Population Density in a City

Corrado Abbate, Gianluigi Salvucci
Istat, abbate@istat.it; salvucci@istat.it

Abstract: The use of simple indicators may address towards incorrect assumptions about regions. As for cities, for example, population density could lead to wrong conclusions in social, economic and environmental analyses. We will demonstrate that the density of Italian cities' population makes Rome seem a rural city rather than a tertiary one, as it actually is. The aim of this paper is to show that some interpretations in socio-economic analysis are potentially wrong and to introduce some alternatives by using simple correctives like including environmental features. For instance, in the centre of Rome, where population is more concentrated, we have calculated a density of 55577 inhabitants per sq km versus the current estimation of 1981 inhabitants per sq km for the entire administrative territory.

Keywords: population density, spatial analysis, land cover.

1 Difficulties in describing a region by its density indicators

When data are related to different areas, a problem of comparability arises: it cannot be said that city A (1 million people) is bigger than B (5 thousand people) if area A is bigger than B. Statistics suggests to normalize the data by area for these cases. Urban geography has based a lot of its considerations on population density as an index for tertiary cities (Clark, 1951; Berry, Simmons and Tennant, 1963): the application of this indicator is supported by literature. Rome is the biggest Italian city, but is population density a real representation of the importance of a city, as suggested by literature? Rome is not in the top ten Italian cities by density.

Indeed, there is no significant correlation between a city's surface and its inhabitants. As a matter of fact, the R^2 index, calculated on the 8,101 Italian municipalities, is equal to 0.1465. It is clear that, if we want population density to mirror the importance of a city, we need to consider the variability in city areas' size. This is possible if one works with coarser resolution data, for example if one considers data aggregated by provinces.

If we think about cities, we imagine them as series of contiguous blocks, but reality is not always like that; we must introduce some information about land cover when interpreting population density. An useful suggestion is to divide a city into different zones and work separately on them. To do this, we need a very fine data resolution, for example referring to the smallest zones used in census cells (enumeration areas).

The EEA official CORINE Land Cover (CLC) dataset is suitable for our aims: it classifies the EU territory into land cover classes, with the aggregated class 1 meaning "Artificial surfaces" (including the sub-class 1.1.1 "continuous urban fabric"), class 2 meaning "Agricultural areas", 3 for "Forests and semi-natural areas", 4 and 5 for "Wetlands" and "Water bodies". By superimposing enumeration areas to a CLC dataset, by geographic coordinates of the perimeter of overlapping enumeration areas, we can obtain the predominant land cover class for each enumeration area and then aggregate

areas to re-calculate the density indicator (Table 1), where we can appreciate that it is not exhaustive to say that Italian population density is about 200 inhabitants per sq km, because the 79% of the population lives in just the 5% of the territory: the actual density in this 5% is 3563 inhabitants per sq km.

CLC level	Name	sq Km	Population	Density	% Area	% Populat.
1	Artificial fabric	12,262	43,694,310	3,563.4	5	79
2	Agricultural areas	135,575	10,817,936	79.8	60	19
3	Forests and semi-natural areas	77,715	1,090,776	14.0	34	2
	Total	225,552	55,603,022	246.5	100	100

Table 1 – Italian population distribution by CLC 2006 code and population density

Population rank	City	sq Km	Population	Density (Population/sqkm)	Density sq km for CLC class 1.1.1 .
1	Roma	1,285	2,546,804	1,981	14,682
2	Milano	182	1,256,211	6,899	16,152
3	Napoli	117	1,004,500	8,565	16,409
4	Torino	130	865,263	6,647	16,751
5	Palermo	158	686,722	4,322	14,892

Table 2 - Top five Italian cities by population, conventional density and density of 1.1.1 CLC class (our elaboration on CORINE land cover and Istat 2001)

Munic.	Land cover							
	CLC 1 pop.	*Percent*	CLC 2 pop.	*Percent*	CLC 3 pop.	*Percent*	CLC 4+5 pop.	*Percent*
Roma	2,390,042	*93.8*	155,904	*6.1*	786	*0.03*	72	*0.00*
Milano	1,241,329	*98.8*	14,847	*1.2*	19	*0.00*	16	*0.00*
Napoli	934,861	*93.1*	58,762	*5.9*	10,877	*1.08*	0	*0.00*
Torino	846,791	*97.9*	13,317	*1.5*	4,621	*0.53*	534	*0.06*
Palermo	669,076	*97.4*	12,762	*1.9*	4,884	*0.71*	0	*0.00*

Table 3 – Top five Italian cities' population distribution by city and land cover

Table 2 and 3 show different concentration for people living in different cities. Indeed, there is a bigger difference between Rome and Naples than between Rome and Milan.
Given all of this, we must consider that population does not live in industrial areas, so we should improve data resolution. These areas, like green areas, are not inhabited, and by including them we underestimate population density. In conclusion, only the 1.1 and 1.2 CLC classes (respectively, urban and industrial fabric) should be considered.
With 9409 people/sq km, the 1.1.1 class is the most densely inhabited type of land in Italy, while the 1.1.2 class (discontinuous urban fabric) is the most populated one only because it is the widest (7718 sq km versus the 1312 sq km of the 1.1.1 class). Population is more concentrated in 1.1.1 class, and density is the common criterion to define cities.

2 Some considerations about Rome

The core city is the area where population is more concentrated, and this is identifiable with land cover class 1.1.1, but we can consider the whole city area according to different land covers, to have different scenarios. Our analysis of Rome considers a radial city and the distribution of land cover and population.
Since Clark (1951), literature has studied the profile of cities without defining what a city and its centre are. When a city is not homogeneously populated, it is very difficult to get a good profile. To overcome this obstacle, we can use several variables related to urban profile, *i.e.* density, distance from mean weighted centre of population and land cover. We converted the CLC classification into 44 dichotomous variables: for each enumeration area a 1 value is assigned to the class corresponding to its prevalent land cover type , and a 0 value is assigned to the other 43 dichotomous variables. We decided to run a cluster analysis on these data to obtain a classification under a new urban perspective, considering all the variables at the same time (Table 4). Clusters may be constituted by different types of enumeration areas: cluster 4 is composed by continuous urban fabric and green urban areas, cluster 5 is composed by continuous urban fabric, discontinuous urban fabric and green urban areas.

		Prevalent Land cover code of enumeration area		
Cluster	Kms from centre	Continuous Urban Fabric (CLC 1.1.1)	Discontinuous Urban Fabric (CLC 1.1.2)	Green Urban Areas (CLC 1.4.1)
2	1.731	0	1	0
4	3.684	1	0	1
1	5.223	1	0	0
3	6.141	1	0	0
5	10.431	1	1	1

Table 4 - Clustering Rome enumeration areas by density, distance and land cover

Cluster	Km from centre	Area sq km	% Area sq km	Population	% Popul.	**Density**	N. of en. areas
2-4-1	3.546	7	0.5	374,031	14.7	**55,577**	818
3	6.141	48	3.7	1,120,155	44.0	**23,424**	3,560
5	10.431	1,233	95.8	1,052,618	41.3	**854**	8,721
Sum		1,287	100.0	2,546,804	100.0	**1,978**	13,099

Table 5 - Results of k-means cluster analysis for area and population

We found five clusters, but clusters 2 and 4 are very small, so we decided to join them to cluster 1. We obtain a partitioned-in-three city (Table 5): the first part includes the Central Business District, where land cover class 1.1.1 is predominant with the highest density (55577 people/sq km). The second cluster is less populated than the first one, with 23424 people/sq km and a prevalent land cover of class 1.1.1 too. The last cluster contains a mix of land covers, with a very low density compared to the other areas (only 854 people/sq km).
Considering all clusters, the analysis of urban profile should go from the city centre to the city boundary, and the central area could coincide (or not) with the most populated

zone. The presence of ruins in Rome city centre assigns this most densely populated area to "discontinuous urban fabric" 1.1.2 class.

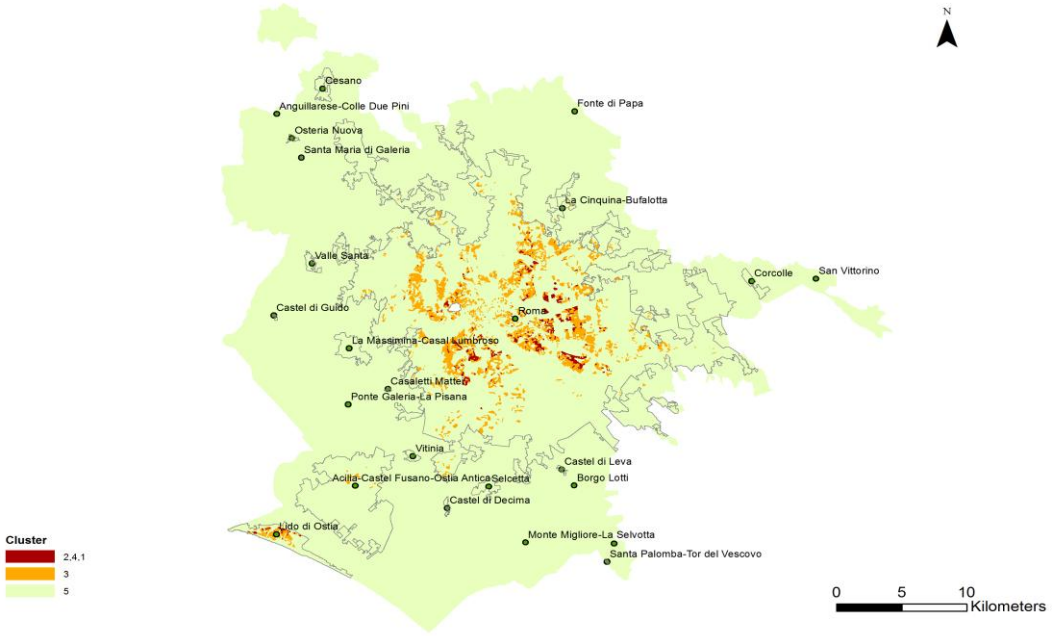

Figure 1 - Distribution of clusters in Rome

3 Conclusions

This paper aims at showing how social indicators must be integrated with environmental indicators to obtain a correct evaluation of a city population density.
Rome appears as a big green city with only 1981 people per sqkm, but, if we consider only the sub-areas where people actually live, we can evaluate a density of 55577 inhabitants per sq km in the most populated areas, and a density of 23424 people per sq km in the medium-populated ones; the 41.3% of the population lives in semi-agricultural areas with only 854 people per sq km (Figure 1).
In the city of Rome, the urbanized area hosts the 58.7% of the population, and it is undoubtedly very crowded. The simple density indicator does not allow a realistic evaluation of living conditions**.**

References

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