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Abstract: This paper presents a free available dataset, the CORINE land cover, which helps dealing with the biases caused by pre-defined and heterogeneous census district boundaries in airport catchment area analysis in Europe. Using this dataset and conventional GIS software it is possible to measure the size of the population within catchment areas at the same spatial level for all EU airports, allowing for consistent comparisons among airports. To illustrate the potential of the CORINE/GIS approach the size of the population in the catchment areas of all European airports was determined. The empirical exercise has an aggregate perspective, but this database presents many other possibilities of analysis to perform in a case-by-case basis.

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*Title Page with Author Information

An appraisal of the CORINE land cover database in airport catchment area analysis using a GIS approach.

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1. Introduction: the Modifiable Area Unit Problem

Catchment area analysis is a way of estimating “the geographic area from which a large proportion of an airport’s outbound passengers originate from, or inbound passengers travel to, and their geographic distribution within this area” (CAA, 2011, pp.5). Insight into the nature and size of the catchment area is important. The size of the originating market is a significant determinant of airport performance, in terms of its attractiveness to airlines, traffic throughput, connectivity and seat capacity offered (Dobruszkes et al., 2011; Fröhlich and Niemeier, 2011; Humphreys and Francis, 2002). Only airports with a substantial airline hub operation or a large inbound (tourism) market are able to grow beyond the size supported by the local originating market. Hence, airports use the catchment area potential in their marketing towards airlines. Catchment area analysis also helps policy makers in the forecasting of passenger demand (Lieshout, 2012).

Nevertheless, calculating the potential size of the catchment area is not as straightforward as it seems. The potential of an airport’s market will depend on basic features of the region where it is located (e.g., amount of population in the area, their propensity to fly, economic activities, airport access time), airport related factors (e.g., network supplied by the airlines) and airport competition. In addition, the depiction of airport catchment areas by drawing concentric circles around the airport based on maximum allowable access time has some important drawbacks. The discrete choice approach has been put forward as a better alternative (Lieshout, 2012). However, this approach is more demanding from a technical and data point of view, and will there be less suitable for analyses at higher geographical scales and for cases where passenger survey data is not available.

A problematic issue in the measurement of catchment area concerns the population in the catchment area. European studies considering population in the catchment area usually take the NUTS 3 level[1] to aggregate population values around the airport (e.g., Papatheodorou and Arvanitis, 2009; Grosche et al., 2007). Two recent studies use lower levels of data aggregation than NUTS 3, Redondi et al. (2013) use municipality level units and Scotti et al. (2012) use zip codes, both represent an advance. Nevertheless, when aggregating point-based geospatial values –such as population– into pre-defined districts, results are influenced by the choice of the district boundaries, which becomes a source of statistical bias. The spatial analysis boundary problem is known as the Modifiable Area Unit Problem (MAUP) (Reynolds, 1998). In particular in multivariate analysis, results are likely to vary with the configuration of the zoning system and the level of aggregation of spatial units (Fotheringham and Wong, 1991). Such statistical biases may lead to non-accurate airport policy decisions.

This paper presents a free available dataset, the CORINE[2] land cover that helps dealing with the biases caused by pre-defined and heterogeneous census district boundaries in airport catchment area analysis. We apply a methodology that uses conventional GIS (Geographical Information System) software and provides an appraisal of the use of the CORINE land cover database for catchment area analysis. The use of GIS in combination with the CORINE land cover database allows researchers and policy-makers dealing with catchment areas to assess their potential size at any geographical level in a relatively simple way. The approach allows researchers to measure population within the catchment area at the same spatial level for all EU airports. To show the potential of the database we calculated the population in the catchment areas of all European airports with scheduled traffic (*N*=459) at three

[1] NUTS stands for Nomenclature of Territorial Units for Statistics. It is a geocode standard for referencing the subdivisions of EU countries for statistical purposes.
[2] CORINE stands for Coordination of Information on the Environment.

geographical levels.

2. Data

The database is the version 4.1 of the "Population density disaggregated with the CORINE land-cover 2000" dataset from the European Environmental Agency (EEA, 2009). This dataset provides information about estimated population density for the EU27, Croatia and Moldova at a pixel size of one hectare. This is a level of detail much higher than the NUTS 3 level used in previous analyses (e.g., Redondi et al., 2013; Scotti et al., 2012; Lieshout, 2012; Papatheodorou and Arvanitis, 2009; Grosche et al., 2007). Table 1 shows the substantial improvement in terms of data disaggregation that CORINE represents over the NUTS units. Considering the different data aggregation levels, in terms of area size, the average size of a NUTS 3 unit is 330,000 ha., while CORINE has a constant definition of 1 ha.

[TABLE 1 ABOUT HERE]

The CORINE dataset solves the issue of heterogeneous census district boundaries. The NUTS units size depends on different national administrative boundaries defined by each member state. For example, while the average size of the NUTS 3 unit in Sweden (Län) has 21,017 km^2, the average size of the NUTS 3 unit in Belgium (Arrondissementen/Arrondissements) has 694 km^2. The same holds true for local administrative boundaries at the municipal level. GIS analysis based on the CORINE database allows the researcher to choose the same boundary for each airport under consideration. Hence, it allows for consistent comparisons, at any geographical scale, between European airports without the influence of administrative boundaries. Figure 1 shows the different population results using CORINE and NUTS 3 for the case of

Amsterdam.[3]

[FIGURE 1 ABOUT HERE]
Figure 1. Population counting with NUTS 3 and CORINE using the case of Amsterdam Airport.

The database uses the CORINE land-cover of the year 2000 as the original source for the estimation of the population-density values, which are calculated for the year 2001. To weight the different land-use types in terms of population, each CORINE land-use cover class is attached to a different weighting coefficient. See Gallego and Peedell (2001) and Gallego (2007) for a detailed explanation on the algorithm used to estimate weighting coefficients.

The countries included in our analysis are the EU27 member states, Croatia, and Moldova. To determine whether an airport had scheduled traffic, we used data from the OAG (Official Airline Guide) for the year 2009, as it was the most recent data at our disposal.

3. Specification of the GIS analysis

Having the EEA's database as the main data source and by using GIS software (ArcGIS 9.3), we have calculated the number of inhabitants within fixed-radius distances (D = 25 km, 50 km and 100 km) from all European airports that had scheduled traffic in 2009 (N = 459). *D25* corresponds to the distance defined by Kasarda (2000) as the Aerotropolis, *D50* to a broad interpretation of Arend et al.'s (2004) definition of Aerotropolis and van Wijk's (2007) city-port size for Europe. Finally, the European Commission considers that 100 km or 1 hour driving time as a first 'proxy' of the airport's typical catchment area (Copenhagen Economics, 2012). We acknowledge the limitations of considering a fixed-radius instead of access time using the underlying transport network for the

[3] In this example we use a fixed-radius limit, but the analysis could be repeated using driving time distance is wished. Be as it may, Figure 1 shows graphically that the MAUP is overcome.

calculation of the potential size of the catchment area. In addition, at the individual airport level, the size of the catchment area should be determined case-by-case to define the size of the relevant market, which might depend on other factors (e.g., propensity to fly, overlapping catchment areas, network supply, etc.)[4]. Nevertheless, given that the main goal of the paper is to show how GIS and CORINE can achieve consistent measurement of population living in the catchment area at the European scale, the same approach can be easily extended towards a fixed access time.

Figure 2 shows the workflow used to carry out the GIS analysis.

[FIGURE 2 ABOUT HERE]
Figure 2. GIS workflow.

4. Results

Table 2 shows the list of European airports with largest numbers of population within 25, 50 and 100 km, and Figure 3 shows the location of these airports. Largest catchment areas are located in the most densely populated urban regions and in big metropolis. For the greatest distance (D = 100 km), airports with largest numbers of population in the catchment area are located in city regions: the Rhein-Ruhr region (Germany), the Brabant region (a long the border of The Netherlands and Belgium), London and English Midlands. Some unexpected airports pop-up within these city-regions, as not all airports with large population around them are airports with a lot of traffic. For example, Weeze (NRN), with less than 1.7 million seats in 2009, is the European airport with more population within a distance of 100 km. Paris-Pontoise airport (POX) also calls the attention; this is a small airport that has few scheduled traffic. This links with the traffic-shadow theory that states that the largest airport in any region will posses the

[4] We have not assigned population to particular airports. In other words, in case of overlapping catchment areas, the population in the overlapped area has been counted in both airports in order to show the full potential of each airport's catchment area in terms of population. Studies using the catchment area population as a variable in multivariate analysis will need to include variables that allow taking into account catchment area overlap/airport competition as well.

greatest attractive power and, therefore, it will be able to attract passengers from distant areas (Taaffe, 1956). Also, traffic is also influenced by other competition variables such as the lack of airport capacity, overlapping catchment areas, hub and airline operations, existence of large inbound markets and distance to the main air market (see, for example, Dobruszkes et al. (2011 and Liu et al. (2006)). In other words, catchment area analysis should considerer competitive and attractiveness factors.[5] Still, in a context of limited airport capacity and a capacity crunch threat (see forecasts by Eurocontrol (2010)), these results may indicate that Europe be able to might increase airport capacity using existing infrastructure and provide a higher level of competition among airports.

[TABLE 2 ABOUT HERE]

[FIGURE 3 ABOUT HERE]
Figure 3. Top 20 airports in terms of population in the catchment area.

5. Conclusions

The CORINE dataset and the GIS analysis have shown to be useful and contribute to consistent airport catchment area examination. This methodology can be of the interest to the aviation sector since it introduces the use of a free available database to do extensive comparative analyses of the population component of airport catchment areas in Europe and helps achieving consistent comparisons among European airports and dealing with the biases caused by pre-defined heterogeneous administrative districts. The study has an aggregate perspective, but this database presents many other possibilities of analysis to perform in a case-by-case basis (e.g., market leakage analysis, catchment area overlap analysis, airport choice modeling, accessibility analysis, forecasting and route feasibility analysis). Future application of the database can, of

[5] See, for example, Scotti et al. (2012).

course, use the underlying transport network to calculate travel times instead of fixed-radius areas. In addition, the CORINE presents a broader database of other variables regarding land-use, such as the share of urban use, transport related land-use and industrial/commercial land-use, which can also be significantly important for airports to know the nature of their local market and define adequate commercial strategies.

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Table 1

Table 1. Level of data aggregation, NUTS versus CORINE. Source: Eurostat (2011).

	Average area of each unit (ha.)	Average population per unit (hab.)
NUTS 1	4,540,000	5,119,000.00
NUTS 2	1,631,000	1,839,000.00
NUTS 3	340,000	384,000.00
CORINE	1	1.13

Table 2

Table 2. List of Top 20 airports in terms of population in the catchment area.

Airport	Seats in 2009	Population within 25 Km.		Airport	Seats in 2009	Population within 50 Km.		Airport	Seats in 2009	Population within 100 Km.
Paris Orly (ORY)	17,135,376	7,325,089		London Heathrow (LHR)	48,288,930	11,187,491		Weeze (NRN)	1,691,706	19,211,037
London City (LCY)	2,724,858	6,394,479		London City (LCY)	2,724,858	11,167,759		Oxford (OXF)	500	18,809,610
Paris Charles de Gaulle (CDG)	40,120,211	4,851,788		Paris Orly (ORY)	17,135,376	10,511,118		Dusseldorf (DUS)	12,411,993	18,704,423
London Heathrow (LHR)	48,288,930	4,768,617		Paris Charles de Gaulle (CDG)	40,120,211	10,354,175		London Heathrow (LHR)	48,288,930	18,487,999
Madrid (MAD)	34,024,044	4,142,975		Paris Cergy Pontoise (POX)	294	10,106,390		Eindhoven (EIN)	1,022,760	17,834,068
Athens (ATH)	12,741,702	3,956,549		London Gatwick (LGW)	18,428,768	9,011,608		London Luton (LTN)	5,941,371	17,682,308
Berlin Tegel (TXL)	10,160,151	3,757,611		Dusseldorf (DUS)	12,411,993	8,878,586		London City (LCY)	2,724,858	17,621,297
Berlin Schoenefeld (SXF)	4,279,794	3,731,988		London Luton (LTN)	5,941,371	8,071,934		Dortmund (DTM)	1,048,156	17,134,785
Napoli (NAP)	3,733,085	3,407,139		Dortmund (DTM)	1,048,156	6,771,546		London Gatwick (LGW)	18,428,768	16,916,283
Milan Linate (LIN)	6,558,116	3,375,081		London Stansted (STN)	12,998,519	6,522,668		London Stansted (STN)	12,998,519	16,687,831
Dusseldorf (DUS)	12,411,993	3,087,422		Milan Linate (LIN)	6,558,116	6,478,472		Cologne (CGN)	6,718,897	16,538,014
Barcelona (BCN)	19,820,927	3,045,829		Manchester (MAN)	10,145,185	5,983,314		Manchester (MAN)	10,145,185	15,370,757
Paris Cergy Pontoise (POX)	294	2,864,782		Amsterdam (AMS)	29,923,395	5,664,523		Maastricht (MST)	95,511	15,143,868
Rotterdam (RTM)	777,322	2,780,049		Madrid (MAD)	34,024,044	5,554,934		London Southend (SEN)	1,560	14,934,182
Birmingham (BHX)	5,860,754	2,640,207		Milan Malpensa (MXP)	12,648,493	5,509,331		Antwerp (ANR)	116,050	14,573,732
Dortmund (DTM)	1,048,156	2,607,486		Cologne (CGN)	6,718,897	5,434,835		London Ashford Lydd (LYX)	1,976	14,434,451
Lisbon (LIS)	9,503,488	2,448,220		Bergamo Orio al Serio (BGY)	4,517,409	5,374,557		Münster Osnabrück (FMO)	908,497	13,739,061
Bucharest Henri Coanda (OTP)	3,710,176	2,421,701		Liverpool (LPL)	3,400,489	4,993,714		East Midlands (EMA)	2,865,378	13,682,592
Bucharest Baneasa (BBU)	1,630,623	2,419,336		Birmingham (BHX)	5,860,754	4,912,898		Paris Cergy Pontoise (POX)	294	13,421,399
Frankfurt (FRA)	38,847,269	2,351,464		Napoli (NAP)	3,733,085	4,828,878		Shoreham (ESH)	819	13,286,210

Figure 1
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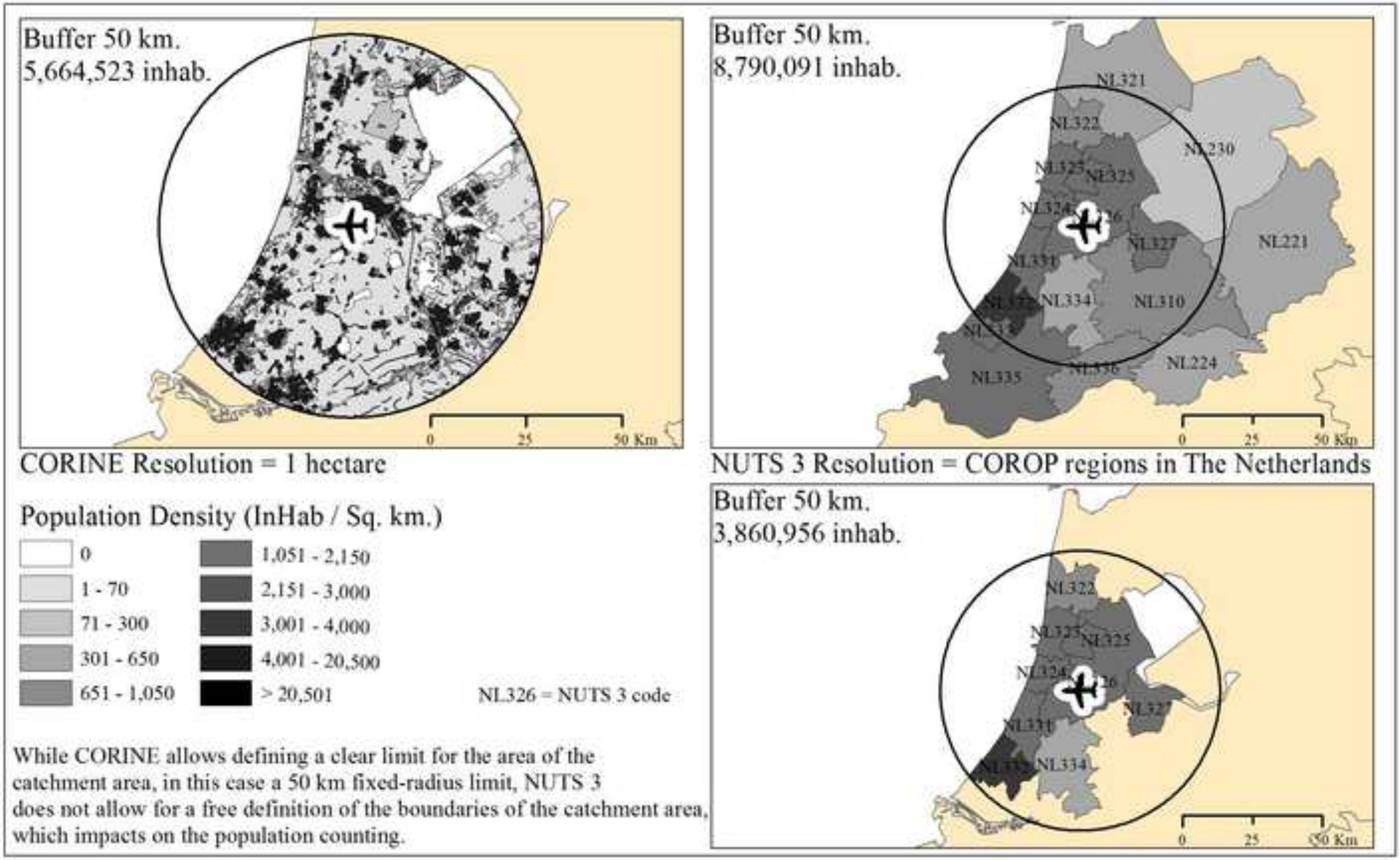

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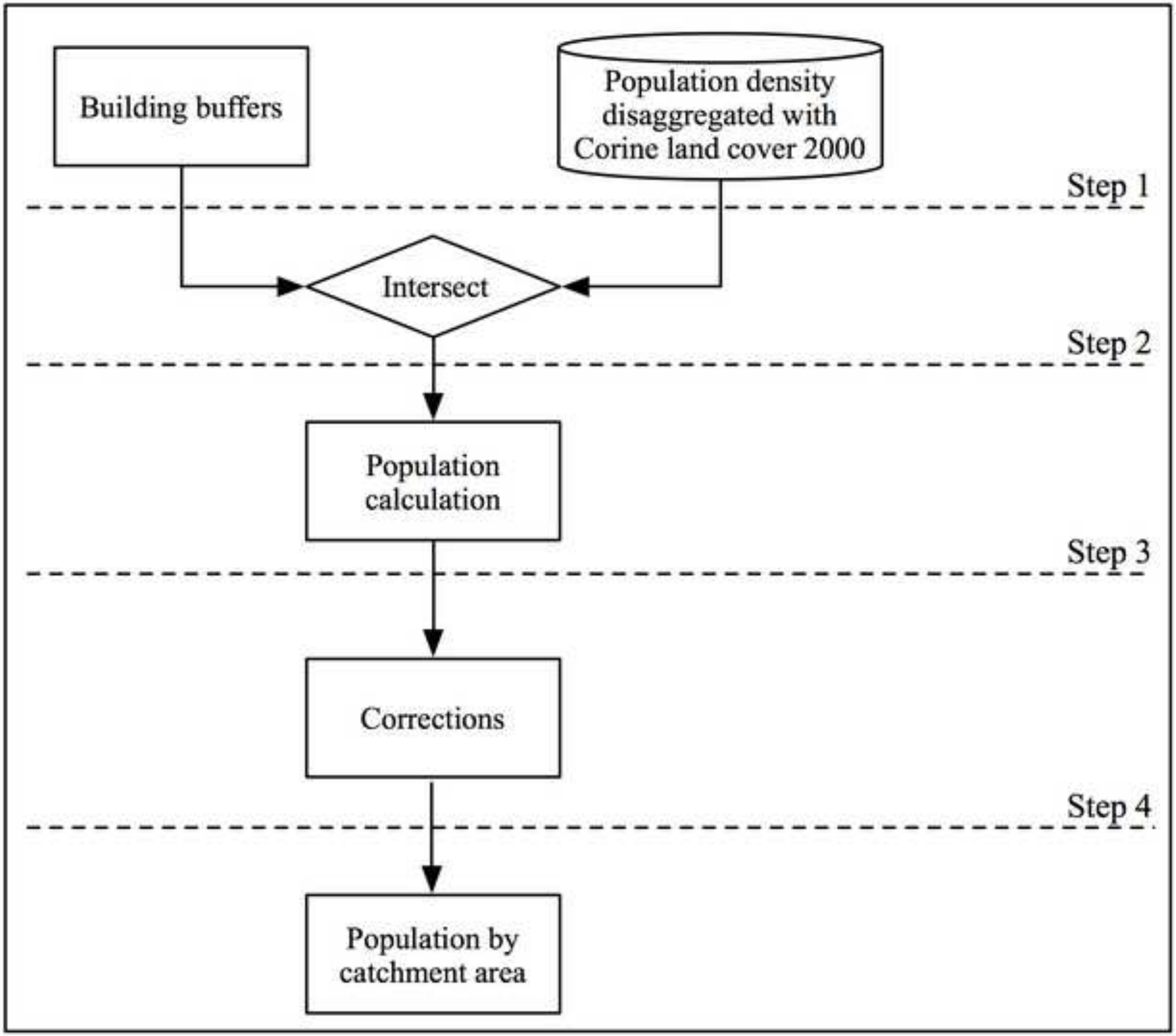

Figure 3

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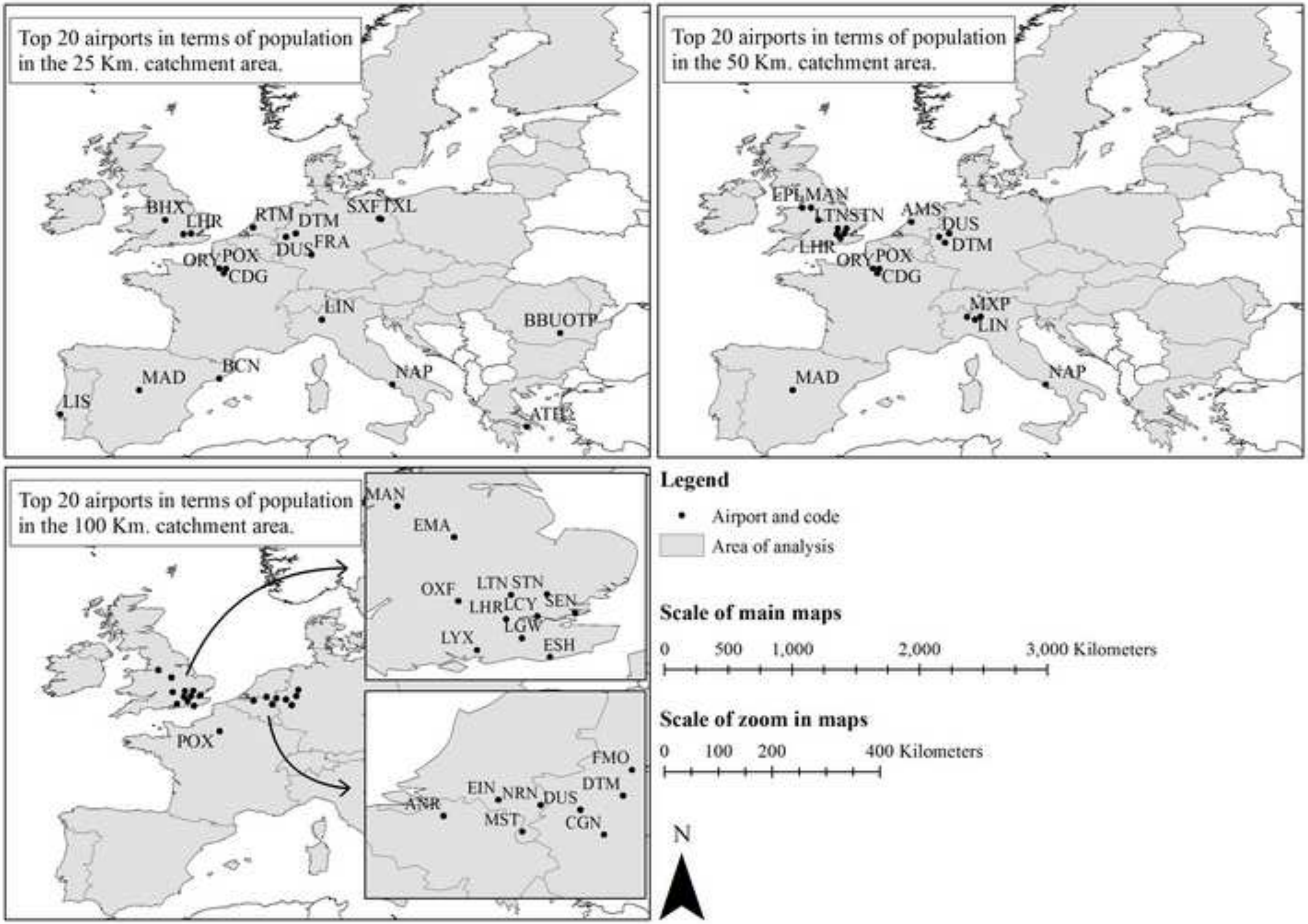

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