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A first reflection on the correlation between urban density and the spread of COVID-19 in Italy

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Highlights

- It can be assumed that compact settlements suffer over-spread of the virus in the Italian provinces, by using some indicators about form and density of urban settlements.
- The edge density and the urban density on anthropized areas have been associated with the number of positive cases of COVID-19.
- The social and environmental costs of different patterns of urban growth need to be revised.
- Health care systems have to be re-tuned in order to face the most challenging crisis of last century.

Abstract

Over 75% of the European population live in cities and towns where, therefore, the challenge of sustainability is at stake. As it is well known, sustainability has many facets, according to the Sustainable Development Goals (SDGs): one of those is the health and well-being of the population. The social and environmental costs of different patterns of urban growth have been addressed in an extensive literature. Nevertheless, the COVID-19 pandemic has undermined many established beliefs and raised new questions.

It is not yet clear whether there is a link between the spread of the virus and consequences on health and environmental conditions. So, it may be of interest to compare the different patterns of viral contamination among Italian regions and provinces, by using some indicators of population density in urban areas. Some indicators, among the many available in the literature, to assess fragmentation and compactness of settlement and population density are selected, collected and represented. In 2020 the analysis shows potentially clusters of settlement suffering over-spread of the virus in the Italian provinces.

The traditional provision of public services and spaces will have to be redefined by planners to protect and serve the population, if a potential link between the density of urban areas and the spread of the COVID-19 pandemic will be identified. That is the goal of the paper.

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1. Introduction

Urban growth is a significant and growing issue in Europe and all over the world (AA.VV., 2004; Brueckner, 2000; Christiansen & Loftsgarden, 2011; EEA, 2006; Hamidi & Ewing, 2014).
“In 2018, an estimated 55.3 per cent of the world’s population lived in urban settlements. By 2030, urban areas are projected to house 60 per cent of people globally and one in every three people will live in cities with at least half a million inhabitants” (UN, 2018, p. 2).
According to the United Nations, “the future of the world’s population is urban. With more than half of the world’s people living in urban areas (55 per cent, up from 30 per cent in 1950), urbanization determines the spatial distribution of the world’s population and is one of the four demographic mega-trends, with the growth of the global population, population ageing, and international migration. Estimates and projections of urbanization [...] indicate that the future growth of the human population can be accounted for almost entirely by a growing number of city dwellers. By mid-century, roughly two thirds (68 per cent) of the world’s population will be living in urban areas. The global urban population is projected to grow by 2.5 billion urban dwellers between 2018 and 2050, with nearly 90 per cent of the increase concentrated in Asia and Africa. In many regions, the share of population living in cities, as well as the number and size of cities, will continue to grow, driven by a combination of factors, including a surplus of births over deaths in urban areas, migration from rural to urban areas and from abroad (Lerch, 2017) as well as the urbanization of formerly rural areas” (UN, 2019, p. 1). Europe is characterized by an urban population growth concurrent with rural population decline and an urbanization rate lower than other less urbanized countries (UN, 2019). This confirms the statement that “the pace of urbanization in a country tends to be associated with the level of urbanization, with more urbanized countries urbanizing more slowly than less urbanized countries” (UN, 2019, p. 48).
Furthermore “urban areas in the EU are often characterised by high concentrations of economic activity, employment and wealth with the daily flow of commuters into many of Europe’s largest cities suggesting that opportunities abound in these hubs of innovation, distribution and consumption. However, cities in the EU are also characterised by a range of social inequalities, and it is commonplace to find people who enjoy a comfortable life living in close proximity to others who may face considerable challenges, for example, in relation to housing, poverty or crime, herein lies the urban paradox” (EU, 2016, p. 11). These features could be linked with the degree of urbanisation. Figure 1 shows, for example, the living environment satisfaction by the degree of urbanisation in the EU. In cities, the living environmental satisfaction is on average good, but for such Country, the liveability in rural areas is better than in cities and in another one, it is the opposite, probably due to the urban paradox.
The evaluation of the degree of urbanisation could be presented in a different way to stress the urban settlements’ degree of sustainability.
Moreover, understanding the key trends, present and future, in urbanization is crucial to the implementation of the 2030 Agenda for Sustainable Development, in particular, the Sustainable Development Goal 11 with the target to make cities and human settlements inclusive, safe, resilient and sustainable.
The topic of healthy cities is well known through the literature (Barton & Grant, 2013; Davies & Kelly, 1993; Duhl et al., 1999; Ramaswami et al., 2016). In the last century, medical and urban planning researches have moved on mutually intrusive but still parallel tracks. On the one hand, public health has focused on the individual and social determinants of healthy lifestyles and the intensity and quantity of physical exercise, mainly in terms of prevention. On the other hand, urban planning has focused on the analysis of citizens' behaviours in daily commuting, on the planning of the quantity and quality of services, on the drafting of tools aimed at defining and creating an adequate housing density, on the virtuous harmonization of intended uses, building types and neighbourhoods, social mixes, aesthetic values (D'Onofrio & Trusiani, 2017).
In many recent urban planning experiences, it is, however, possible to recognize the effects of the integration process of the two subjects. Above all, the approach expressed by the Healthy Cities movement aims directly at placing the issue of health as a priority in the political and social choices of the city . According to the World Health Organization (WHO), the concept of health is an essential element for the well-being of a society and does not refer merely to physical survival, but includes psychological aspects, natural, environmental, climatic and housing conditions and also lifestyle

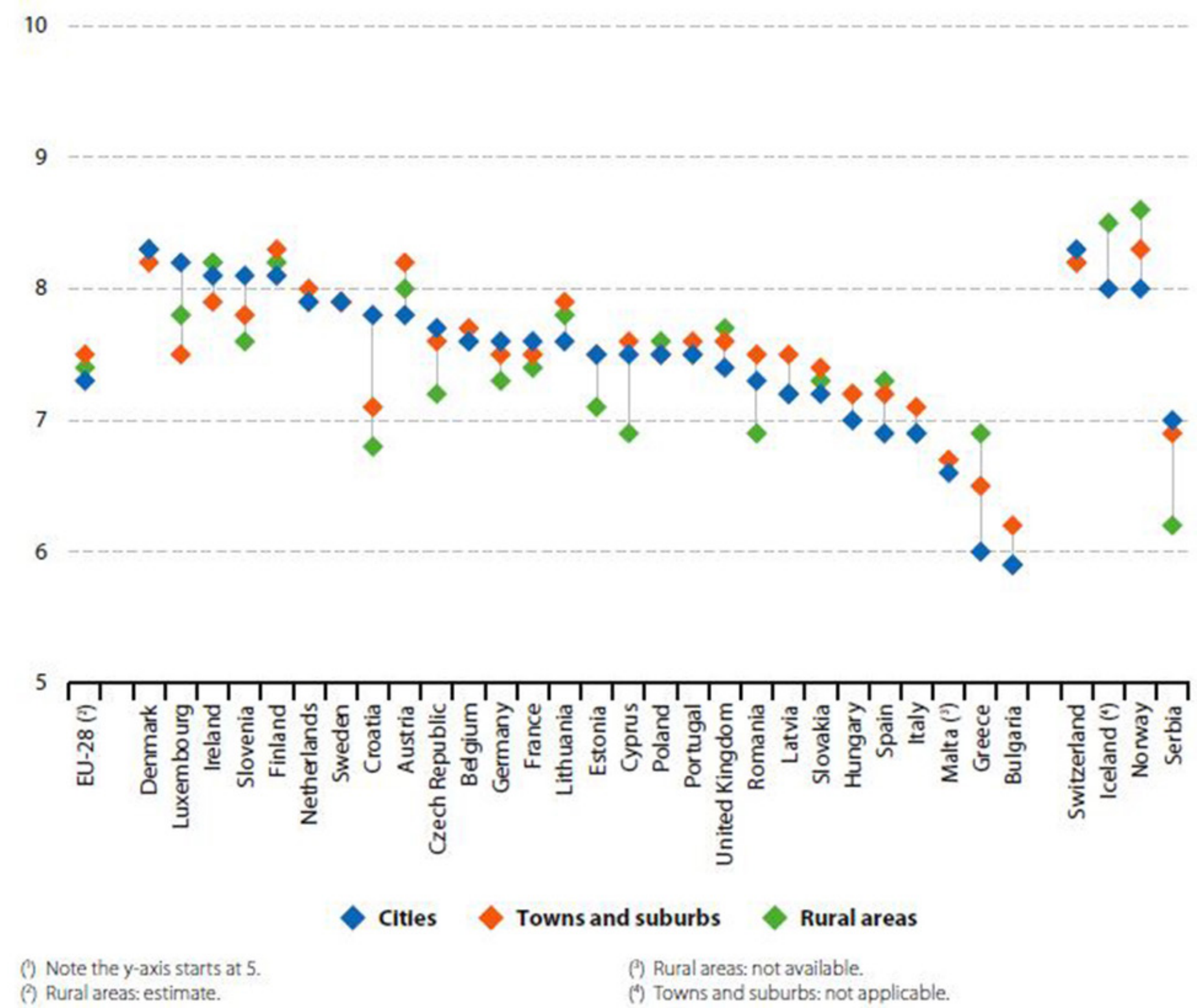

Figure 1: Living Environment Satisfaction, by degree of urbanisation, 2013 (rating, 0-10) *Source: EU, 2016, p. 38*.

(working, economic, social and cultural life) (see the Ottawa Charter for Health Promotion, 1986). This affirmation of the meaning of health is even more evident following the COVID-19 pandemic, during which the problems of managing sick, healed and healthy people emerged very strongly, in particular as regards the space organisation.
The paper would like to evaluate the possible causes that have facilitated or inhibited the spread of the pandemic. The morphology of urban settlements, theoretically, could have favoured diffused and scattered con-urbations and disadvantaged compact and dense cities. The article, therefore, proposes some basic data on the COVID-19 pandemic in Italy at the provincial level and, based on a brief presentation on the various possibilities of measuring the form and density of anthropized areas, presents some indicators that support the thesis.

2. The COVID-19 pandemic

The COVID-19 pandemic is a global health crisis and it is the biggest challenge humanity has faced since World War II. Since its appearance in Asia in late 2019, the virus has spread to all continents except Antarctica. Countries have fought to slow down the spread of the virus in the most diverse ways.
COVID-19 is much more than a health crisis: it has

Table 1: Cases of COVID-19 in the Italian provinces (numbers and percentage of cases for 1,000 inhabitants). The name of the Region to which the province belongs is also indicated.

PROVINCE	*Region*	*Cases*	*Cases out of 1,000 inh.*	*PROVINCE*	*Region*	*Cases*	*Cases out of 1,000 inh.*
Roma	Lazio	7,378	1.699	Lucca	Toscana	1,490	3.841
Milano	Lombardia	25,558	7.863	Chieti	Abruzzo	898	2.329
Napoli	Campania	3,175	1.029	Novara	Piemonte	2,912	7.891
Torino	Piemonte	16,197	7.168	Potenza	Basilicata	199	0.545
Brescia	Lombardia	16,243	12.831	Cremona	Lombardia	7,665	21.354
Palermo	Sicilia	601	0.480	Pesaro e Urbino	Marche	2,903	8.089
Bari	Puglia	1,641	1.311	Catanzaro	Calabria	226	0.631
Bergamo	Lombardia	15,253	13.685	Sud Sardegna	Sardegna	172	0.490
Catania	Sicilia	1,017	0.918	Ferrara	Emilia-Rom.	1,192	3.448
Salerno	Campania	883	0.804	Arezzo	Toscana	758	2.212
Bologna	Emilia-Rom.	5,884	5.799	Rimini	Emilia-Rom.	2,313	6.823
Firenze	Toscana	3,460	3.421	Lecco	Lombardia	3,932	11.655
Padova	Veneto	4,556	4.858	Livorno	Toscana	562	1.678
Verona	Veneto	5,481	5.916	Ragusa	Sicilia	353	1.100
Caserta	Campania	798	0.865	Pescara	Abruzzo	1,674	5.249
Varese	Lombardia	4,110	4.614	Viterbo	Lazio	491	1.549
Treviso	Veneto	3,611	4.067	Macerata	Marche	1,196	3.807
Monza/Brianza	Lombardia	6,006	6.872	Pordenone	Friuli VG	798	2.553
Vicenza	Veneto	3,065	3.554	Teramo	Abruzzo	701	2.276
Venezia	Veneto	3,093	3.625	L'Aquila	Abruzzo	341	1.140
Genova	Liguria	5,884	6.995	Pistoia	Toscana	794	2.715
Lecce	Puglia	647	0.814	Piacenza	Emilia-Rom.	4,604	16.033
Cosenza	Calabria	507	0.718	Benevento	Campania	227	0.819
Modena	Emilia-Rom.	4,211	5.970	Savona	Liguria	1,775	6.430
Perugia	Umbria	1,122	1.709	Siena	Toscana	471	1.763
Messina	Sicilia	558	0.890	Caltanissetta	Sicilia	221	0.842
Foggia	Puglia	1,313	2.110	Prato	Toscana	597	2.317
Como	Lombardia	4,260	7.109	Rovigo	Veneto	516	2.196
Cuneo	Piemonte	3,054	5.202	Trieste	Friuli VG	1,455	6.205
Taranto	Puglia	293	0.508	Lodi	Lombardia	3,677	15.973
Latina	Lazio	762	1.325	Terni	Umbria	435	1.928
Reggio C.	Calabria	353	0.644	Grosseto	Toscana	441	1.990
Pavia	Lombardia	5,707	10.455	Campobasso	Molise	420	1.898
Trento	Trentino-AA	5,028	9.292	La Spezia	Liguria	936	4.263
Reggio E.	Emilia-Rom.	5,237	9.846	Asti	Piemonte	1,908	8.889
Bolzano	Trentino-AA	2,869	5.401	Imperia	Liguria	1,563	7.309
Udine	Friuli VG	1,138	2.152	Nuoro	Sardegna	108	0.518
Sassari	Sardegna	1,067	2.171	Ascoli Piceno	Marche	346	1.670
Frosinone	Lazio	721	1.474	Belluno	Veneto	1,244	6.130
Ancona	Marche	1,924	4.083	Matera	Basilicata	222	1.122
Parma	Emilia-Rom.	3,863	8.553	Massa Carrara	Toscana	1,124	5.768
Agrigento	Sicilia	202	0.465	Sondrio	Lombardia	1,628	8.990
Cagliari	Sardegna	326	0.756	Biella	Piemonte	1,062	6.048
Trapani	Sicilia	152	0.353	Crotone	Calabria	128	0.732
Alessandria	Piemonte	4,147	9.844	Fermo	Marche	485	2.791
Pisa	Toscana	1,007	2.403	Vercelli	Piemonte	1,462	8.554
Avellino	Campania	593	1.418	Enna	Sicilia	459	2.785
Mantova	Lombardia	3,932	9.537	Vibo Valentia	Calabria	92	0.575
Siracusa	Sicilia	405	1.014	Verbano-Cusio-Ossola	Piemonte	1,164	7.351
Forli-Cesena	Emilia-Rom.	1,870	4.739	Oristano	Sardegna	61	0.387
Brindisi	Puglia	690	1.756	Rieti	Lazio	447	2.875
Barletta-Andria-Trani	Puglia	405	1.038	Gorizia	Friuli VG	242	1.736
Ravenna	Emilia-Rom.	1,257	3.228	Aosta	Valle d'Aosta	1,217	9.684
				Isernia	Molise	71	0.841

Data source: official database Civil Protection Service, consulted on 24 August 2020

the potential to create devastating social, economic and political crises that will leave deep scars. Every day, people lose jobs and income, with no way of knowing when normalcy will return. Already in Spring 2020, the International Labor Organization estimates that 195 million jobs could be lost (UNDP, 2020).

Over 37,109,000 cases and 1,070,000 deaths have been recorded so far (WHO, 2020a), 11 October 2020), but the pandemic is not over yet and many countries are still facing growing challenges.

The variation by age group is quite clear (or at least it used to be in the first wave, last Spring; at that time, in Italy the cases were mainly concentrated on over 70-years old people), while the evidence on the geographical spread of the virus is still very scarce and therefore the (possible) correlation with urban environments.

In 2005 the WHO created the International Health Regulations (IHR). IHR is an agreement between 196 countries and territories to work together for global health security with a commitment to develop and improve public health capacities that make the world ready to respond to emerging public health emergencies. This agreement provided a scoring system to measure a country's ability to prepare for and respond to these health emergencies. The IHR scoring system is based on 13 core capacities which include, for example, measures taken at ports, airports and ground crossings to limit the spread of health risks. In 2019 Europe has a score of over than 70% for 10 of 13 core capacities. The three more critical aspects are: risk communication, points of entry, chemical events (WHO, 2020b). This high score, however, did not have a particular impact in dealing with the virus: Europe recorded over 6,945,000 cases of COVID-19 with over 246,900 deaths (WHO, 2020a).

In Italy, after the bad period of March-April 2020, the daily cases have decreased and at the moment their complessive number is over 280,000 (35,500 deaths) (WHO, 2020a). The data are continuously updated and can be observed at different scales of detail (national, regional, provincial, municipal, etc.).

The provincial scale is the disaggregation level for the case study. Table 1 shows the number of Positive cases for COVID-19 in the Italian provinces and the percentage over 1,000 inhabitants. The data source is the official database of the Civil Protection Service (updated at 24th August 2020).

3. Urban density and morphology

The density and the form of a settlement can be evaluated in many different ways. Sometimes the density refers to population density (number of people per unit area), in other cases to the buildable or built volume per unit area, while in other cases the Floor Space Index (FSI) is still used - that is the number of housing units per unit area. The urban parameters used for city development are also strongly linked to the ways of living, to cultural factors and the environmental contest; these are not only represented by the height of the buildings but also by how the buildings are articulated into the lot (e.g. F. L. Wright one mile-high skyscraper). For example, Berghauser Pont and Haupt (2009) use a multi-parameter to summarize this complexity in a single indicator ("density"), divided into: population density, residential density, building intensity, covered area, the average height of buildings and the extent of the unbuilt urban environment(Berghauser Pont & Haupt, 2009)(Berghauser Pont & Haupt, 2009)(Berghauser Pont & Haupt, 2009). These parameters make it possible to describe the characteristics of urban space through simplified indexes, regardless of the regulatory approach already present in a city. The scale of use is local (for municipalities, neighbourhoods or groups of buildings).

In contrast, on the overall-national scale, the degree of urbanisation is a classification of local administrative units (LAUs) that indicates the characteristics of a particular area, based on a population grid composed of 1 km^2 cell, identifying (EU, 2016, pp. 24-25):

- "urban areas, defined here as the sum or average of cities and towns and suburbs;
- cities (densely populated areas), where at least 50 % of the population lives in urban centres;
- towns and suburbs (intermediate density areas), where at least 50 % of the population lives in urban clusters, but is not classified as a city;
- rural areas (thinly populated areas), where at least 50 % of the population lives in rural grid cells".

This parameter is available on a national to regional scale.

In Italy, ISPRA (Istituto Superiore per la Protezione dell'Ambiente - National Network for the Enviromental Protection) proposes a parameter called "Total density" that weights the population on the

administrative area. This parameter is collected at the national level, but available at the regional and local scale (provinces and municipalities).
Another parameter could be used to evaluate density: "urban density" This parameter is more effective than classic density (population on the administrative surface) because it relates the population with the areas effectively built. Probably the density measurement would be even more effective if it compared the population to residential areas only, but this data is not available in a homogeneous way at the national level (at least in Italy).
Not only the density is important to analyse the urban form. Also, the compactness or the fragmentation of urban settlements is significant. ISPRA proposes 4 different indicators (at the national, regional, provincial and municipal level) to evaluate the morphology of urban areas:

- Edge density - Fragmentation of the edges of the built area through the ratio between the total sum of the polygon perimeter of the built areas and the extension of their surface. High values indicate more fragmented areas;
- Largest Class Patch Index (LCPI) - Percentage width of the largest constructed area polygon. It is an indicator of compactness;
- Remaining Mean Patch Size (RMPS) - Average width of residual polygons, excluding the largest one. Provides the size of the spread of cities around the core;
- Dispersion Index (DI) - Ratio between the extension of medium/low-density areas on the total of areas (medium/low-density and high-density areas).

The indicators are built through an analysis of polygons corresponding to the different types of land cover, with the application of metrics dedicated to the study of the landscape structure at the municipal level (Botequilha Leitao & Ahern, 2002; EEA-FOEN, 2011; ISPRA, 2016; Schwarz, 2010).

4. The effect of population density and city fragmentation on the spread of the virus

Starting from the possible indicator of urban form and urban density just exposed, in figure 2 a demonstration of the theoretical link between the form of urban settlement and the spread of the virus COVID-19 at the provincial scale in Italy is shown.

The selected indicators of urban morphology are Edge density (proposed by ISPRA) and urban density on antropised areas. The data for Italian provinces came from the ISPRA database of soil consumption (2020 edition, referred to 2019 data). The Edge density is provided directly by ISPRA. The urban density is calculated using the data of soil consumption and the populations collected by ISPRA.
According to the classification of urban areas proposal by Marinosci et al. (Marinosci et al., 2015), the graph in Figure 2 is developed. Edge density and urban density are represented on the graph axes. The averages of the two groups of data identify 4 dials that distinguished 4 urban settlement features:

- fragmented with low density;
- fragmented with high density;
- compacted with low density;
- compacted with high density.

In figure 2 the colours identify le population classes of the provinces:

- over one million of inhabitants;
- from 500,000 to 1 million of inhabitants;
- from 250,000 to 500, 000 inhabitants;
- under 250,000 inhabitants.

The radius of the circle is proportional to the positive cases of COVID-19 (at 24 August 2020) presented in the previous paragraph.
Figure 2 shows, in the first dial, the provinces with fragmented and low-density settlements: the circles'size in this deal is little then in the other deals, so the positive cases of COVID-19 are few. In the second dial, that identify the provinces with fragmented and high-density settlements, fewer values fall and the positive cases continue to be few (little size of the circles). In the third dial, the provinces have compact and low-density settlements and the size of the circles grows indicating a greater number of COVID-19 positive cases. The last diel, that identify the provinces with compact and high-density settlements, has the larger rims or the greater incidence of positive COVID-19 cases.
According to Figure 2, the fragmentation/compactness of the urban settlement is more important than the density: the more compact settlements present more cases of COVID-19 than the fragmented ones. The difference between high-density settlements and low-density ones is not so sensitive.
As regards the size of the settlements in terms of inhabitants (identifiable by colour in Figure 2), the settlements over 500,000 inhabitants are predom-

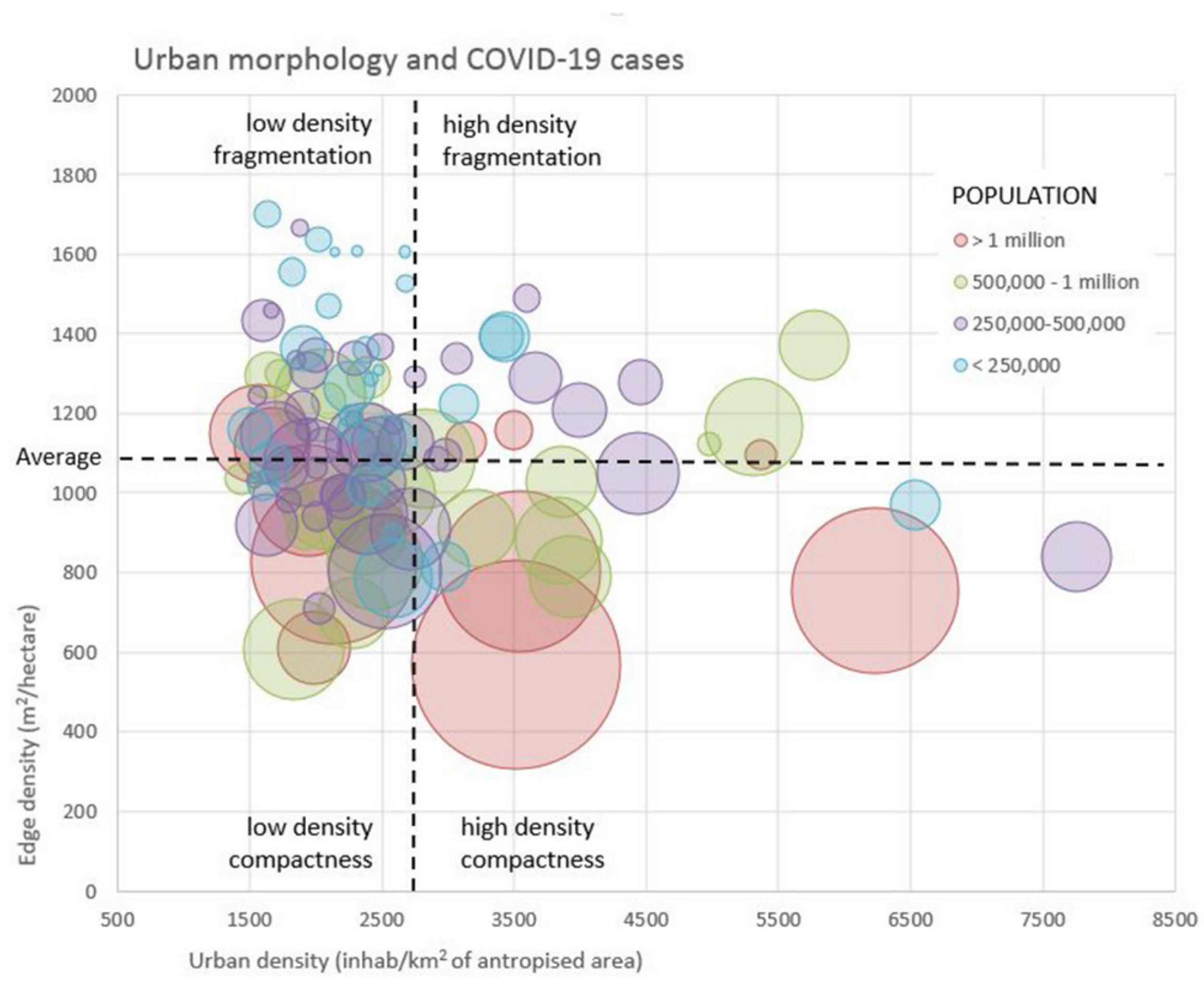

Figure 2: Urban morphology and positive cases of COVID-19 in the Italian provinces. The radius of the circle is proportional to the positive cases of COVID-19. *Source: authors' elaboration from the database of ISPRA, 2020 and official database Civil Protection Service, 2020.*

inantly compacted. Conversely, the settlements under 250,000 inhabitants have predominantly low urban densities.

5. Discussion and conclusion

Starting from the first results of the relationship between urban density and COVID-19 pandemic proposed in Italy at the regional scale (Tira, 2020), the paper proposes to apply the same considerations at the provincial scale.
The indicators of urban form and density are quite similar, but only a combination of them showed appreciable results at the local scale. In particular, only two indicators of fragmentation and urban density showed a link with the number of positive cases of COVID-19. They need to be evaluated contemporary to understand the phenomenon, so a graph that shows 4 dimensions was realised to demonstrate the thesis of the paper: using the Edge density, the urban density on atropised areas, the population and positive cases of COVID-19 it is possible to understand that compact settlements suffer over-spread of the virus.
The debate around the pros and cons of a compact city, even concerning sustainability is long-lasting and the results controversial.
From one side, there is a remarkable consensus among international institutions as well as local and national governments to implement large

and compact cities as a way of reducing the ecological impact of urban settlements, and hence of contributing to the achievement of sustainable development (Gaigné et al., 2012). On the other side, density has always been and continues to be a tricky matter (see among others (Burton et al., 1996). During the first industrial revolution, it was a dramatic negative feature of cities and towns. “Pandemic dramatically brings us back in time: even the most efficient urban settlements can suffer from the spread of the unknown virus, quickly transmitted by an increasingly complex and inter-related urban environment”(Tira, 2020, p. 365).

One Century ago, the Garden city movement and also rational urban planning with the definition of urban standards aimed at reducing overcrowding, the cause of countless negative impacts. This could have been a smart way to deal with the problem and it is still considered as a possible solution (Hardy, 2006).

“The compact city shows its ecological impact, due to the growing energy demand especially for buildings and the great dependence on a large (and so often distant) rural area. It can maximise the scale economies for many public facilities, like transport systems, but we observed a high vulnerability to pandemic.

The low-density scheme pays the cost of extending lifelines and road network to an unwise dimension and paves the way to the irrational use of motorised private cars. At the same time, it is the most suitable scheme to energy self-sufficiency and easier for arranging social distances, for example, during the pandemic” (Tira, 2020, p. 365).

The Comprehension of the main trends in urbanisation likely to unfold over the coming years is crucial to the implementation of the 2030 Agenda for Sustainable Development, namely by defining sustainable urbanisation approaches. Unexpectedly, that analysis is now crucial to prepare health care systems and public services to face a future challenging crisis like the one the world is still suffering.

What about the direct impact of environmental pollution on virus transmission? Viruses need a "carrier" to transmit. COVID19 is a "flyer" and environmental air pollution generally and particularly PM10 and PM 2,5 provide the "perfect" transporter. In the winter, particularly with cold weather and denser air, these values are very high in densely packed cities (with about 60-70% of PM coming from household heating). So another issue that could be studied is the possible link between the presence of air pollutions and the spread of the virus in cities.

As with environmental problems such as hydrogeological risk, it is also a question of being aware of and evaluating the consequences that life in the city entails. A new type of health risk dependent on the urban form of the cities we live in has emerged and deserves attention.

A new challenge arises for urban density and new requirements for public spaces and services.

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