construction of HDUC polygons 'by elimination' from the set of polygons created that are to be considered SMST. The method used is substantially different from the one that identifies SMST: in fact, if HDUC were built by aggregation of contiguous cells that were all superior to 1,500 inh./km^2, as in the DEGURBA document, some 'fringe' areas whose overall density is likely to be lower than 1,500 inh./km^2 would have been left out (maybe resulting as SMST or VST 'attached' to HDUC). This means that our approach 'over-represents' HDUC – there are parts of HDUC polygons which have the characteristics of SMST in terms of their density and population dimensions. From the functional point of view (that we are privileging in our approach, because the main focus of this project is on the 'role' of SMST, which is addressed primarily through a functional analysis at urban system level – and not on the shape or role of HDUC, as in the DEGURBA study) separating these areas would make little sense because they indicate a sort of 'functional continuity' that should be taken into account. Yet from a purely morphological one it does create problems in specific contexts of high urban sprawl and dense urbanisations according to 'ribbon development', problems which have only been dealt with in the stages of verification and revision of the geo-database in case study regions. In order to address this issue, and further fine-tune the morphological identification and representation of SMST to the one carried out in the DEGURBA document, we proceed to investigate the inner structure of SMST polygons.

Thus, we have gone back at the grid level to pick those 1 km^2 cells within SMST polygons and classify them by their individual density. In this way we have a grasp of the 'underlying' structure of urban polygons. This method allows distinguishing, within one polygon, the existence of a 'core' and a 'fringe', and even, possibly, of high-density urban nuclei within the core. Clearly, this method does not lend itself to visualisation and representation at the global EU scale; for this reason it is more useful to show a number of examples of the underlying urban settlement structure in the case of 'exemplary' SMST polygons. In Figure 3 (upper part) we have mapped the resulting settlement structure in the urban area of Gent, a municipality of approx. 240,000 inhabitants and a density of 1,550 inh./km^2, which would therefore classify it as a HDUC; yet, because of the sprawling morphological structure at its edges, and of the aggregation method employed, the polygon that includes it sprawls counts 382,425 inhabitants and a density of 1,400 inh./km^2, thus qualifying as a 'large SMST' in Typology 3 below (map on the left side) in spite of the existence of a higher density 'core' – as can be seen from the map on the right side.

Conversely, the maps in Figure 2 (lower part) illustrate the situation of the HDUC polygon of Brussels, a HDUC of 1.84 M inhabitants with a global density of 2,225 inh./km^2 characterised by a sprawling lower-density 'ribbon development' into surrounding areas, especially to the Flanders territory in the North-west (left side); in the map on the right we can again see that the 'high density core' would exclude the larger parts of these ribbons. These maps make evident that the focus on SMST of this study produces a delimitation of urban settlements which may differ from that of DEGURBA, as argued in the previous section. In order to pick systematically such internal structures, we have used a common threshold of 1,500 inh./km^2 to characterise high-density grids within urban settlement polygons and produced a mapping of the overall ESPON space.

A third order of problems that was faced is due to the fact that the 1 × 1 km dimension for the original raster database on which the construction of this geo-database is based, is relatively 'rough' – small discontinuities in the urban fabric could be significant in the process of 'isolating' urban settlements for the analysis also at distances that are far inferior to 1 km. In fact, the construction of polygons in TOWN could be compared to the work recently conducted by the M4D project in the creation of a geodatabase of urban morphological zones, which elaborated Corine-based urban cover grids at a much finer definition of 200m grid cells (Guerois at al. 2012). It must be noted that our work did not use the Corine database for the conceptual difficulty to separate out 'populated' land grids. As for other alternative sources, the LandScan database providing population information for grid cells was considered and subsequently discarded. In fact, the LandScan database does not include statistical population but 'livelihood space' information; therefore it is hardly apt to construct population-based polygons by

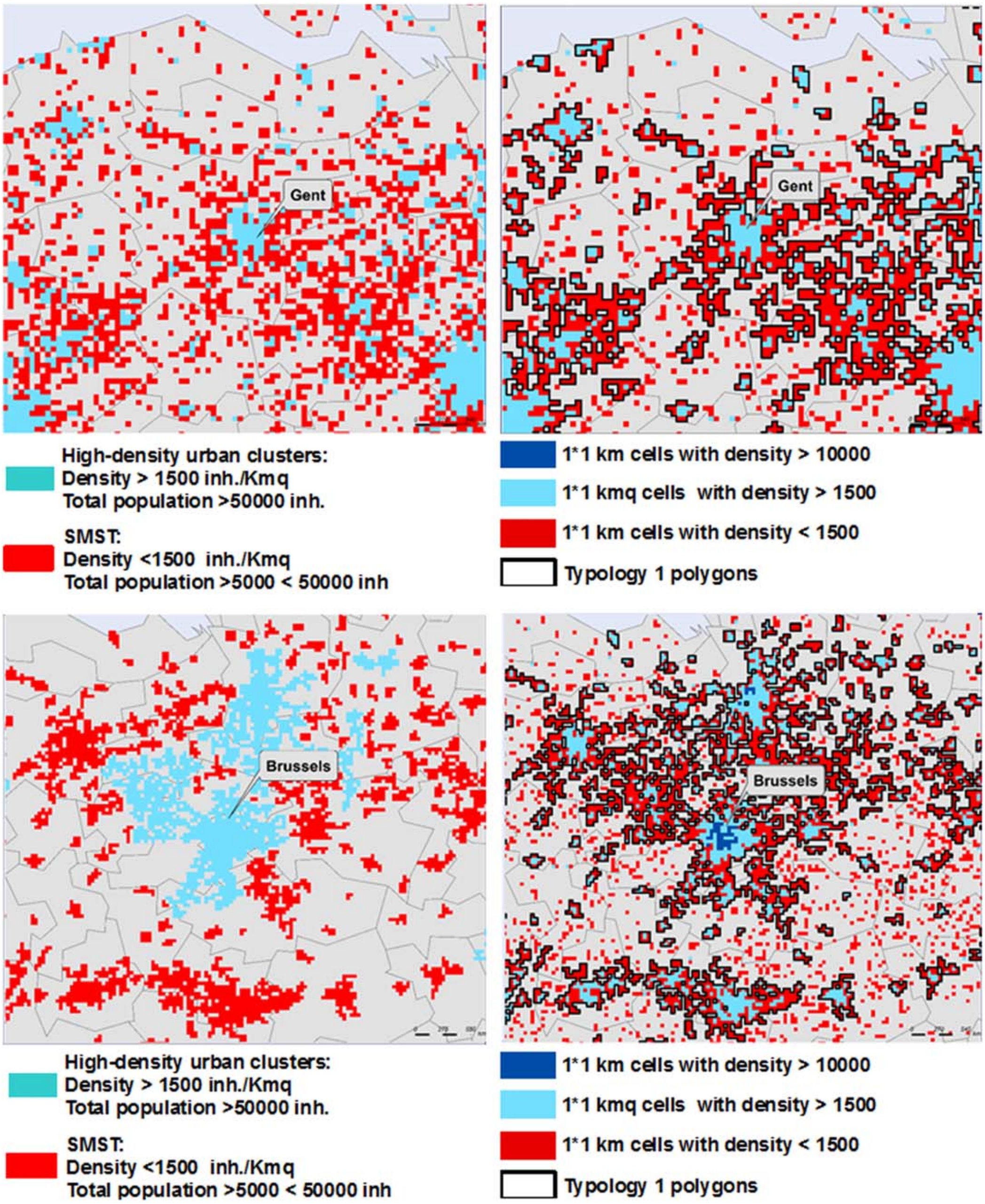

Figure 3. *Above: urban agglomeration of Gent, Belgium. (left): SMST and HDUC polygons; (right): grid cells of 1 km^2, classified in three density ranges. Below: Urban agglomeration of Brussels, Belgium. (left): SMST and HDUC polygons; (right): grid cells of 1 km^2, classified in three density ranges.* [Colour figure can be viewed at wileyonlinelibrary.com]

aggregation.[5] Moreover, for a study area with distinct latitudes, as in this case the ESPON space, data are better compared and aggregated using cells of a regular measure than with variable grid cells (the '30 minutes' grid cells as in the case of LandScan).

Table 2. •••

Classes	Delimitation criteria	Count	Av. Pop	Av. Sq.km	Av. Density	Total pop. in this class	As % of ESPON space*
High-density Urban Clusters (HDUC)	Pop. > 50,000, AND Pop. Density > 1,500 inh/km^2	850	275,476.10	92.3	2,927.10	234,154,670	46.3%
Small SMST	Pop > 5,000 < 25,000, AND Pop. Density > 300 inh/km^2	7348	10,241.50	7.6	1,470.09	75,254,510	14.9%
Medium SMST	Pop > 25,000 < 50,000, AND Pop. Density > 300 inh/km^2	966	35,162.90	19.7	2,060.59	33,967,357	6.7%
Large SMST	Pop > 50,000, AND Pop. Density > 300 < 1,500 inh/km^2	100	132,331.42	101.8	1,299.64	13,233,142	2.6%
Very Small Towns (VST)	Pop. < 5,000 AND Pop. Density > 300 inh./km^2	69,043	1,193.10	1.7	699.3	82,376,586	16.3%

TYPOLOGIES OF SMST

SMST polygons have been further classified, considering different values of population and density of inhabitants.

Population thresholds – A first enhancement oriented at a better understanding of population settlements introduces the subcategory of 'large SMST' as those SMST that have more than 50,000 inhabitants, though having a total population density below the 1,500 inh./km^2 threshold of large urban areas. This typology (TOWN Typology 2) subdivides SMST into a class of 8,253 'normal' and 100 'large' SMST polygons across Europe. The latter correspond to a number of sprawling medium-density regions across Europe. The most evident cases in our geo-database refers to the metropolitan region of Porto (a ribbon shaped metropolitan area of 2.5 million inhabitants, with an overall population density of 1,330 inh./km^2), the Saar region and the region of Gent, both above half million inhabitants, and other 29 urban areas of more than a 100,000 inhabitants. A more sophisticated refinement of this SMST typology subdivides them further also including 'small SMST' as SMST with a population below 25,000 (TOWN Typology 3).

As a result, we now include among SMST (and provide key stats for in Table 2):

- 7,348 small SMST, with a population density of more than 300 inh./km^2 and a population of less than 25,000;
- 966 medium SMST, with a population density of more than 300 inh./km^2 and a population between 25,000 and 50,000; and
- 100 large SMST, with a population density of more than 300 inh./km^2 (but smaller than 1,500 inh./km^2) and a population of more than 50,000.

The corresponding classification is mapped out in Figure 4. Large SMSTs are generally sprawling conurbations which in spite of a medium-sized compact city centre or a constellation of smaller centres, do not achieve globally sufficient density to be considered HDUC in the terms of our classification.

Among them, the most surprising examples are provided by the Porto metropolitan area in

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		DENSITY (inh. / kmq)		
		< 300	> 300 and < 1500	> 1500
POPULATION (inh.)	< 5000	OTHER SETTLEMENTS	VST (Very Small Towns)	
	> 5000 and < 25000		Small SMT	
	> 25000 < 50000		Medium SMT	
	> 50000		large SMT	HDUC (high-density urban clusters)

NO DATA

Figure 4. *TOWN Typology of urban settlements based on 3 population classes (TOWN typology 3).* [Colour figure can be viewed at wileyonlinelibrary.com]

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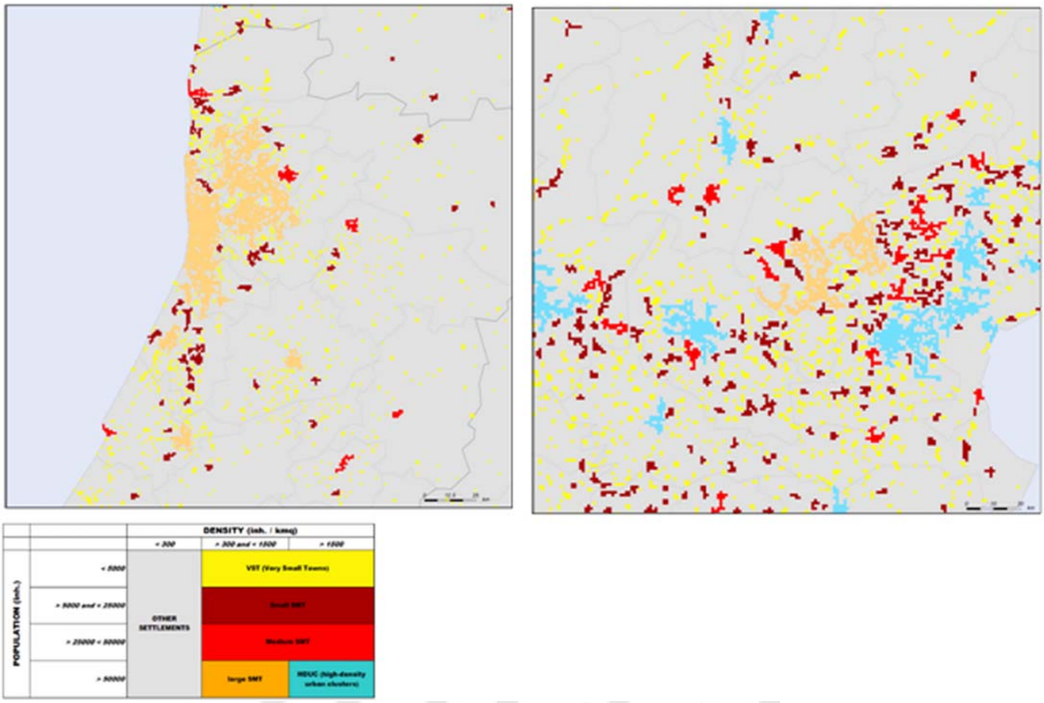

Figure 5. *Zoom-in maps of Typology 3 urban settlements in (a – left side) Northern Portugal (Porto metropolitan region) and (b –right side) Western Veneto (Vicenza and Verona provinces).* [Colour figure can be viewed at wileyonlinelibrary.com]

Northern Portugal (2.5 million inhabitants), and setting around a population of half million, the Saar area in Western Germany, many ribbon-shaped intermediate systems at the edge of the Brussels metropolitan region in Flanders and Wallonia, and multi-polar small

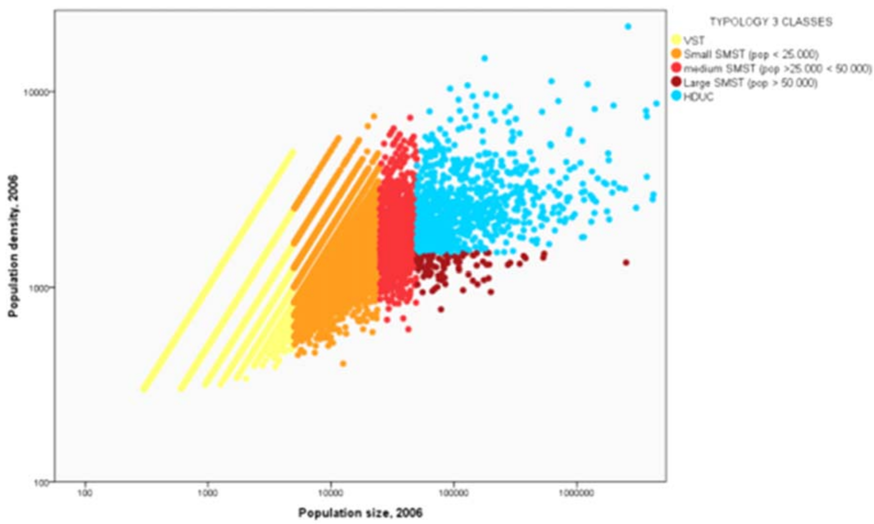

Figure 6. *Cross-plot of populations and densities of SMST in TOWN typology 3.* [Colour figure can be viewed at wileyonlinelibrary.com]

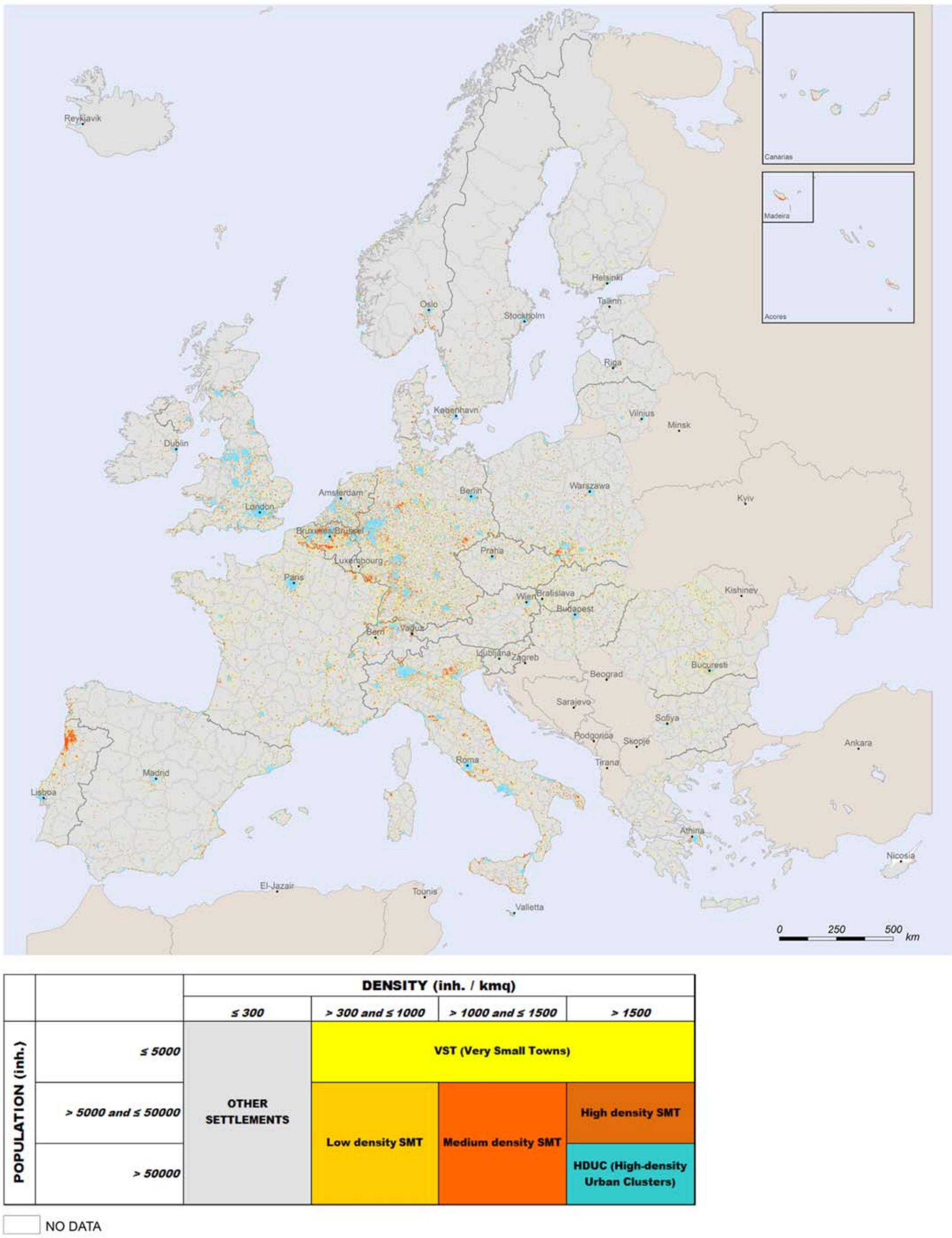

Figure 7. *TOWN Typology of urban settlements based on three population density classes (TOWN typology 4)*. [Colour figure can be viewed at wileyonlinelibrary.com]

Table 3. •••

Classes	Delimitation criteria	Count	Av. Pop	Av. Sq.km	Av. Density	Total pop. in this class	As % of ESPON space*
High-density Urban Clusters (HDUC)	Pop. > 50,000, AND Pop. Density > 1,500 inh/km^2	850	275,476.10	92.3	2,927.10	234,154,670	46.3%
Low-density SMST	Pop > 5,000, AND Pop. Density > 300 < 1,000 inh/km^2	1606	8,947.97	10.7	837.43	57,374,411	11.4%
Medium-density SMST	Pop > 5,000, AND Pop. Density > 1,000 < 1,500 inh/km^2	3382	14,994.13	11.9	1,242.96	50,710,155	10.0%
High-density SMST	Pop > 5,000 < 50,000, AND Pop. Density > 1,500 inh/km^2	3,426	16,746.76	8.1	2,152.39	14,370,443	2.8%
Very Small Towns (VST)	Pop. < 5,000 AND Pop. Density > 300 inh./km^2	69,043	1,193.10	1.7	699.3	82,376,586	16.3%

towns' system in the Western Veneto region. 'Zoom-in maps' of Northern Portugal and Western Veneto regions are provided in Figure 5 (a) and (b).

The distribution of the three classes is captured by Figure 6, which cross-plots the various classes in this typology in terms of their population size and density (in logarithmic scales). The ribbon-shaped configuration is due to the discrete nature of surface values which produce discontinue values of density.

This figure shows the relative dimensions and distributions of the various urban settlement classes in this typology along the two defining dimensions. It highlights the relatively large number of small-sized towns (below 25,000 inh.), compared to medium-sized towns above 25,000, and, within them, the 'anomaly' of large SMST with a population of more than 50,000 but a density lower than 1,500 inh./km^2.

Density thresholds – A second advanced typology of urban settlements (TOWN Typology 4) introduces an intermediate density threshold of 1,000 inh./km^{2}and identifies:

- 1,606 low-density SMST, with a population of more than 5,000 and a population density between 300 and 1,000 inh./km^2;
- 3,382 medium-density SMST, with a population of more than 5,000 and a population density between 1,000 and 1,500 inh./km^2; and
- 3,426 high-density SMST, with a population of more than 5,000 (and less than 50,000) and a population density of more than 1,500 inh./km^2.

The correspondent classification is mapped out in Figure 7, and key stats of this typology are offered in Table 3. In this map, the majority of SMST in most countries belong to the higher density class, coinciding with traditional market towns and secondary poles in metropolitan regions, but we can also devise the presence of low-density SMST clusters around large metropolitan areas like Paris, Athens or Rome, and more diffused medium-density SMST networks in industrial areas in the Flanders, Northeast Italy, and Southern Poland, as well as on Italian coasts and along the main communication arteries in the European core.

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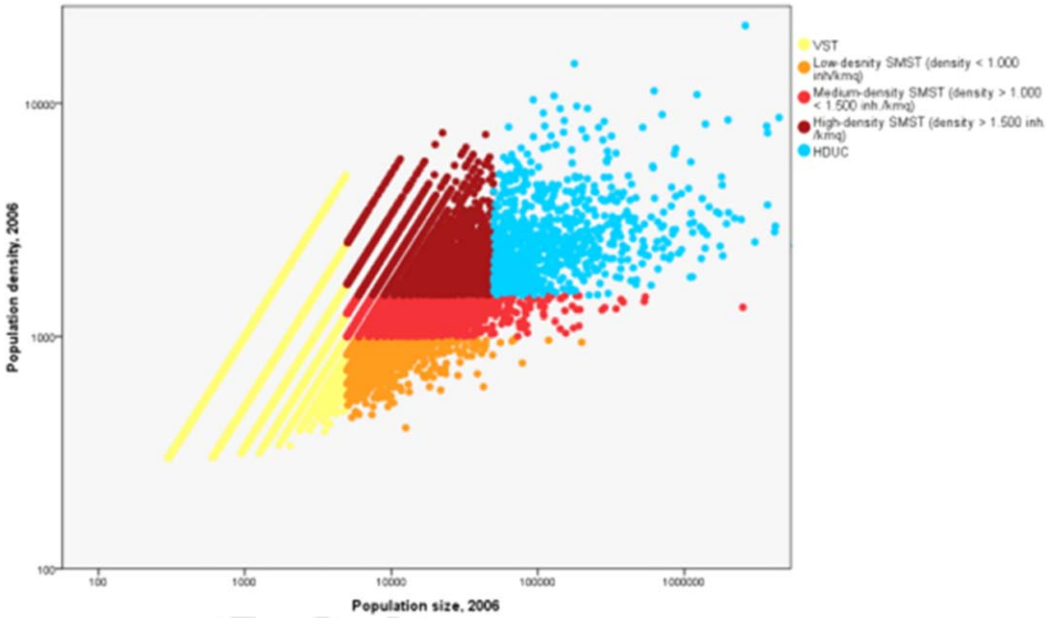

Figure 8. *Cross-plot of populations and densities of SMST in TOWN Typology 4.* [Colour figure can be viewed at wileyonlinelibrary.com]

Figure 8 cross-plots the values of population and density of the three SMST classes so obtained. In contrast to Figure 5, this plot returns an image of a more balanced membership of the three classes of SMST, distinguishing neatly low density urban settlements (in orange), arguably identifying sprawling sectors at the fringe of metropolitan areas and other higher density nuclei, with the 'core' groups of average density SMST (in darker orange) and high-density SMST, having a comparable urban fabric but a lower population size than larger cities.

Spatial patterns of SMST – These classifications allow a first observation of spatial distribution patterns of SMST polygons, which will be further extended in analytic terms in other papers included in this special issue (namely by Smith and Servillo & Russo), relating urbanisation structures with local and regional performance. In this purely exploratory exercise we rather look at the existence of general trends of concentration and dispersion of small and medium sized town throughout the ESPON space.

Figure 9 maps a kernel representation[6] of the dispersion of the centroids of SMST polygons and plots the average of such values within NUTS3 regions against the locations of HDUC centroids. The technique used to build kernel dispersion measures guarantees that this analysis does not depend by the uneven scale of NUTS 3 delimitations. The map shows a high concentration of SMST in the most densely populated NUTS 3 regions of the ESPON space of the EU core, which is expected. Yet the correlation index between the average kernel values and population densities of NUTS3 is not particularly high (R^2: 0.16), leaving space for a large variation according to territorial contexts.

Indeed, when picking correlations nation by nation, such correlations are significant at the 1 per cent level only for the cases of Bulgaria (R^2: 0.54), Germany (R^2: 0.19), Greece (R^2: 0.39), Finland (R^2: 0.75), France (R^2: 0.45), Italy (R^2: 0.27), and Sweden (R^2: 0.64), plus Iceland and Malta. In most other countries the relation is looser and only significant at the 5 per cent level (Denmark, Hungary, Latvia, Portugal, Romania) or not significant in all other cases, whereas in the Netherlands, Spain and Switzerland it is (not significantly) negative.

Although the size and shape of SMST is not taken into account in this analysis, this

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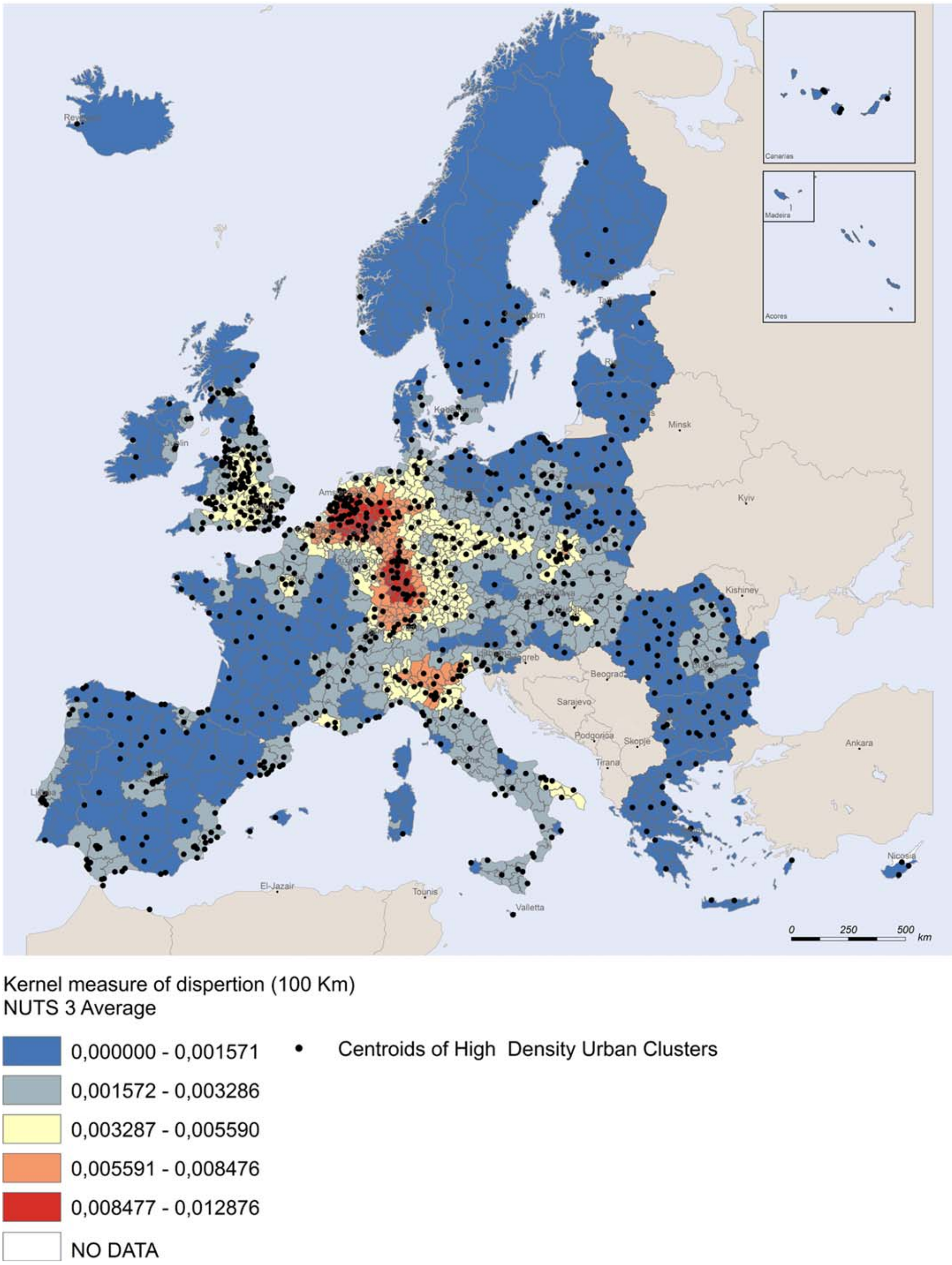

Figure 9. *Kernel analysis of SMST centroids, 100 km search radius.* [Colour figure can be viewed at wileyonlinelibrary.com]

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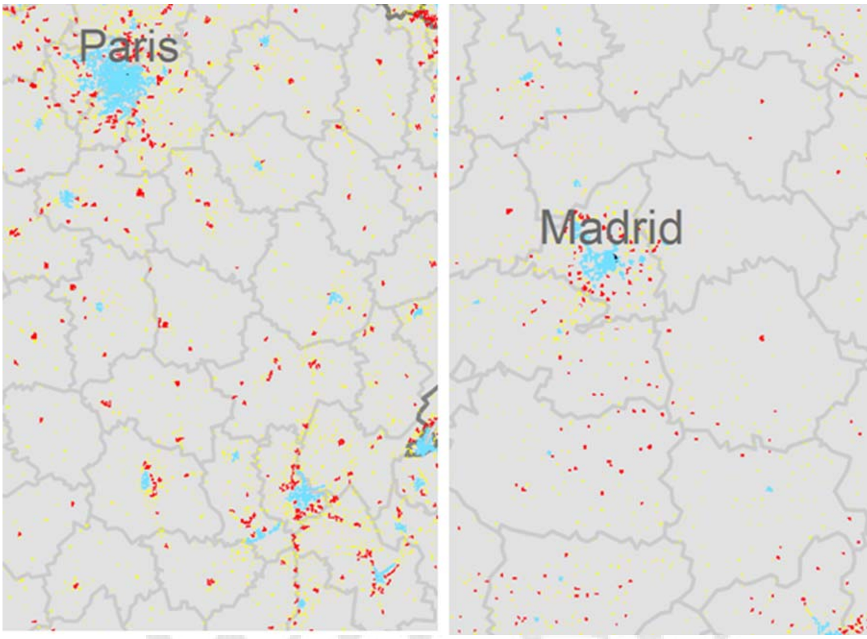

Figure 10. *(a) urban structure of the estern region of Germany; (b) urban structure of the central region of Spain.* [Colour figure can be viewed at wileyonlinelibrary.com]

suggests a certain diversity of territorial population structures, with regions and countries where SMST are rather organised in dense urban hierarchies pivoted by HDUC and other situations in which the territory has a more balanced and loose structure of SMST which does not strictly depend on the role of HDUC but rather tends to form regional systems pivoted by SMST themselves. As two exemplary representations of these territorial structures, we show in Figure 10 *a* and *b* two ‘zoom in’ maps of the German Western region and of the central region of Spain.

CONCLUSIONS

By way of conclusions, we point at the value that this exercise may have in the scope of an enquiry into the role of small and medium-sized towns in their territorial context and for further research into this topic. However functional to subsequent tasks, this geomatic exercise is per se a relevant legacy of the TOWN project: from a methodological point of view, because it contributes towards the creation of a geo-database at the finest spatial scale beyond the limitations of unevenness in scale, nomenclature, and political status, which is known to affect spatial analysis carried out at the ‘traditional’ administrative levels of NUTS 2/3 or LAU 2. From a scientific perspective, it provides a first impression of territorial structures of urbanisation throughout Europe, at different scales: the pan-European, illustrating the diversity of the European space in terms of prevailing settlement types and their territorial distribution; the regional, especially in relation to urban and metropolitan systems, their compactness and nuclear form; and the local, which looks at the inner structure of urban settlements.

Two pieces of information stand out in this sense: first, that a consistent share of the European population – almost a quarter – does not dwell in large, high-density cities, or in rural areas, which have nevertheless been the main focus of territorial policy by the European Union, let alone being the privileged objects of urban and regional research; and second that the European territory displays a large variety of population and urban system structures, beyond the archetypal metropolitan regional systems by which small and medium-sized towns and conceived (and catered for by regional policy) only as appendices of hierarchical urban systems pivoted by large high-density urban cores.

Notes

1. The TOWN project, a collaborative research project funded by the ESPON 2013 programme, has investigated the status, role and potentials and barriers for development of small and medium-sized towns in their functional territorial context, and provided insights for a new urban and regional strategy focusing on this type of urban settlements as an instrument for achieving the EU policy objective of territorial cohesion. In this sense, the project has filled the gap left by more traditional approaches in which larger metropolitan areas have been situated at the centre of the research (and political) agenda.
2. The procedure might have included the following additional geomatic manipulations carried out in the DEGURBA document:
   - contiguity at diagonal level could be considered; in this case, a larger number of grid cells could fall within urban areas and so larger polygons could be created; and
   - empty gaps inside the polygons could be filled; they may identify empty spaces which nevertheless represents element of urban continuity (a lake, a large park, etc.), and including them in the polygons that surround them would seem appropriate, but from a merely geo-statistical point of view it is better at this stage to leave them out.

   The TOWN project did not eventually carry out these manipulations, having considered that they would have extended the dimension and complicated the morphology of urban area units beyond the analytic needs of the TOWN project; besides, it has been considered that at the relatively smaller scale of SMST settlements, including 'gaps' could lead to a misrepresentation of their morphology.
3. These were three individual countries and (mostly) NUTS 1 regions in seven other different EU member countries, which have been the object of close scrutiny and analysis by TOWN partners and subcontractors: the region of Flanders in Belgium, the Czech Republic, the region of Catalonia in Spain, the Central Region of France, the region of Piedmont in Italy, the region of Mazovia in Poland, Northern Sweden, Slovenia, Wales, and Cyprus.
4. The source geodatabase did not include raster data on Cyprus' population. In order to include the Cyprus ESPON space in our analysis, some further operations needed to be carried out, combining data from the Corine land-cover map (version 16 [04/2012], including data from 2006) and the Cyprus demographic census (2011) at post-code level. This methodology yielded the geomatic identification of 3 HDUC, 2 SMST and 6 VST in the Cyprus ESPON territory. In order to verify the goodness of this approach, an expert opinion was asked to the subcontracted Cyprus case study team. Following their advice, some arrangements on the number and shape of final delimitations were made, establishing 3 HDUC, 10 SMST and 1 VST.
5. LandScan offers a global ambient population distribution considering 30 × 30 minute cells, built through a multivariable dasymetric model. The ambient population is an average population distribution, which considers the spatial extension of livelihood routines of a population beyond its dwelling locations, whereas the former is a dynamic way to conceive population distributions, in contrast to the static properties of the latter. LandScan departs from subnational census data, tailored to the country or region referred, using a number of ancillary data as dependent variables, such as land cover, roads, slope, urban areas, or village locations. The resulting analysis is a dynamic spatial modelling approach revealing where people move around, but unable to show where people dwell or how they do it (Balk *et al.* 2010).
6. This kernel analysis has used 10 × 10 km grids and a search radium of 100 km. It picks for every quadrat the number of SMST centroids, calculates the sum of their distances, and averages these values within each NUTS 3 region.

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