TECHNICAL REPORT

ESPON

Naming UMZ: a database now operational for urban studies

MAIN RESULTS

- <u>From physical zones to urban settlements</u>. Currently, the UMZ (CLC 2000, EEA) are not described by a name. This attribute is yet essential for creating a semantic link to the territory.
- <u>Automatic algorithm</u>. According to the way an UMZ overlaps reference units (LAU or other), a new method attributes automatically one or several names.
- <u>Validation.</u> A final check is done automatically, by comparing results to other European database names. Some particular cases are corrected by expertise.
- <u>A first thematic insight.</u> An exploration of the main features is proposed in the last part. New results are given concerning the European city size distribution, the general and regional density patterns, and the main characteristics of international UMZ.

ESPON 2013 DATABASE
MARCH 2011

EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

39 pages

LIST OF AUTHORS

Anne Bretagnolle, University Paris 1, UMR Géographie-cités

Marianne Guérois, University Paris 7, UMR Géographie-cités

Guilhain Averlant, UMR Géographie-cités

Hélène Mathian, C.N.R.S., UMR Géographie-cités

François Delisle, UMR Géographie-cités

Liliane Lizzi, C.N.R.S., UMR Géographie-cités

Timothée Giraud, UMR Géographie-cités, UMS 2414 Riate

Contact

anne.bretagnolle@parisgeo.cnrs.fr

tel. + 33 1 01 40 46 40 00

TABLE OF CONTENT

1 Stakes and matter

Urban Morphological Zones have been created in 2004 by the European Environment Agency. This data base forms a perspective for the future, for three main reasons: it is constructed using highly automated methods, it is regularly updated (two dates are now available for UMZ perimeters, 1990 and 2000 and the 2006 version will be soon available) and it is fully documented.

This database has however not been widely used to date in urban studies, mainly because it is not operational: the objects are simply spots or patches, without names, and hence without semantic links with the territory. They only constitute a set of geometrical objects, and not of geographical objects. The general aim of this Technical Report is to describe the automatic methods and expertises that have been used for naming UMZ and getting them usable for a first exploration of the European urban settlements.

1.1 Presentation of UMZ

UMZ have been created in order to analyze "the extent of urban land-take in Europe, where sprawl happens and how it is shaped" (*EEA activities*, http://www.eea.europa.eu/themes/urban/eea-activities). An UMZ can be described as "a set of urban zones, defined from land cover classes contributing to the urban tissue and function", forming a continuous built-up area (i.e. laying less than 200 m. apart)[1].

Since September 2009, the geographical coverage of the UMZ 2000 database is the following one:

- the 27 countries of the European Union

- 5 countries in the Balkan region (Albania, Bosnia-Herzegovina, Kosovo, Macedonia and Serbia)

- Norway, Lichtenstein and Island[2].

The UMZ dataset can be downloaded freely on EEA website[3].Different attributes are available:

- Identification code (not the same than for UMZ 1990)

- Population (estimated from JRC's Population density grid, see Javier Gallego, *Joint Research Center*)[4].

- Area and perimeter

[1] Urban Morphological Zones 2000 Version F1v0. Definition and procedural steps, Roger Milego, February 2007, http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=995.

[2] CLC2006 should also cover Switzerland.

[3] http://www.eea.europa.eu/data-and-maps/figures/urban-morphological-zones-umz-2000

[4] For further details, see Downscaling population density in the European Union with a land cover map and a point survey, http://www.eea.europa.eu/data-and-maps/data/population-density-disaggregated-with-corine-land-cover-2000-2.

1.2 From physical zones to urban settlements?

Going from physical zones to urban settlements is not a trivial operation. For example, overlaying on a GIS the UMZ and Google Earth or LAU 2 names is not sufficient: if we make a zoom on Berlin surroundings, it will be easy to put the "Berlin" name on the UMZ whose centroid is the closest to the historic center, but several difficult questions remain:

- Should other close UMZ inside the same LAU 2 receive also the name "Berlin" or another one (for instance, more local names given by Google Earth)?

- What are the reference units for choosing the right names? In most of the cases, city names fit with LAU 2 names (for instance in France, Germany or Belgium, as the eponym name of city fits with the central municipality). But in some other cases, like in Portugal, Greece or Denmark, city names fit with LAU1 names. And it is even more complicated in United Kingdom or Ireland, where city names don't fit with one only administrative level but with other administrative entities.

- How can we manage the case of polycentric cities, like industrial or littoral conurbations? Should they receive several names, for instance when the population is well distributed among the different cores, or just one name?

- What about large cities cases, which are extending now at the scale of one NUTS 3 rather than LAU 1 or 2? Should we give them the name of the eponymous LAU 2 or the name of the region that currently fits with their spatial coverage?

- How ensuring a quick update of UMZ names, facing the evolution of perimeters (corrections or new dates), the evolution of population density grid (JRC), or the need to apply the methods to smaller objects (in the current data base, names are given only to UMZ larger than 10 000 inhabitants, i.e. less than 50 % of the total number of UMZ)?

The answers given to these different questions are discussed and fully described and illustrated in the following sections of the Technical Report.

1.3 A new version of UMZ data base

Different adjustments have been made to UMZ database in order to facilitate its use by ESPON partners. UMZ larger than 10 000 inhabitants have been considered (a total of 4437 UMZ).

- Updated Population: using automatic methods, we have updated the population of all the UMZ with the last version (v.5) of the Population density grid built in 2007 by *Joint Research Center*[5]. The scale used for this grid is 100x100 meters.

- New indicators: Name(s), Centroid[6], Density (inh./km^2), Country[7], International code (number of countries crossed by the UMZ), International index (% of population not living in the main country).

[5] Gallego J., 2007; Downscaling population density in the European Union with a land cover map and a point survey, http://dataservice.eea.europa.eu/dataservice.

2 Naming methodology

2.1 Automatic algorithms

2.1.1 General presentation

The methodology that has been chosen is largely inspired by the one used by French Census Board (INSEE) to give names to French urban areas (*unités urbaines*)[8]. Rules and criteria have been elaborated to differentiate three types of spatial configurations resulting from the overlap of UMZ data base, Population density grid and the reference units data base (i.e. the data base that has been selected for giving the names, for example LAU 2) (Figure **1**).

In the first situation, the major part of the UMZ population (more than 50%) is located inside one reference unit[9]. The urban settlement extends rather clearly around one morphological centre, and receives one name.

In the second and third situations, no reference unit concentrates more than 50 % of the UMZ population: we retain therefore the unit that has the major contribution as the main one, then we examine the other reference units that largely contribute to the UMZ population. If they represent more than 50% of the main reference unit contribution, we retain them and the UMZ is considered as "UMZ with several cores" (Situation 2). If not, we keep only the main reference unit for naming UMZ. It is then considered as "UMZ with a weak core" (situation 3).

- *Situation 1 : UMZ with a strong core* (it receives one name)
- *Situation 2: UMZ with several cores* (it receives several names)
- *Situation 3: UMZ with a weak core* (it receives one name)

2.1.2 Algorithm steps and illustrations

In order to simplify the presentation of this sub-section, the selected reference source for city names is LAU 2.

---

[6] The centroid is the centre of gravity computed as the average of the coordinates of all the UMZ's vertices.

[7] If the UMZ overlays more than one country, it is associated to the country which includes the largest part of the UMZ population (main country)

[8] « Composition communale des unités urbaines, Population et délimitation 1999, Nomenclatures et codes » ; INSEE, mars 1999.

[9] We have retained, like INSEE, the minimal threshold of 50% inhabitants, which gives rather goods results (see validation section below).

The methodology can be presented as a succession of steps or algorithms. Each step involves automatic calculations.

2.1.2.1 Geometrical and statistical sources

Three different types of objects are overlaid:

- UMZ 2000[10]

- Population density grid from JRC (version 5)[11]

- Local administrative units (LAU 2, EuroBoundaryMap 2006 v2.0 from EuroGeographics, validity: 2006).

2.1.2.2 Computation steps

We compute the population intersecting LAU and UMZ and we observe the maximal value for each LAU related to one UMZ.

Let L describe the LAU and u the UMZ. After the intersection, let $L(u)$ be the part of the LAU L intersecting the UMZ u, and $P_{L(u)}$ be the population of this part, when P_u. is the population of the whole UMZ.

$$P_u = \Sigma \{ P_{L(u)}, L \text{ intersecting } u \}$$

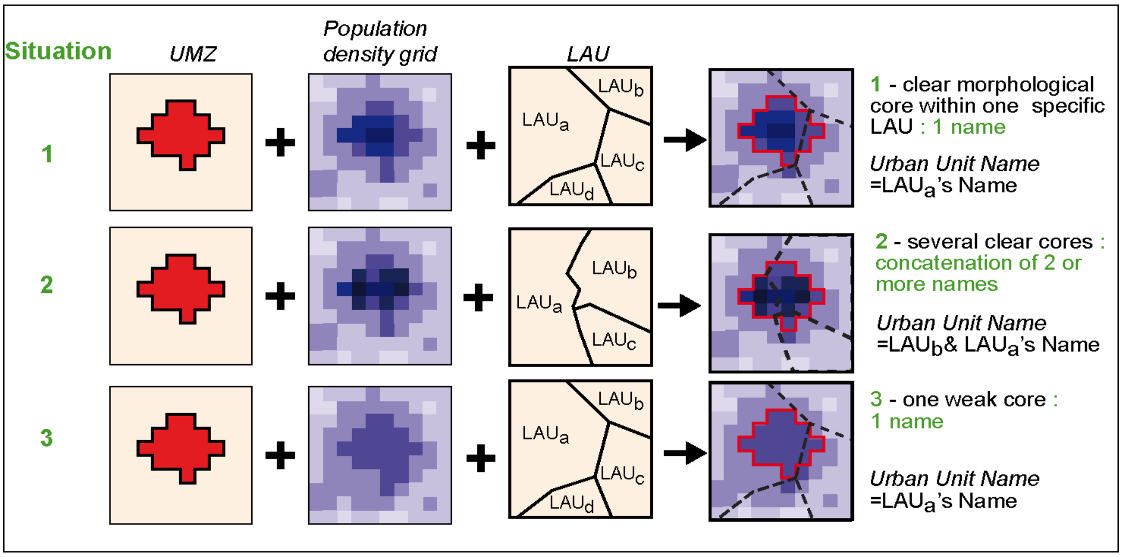
Thus for each UMZ u , the series of $\{ P_{L(u)}, L$ intersecting $u\}$ is considered, ranked by decreasing order, and let then $L_i(u)$ be the i^{th} part in this ordered series.

For a given UMZ u, three different situations can occur (Figure 1).

[10] Latest version given by the European Topic Center on Land Use and Spatial Information (ETCLUSI) in June 2010, which should be available in the future EEA dataserver. Official distribution: http://www.eea.europa.eu/data-and-maps/figures/urban-morphological-zones-umz-2000.

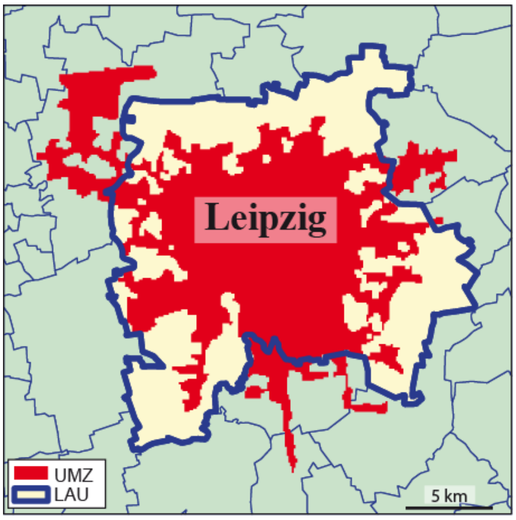
[11] http://www.eea.europa.eu/data-and-maps/data/population-density-disaggregated-with-corine-land-cover-2000-2/population-density-grid-geotiff-format.

Figure 1 : Naming methodology (Situation 1, 2 and 3)



SITUATION 1: The largest population of the LAUs intersections is more than 50% of the UMZ's population. We have an UMZ with one strong core, clearly organized around one center. The UMZ is named with the name of this LAU_a (Figure 1). This is the case of Leipzig example (Figure 2).

Figure 2 : Leipzig (Germany), an UMZ with one strong core (Situation 1)



UMZ population: 536 552 inh.
UMZ population in Leipzig LAU 2: 483 285 inh.

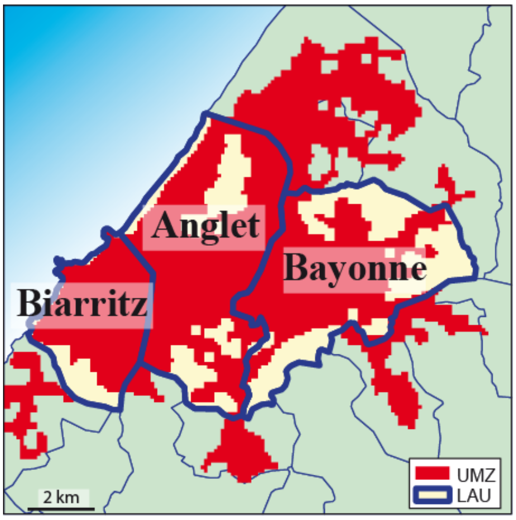
Sources: LAU 2 (EuroBoundaryMap 2006, v2.0) from EuroGeographics, UMZ2000 from European Environment Agency, Population density Grid v.5 from Joint Research Center.

SITUATION 2 and 3: There is not a unique main core as defined above, thus the larger part is retained as the reference, and the other parts are considered successively, in decreasing order of population, as long as their populations exceed 50% of the first part population.

$$\textit{Secondary units}=\{\boldsymbol{L_j(u)}\ /\ \boldsymbol{P_{Lj(u)}} >= 0.5 * \boldsymbol{P_{L1(u)}}\}$$

Situation 2 : one or several secondary units' population represent more than 50% of the population of the largest part. We retain the name of the concerned secondary units, and the final name of the UMZ is a compounded name. The order of the names is not alphabetical but follows the decreasing order of population contributions to UMZ. This is the case of Bayonne-Anglet-Biarritz (Figure 3).

Figure 3 : Bayonne-Anglet-Biarritz (France), an UMZ with several cores (Situation 2)

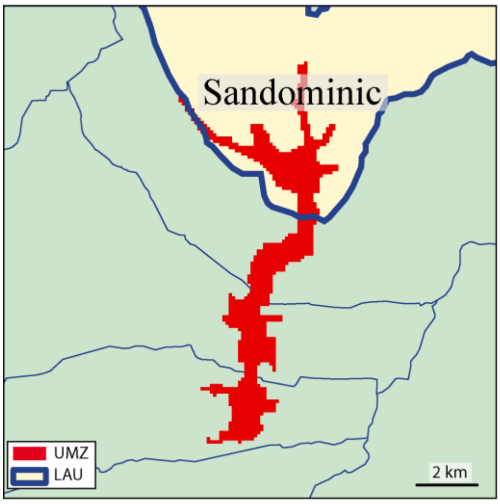


UMZ population: 128 554 inh.
Bayonne LAU 2 population inside UMZ: 39 708inh.
Anglet LAU 2 population inside UMZ: 35 185 inh.
Biarritz LAU 2 population inside UMZ: 30 156 inh.
Other LAU 2 population inside UMZ < 12 000 inh.

Sources: LAU 2 (EuroBoundaryMap 2006, v2.0) from EuroGeographics, UMZ2000 from European Environment Agency, Population density Grid v.5 from Joint Research Center.

Situation 3: no secondary unit's population represents more than 50% of the larger part. We retain finally only the name of the main LAU unit, fitting again with a "one core" context (one morphological core, but less strong than in Situation 1) (Figure 4).

Figure 4: Sandominic (Romania), an UMZ with one weak core (situation 3)



UMZ population: 10 678 inh.
Sandominic LAU 2 population inside UMZ: 4 893 (46% of total UMZ inhabitants)
Other LAU 2 population inside UMZ < 2446 inh.

Sources: LAU 2 (EuroBoundaryMap 2006, v2.0) from EuroGeographics, UMZ2000 from European Environment Agency, Population density Grid v.5 from Joint Research Center.

The different steps of the algorithm can be summarized by:

IF $\boldsymbol{P_{L1(u)}} \geq \mathbf{0.5} * \boldsymbol{P_u}$ THEN Name($\boldsymbol{u}$)=Name($\boldsymbol{L_{1(u)}}$)

ELSE IF *Secondary units*={$\boldsymbol{L_j(u)}$ / $\boldsymbol{P_{Lj(u)}} \geq 0.5 * \boldsymbol{P_{L1(u)}}$} $\neq \emptyset$

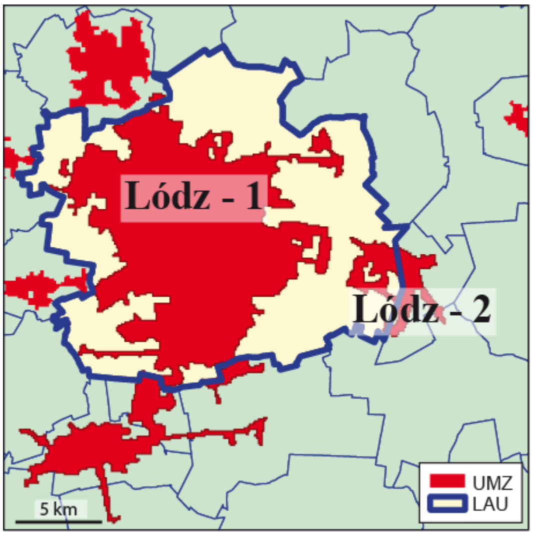
THEN Name($\boldsymbol{u}$)=Name($\boldsymbol{L_{1(u)}}$)+{Name($\boldsymbol{L_{j(u)}}$), j / $\boldsymbol{P_{Lj(u)}} \geq 0.5 * \boldsymbol{P_{L1(u)}}$}

ELSE Name($\boldsymbol{u}$)=Name($\boldsymbol{L_{1(u)}}$)

2.1.2.3 A particular case: different UMZ with identical names

In the large majority of cases, each UMZ could be associated to a unique name (situations 1 and 3) or to a unique combination of names (situation 2). However, in about 10% of the cases, several UMZ share the same administrative unit. It is for instance what happens in the case of the city of Lódz in Poland (Figure 5): the most populated parts of two different UMZ fall into the same LAU2, so that they both receive exactly the same name. In order to maintain the attribution of distinct identifiers for UMZ, we add a number after the name, according to the decreasing size of UMZ populations (Lódz - 1 and Lódz - 2).

Figure 5 : Lódz (Poland), two UMZ with the same name

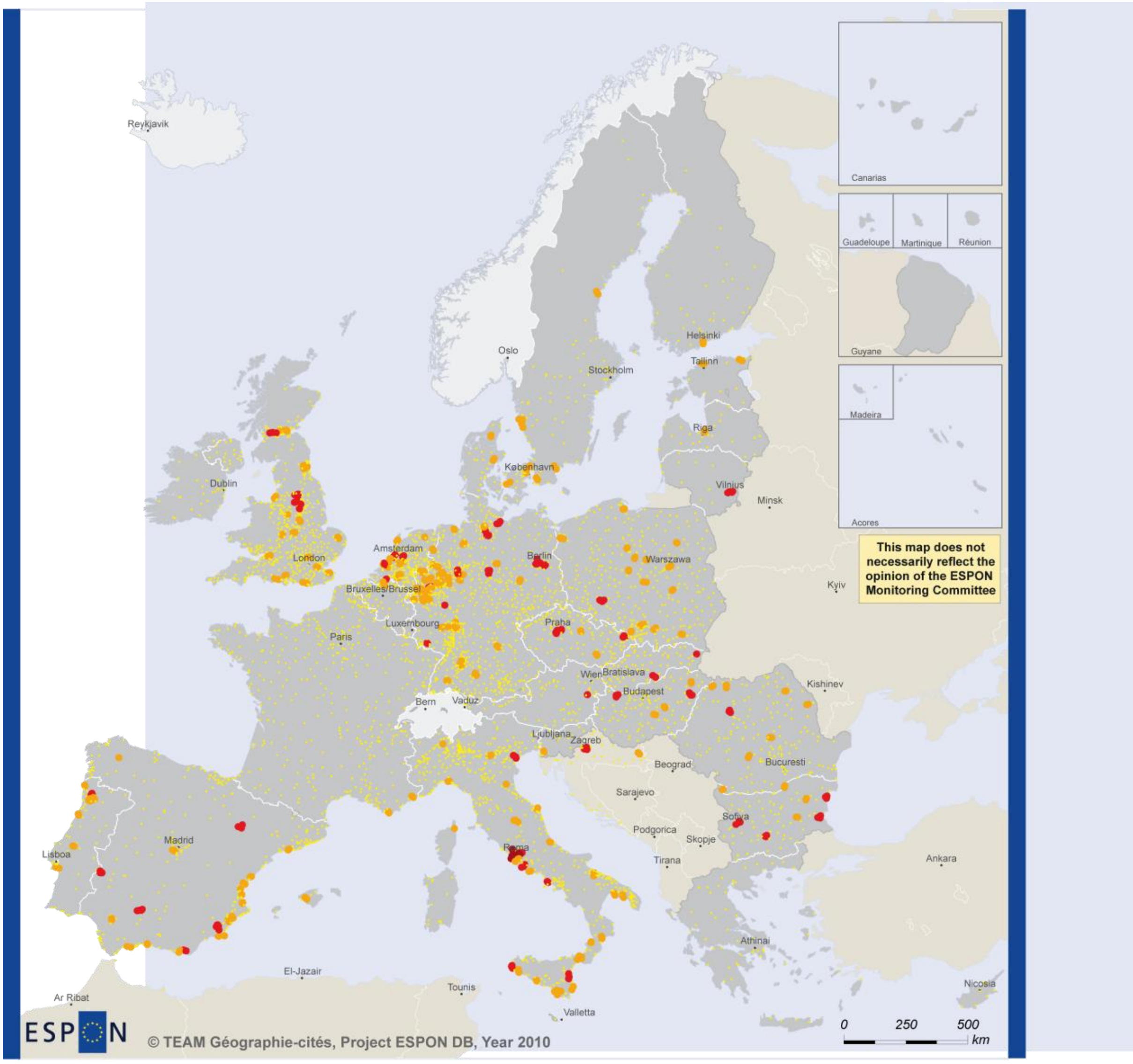


UMZ Lódz - 1: 822545 inh.
UMZ Lódz - 2: 43894 inh.

Sources: LAU 2 (EuroBoundaryMap 2006, v2.0) from EuroGeographics, UMZ2000 from European Environment Agency, Population density Grid v.5 from Joint Research Center.

Figure 6 displays the location of those cases all over Europe. They appear to be quite well distributed from one country to another, even if some regions concentrate a large number of cases (like in the Rhine-Ruhr Valley or in the Netherlands) and even if some countries do not host any of them (like in France, where administrative units are particularly small).

Figure 6 : UMZ 2000 with identical names



EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

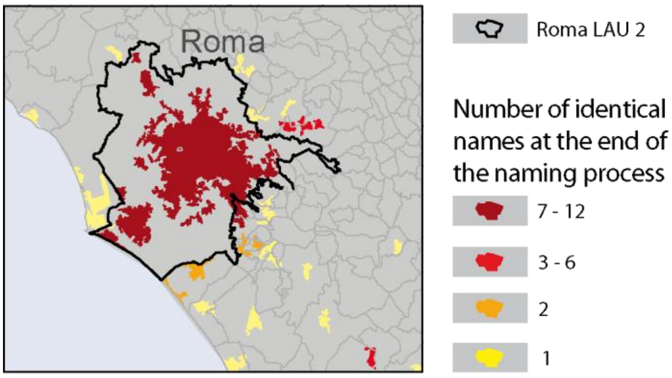
Regional level: NUTS 0
Source: ESPON DB, year 2010
Origin of data: The European Environment Agency (UMZ 2000 V.2), Joint Research Center (Density Grid V.5), LAU2 (2006, V.2) and national sources (see figure 9)
© EuroGeographics Association for administrative boundaries

Number of identical names at the end of the naming process

- 7 - 12
- 3 - 6
- 2
- 1
- no UMZ data

In most of the cases, only 2 identical names result from the naming process, and in a few cases we obtain 3 to 6 repetitions of the same name. The last class in the map (more than 6 repetitions) is only illustrated by Roma: 12 UMZ share this name! This is due to the very large size of the Roma LAU 2 (Figure 7), where local units have probably been merged into a unique metropolitan level.

Figure 7 : The case of Roma: 12 UMZ sharing the same name



Sources: LAU 2 (EuroBoundaryMap 2006, v2.0) from EuroGeographics, UMZ2000 from European Environment Agency, Population density Grid v.5 from Joint Research Center.

2.2 Automation of processing chain

2.2.1 The need for an automated process

The automation of the rules defined for naming UMZ is necessary for three main reasons:

- The inputs represent a huge mass of data emanating from different files which requires automatic support instead of manual process inside a GIS:
    UMZ: 4 437 UMZ over 10 000 inhabitants
    Euroboundary, LAU2: 106 452 administrative units
    Population Grid: More than 2 billion pixels in the density grid

- The calibration of the naming method supposes to conduct different tests which are useful to choose the right administrative level of reference in some specific cases (see below, 2.3.1).

- The databases contents are constantly evolving and it is essential to be reactive to these changes. Automation allows quick updating with new versions of sources or methods (EEA and JRC; for example, there are at least two different versions of UMZ2000) or new dates (as regards for instance to the integration of the future UMZ 2006, 2010…).

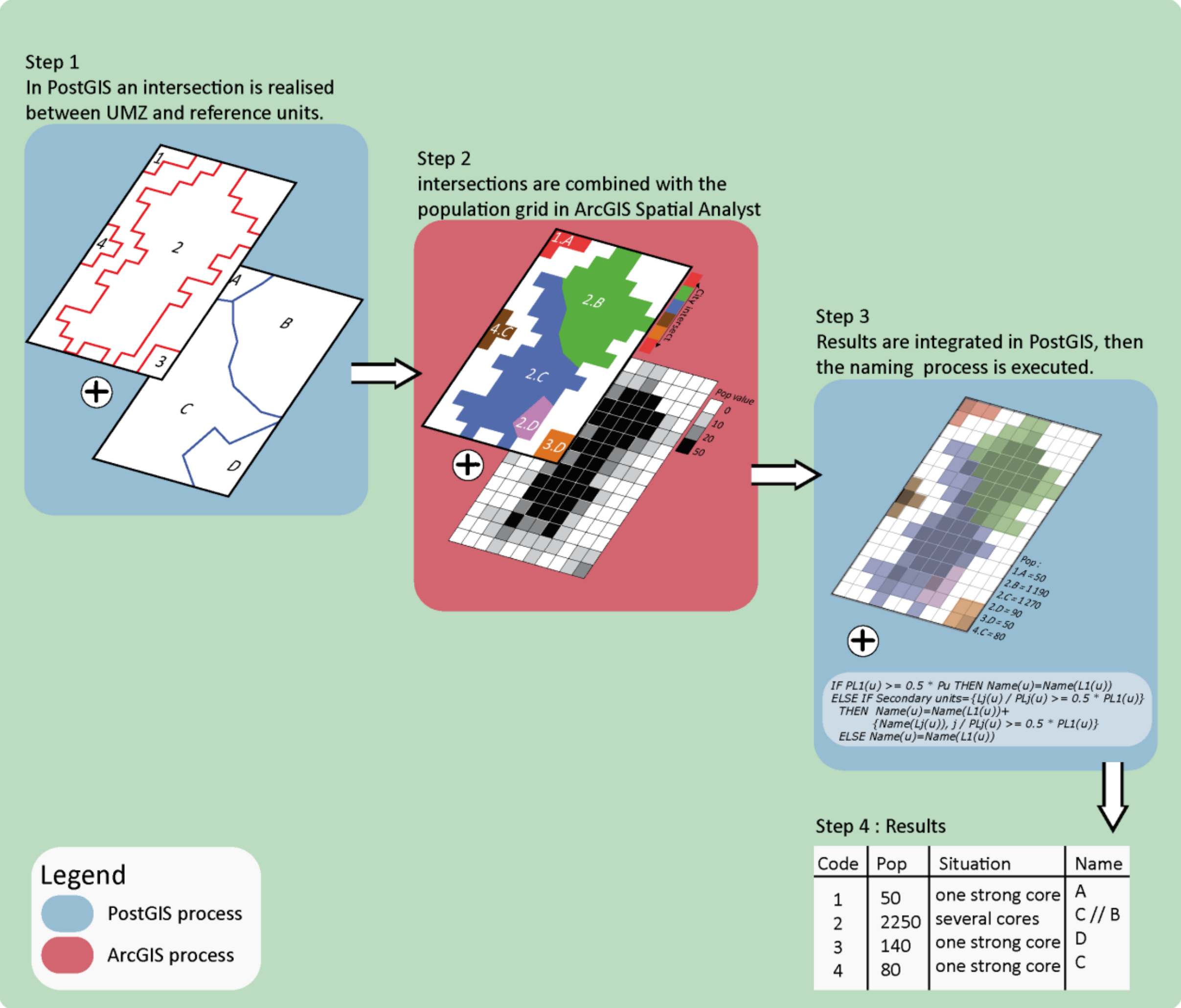
2.2.2 Process description and software solution

From a technical point of view, the automated implementation of the naming algorithm is based on three different steps which have been executed through

PostGIS and ArcGIS softwares, thanks to an integrated processing chain (Figure 8)[12]:

- Step 1: the geometrical intersections between the UMZ and the reference units are created through PostGIS
- Step 2: the population of the resulting intersections is calculated with ArcGIS Spatial Analyst. To a recent date indeed, PostGIS could not allow manipulating any raster data and the program had to use the raster solutions of the spatial analyst add-on of ESRI®. A Python language program using the Geospatial Data Abstraction Library (GDAL) has thus been developed to interface the two softwares.
- Step 3: the population computed is retrieved and integrated into PostGIS, in which the algorithm of naming is implemented

Figure 8 : The different steps of the processing chain



This program can process all the data and all the steps at once, which prevents from errors and duplicates. Eventually the automatic naming for the whole Europe could be realized in about one hour.

[12] Ultimately, this program should only rely on open sources technologies. The statistical processes can be now implemented through a PostgreSQL database with the help of the PostGIS add-on, which allows processing data with a geometry and realizing spatial requests.

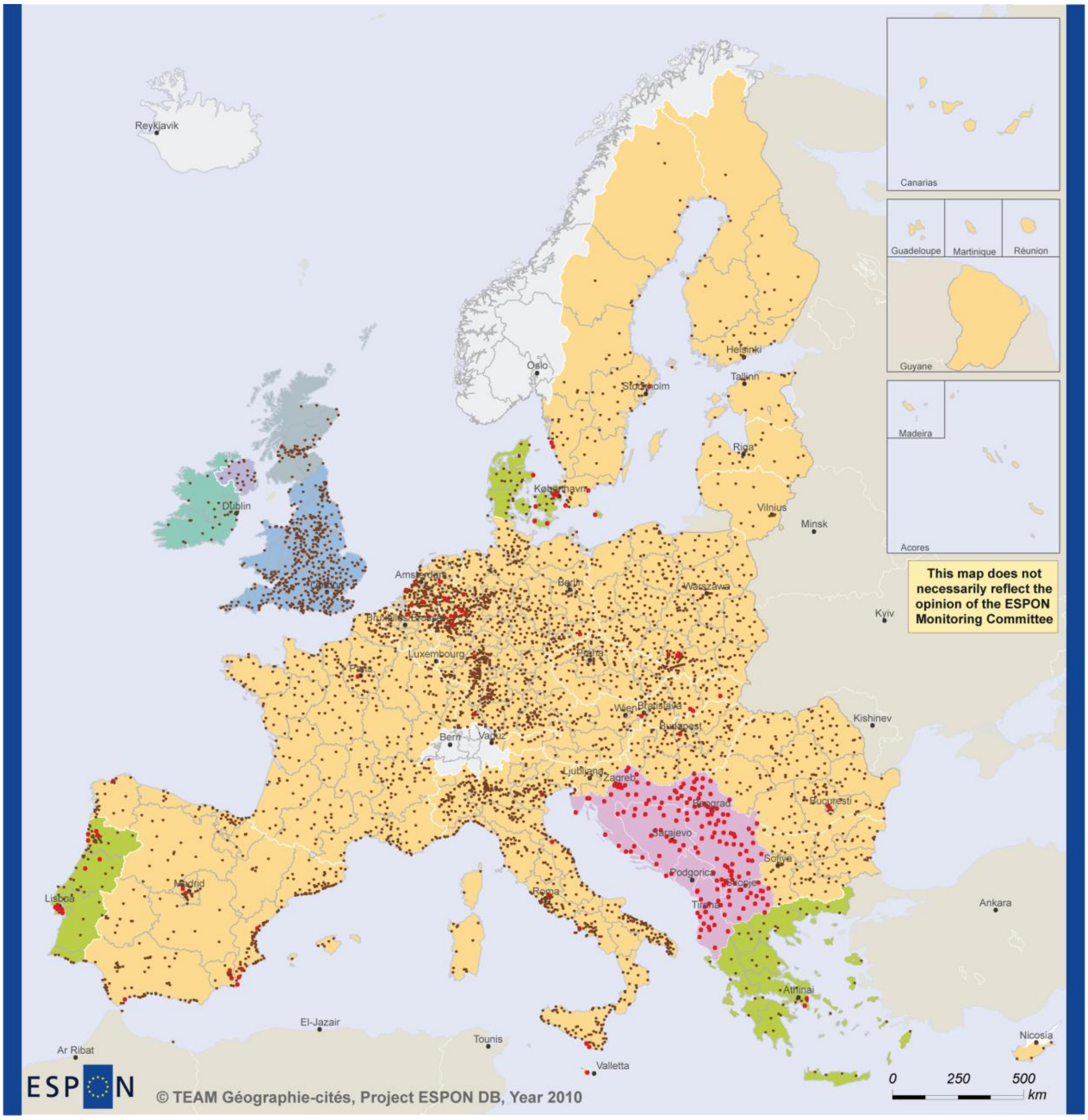
2.3 Expertise and validation

The validation of the naming method results from an expertise based on a comparison with the relevant national data base for city names (LAU 2 in majority, but also LAU1 or national settlement areas). Final results are then systematically matched to other sources (Eurostat, Geopolis) for validation. The last particular cases are checked manually, using Google Earth.

2.3.1 Selecting relevant reference units

The identification of relevant units of reference for choosing UMZ names deals with a critical issue: is there a semantic level more suitable than another for naming towns and cities? At first sight, LAU 2 seems to be the most accurate level and the most usual reference at European scale. This level is relevant in the large majority of cases, but it cannot be used for the whole countries: the correlation between cities usual names and administrative levels names depends indeed on the history of administrative divisions and on the way the status of city was formerly given. It may thus vary in some countries or experiment local variations within some countries. The name "Leipzig" fits for instance with LAU 2 level whereas the name "Dublin" fits with LAU 1 level and the name "Paris" with NUTS 3. An expertise was thus necessary to select the best reference unit for each country (Figure 9).

Figure 9 : Relevant reference units for naming UMZ



EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

Regional level: NUTS 0
Source: ESPON DB, year 2010
Origin of data: The European Environment Agency (UMZ 2000 V.2), Office for National Statistics (England & Wales), Nothern Ireland Statistics & Research Agency, General Register Office for Scotland.
© EuroGeographics Association for administrative boundaries

City names

- naming from manual process
- naming from automatic

Sources

Homogeneous sources and data grid population

- SIRE (Lau2 level)
- SIRE (Lau1 level)

No data grid population

- www.citypopulation.de

National sources and data grid population

- *Urban areas* (England and Wales)
- *Settlement Development Limits* (Northern Ireland)
- *Census town* (Ireland Republic)
- *Settlements* (Scotland)

- no UMZ data

2.3.1.1 LAU1 instead of LAU2

In some countries, the relevant administrative level appeared to be rather LAU1 than LAU2. We have used the LAU 1 version of EuroBoundaryMap 2006 v2.0 from EuroGeographics (validity: 2006).

Portugal

In Portugal, the status of a city was formerly given by decree and most of the cities corresponded to LAU 1 capital cities (*capitais de distrito*). This legacy is still present, in the sense that the current names of the LAU 2 have no relation with the names of the cities. We have then chosen LAU 1 (*concelhos-municipios*) for naming UMZ.

Denmark

In Denmark, the LAU 2 level corresponds to a parish level, whose names do not fit with the real names of cities. The most accurate level for naming UMZ is the *Kommuner* level (LAU 1).

Greece

The same issue occurs for Greece where the LAU2 level has no relation with the city name usually used. The LAU 1 level (*Demoi* and *Kointites)* has thus been chosen.

2.3.1.2 NUTS instead of LAU

NUTS level has been selected for some capital cities or other particular cases.

- Paris, Bucharest, and Budapest: the LAU 2 fits with sub-city districts (called "arrondissement" or "sector"), so that NUTS 3 level has been used in the algorithm.

- London: the name "London" is not represented at LAU 2 level (and the algorithm gives a "UMZ with several cores", with several hundred of names) neither at LAU 1 level (28 names obtained). At NUTS 3 level, the names are like "Inner London West" etc., at NUTS 2 level "Inner London" and "Outer London". The best administrative level fitting with the name "London" and with the spatial extent of the UMZ is the NUTS 1.

- Brussels: there is one LAU 2 called Brussels but it is a very little one compared to the present extent of the city, so that the name of the LAU 2 is not retained by the automatic process (the final name of the "UMZ with several cores" would be Antwerpen-Gent). Thus we have chosen the NUTS 3 level ("Arr. de Bruxelles-Capitale / Arr. van Brussel-Hoofdstad"). The definitive name resulting from the algorithm is Brussel-Antwerpen-Gent.

- Valetta (Malta): there is just one administrative level below the national one (a LAU 2 level), and the eponym LAU 2 is too small to emerge from the automatic algorithm in the final name of the UMZ. We have then attributed the name Valetta.

- In Slovakia: Bratislava and Košice are divided in several districts at LAU 2 and LAU 1 levels. The best level for naming is NUTS 3 ("Bratislava region" and

"Košice region") but it is very large compared to the UMZ spatial extents. Here again, we have attributed the names Bratislava and Košice to the UMZ.

2.3.1.3 National settlement areas

In some other countries, neither LAU2 nor LAU1 appeared suitable for naming and national data bases have been used as a reference.

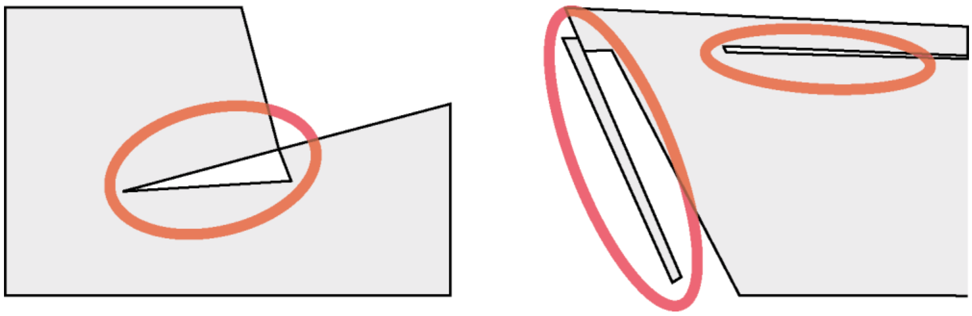
United-Kingdom

In United Kingdom the LAU 2 level does not fit with names given historically to cities. LAU 2 correspond to "electoral wards" (or "parts thereof") and LAU1 to "district/unitary authorities". The city names of the "urban areas" (morphological agglomerations built by the Ordnance Survey) do not necessary fit with LAU2 or LAU1, so that we have used these urban areas as the reference units in the automatic algorithms. Three different data bases have been used:

- *Urban areas* of England and Wales (2001)[13]
- *Settlements* of Scotland (2009)[14]
- *Settlements Development Limits* of Northern Ireland (2005)[15]

The vector format versions of these databases have been kindly sent by the National Statistics Office of United Kingdom. They could be used to give names by spatial requests, after correcting a hundred of topological errors that hampered the application of the automatic processes (Figure 10).

Figure 10 : Some examples of topological errors



Ireland

In Ireland, LAU2 corresponds to "electoral districts" and LAU1 do not systematically fit with the city names given to Census Towns by the Central Statistics Office of Ireland (for example when the LAU1 is a county). We have then used the Census Towns of Ireland (2006) data base, sent in vector format by the National Statistics Office of Ireland.

[13] http://www.statistics.gov.uk/
[14] http://www.gro-scotland.gov.uk/
[15] http://www.cso.ie/

2.3.2 Countries without population density grid

For the 149 UMZ larger than 10 000 inhabitants that are located in Balkan countries (Albania, Bosnia-Herzegovina, Kosovo, Macedonia and Serbia), the population has not been attributed by EEA using the Population density grid but using other sources (www.citypopulation.de). Consequently, the automatic algorithms have not been applied to these 149 UMZ and we have used the same source for giving names.

In order to ensure a good comparability in thematic explorations (section 3) these countries have not been included in the analyses.

2.3.3 Validation process

2.3.3.1 Sources

Implementing an automatic process is essential in order to quickly adapt the naming method to new sources, to avoid errors and to establish the process traceability. Yet it is equally important to validate the resulting names by comparing them to other existing urban databases. Two sources were used to check the quality of the method:

- Geopolis database (Moriconi-Ebard, 1994)
- Eurostat compilation of national city names: database "Geographical names: Settlements"[16]

In each of these databases, the cities are only represented by points (centroids) which are associated to a name. The checking method relies on successive steps:

- First, a spatial overlay of the names attributed by the algorithm and of the names associated to Geopolis and Eurostat databases. This comparison is based on a spatial request that retrieves the centroids intersecting UMZ. Specific spatial patterns have to be taken into account (for instance when Eurostat or Geopolis centroids intersect UMZ "holes").
- Secondly, a semantic comparison. The associated names are gathered into common tables and UMZ naming is validated if the names are the same. In order to optimize the matching process, it is necessary to realize textual corrections: lowercases everywhere, same local abbreviations, same spellings and universal translations (differences like Warszawa/Varsovie, Praha/Prague, Aix en Provence/Aix-en-Provence, etc., have been corrected by choosing the name of the referent database –LAU or national settlement areas-). These corrections enabled to identify and correct 1081 mismatches in names.

[16] http://epp.eurostat.ec.europa.eu/portal/page/portal/gisco/geodata/archives

2.3.3.2 Typology of errors

85 names on 4437 UMZ did not match after those first checks and required case by case semantic modifications. A typology of errors has been proposed in order to make easier the future checks. These errors refer to 4 types of mismatches:

- The name of the reference unit (LAU or national settlement area) does not fit with any urban locality. This case happens generally when the name is related to some topographical features, rather than to the settlement itself (for instance the UMZ named Farum in Denmark was first called Fureso by the algorithm, whereas it is the name of a lake near the city). It happens also sometimes when it refers to a general location (for instance the large LAU named Westland, located in the south of Den Haag, Netherlands, is not suitable for naming the UMZ which corresponds more precisely to Monster locality in Google Earth).

- The name of the reference unit was historically given by an eponymous city that is currently less populated than another city included in this unit. There has been a sort of reversal between historic names and population trends, so that the most important UMZ does not receive the name of the most populated locality. This is for instance the case of the UMZ which is named Pamela (Portugal) according to the algorithm, whereas it should receive the name of the largest city (Pinhal Novo) of this LAU, identified by using Google Earth.

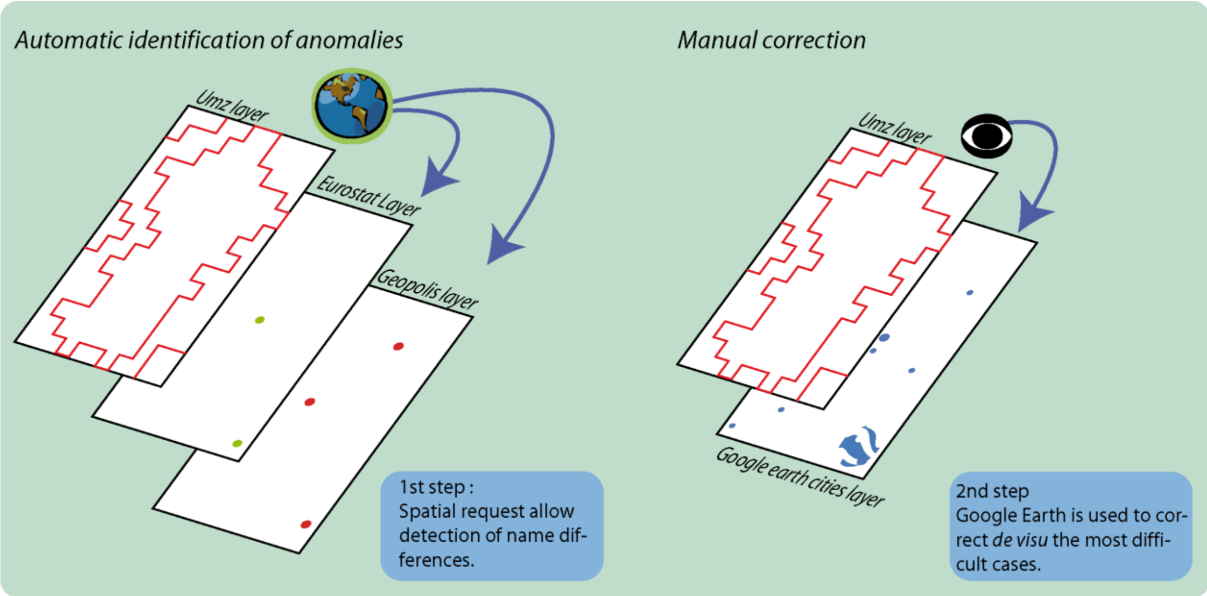
- The manual expertise of UMZ with identical names ("Lodz cases") has revealed another inconsistency: two UMZ included in the same reference unit can receive the same name even if they are very distant from each other. This is for instance the case of the two UMZ named Kristianstad-1 and Kristianstad-2 (Sweden): the UMZ of Kristianstad-2, which is distant from 10.5 km to Kristianstad-1, clearly overlays the locality of Åhus in Google Earth.

- In the peripheral parts of some industrial conurbations (Mannheim, Düsseldorf, Katowice…), a small UMZ located in the periphery of a reference unit takes the name of this unit whereas the most urbanized part of this unit belongs to the conurbation. As this urbanized part counts a relatively few population, the name of the reference unit is not taken into account in the name of the UMZ conurbation, so that this name is finally attributed only to the small UMZ. We have then chosen to give the Google Earth name and not the reference unit name to this small UMZ. An illustration can be given by the case of the locality of Rucheim, in Germany, which is included in the LAU 2 Ludwigshafen, whose larger urbanised part belongs to Mannheim UMZ. As the automatic algorithm gives the name "Ludwigshafen" to the UMZ situated at Rucheim place, we have corrected manually this name.

2.3.3.3 Solutions proposed

Ultimately these remaining mismatches are corrected by referring to the Google Earth database whose names layer is based on Multinet® from TeleAtlas®. The 85 UMZ have been converted to KLM format in order to be overlaid with other Google Earth layers. Names are then corrected *de visu* for the last mismatches (Figure 1).

Figure 11 : Steps of the validation process



2.4 Results : typology of naming situations

A simple count gives a first idea of the results obtained by automatic algorithms coupled with expertise on relevant administrative levels. We have considered UMZ larger than 10 000 inhabitants (4437 objects, including Balkans). The results have been summarized in Table 1:

Table 1 : Naming UMZ through automatic methods

	SITUATION 1 "UMZ with one strong core"	**SITUATION 2** "UMZ with several cores"	**SITUATION 3** "UMZ with a weak core"
Total number	4164	193	80
Percentage	94%	4%	2%

Sources: LAU 2 (EuroBoundaryMap 2006, v2.0) from EuroGeographics, UMZ2000 from European Environment Agency, Population density Grid v.5 from Joint Research Center.

The typology presented in Table 1 has been mapped in Figure 12.If we focus first on "situation 2" (several cores), we recognise the industrial conurbations of the Midlands, the French and Belgium basin, the Ruhr basin, Silesia and Galicia regions. We also identify some sea-side conurbations, for example in Portugal, Spain, Italy or France. Another type of "UMZ with several cores" consists in large cities sprawling and connecting other large and close cities, like in Belgium (around Brussels) or in Romania.

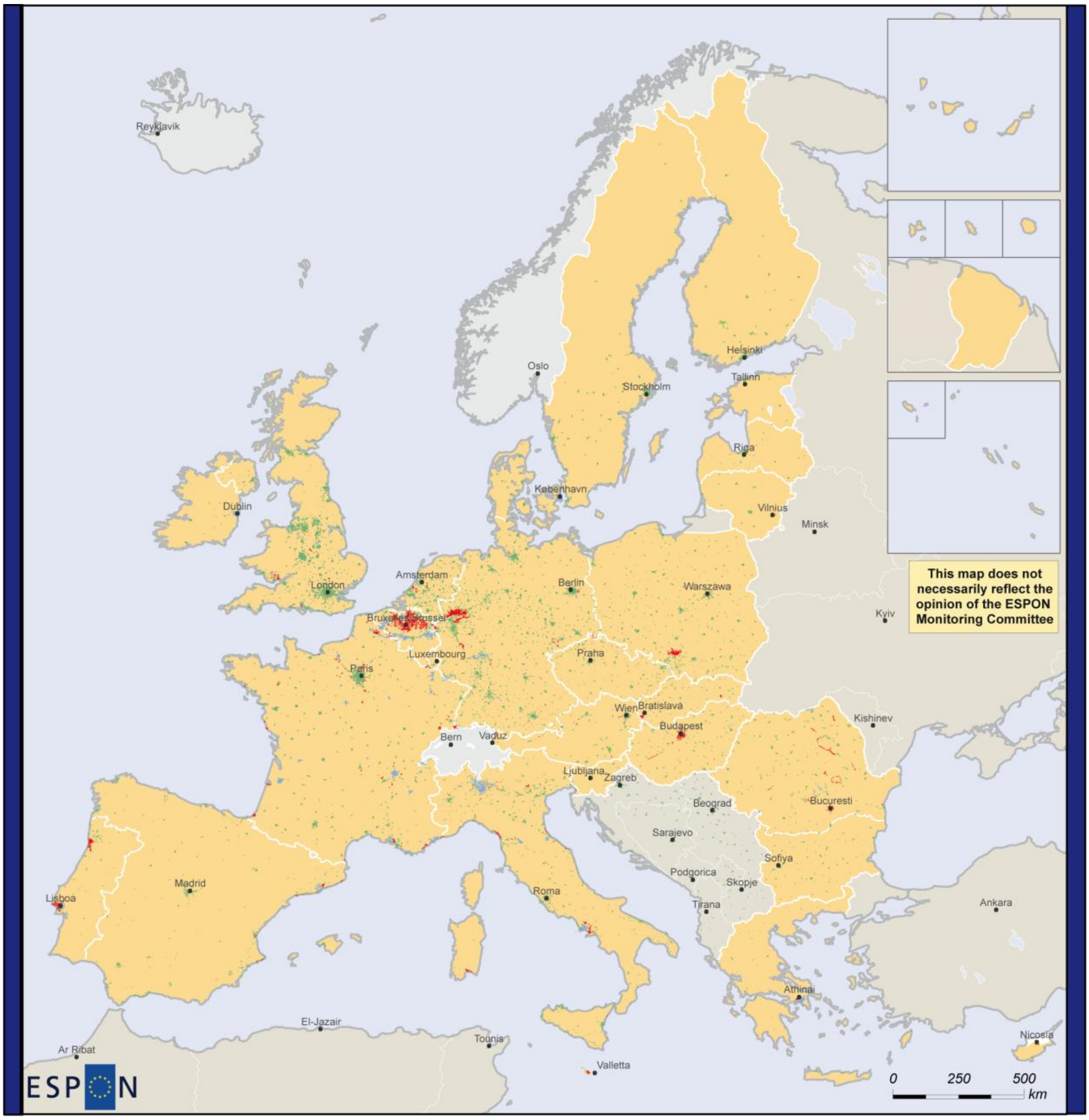
For the "situation 3" (one weak core, less strong than in situation 1), we can notice that locations are mostly the same than for UMZ with several cores (see in Italy, United Kingdom, Belgium, France…).

The "one strong core" cases, which represent the great majority (94% of the UMZ) are spared all around Europe but more represented in Northern Europe

(Sweden, Baltic countries, Denmark), characterised by relatively sparse urban settlements.

Let us notice that it is difficult to give more interpretations: situations 2 and 3 do not necessarily enlighten some "polycentric cities" but may result from the specific local or national average size of the reference units that have been used in the algorithm: we have more chances to obtain a "several cores" situation when this average size is little (like in France), and a real polycentric city could appear as "with one core" if the average size is large (like in Denmark).

Figure 12 : UMZ typology according to naming results



EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

Regional level: NUTS 0
Source: ESPON DB, year 2010
Origin of data: The European Environment Agency (UMZ 2000 V.2), Joint Research Center (Density Grid V.5), LAU2 (2006, V.2) and national sources (see figure 9)

UMZ type :

- Situation 1 : UMZ with one strong core
- Situation 2 : UMZ with one weak core
- Situation 3 : UMZ with several cores
- no UMZ data

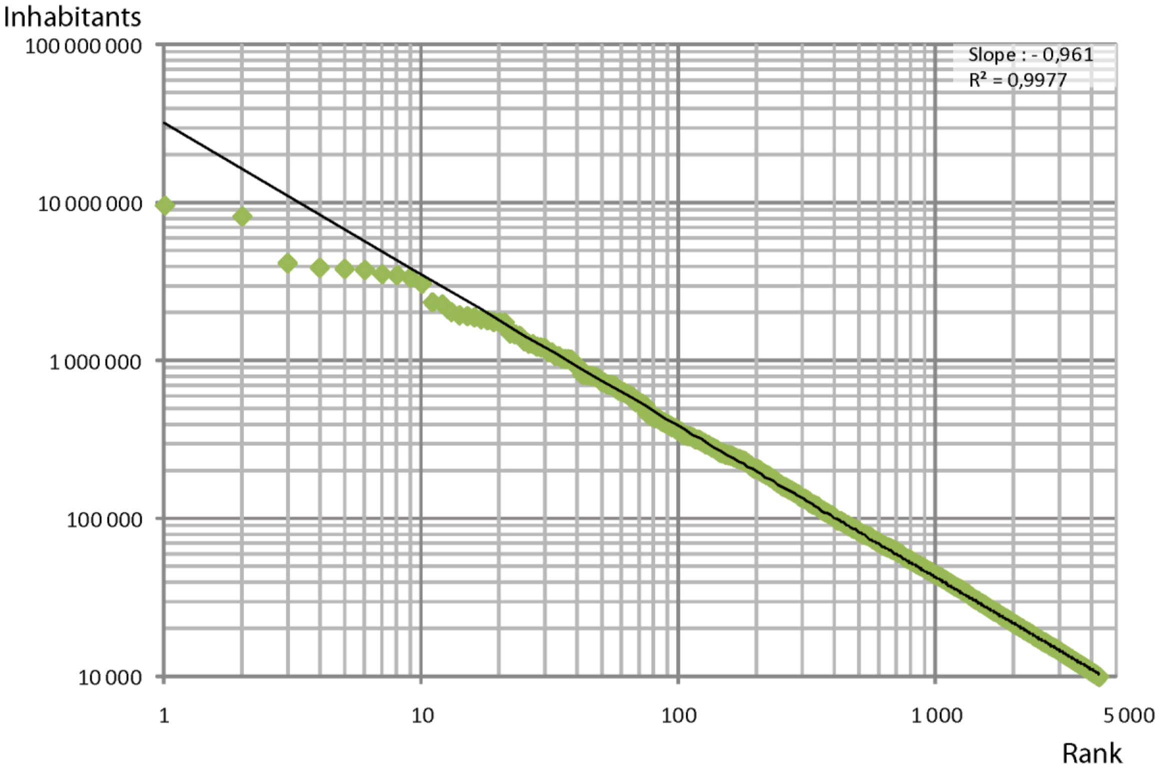
3 A thematic insight into European cities

The UMZ data base is now operational for a deep exploration of the common features and diversity of European urban settlements. Three types of analyses can be presented as a preview: in addition to classical indicators referring to the hierarchical structure of city systems or to the population density of cities, a new indicator has been created to identify and compare international UMZ.

3.1 Urban hierarchy and city-size distribution

The classical rank-size distribution, plotted for the 4437 cities over 10 000 inhabitants (Figure 13), confirms the very high regularity of the hierarchical structure at the European level (the determination coefficient R^2 equals to 0.99). The absolute value of the slope, used as an indicator of city size inequality level, is 0.96, very close to other values computed by European researchers with former databases (for instance, Geopolis data base, 1994). National studies and computation of primacy index should fruitfully complete this overview of urban hierarchy in Europe.

Figure 13 : Pareto-Zipf distribution of city sizes (UMZ 2000 data base)



Sources: LAU 2 (EuroBoundaryMap 2006, v2.0) from EuroGeographics, UMZ2000 from European Environment Agency, Population density Grid v.5 from Joint Research Center.

A closer look at the head of this hierarchy can be proposed through the "top ten" UMZ (Table 2), which are compared here to other urban rankings resulting from

European databases (Morphological Urban Areas from IGEAT[17] and Larger Urban Zones from Urban Audit[18]). Seven of these UMZ are also part of the largest set of MUA and LUZ. Main differences concern conurbations like Bruxelles-Antwerpen-Gent, Liverpool-Manchester and Essen-Dortmund-Duisburg, which are clearly overestimated by UMZ as compared to MUA which are built from similar morphological criteria. Further details about UMZ ranking are given in the table of the 50 first UMZ (see Annex, table 1).

Table 2 : "Top ten" UMZ compared to MUA and LUZ (2000, population in thousand inhabitants)

UMZ			MUA			LUZ		
Rank	**Name**	**Pop.**	**Rank**	**Name**	**Pop.**	**Rank**	**Names**	**Pop.**
1	Paris	9 476	**1**	Paris	9 591	**1**	London	11 917
2	London	8 208	**2**	London	8 265	**2**	Paris	11 089
3	Milano	4 156	**3**	Madrid	4 955	**3**	Madrid	5 805
4	Essen-Dortmund-Duisburg-Bochum	3 891	**4**	Berlin	3 776	**4**	Ruhrgebiet	5 302
5	Madrid	3 843	**5**	Barcelona	3 755	**5**	Berlin	4 971
6	Bruxelles-Antwerpen-Gent	3 790	**6**	Milano	3 698	**6**	Barcelona	4 234
7	Liverpool-Manchester	3 531	**7**	Athinai	3 331	**7**	Athina	4 013
8	Athinai	3 489	**8**	Roma	2 532	**8**	Roma	3 458
9	Berlin	3 435	**9**	Birmingham - Wolverhampton	2 363	**9**	Hamburg	3 135
10	Barcelona	3 106	**10**	Lisboa	2 315	**10**	Milano	3 077

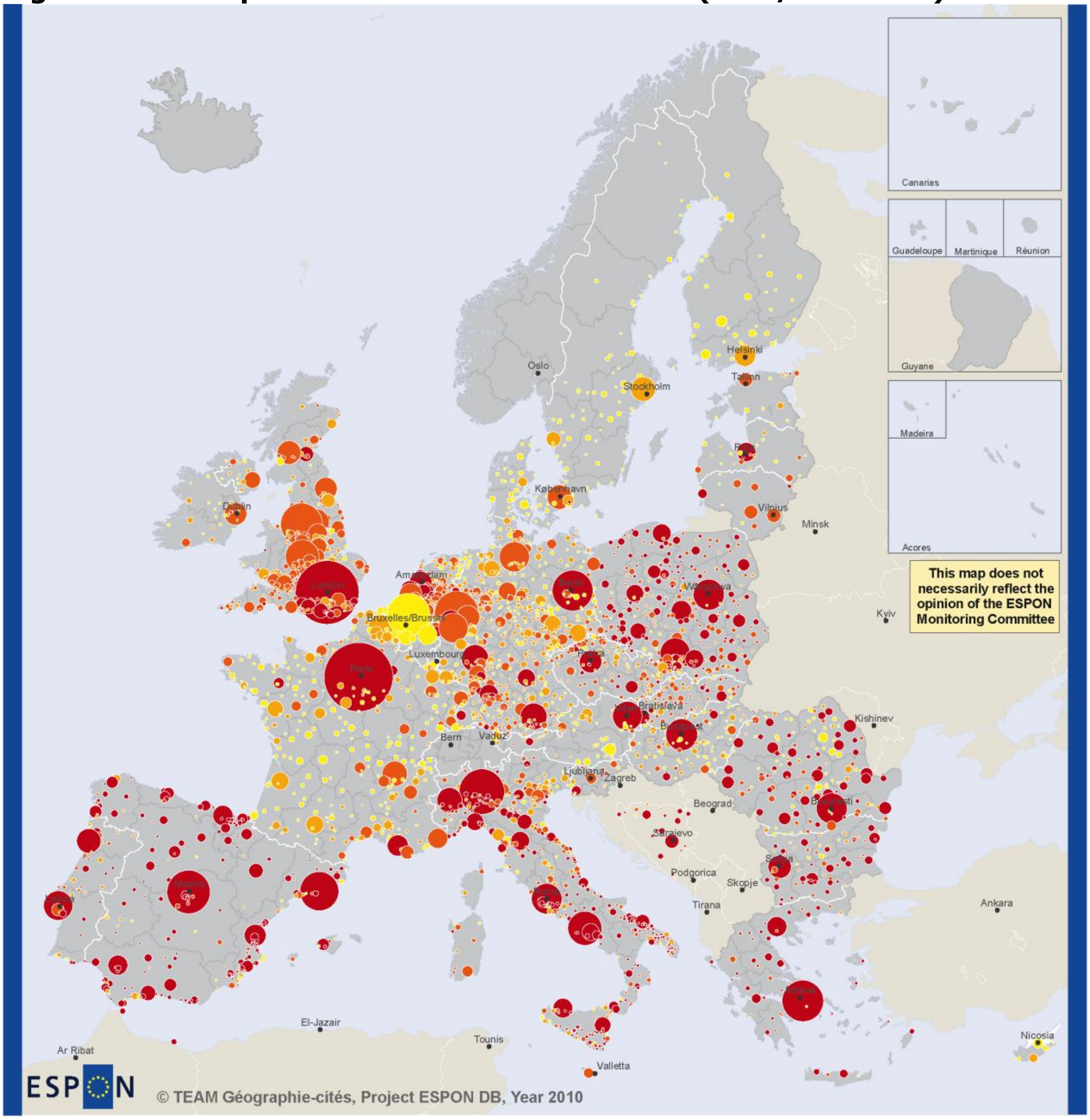
Sources: LAU 2 (EuroBoundaryMap 2006, v2.0) from EuroGeographics, UMZ2000 from European Environment Agency, Population density Grid v.5 from Joint Research Center, ESPON 1-4-3, Urban Audit.

3.2 Density patterns

A multiscalar analysis of density levels in Europe gives striking results, with a major North-South gradient (Figure 14): for example, average urban density is lower than 2000 inh./km^2 in Sweden, Denmark, Finland, whereas it reaches 4000 inh./km^2 in Italy and more in Spain or Greece (Table 3).

[17] MUA have been defined in Vandermotten et *alii* 1999 and in ESPON 1-4-3 « Study on urban functions ». IGEAT refers to Institut de Gestion de l'Environnement et d'Aménagement du Territoire, Université Libre de Bruxelles.
[18] http://www.urbanaudit.org/

Figure 14 : European cities sizes and densities (UMZ/CLC 2000)



EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

Regional level: NUTS 0
Source: ESPON DB, year 2010
Origin of data: The European Environment Agency (UMZ 2000 V.2), Joint Research Center (Density Grid V.5), LAU2 (2006, V.2) and national sources (see figure 9)
© EuroGeographics Association for administrative boundaries

Number of inhabitants

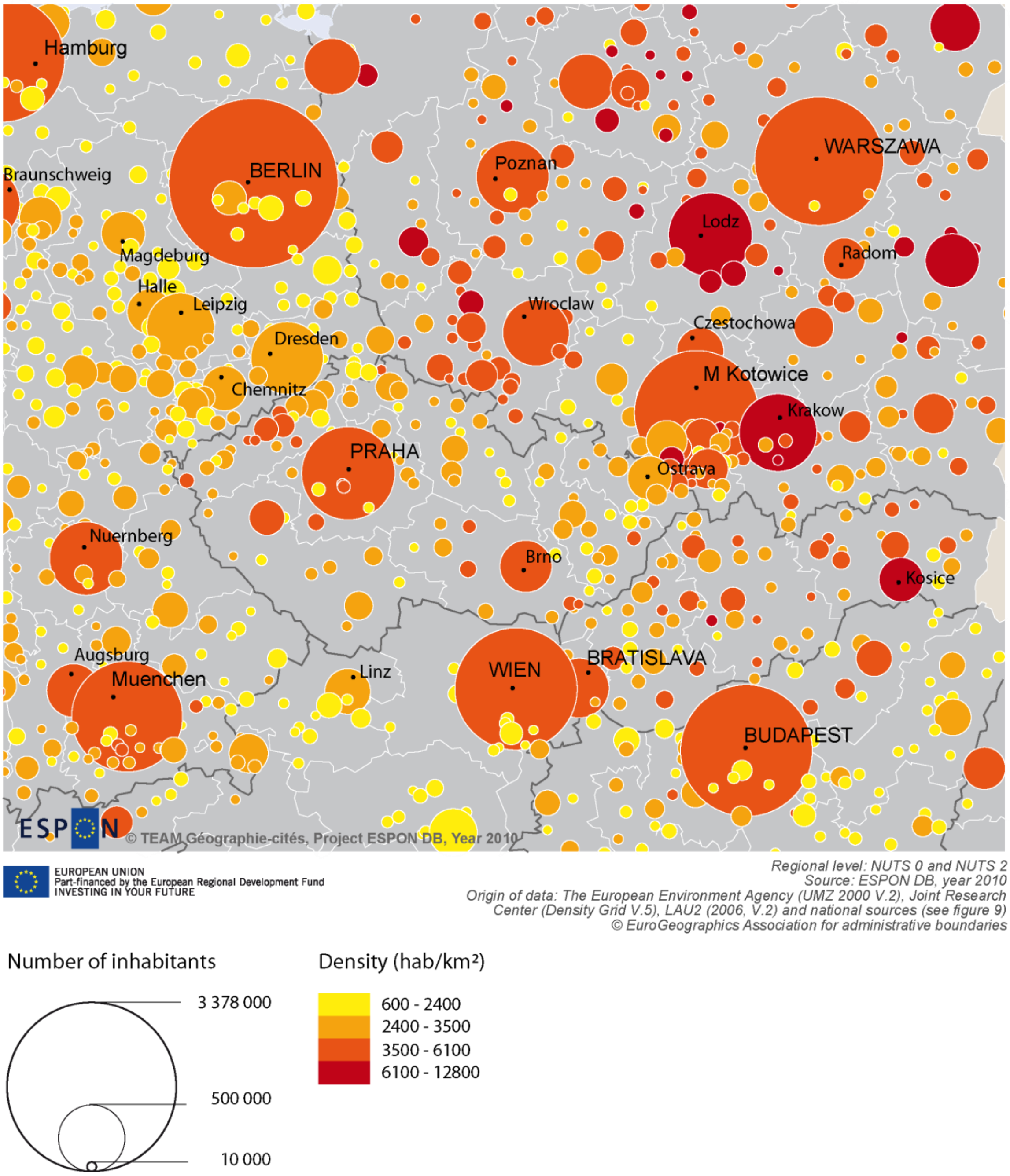
10 000 000
1 000 000
10 000

Density (inhab/km²)

340 - 2 150
2 150 - 2 900
2 900 - 3 800
3 800 - 33 600

Some national specificities appear also very strongly, as revealed by the higher densities of Dutch cities, the strong discontinuities observed for instance at the Franco-Spanish frontier and at the German-Polish border (Figure 14), or as suggested by the high densities of some Eastern countries like Poland (see Annex, Table 2).

Figure 15 : European City sizes and densities (UMZ/CLC 2000)



Furthermore, a strong and regular relationship with city size levels can be enhanced (Table 3): densities exceed 5700 inh./km^2 in cities larger than 2 millions inhabitants, then decrease regularly until 3000 inh./km^2 for cities between 10 000 and 25 000 inhabitants. This higher level of densities in the largest cities can be interpreted as the result of a historical accumulation process and as the expression of a more pronounced centrality and competition for land.

Let us recall that density indicator is of high interest for urban planning issues, for example in environmental topics, especially when it can be coupled with other transportations indicators. Even if current debates enlighten a lack of consensus between researchers, we can mention for instance the question of the minimal city or sub-district density level necessary for providing efficient public transportation networks, or the one of the possible link between average city density level and pollution gas emissions.

Table 3 : Urban population density per class of population

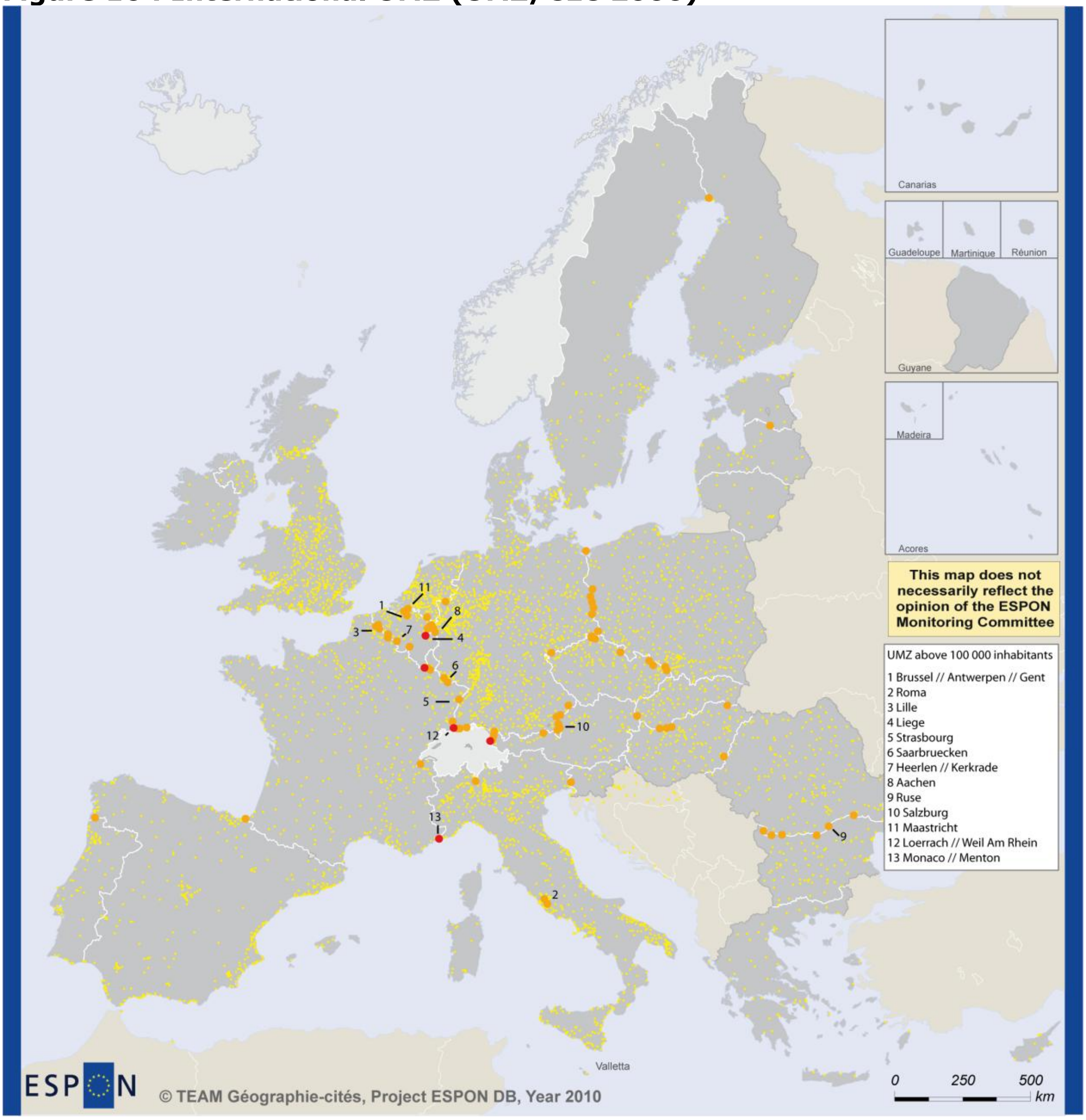
Class of population	Number of UMZ	Density (inh./km²)
1 to 10 millions inh.	39	4787
0,5 to 1 millions inh.	36	4 892
250 to 500 thousands inh.	136	4 235
100 to 250 thousands inh.	203	3 932
50 to 100 thousands inh.	512	3 469
25 to 50 thousands inh.	904	3 214
10 to 25 thousands inh.	2607	3 053

Sources: LAU 2 (EuroBoundaryMap 2006, v2.0) from EuroGeographics, UMZ2000 from European Environment Agency, Population density Grid v.5 from Joint Research Center.

3.3 International UMZ

International UMZ can now be identified through a new indicator (international code) that describes the number of countries crossed by each UMZ. The distribution of international UMZ (Figure 16) is a first important result that offers an overview of cross-national cities, independent from institutional or administrative frames. Furthermore, an index of internalization (% of population living in one or more countries different than the main one) has been computed. It allows to qualify in a comparable way to what extent the city is embedded in a multi-national context and completes in a fruitful way the population indicator of these UMZ: for example, the most populated international UMZ is Brussels/Antwerpen/Gent, but it extends in a very small part in Netherlands (international index is only 1%). At the opposite, some UMZ located at the Poland/Germany, Slovakia/Hungary or Austria/Germany frontiers are not very populated but their international index is over 40% (Table 5). Two other tables are presented in Annex, with the most important international UMZ by countries, according to their population (see Annex, Table 3) and according to their international index (see Annex, Table 4).

Figure 16 : International UMZ (UMZ/CLC 2000)



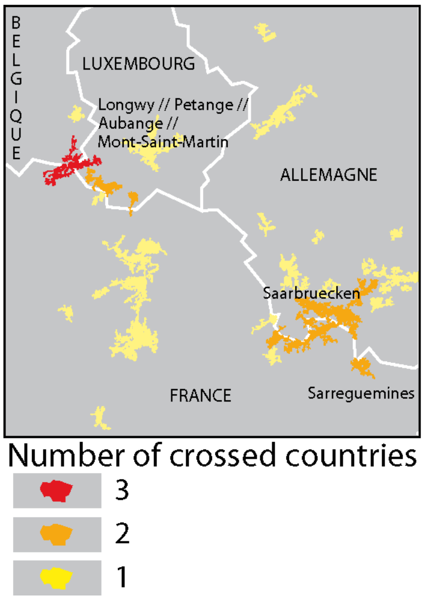
EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

Regional level: NUTS 0
Source: ESPON DB, year 2010
Origin of data: The European Environment Agency (UMZ 2000 V.2), Joint Research Center (Density Grid V.5), LAU2 (2006, V.2) and national sources (see figure 9)
© EuroGeographics Association for administrative boundaries

Number of crossed countries

- 3
- 2
- 1
- no UMZ data

Figure 17 : A zoom on some international UMZ



Sources: LAU 2 (EuroBoundaryMap 2006, v2.0) from EuroGeographics, UMZ2000 from European Environment Agency, Population density Grid v.5 from Joint Research Center.

Table 4 : Top Ten of main populated international UMZ

UMZ Name	Population	Main Country	All countries*	International index**
Brussels-Antwerpen-Gent	3 769 885	BE	BE // NL	0,1
Roma	1 891 236	IT	IT // VA	0,03
Lille	1 335 026	FR	FR // BE	30,1
Liege	760 811	BE	BE // DE // NL	1,03
Strasbourg	435 410	FR	FR // DE	3,4
Saarbruecken	367 294	DE	DE // FR	28,5
Heerlen-Kerkrade	259 447	NL	NL // DE	12,6
Aachen	213 930	DE	DE // NL	3,9
Ruse	201 106	BG	BG // RO	35,1
Salzburg	181 407	AT	AT // DE	10,2

Sources: LAU 2 (EuroBoundaryMap 2006, v2.0) from EuroGeographics, UMZ2000 from European Environment Agency, Population density Grid v.5 from Joint Research Center.

* Ranked by decreasing population.
**% of population of UMZ that is not in the main country.

Table 5: Top ten of most internationalised UMZ

UMZ Name	Population	Main country	All countries*	International index**
Comines/Wervik/ Comines-Warneton-Komen-Waasten	33 796	FR	FR // BE	47,2
Longwy- Petange – Aubange-Mont-Saint-Martin	70 371	FR	FR // BE // LU	45
Oberndorf bei Salzburg	10 096	AT	AT // DE	44,1
Braunau am Inn	29 933	AT	AT // DE	42,2
Monaco / Menton	105 193	FR	FR // IT // MC	41,1
Komarno	44 404	SK	SK // HU	40,8
Hamont	16 854	NL	NL // BE	40,7
Cieszyn	53 152	PL	PL // CZ	40,6
Guben	34 413	DE	DE // PL	40,1
Tui	17 801	ES	ES // PT	39,9

Sources: LAU 2 (EuroBoundaryMap 2006, v2.0) from EuroGeographics, UMZ2000 from European Environment Agency, Population density Grid v.5 from Joint Research Center.

* Ranked by decreasing population.
**% of population of UMZ that is not in the main country.

4 Conclusion

UMZ present a great potential for future, as they result from the same building methodology and are defined with the same criteria in all the countries. They have been here completed and validated as a European database operational for urban studies: 4437 urban settlements over 10 000 inhabitants are now defined from CLC2000 with harmonized criteria (EEA, last version of Urban Morphological Zone shapes), population (JRC, last version of Population Density Grid), names and metadata. The establishment of an automated process for naming UMZ allows quick updating with new versions of sources or methods (EEA and JRC) or new dates (2006, 2010…). The validation of the method results from an expertise which selects the relevant data base for city names and relies on systematic matches with other sources (Eurostat, Geopolis). This protocol leads to a powerful data base for exploring the features of European cities in 2000 as regards to their settlement characteristics, distribution of city sizes, density patterns or international UMZ configurations.

Further work should improve the operational dimension of UMZ in future:
- Their integration in the ESPON Data Base could be hugely improved by building a zoning correspondence Table with LUZ or other functional database.
- Interoperability with other geo-referenced data bases (urban transport infrastructures, urban mobility, socio-economic LAU data…) opens a wide range of environmental and social studies. Enlargement of urban indicators, towards environmental (grid/raster) and socio-economic data should be realised by using the "OLAP Cube for Urban analysis" developed by UAB[19] and indicators collected at LAU2 level and aggregated in UMZ delineations
- Urban indicators were here computed for the year 2000. A very important challenge lies in the possibility of adding a temporal dimension to these indicators and making them vary in time. Development of a temporal urban data model would enable to follow UMZ urban indicators through time (1990, 2010 and future other dates).

[19] See Technical Report « Social/Environmental data », ESPON Database 2013, written by the Autonomous University of Barcelona.

Annex:

Table 1: UMZ ranking, "Top 50"

Rank	Name	Country	Population 2001	Density (inh./km²)
1	**Paris**	FR	9 656 819	5 386
2	**Greater London Urban Area**	UK	8 221 307	4 861
3	**Milano**	IT	4 164 504	4 166
4	**Essen / Duisburg / Dortmund / Bochum /Gelsenkirchen - 1**	DE	3 892 380	3 674
5	**Madrid - 1**	ES	3 823 031	9 637
6	**Brussel / Antwerpen / Gent**	BE	3 769 885	1 841
7	**Manchester**	UK	3 546 819	3 538
8	**Dimos Athinaion**	GR	3 489 768	9 896
9	**Berlin - 1**	DE	3 367 457	4 648
10	**Barcelona**	ES	3 088 470	10 533
11	**Napoli**	IT	2 354 010	9 007
12	**West Midlands Urban Area**	UK	2 286 859	3 480
13	**Budapest**	HU	2 042 024	3 963
14	**M. St. Warszawa - 1**	PL	1 948 024	4 665
15	**Bucaresti - 1**	RO	1 925 741	9 066
16	**Roma - 1**	IT	1 891 236	6 300
17	**Hamburg - 1**	DE	1 838 019	3 549
18	**M. Katowice / M. Sosnowiec / M. Gliwice / M. Zabrze / M. Bytom - 1**	PL	1 810 260	3 845
19	**Koeln - 1**	DE	1 767 659	3 525
20	**Wien**	AT	1 756 034	4 304
21	**Lisboa / Sintra**	PT	1 749 316	5 906
22	**Frankfurt Am Main - 1**	DE	1 493 470	3 971
23	**West Yorkshire Urban Area - 1**	UK	1 473 892	3 541
24	**Muenchen**	DE	1 444 902	4 677
25	**Lille**	FR	1 335 026	2 831
26	**Lyon**	FR	1 287 802	3 092
27	**Torino**	IT	1 278 016	6 640
28	**Stockholm**	SE	1 233 147	2 822
29	**Kobenhavn**	DK	1 218 013	2 986
30	**Porto / Vila Nova De Gaia / Matosinhos / Gondomar**	PT	1 208 098	3 904
31	**Wuppertal / Hagen /**	DE	1 138 180	3 754
32	**Glasgow - 1**	UK	1 135 155	3 290
33	**Sofia - 1**	BG	1 079 088	6 271
34	**Rotterdam - 1**	NL	1 072 014	3 436
35	**Tyneside - 1**	UK	1 037 720	3 463
36	**Dublin**	IE	1 029 106	3 339

Rank	Name	Country	Population 2001	Density (inh./km²)
37	**Amsterdam**	NL	1 028 359	4 270
38	**Praha - 1**	CZ	1 020 584	4 303
39	**Valencia - 1**	ES	967 206	10 874
40	**Helsinki-helsingfors - 1**	FI	917 813	2 218
41	**Marseille**	FR	902 756	5 215
42	**M. Lodz - 1**	PL	822 545	5 232
43	**Bilbao**	ES	819 465	13 869
44	**Nice - 1**	FR	812 330	3 092
45	**Duesseldorf - 1**	DE	809 770	3 899
46	**Dimos Thessalonikis**	GR	804 095	11 600
47	**Sevilla**	ES	797 127	7 984
48	**Palermo**	IT	786 622	7 058
49	**Liege**	BE	760 811	1 401
50	**Gijon**	UK	736 438	3 276

Sources: LAU 2 (EuroBoundaryMap 2006, v2.0) from EuroGeographics, UMZ2000 from European Environment Agency, Population density Grid v.5 from Joint Research Center.

Table 2 : Urban population density per country

Country	Number of UMZ	Density (inh./km²)
Albania	19	-
Austria	60	1 986
Bosnia and Herzegovina	21	4 602
Belgium	50	1 449
Bulgaria	83	4 207
Cyprus	5	1 700
Czech Republic	116	2 889
Germany	846	2 799
Denmark	51	1 631
Estonia	16	2 396
Spain	348	5 752
Finland	44	1 135
France	391	2 037
Greece	51	4 493
Croatia	36	-
Hungary	107	2 202
Ireland	26	2 359
North Ireland	1	3 032
Italy	575	3 922
Kosovo	16	-
Liechtenstein	1	1 265
Lithuania	16	3 509
Luxembourg	3	2 532
Latvia	23	2 730
Monaco	1	5 818
Macedonia	20	-
Malta	1	3 297
Netherlands	201	3 398
Poland	327	3 658
Portugal	70	3 545
Romania	159	3 249
Serbia	58	-
Sweden	88	1 316
Slovenia	12	2 943
Slovakia	66	3 151
San Marino	1	4 314
United Kingdom	528	3 114

Sources: LAU 2 (EuroBoundaryMap 2006, v2.0) from EuroGeographics, UMZ2000 from European Environment Agency, Population density Grid v.5 from Joint Research Center.

Table 3 : Main international UMZ by country (ranked by population)

Country	Number of international UMZ	Main international UMZ		
		Population	International index*	Name
Austria	6	181 407	16,2	Salzburg
Belgium	4	3 769 885	0,1	Brussel / Antwerpen / Gent
Bulgaria	6	201 106	35,1	Ruse
Czech Republic	5	64 774	0,8	Karvina
Germany	19	367 294	28,5	Saarbruecken
Estonia	1	20 500	39,2	Valga
Spain	2	83 206	15,7	Irun
Finland	1	12 026	36,9	Tornio-Tornea
France	12	1 335 026	30,1	Lille
Hungary	4	26 606	36,9	Esztergom
Italy	4	1 891 236	0,03	Roma
Lithuania	1	10 029	5,8	Mauren / Eschen / Ruggell
Luxembourg	2	62 104	1,3	Esch-Alzette / Differdange
Netherlands	6	259 447	12,6	Heerlen / Kerkrade /
Poland	3	53 152	40,6	Cieszyn
Slovakia	2	44 404	40,8	Komarno

Sources: LAU 2 (EuroBoundaryMap 2006, v2.0) from EuroGeographics, UMZ2000 from European Environment Agency, Population density Grid v.5 from Joint Research Center.

*% of population of UMZ that is not in the main country.

Table 4 : Main international UMZ (ranked by International index)

Country	Number of International UMZ	Main international UMZ		
		International index*	Name	Population
Austria	6	44,1	Oberndorf bei Salzburg	10 096
Belgium	4	8,5	Essen (BG)	14 407
Bulgaria	6	35,1	Ruse	201 106
Czech Republic	5	31,1	Nachod	29 071
Germany	19	40,1	Guben	34 413
Estonia	1	31	Valga	20 500
Spain	2	39,8	Tui	17 801
Finland	1	36,9	Tornio-Tornea	12 026
France	12	47,2	Comines / Wervik / Comines-Warneton - Komen-Waasten	33 796
Hungary	4	36,9	Esztergom	27 000
Italy	4	36,7	Gorizia	44 518
Lithuania	1	5,8	Mauren / Eschen / Ruggell	10 029
Luxembourg	2	8,3	Dudelange	18 284
Netherlands	6	40,7	Hamont	16 854
Poland	3	40,6	Cieszyn	53 152
Slovakia	2	40,8	Komarno	44 404

Sources: LAU 2 (EuroBoundaryMap 2006, v2.0) from EuroGeographics, UMZ2000 from European Environment Agency, Population density Grid v.5 from Joint Research Center.

*% of population of UMZ that is not in the main country.

Figures list:

Tables:

Annex Tables: