TeMA

Journal of
Land Use, Mobility and Environment

This Special Issue of TeMA - Journal of Land Use, Mobility and Environment, collects twenty-seven contributes of international researchers and technicians in form of scenarios, insights, reasoning and research on the relations between the City and the impacts of Covid-19 pandemic, questioning about the development of a new vision and a general rethinking of the structure and urban organization.

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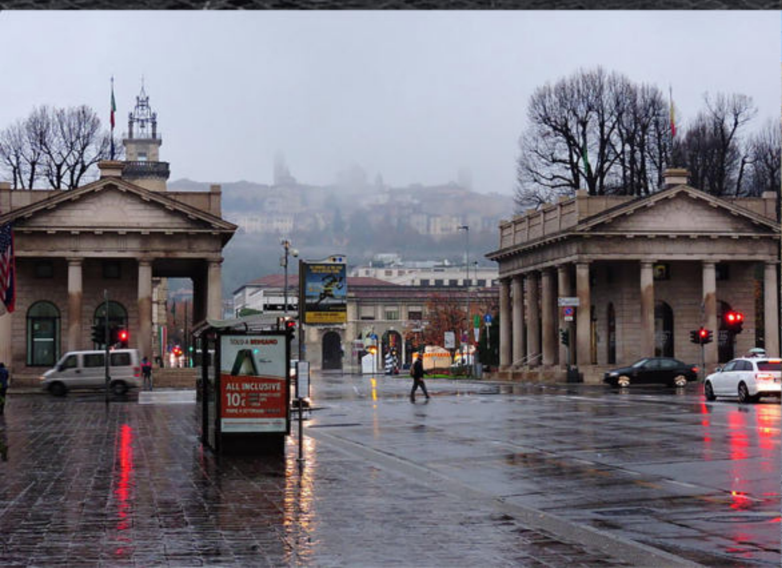
Special Issue

Covid -19 vs City -20

scenarios, insights, reasoning and research



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SCENARIOS, INSIGHTS, REASONING AND RESEARCH

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The cover image is a photo collage of some cities during the Covid-19 pandemic quarantine (March 2020)

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Geographical analyses of Covid-19's spreading contagion in the challenge of global health risks

The role of urban and regional planning for risk containment

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Abstract

This research develops from a set of basic geographical questions about the outbreak of Covid-19 out of China in Europe. The questions dealt with why and why with such strength Italy has been seriously hit, one of the most important cases in terms of death toll out of Hubei Province and mainland China, in the world, making the country a worldwide study case for epidemic concentration and diffusion. Questions were also related to geographical similarities among the areas hit, and particularly the Po Valley region and Wuhan metropolitan region in Hubei province, and also related to why such a divide of the virus spreading was identified in Italy between Northern and Central and Southern regions and provinces. In order to try to give an answer these questions, authors realized a vast and articulated database of indicators at provincial level in Italy, performing several geographical analyses - ecological approach - based on Spatial autocorrelation and Geographical Weighted Regression, coming to the conclusion that aspects such as land take, pollution can seriously influence the phenomenon and justify a pattern as that observable in Italy. The analyses and observation of the phenomenon also suggests that policies based on urban regeneration, sustainable mobility, green infrastructures, ecosystem services can create a more sustainable scenario able to support the quality of public health.

Keywords

Covid-19; Italy; Po-valley; Air quality, Climate changes; Land take; Spatial diffusion processes

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1. Introduction

With this research, we tried to find some answers to the questions raised by the Covid-19 outbreak in Italy, first among European countries, after Southeastern Asia. In particular, an attempt was made to highlight some elements connected to the causes of the diffusion of the virus in Northern Italy, in the Po Valley megalopolis, which also includes the metropolitan city of Milan.

In this sense, we analyzed the data relating to Covid-19 - infected and deaths at the provincial level - as of 31 March 2020 and 30 April 2020, useful dates for observing the phenomenon after the country's lock down of 10 March, which placed severe restrictions on mobility and industrial production and services, in order to slow down the spread of the epidemic, and the disease’s spatial behavior after such policies.

Furthermore, as a starting point it was possible to observe similarities between the Wuhan area in the province of Hubei with those of the metropolis in the Po Valley, referring in particular to the geographical and climatic conditions - presence of rivers and water bodies, flat land, limited atmospheric circulation and scarcity of wind – socio-economic conditions - industrial production, transport and mobility infrastructures, population distribution and density, population aging and life expectancy -, as well as similarities relating to concentrations of pollutants in the atmosphere and soil consumption. We hypothesized the existence of a relationship between pollutants and the spread of the virus in the outbreak of the epidemic and its lethality.

In particular, we took into consideration soil consumption and air pollution, referred to particulates - $PM_{2.5}$ and PM_{10} - and those deriving from human activities, as industry, traffic, domestic heating, agro-industry and intensive farming, as CO_2 and nitrogen-based components, such as NO_x and NH_3. - The basic idea is that the presence of atmospheric pollutants can generate health pressures on the population and determine the pre-conditions for the development of both stress on the diseases related to the respiratory system and of complications related to them, including those that are health-threatening, which may explain the excess lethality that occurred in the area under consideration.

Fig.1. Synthetic comparison - Wuhan urban agglomeration and Great Milan metropolis. Authors’ elaboration

In particular, relations between high concentration of atmospheric pollutants and the diffusion of pathogenic microorganisms has already been demonstrated (Peng et al., 2020). Moreover, being exposed to higher concentration of atmospheric pollutants can also explain the basa inflammation condition that can afflict the population altering the physiological conditions and leading to a greater predisposition to infection and symptomatic development of the disease (Chen & Schwartz, 2008; Conticini et al., 2020).

Furthermore, the particular weather conditions, including thermal inversion, typical of the winter period, may have worsened the environmental situation in the areas - of Wuhan and the Po Valley - such as low rainfall and a milder winter than the previous ones.

The two areas, in fact, have the same Köppen climatic classification Cfa subclass 'humid subtropical', typical of temperate continental areas (*Global climate change, 2020*, 2020; Skarbit et al., 2018) and profound analogies typical of the fluvial plain contexts, characterized by a fairly isotropic space. Both are located in an alluvial plain, Wuhan urban agglomeration - Yangtze river and Great Milan metropolis - Po river (Fig.1).

Both mega urbanizations have industrial and post-industrial functions, with a heavy presence of manufacturing companies, in machinery, automotive and ICT, as well as advanced and cultural services, particularly in the major center. Both the areas share a strong promiscuity with agricultural activities and a wide progression of the sprawl (Lu et al., 2020; Pezzagno et al., 2020; Romano et al., 2017; Senes et al., 2020).

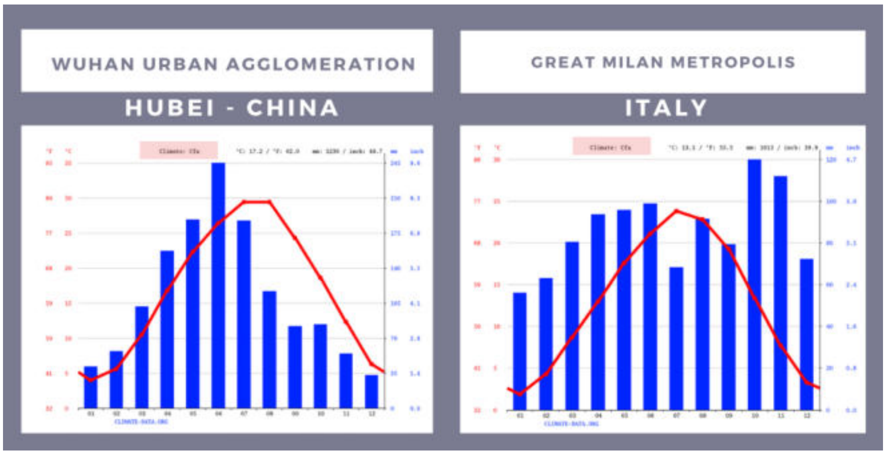


Fig.2 The climatic classification of Köppen. Authors' elaboration

In this complex international framework, we developed the present research, which does not pretend to be exhaustive, but to show the first results of an interdisciplinary ecological approach. In this regard, the basic conditions refer - for both cases examined as Wuhan agglomeration and Greater Milan metropolis - to an intense and prolonged exposure to air pollution, as peaks of concentration of fine dust and other pollutants, constitute a pejorative factor in cases of epidemics Covid-19 (Setti et al., 2020). We also paid particular attention to the relationship between climate and air quality (Du et al., 2019). Climate changes on the one hand affect the atmospheric processes and on the other cause changes in the functioning of terrestrial and marine ecosystems which can, in turn, affect the atmospheric processes (Jacob & Winner, 2009). However, these two environmental emergencies are still considered separately both at the level of the scientific community and those responsible for environmental policies, as in the case of the Covid-19 emergency (Setti et al., 2020).

According to the EEA - European Environmental Agency - although air pollution (European Environment Agency, 2018) affects the whole population, as collective health costs, only a part is more exposed (European Environment Agency, 2020) to individual risks (Chalvatzaki et al., 2019; Mitsakou et al., 2019; Reames & Bravo, 2019). In particular, Greater Milan metropolis and most of the Po Valley represent the outcome of industrial, agricultural and intensive farming globalization in Italy, which presenting an increasingly critical quality of air (Pezzagno et al., 2020). Although in the last decade in Italy there have introduced important taxation and incentive measures for the purchase or improvement of the ecological performance of home heating (Magnani et al., 2020)) and public and private road vehicles however, the levels of air pollution for 150 days (2018) have exceeded EU regulatory limits - much lower than WHO ones. Furthermore, this situation is prolonged in time as high level of air pollution and concentration of pollutants in the air have been constantly reported in the previous years (Legambiente, 2020). In addition, the climatic and geographical 'handicap effect' of Greater Milan metropolis, is not secondary in the air quality (Zullo et al., 2019). This geographical framework - mainly isotropic - is also characterized by a community with a high life expectancy and a strong national hospital migration that can put health services under stress (Volpato et al., 2020).

The rest of the paper is organized as follows. Paragraph 2 is dedicated to Materials and Methods. In paragraph 2.1 we present the study area, Italy with its intermediate administrative units; paragraph 2.2 presents the data used for the analysis. In paragraph 2.3 the methodology adopted is presented, consisting in the ecological approach and a set of fitted for purposes spatial analyses, including the SMR (Standardized Mortality Ratio) and areal analysis for autocorrelation and estimates, as the GWR (Geographical Weighted Regression) and LISA (Local Indicator for Spatial Autocorrelation).

Paragraph 3 hosts the results, with paragraph 3.1 dedicated to the results obtained from GWR, while paragraph 3.2 dedicated to the results obtained from LISA; paragraph 4 Discussion and 5 Conclusions the paper and propose further developments.

2. Materials and methods

2.1 The study area (Italy)

The analysis regards Italy as the area where the outbreak of Covid-19 is analyzed. Italy spans over a surface of 302,072.84 sq km, with a population of 60,359,546 inhabitants (ISTAT, 2019) for an average population density of 200 inhabitants per square kilometer. Italy is organized in 20 Regions - one of them,Trentino Alto Adige, organized in 2 Autonomous Provinces with regional competences. In the analysis, we considered the intermediate administrative subdivision in Provinces, Metropolitan Cities (Ref. L. No. 56 of April 7, 2014) and a set of former provinces now used only for statistical purposes.

We considered the overall country for the analysis, although our initial attention was concentrated on the Po Valley geographical region. Such an area covers approximately 55,000 km2, with nearly 22 million inhabitants, with a population density of 400 inhabitants per km2 - double than that of the rest of the peninsula, reaching different peaks in the main urban areas of the Greater Milan metropolis - the neighboring Milan and Monza Provinces exceed 2000 inhabitants per square kilometer. It is the economic engine of the country, and is also the mostly affected area by Covid-19 outbreak.

2.2 Data

The research has been performed using different datasets mainly referred to Italy and related to the Covid-19 outbreak, as well as socio-economic and environmental data, considered useful for examining the territorial aspects of the virus outbreak in Italy. Covid-19 data considered the number of total infected people at 31 March and 30 April 2019 at province level, as reported by Italian Ministry of Health, as collected by the Civil Protection. An important novel dataset, originally built from scratch by the research group, is the number of deaths at province level. In many cases data were provided by regional administration, while in other cases the research required counting and referring data to provinces from the local health agencies and other official sources (Istituto nazionale di statistica (ISTAT), 2020; Istituto superiore di sanità (ISS), 2020).

Among the others, the major difficulties were found in locating at province level data for important regions in terms of the Covid-19 outbreak as Lombardy and Piedmont; also, big regions as Liguria, Lazio, Campania and Sicily required an extra-effort for locating deaths at provincial level.

Date	Provincial level deaths	Regional level deaths	Provincial level infected	Regional level infected
31 March 2020	12,105	12,428	102,440	105,792
30 April 2020	27,249	27,967	215,084	205,463
Source	authors data - set	Italian civil protection	authors data-set	Italian civil protection

Tab.1 Covid-19 deaths and infected localized at Provincial and Regional level

The complete study data set consists of over 100 indicators/indices. However, to simplify the discussion, we indicate only the specific ones mentioned in the paper, divided into four categories representative of the ecological approach taken. (Tab.1).

	GWR	LISA	DATA INDEX	UNIT OF MEASURE	SOURCE
Land use	✓	COV_03	Soil Consumption	Km^2 of Land take (2014-2018)	ISPRA 2017-19 https://www.isprambiente.gov.it/it/attivita/suolo-e-territorio/il-consumo-di-suolo/i-dati-sul-consumo-di-suolo
	✓	COV_82	CO2/non urbanized areas	$\mu g/Km^2$ (2015)	ISPRA 2017 http://www.sinanet.isprambiente.it/it/sia-ispra/inventaria/disaggregazione-dellinventario-nazionale-2015/view
	✓	COV_49	Surface waterproofed	Km^2 (2016)	ISPRA 2017 https://www.isprambiente.gov.it/it/istituto-informa/dossier/consumo-di-suolo-2017/consumo-di-suolo-2017
Air Quality	✓	COV_14	PM2.5	$\mu g/m^3$ (2019/20)	EEA 2020 https://www.eea.europa.eu/themes/air/air-quality-and-covid19/monitoring-covid-19-impacts-on
	✓	COV_15	PM10	$\mu g/m^3$ (2019/20)	EEA 2020 https://www.eea.europa.eu/themes/air/air-quality-and-covid19/monitoring-covid-19-impacts-on
	✓	COV_19	O_3	No. of days to exceed the 8 hour moving ayerage of 120 $\mu g/m^3$ (2018)	Ecosistema urbano 2019 https://www.legambiente.it/wp-content/uploads/rapporto-ecosistema-urbano-2019.pdf
Climate and weather	✓	COV_39	Wind	No. days/year with gusts > 25 knots (2008-18)	Il SOLE 24 ORE 2019 https://lab24.ilsole24ore.com/indice-del-clima/
	✓	COV_41	Fog	No. days/year with fog (2008-18)	Il SOLE 24 ORE 2019 https://lab24.ilsole24ore.com/indice-del-clima/
	✓	COV_55	Wind	Km/h wind (Jan/Feb/Mar 2020)	Il Meteo https://www.ilmeteo.it/
Population, health and life expectancy	✓	Cov_33	Hospital emigration	% No. of discharges of residents outside the region	IL SOLE 24 ore 2019 https://lab24.ilsole24ore.com/qualita-della-vita/classifiche-complete.php
	✓	Cov_83	Commuting	OD flows/internal flows	ISTAT 2011 https://www.istat.it/pendolarismo/grafici_province_cartografia_2011.html
	✓	Cov_102	Life expectancy	Increase in life expectancy (2002-2017)	Qualità della vita 1990-19 https://lab24.ilsole24ore.com/indice-della-salute/indexT.php

Fig. 3 Data set - Ecological approach

In particular, the retrieval of data - open data -, their cataloging, representation has always been consistent with the ecological approach (Fig.3), precisely in order to evaluate the phenomena in their complexity and entirety, to confirmed within the geospatial correlation - GWR and LISA, as presented in the next paragraph.

2.3 Methodology

The research carried on is based on an ecological approach, where the physiological traits of the virus are examined together with a set of selected relevant variables, covering different environmental and socio-economic aspects. Virus-related data as infected cases and (standardized) deaths were examined and referred to several variables. We concentrate on particular elements related to aspects that, in an integrated manner, can be considered important in understanding the human-environment relations between human activities, geographic and climatic conditions and virus outbreaks.

The quantitative analysis supporting our approach has been performed on area-based methods, particularly aimed at analyzing spatial autocorrelation among the area units considered – data at Italian province level. Autocorrelation is analyzed at local and global level by means of Geographically Weighted Regression (GWR) and Spatial Autocorrelation (LISA).

Standardized Mortality Ratio (SMR)

Mortality has been standardized using Standardized Mortality Ratio, that is keeping tracks of the different age structures that can be found in different regions considered for an analysis. It in fact takes into account the fact that different regions can have different population structures, and / or different mortalities. Standardized Mortality Ratio is therefore a method to analyze the patterns of deaths considering age composition. It calculates the expected number of deaths over the distribution of population by age group, and considering the age-specific rates of deaths for each areal unit considered.
Values around unity portrays a situation where mortality is behaving ‘as expected’, or in line with the trend of the area. Values higher than 1 are characteristic of a situation of a higher than expected mortality, while values lower than 1 suggest a mortality lower than that expected (Gatrell & Elliott, 2002). Mortality was standardized for the Italian provinces and for age groups - 10 groups; first group 0-9 years; last group 90-∞ -, with reference to the national population figures in the year 2019 (Istituto Nazionale di Statistica, 2019).
An indirect standardization was performed for computing specific mortality values by age group, obtained by dividing the number of Covid-19 deaths confirmed by the Italian Higher Institute of Health Care (ISS - Istituto Superiore della Sanità, sorveglianza integrata Covid -19) with the 10 defined age groups. The number of expected deaths for Italian provinces for the age groups previously identified and based on the Italian provincial population at provincial level (Istituto Nazionale di Statistica, 2019), was calculated as in the formula:

$$e = \sum_{i=1}^{K} n_i R_i \, , \tag{1}$$

with ni being the specific age group population in each observed province; Ri the national mortality rate for the specific age group.
The Standardized Mortality Ratio (SMR) was than calculated comparing the number of events observed in each province with the respective number of expected events:

$$SMR = 100\frac{d}{e} \tag{2}$$

with d the number of observed deaths and e the number of expected deaths.
Finally, the 95% confidence intervals (95% CI) were calculated, following the rule as in Vandenbroucke (Vandenbroucke, 1982).

Geographically Weighted Regression (GWR)

Geographically Weighted Regression (GWR) (Brunsdon et al., 1996; Casetti & Jones, 1992; Casetti, 2010; Fotheringham et al., 2002; Fotheringham et al., 1997; Stewart Fotheringham et al., 1996) is a method which allows to analyse how a phenomenon spatially changes within a particularly place. Starting from Tobler (Tobler, 1970) first law of geography "Everything is related to everything else, but near things are more related than distant things", GWR can be considered as a spatial extension of multiple linear regression. GWR is not limited to global parameters, but it considers also local parameters. Also, the mathematical formulation is very similar to the typical regression analysis (equations 3, 4).

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_m x_{mi} + \varepsilon_i \quad with \ i = 1 \ldots . n \tag{3}$$

Where:

- y_i = Dependent variable
- x_i = Independent (also the term Explanatory is adopted) variables
- β_0 = Coefficients (sometimes the term Parameters is used) expressing the relationship between dependent and independent variables.
- ε_i = Residuals, i.e. the part of dependent variable not explained in the model
-

$$y_i = \beta_0(u_i, v_i) + \beta_1 \ (u_i, v_i) \ x_{1i} + \beta_2 \ (u_i, v_i) \ x_{2i} + \ldots + \beta_m \ (u_i, v_i) \ x_{mi} + \varepsilon_i \tag{4}$$

In Geographically Weighted Regression the term (u_i, v_i) is also considered, which represents coordinates of point i in the space.

It is possible to have positive or negative relationships between dependent and independent variables: according to the kind of relationship, a sign (+/-) is associated to the coefficients.

In order to model in the best way, the phenomenon to be investigated it is fundamental to define all factors which may influence the analyses. The central point is to find the main variables in phenomenon modelling, defining the dependent variable and identifying the possible independent variables. It is also important, before analysing data with GWR, to test with Ordinary Least Squares the possible independent variables to adopt.

Two main measures of Ordinary Least Squares are useful in understanding if the variables adopted in the analysis are meaningful: R2 or adjusted R2 and Akaike. R2 results are generally included between 0 and 1. A better predictive performance has been highlighted by values close to 1. Akaike Information Criterion (AIC) (Akaike, 1973; Hurvich et al., 1998) has not an absolute scale of measure, but it is useful in comparing two models, with the same dependent variable, in order to assess which of them fits better the phenomenon. Smaller values of the AIC indicate a better simulation, if the difference is not big, less than 3, two models can be considered equivalent.

Another important check in model performance concerns Residuals. It is fundamental to analyse that spatial dependence does not occur in residuals, verifying a random spatial distribution. Residuals have to be analyzed by Moran Index I. Moran Index I (Moran, 1948) is a global measure of spatial autocorrelation and its values can be included between -1 and 1. If Moran Index I is close to zero data are randomly distributed, if the term is higher than zero, autocorrelation is positive, otherwise it is negative.

Regression coefficients are estimated using nearby feature values. Consequently, main parameters are kernel and bandwidth which provide a definition of nearby.

There are two kinds of kernel, fixed and adaptive: the first one defines nearby according to determined fixed distance band; while adaptive kind defines nearby according to determined number of neighbours.

Fixed kernel is adopted if observation points are regularly located, otherwise, if observation points are clustered, adaptive kernel is more suitable.

Bandwidth controls the size of kernel and can be defined in three ways: directly by the analyst (it is possible to directly define distance or neighbours number), by means of AIC method, which minimises Akaike Information Criterion (AIC), or by using CV, which minimises the CrossValidation score.

Spatial Autocorrelation

Geographical objects are generally described by means of two different information categories: spatial location and related properties. In data analysis there is a huge literature concerning methods which separately compute attributes from spatial components.

The most interesting property of spatial autocorrelation is the capability to analyze at the same time locational and attribute information (Goodchild, 1986). Consequently, spatial autocorrelation can be considered as a very effective technique in analyzing spatial distribution of objects assessing at the same time the degree of influence of neighbour objects. This concept is well synthesized in the first law of geography defined by Waldo Tobler (Tobler, 1970) "All Things Are Related, But Nearby Things Are More Related Than Distant Things". Adopting Goodchild (Goodchild, 1986) approach, (Lee & Wong, 2000) defined spatial autocorrelation as follows:

$$SAC = \frac{\sum_{i=1}^{N}\sum_{J=1}^{N} c_{ij} w_{ij}}{\sum_{i=1}^{N}\sum_{J=1}^{N} w_{ij}}, \tag{5}$$

Where:

- N is the number of objects;
- i and j are two objects;
- c_{ij} is a degree of similarity of attributes i and j;
- w_{ij} is a degree of similarity of location i and j.

defining x_i as the value of object i attribute; if $c_{ij} = (x_i - x_j)^2$, Geary C Ratio (Geary, 1954) can be defined as follows:

$$C = \frac{(N-1)\left(\sum_i \sum_j w_{ij}\,(x_i - x_j)^2\right)}{2\left(\sum_i \sum_j w_{ij}\right)\sum_i (x_i - \bar{x})^2}, \tag{6}$$

If $C_{ij} = (x_i - \bar{x})(x_j - \bar{x})$, Moran Index I (Moran, 1948) can be defined as follows:

$$I = \frac{N \sum_i \sum_j w_{ij}\,(x_i - \bar{x})(x_j - \bar{x})}{\left(\sum_i \sum_j w_{ij}\right)\sum_i (x_i - \bar{x})^2}, \tag{7}$$

These two indices are very similar, mainly differing in the cross-product term in the numerator, which in Moran is calculated using deviations from the mean, while in Geary is directly computed.

These two indices are global indicators of spatial autocorrelation. They provide an indication about the presence of autocorrelation. The precise location of elevated values of autocorrelation is provided by Local Indicators of Spatial Association. One of the most adopted indices of local autocorrelation is LISA-Local Indicator of Spatial Association developed by Anselin (Anselin, 1988, 1995), considered as a local Moran index. The sum of all local indices is proportional to the value of Moran one:

$$\sum_i I_i = \gamma\, I, \tag{8}$$

The index is calculated as follows:

$$I_i = \frac{(X_i - \bar{X})}{S_X^2} \sum_{j=1}^{N} \left(w_{ij}\,(x_j - \bar{x})\right), \tag{9}$$

It allows, for each location, to assess the similarity of each observation with its surrounding elements. Five scenarios emerge:

- locations with high values of the phenomenon and high level of similarity with its surroundings (high-high H-H), defined as *hot spots*;
- locations with low values of the phenomenon and high level of similarity with its surroundings (low-low L-L), defined as *cold spots*;

- locations with high values of the phenomenon and low level of similarity with its surroundings (high-low H-L), defined as potentially *spatial outliers*;
- locations with low values of the phenomenon and low level of similarity with its surroundings (low-high L-H), defined as potentially *spatial outliers*;
- locations completely lacking significant autocorrelations.

LISA (Local Indicator of Spatial Association) provides an effective measure of the degree of relative spatial association between each territorial unit and its surrounding elements, allowing highlighting type of spatial concentration for the detection of spatial clusters.

In equations 5, 6, 7, 9 the only term not well formalized is w_{ij} related to neighbourhood property. The most adopted approach in formalizing this property is spatial weights matrix, w_{ij} are elements of a matrix considered as spatial weights, equal to 1 if i and j are neighbours equal to 0 in the case of self-neighbour or if i and j are not neighbours. This approach is based on the concept of contiguity, where elements share a common border of non-zero length. It is important to give a more detailed definition of contiguity and more particularly what does a border of non-zero length exactly mean.

Adopting chess game metaphor (O'Sullivan & Unwin, 2010), contiguity can be considered as allowed by paths of *rook*, *bishop* and *queen.*

3. Results

3.1 Ordinary Least Squares and Geographically Weighted Regression (GWR)

All variables, previously described, have been tested using Ordinary Least Squares in order to understand in which measure they are reliable. First results and elaborations of statistical tests suggested to exclude some variables from the analyses for low correlation or redundancies. More particularly, the number of deaths have been considered as a dependent variable and annual average of $PM_{2,5}$ and PM_{10}, Ozone (O_3 - number of days to exceed the 8 hour moving average of 120 µg/mc), Wind gusts (annual days with gusts> 25 knots), Fog, Surface waterproofed to year 2016, Wind (Km/h, Jan - Feb - Mar 2020), Hospital emigration, Commuting, CO_2 in not urbanized areas have been adopted as explanatory variable. The results are quite interesting, R2 is 0.705979, Adjusted R2 0.671935 and Akaike Information Criterion (AIC) 1392.44. Variance Inflation Factor is less than 7.5, all values are lower than 3.5, this means that the explanatory variables are not redundant.

It is also important to analyze residuals. The residuals of a good model should be normally distributed with a mean of zero. I our case the residuals histogram matches the normal curve indicated in blue in Fig.4.

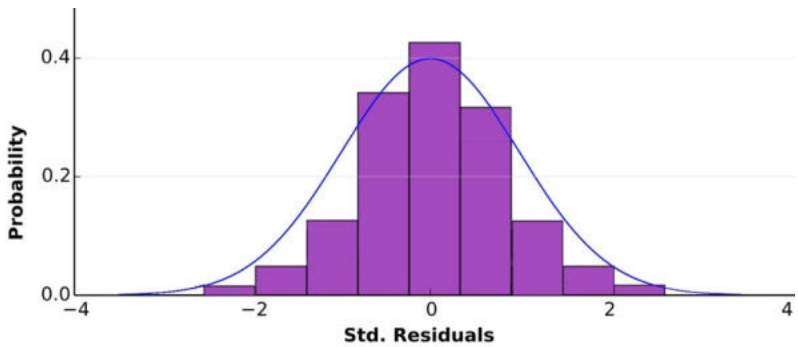


Fig. 4 Histogram of Distribution of Standardized Residuals

The other important aspect is the spatial distribution of residuals. More particularly, standardized values of residuals, calculated by means of Ordinary Least Squares, have been used as input data in calculating spatial autocorrelation, in order to understand if residuals were autocorrelated or not.

Spatial autocorrelation has been calculated adopting Moran scatter plot and considering standardized variables of residuals as abscissa and spatial weighted standardised variable of residuals as ordinate. In the graph, Moran Index corresponds to direction coefficient of linear regression, which represents the scatter plot. Positive autocorrelation corresponds to spatial clusters in upper right and lower left quadrants. Lower right and upper left quadrants can be classified as spatial outliers.

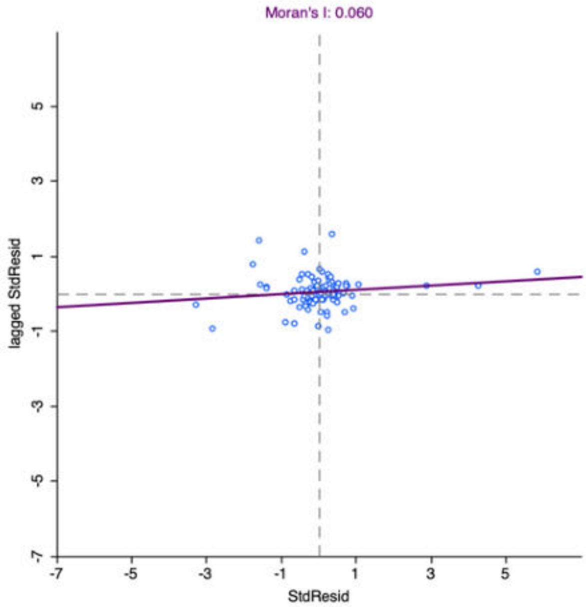


Fig.5 Moran scatter plot of residuals standardized variable

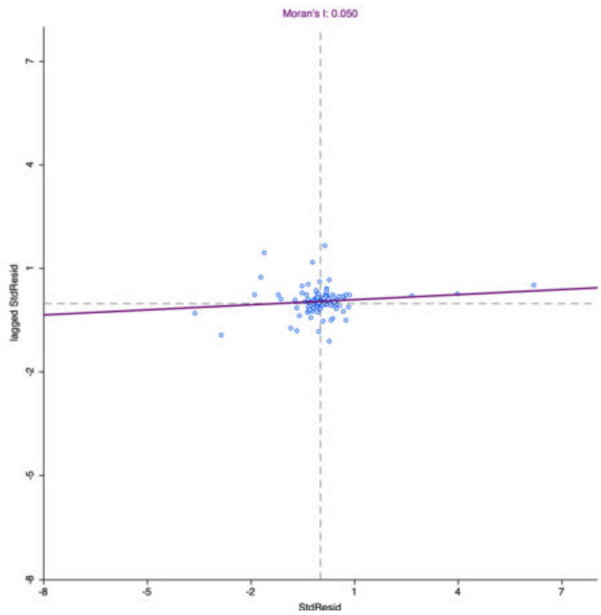


Fig.6 Moran scatter plot of residuals standardized variable

Fig.5 shows that the slope of Moran Index is close to zero coinciding with abscissas axis, this means that residuals are not spatially autocorrelated.

Ordinary Least Squares allows to analyse the relationship between dependent variable and explanatory variables, deleting also redundant and not significant variables.

After the good results obtained with Ordinary Least Squares it is important to analyse how these relationships vary over space. This is possible using Geographical Weighted Regression. As expected GWR results are better than those achieved with OLS: namely, R2 is 0.741573518, Adjusted R2 0.689031597 and Akaike Information Criterion (AIC) 1389.801618.

Also, in this case residuals are not spatially autocorrelated. Fig.6 shows that Moran Index is 0.05 this means that the spatial distribution is random.

Local R^2 is a parameter included between 0.0 and 1.0, it is an indicator on how the local regression model fits the observed values. If the indicator is close to zero the local model is far from the observed values. In this case all values are close to 0.7 (figure 7) and there are not great differences. Despite the local values are quite equivalent the map at national scale describes the Italy divided in four zones with the highest level of R2 in the northern part of Italy.

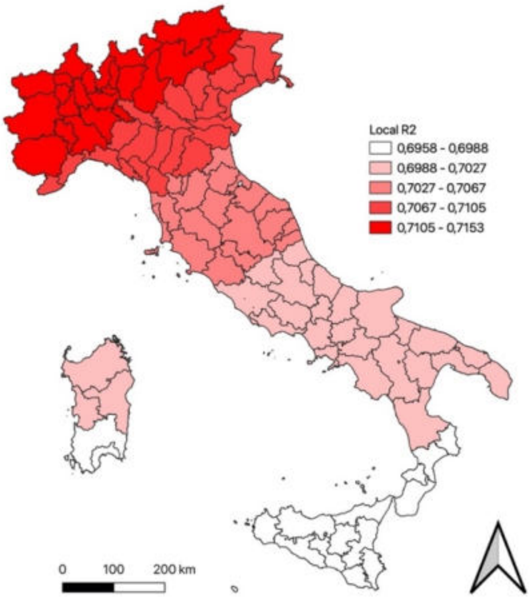


Fig.7 Local R^2 map

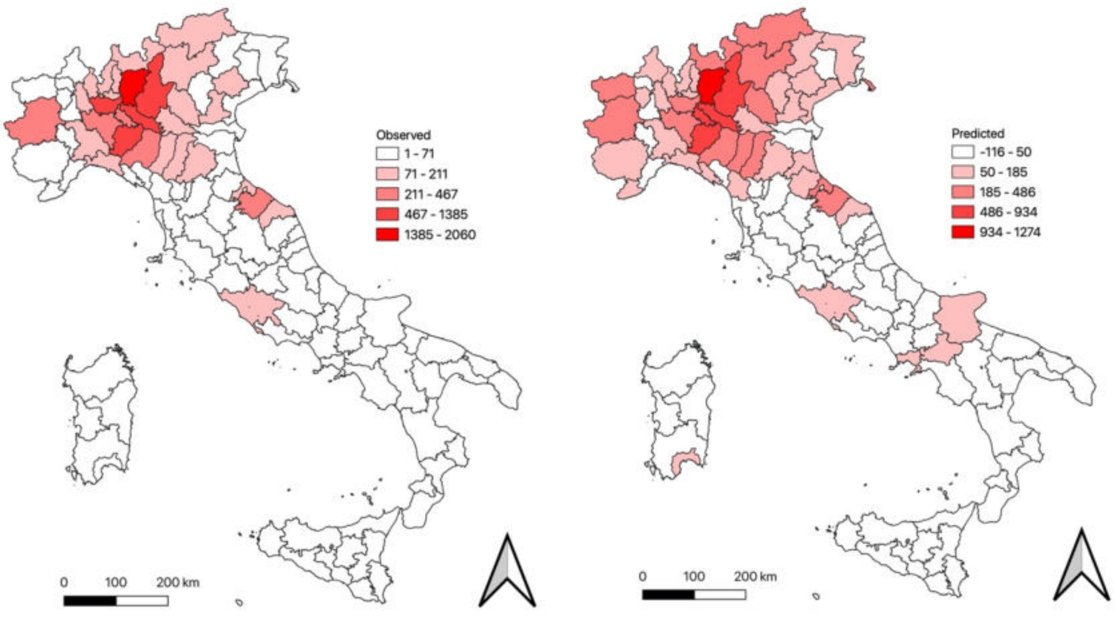


Fig.8 Observed (a) and predicted (b) values

Analyzing Fig.8 It is possible to observe that there are small differences between the observed and predicted values also at local level, this means that the local regression model fits very well the analysed phenomenon.

3.2 Local Indicators of Spatial Autocorrelation (LISA)

In the Po Valley megalopolis the local climate changes (Fig. 9) and the significant change in relative humidity and air quality - non-disjointed phenomena - (Blum, 2017; Maione et al., 2016; Manes et al., 2016; Reames & Bravo, 2019)) affect the quality of life, which is exposed to several actions combined with poor air quality (Reames & Bravo, 2019).

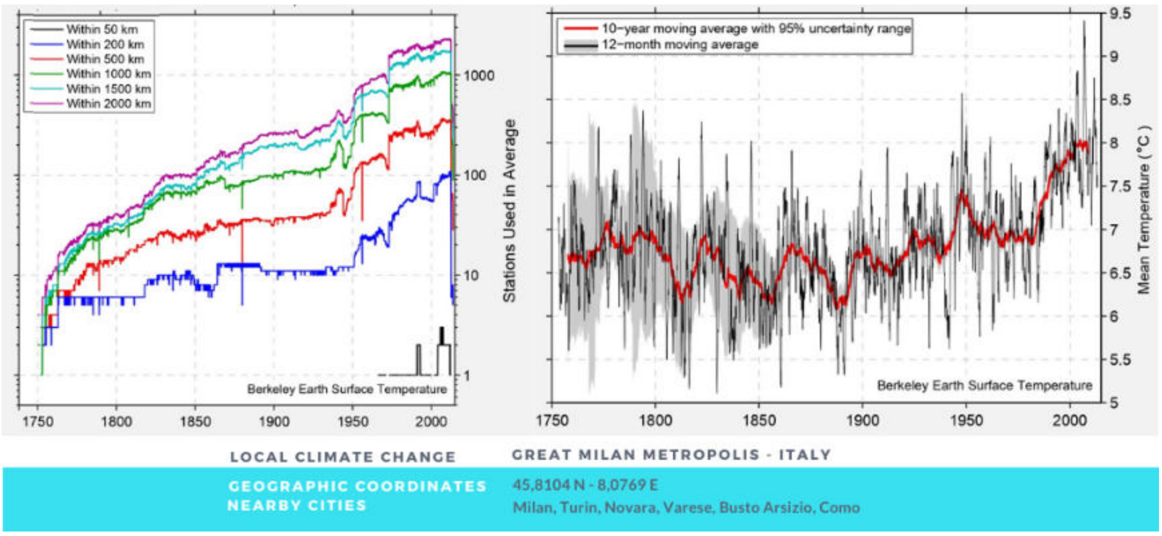
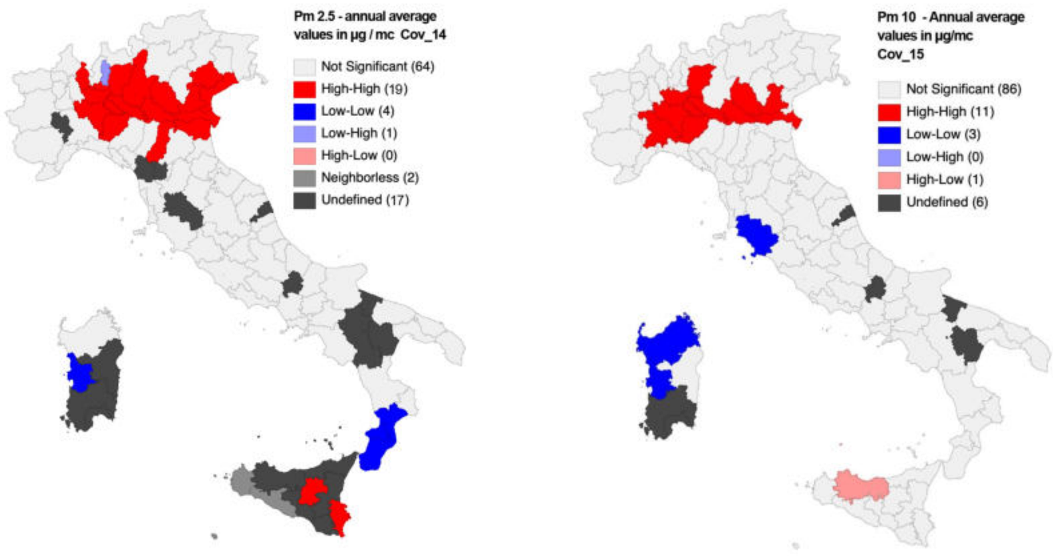


Fig.9 Local Climate Change - Great Milan Metropolis

These are in fact apparently unrelated phenomena, which in reality, besides being profoundly dependent on each other, do not act as a mere sum on environmental ecosystems and communities, but in the form of combinations that are in turn related to urban geography - land use: efficient land use, sprawl and ecosystem services. It should be noted that the law on air quality has substantial differences from country and country (Fig 10). Furthermore, the reference targets for making comparisons are still those of the 2005 WHO guidelines. It is worth mentioning WHO Guidelines (*WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide*, 2006) that for $PM_{2.5}$, they set a daily limit of 25 $\mu g/m^3$; year limit 10 $\mu g/m_3$ and that in Italy with Legislative Decree of 13 August 2010, n. 255: 25 $\mu g/m^3$ year limit was lowered to 20 $\mu g/m^3$ only from 1st January 2020. However, this new national target of $PM_{2.5}$ does not take into account the direct and indirect effects deriving from the geography, urban and climatic weather conditions of the contexts, which in the Po Valley are certainly an important element for the purposes of air quality (Ferrero et al., 2019). In particular, local climate changes such as temperature and humidity, poor air quality and the persistent absence of wind, make the Po Valley a one of a kind area, both at national and international level. Furthermore, frequent and persistent thermal inversion phenomena in the winter months, especially in periods of high atmospheric pressure, traps the cold air near the ground, together with the pollutants (Caserini et al., 2017). In the Po valley, urban phenomena of industrialization and intensive farming (Romano & Zullo, 2016), intertwine and more than 50% of national GDP is produced, as well as almost 50% of national energy is consumed (Arpa Emilia-Romagna ARPAE, 2018). The transition to compatible solutions related to well-being seems not exactly close, despite the several regional and national plans to monitor and improve air quality (Marongiu et al., 2019). Furthermore, life expectancy for both genders is substantially stable, confirming for longer in Northern Italy (Istituto Nazionale di Statistica, 2019), also a consequence of social inequalities, disabilities and access to health services, contributing to the North - South social divide. Finally, also in the North there is also a greater and specific health care over 65. In this complex framework, land use takes on a significant dimension.

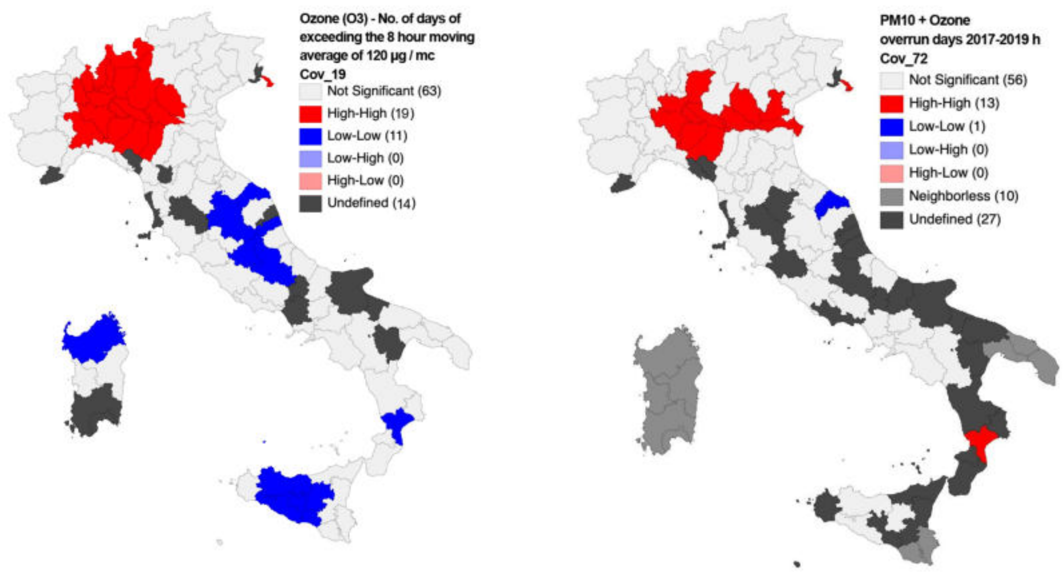
In this research aimed at evaluating why Northern Italy was marked by Covid-19, the data set - selected from different sources and open data) used for the development of the Lisa Maps played an important role, supporting the interdisciplinary ecological approach: Land use; Air quality; Climate and weather; Population, health and life expectancy. In particular, the LISA maps on indicators relating to these phenomena: Cov_14, Cov_15, Cov_19 and Cov_72 - confirm these first evaluations of the air pollution in Po Valley megalopolis (Fig. 11, Fig. 12 and Fig.13) and at the same time highlight the other side of the metropolis: the increase in life expectancy and the provision of related health care (no. of geriatricians / 1000 ab over 65).

Fig.10 The WHO PM 2.5 target in 2019



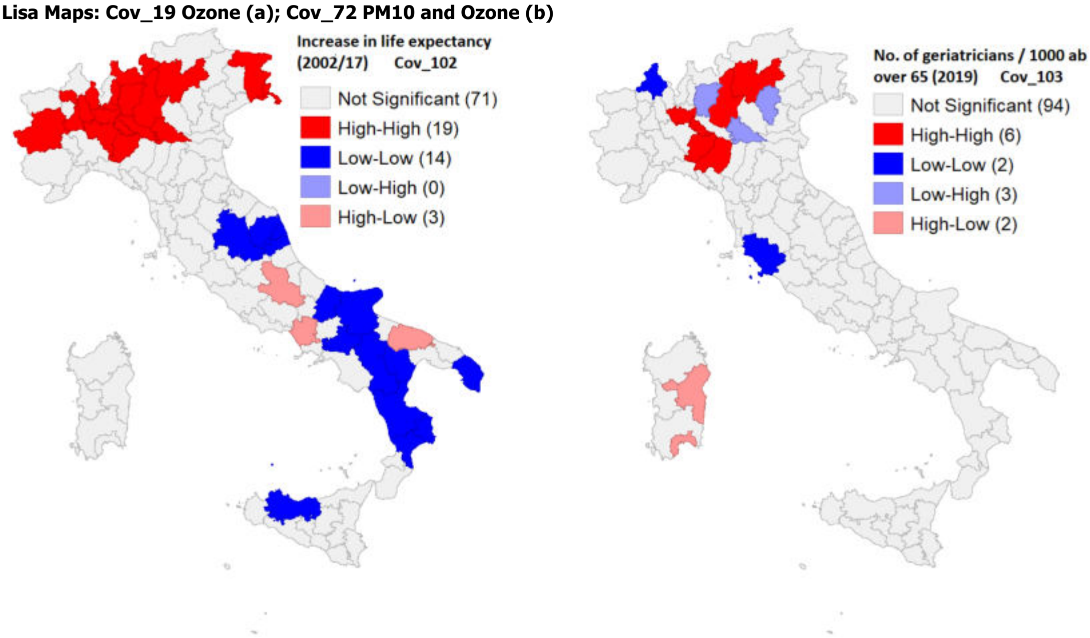
(a) (b)

Fig.11 Lisa Maps: Cov_14 PM2.5 (a); Cov_15 PM10 (b)



(a) (b)

Fig.12 Lisa Maps: Cov_19 Ozone (a); Cov_72 PM10 and Ozone (b)

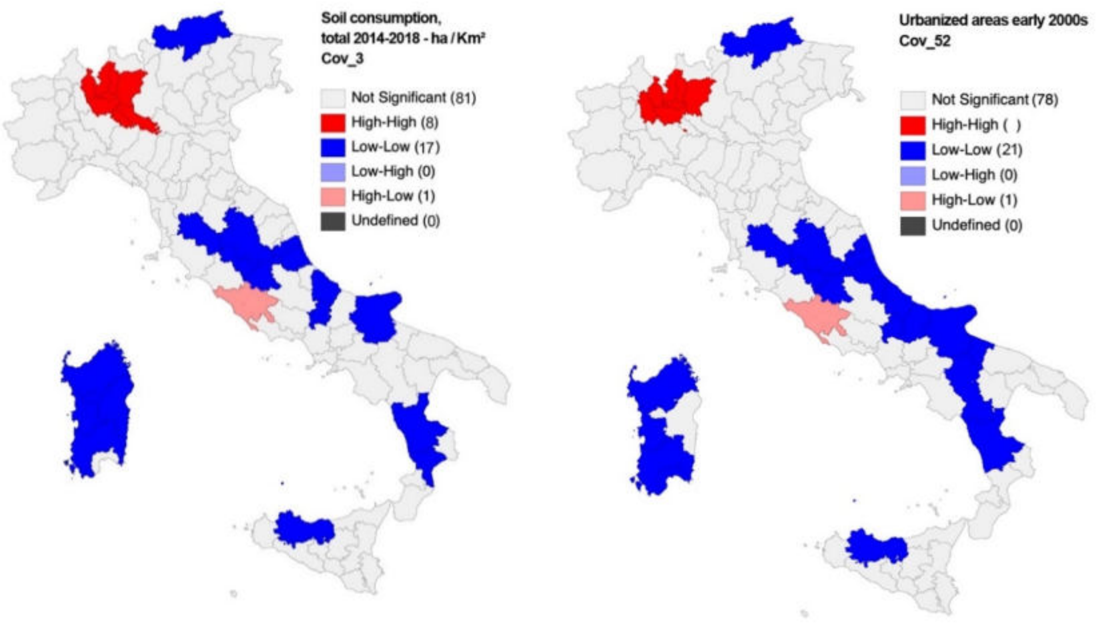


(a) (b)

Fig. 13 Lisa Maps: Cov_102 Increase in life expectancy (2002-2017) (a); Cov_103 No. of geriatricians / 1000 ab over 65 (2019) (b)

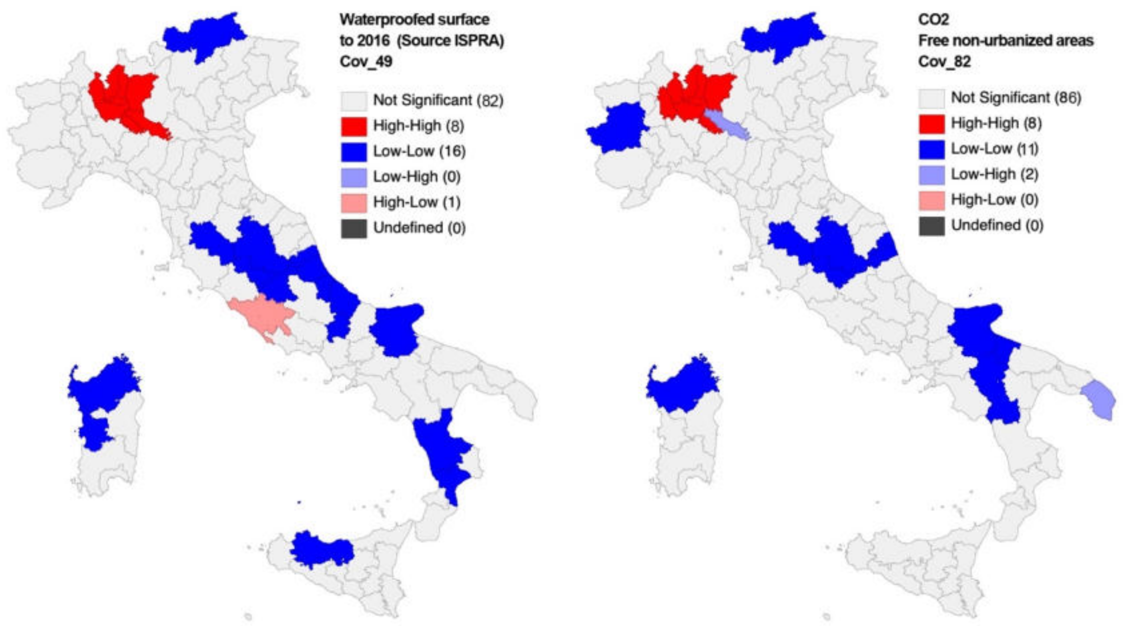
In other words, in this complex case study of the Po Valley megalopolis we can observe the persistency of: poor air quality - climatic handicap (Ferrero et al., 2019), inefficiency of land use (Romano et al., 2017) and increased life expectancy (Poli et al., 2019; Sarra & Nissi, 2020) of the population with a presumably consequent impact of Covid-19 in terms of both infections and deaths (ISTAT & ISS, 2020).

As previously explained, Po Valley has spatial configuration as basin completely closed by Alpine Chain and Apennines and it is characterized by an a homogeneous and isotropic space. While the former feature represents a strong impediment to air circulation and distribution the later increases the probability that urban sprawl phenomenon occurs. The two aspects are strongly related because the soil is an important element in the carbon cycle allowing CO_2 sequestration and storage. Consequently a lack of attention to the spatial planning can generate negative effects producing a loss of these properties (Zomer et al., 2017). Soil and related ecosystem services are important elements in the improvement of air quality reducing PM10 and O_3 (Fusaro et al., 2017; Manes et al., 2016). Po Valley is the most attractive area of the country because great part of productive activities are concentrated, consequently it is fundamental to have a lot of not urbanized areas capable of allowing CO_2 storage. Unfortunately annual reports of Italian Institute for Environmental Protection and Research (ISPRA) (Munafò, 2019), other important researches (Martellozzo et al., 2018; Pileri & Maggi, 2010; Romano & Zullo, 2016) highlight that Land take phenomenon in Italy is mainly concentrated in the northern part of the country.



(a) (b)

Fig.14 Lisa Maps: Cov_3: land take between 2014-2018 (a); Cov_52: land take up to 2000 (b)



(a) (b)

Fig.15 Lisa Maps: Cov_49: sealed soils (a); Cov_82: CO_2/non urbanized areas (b)

Also spatial autocorrelation analysis confirms this trend with the more elevated values concentrated in Lombardy region. More particularly figures 14 and 15 analyze LISA index of land take between 2014-2018 and up to 2000, sealed soils at 2016 and CO2/non urbanized areas. The concurrence of these factors led to a dangerous combination with a high concentration of elements dangerous to health with a strong decrease of areas which, in some way, represent the only possibility to air cleaning.

4. Discussion

In the geographical context of Po Valley, elements as land use, life expectancy, commuting, climate handicap and poor air quality certainly played a role and contributed to increasing the effects of the epidemic. Furthermore, local climate changes such as temperature and humidity, poor air quality and the absence of wind make the Po Valley an area unique of its kind, both nationally and internationally. It represents an isotropic territorial context suitable for anthropic activities, but at the same time with latent health risks. In particular, in the Po Valley, urban industrialization phenomena are characterized by a high entropy and by an increasing consumption of resources, given its contribution to over 50% of national GDP and, as a side effect, the consumption of almost 50% of national energy. Despite the existence of several regional and national plans to monitor and improve air quality, climate, soil consumption, etc. the transition to compatible solutions related to well-being does not seem close. Furthermore, on the occasion of the Covid-19 epidemic, PM_{10} emissions in the Po Valley were high and sometimes exceeded the limits and must be related to the combined climate - wind, winter thermal inversion - and human actions - remained active in the lockdown period - domestic heating, urban logistics, food production and retail. In this context, certainly not simple for both human, environmental and anthropic geography, the ecological approach has allowed us to obtain the first results and the first policy proposals with supported by GWR and LISA analysis, referring to the combined action between urban design, monitoring and health risk plan (Fig.16).

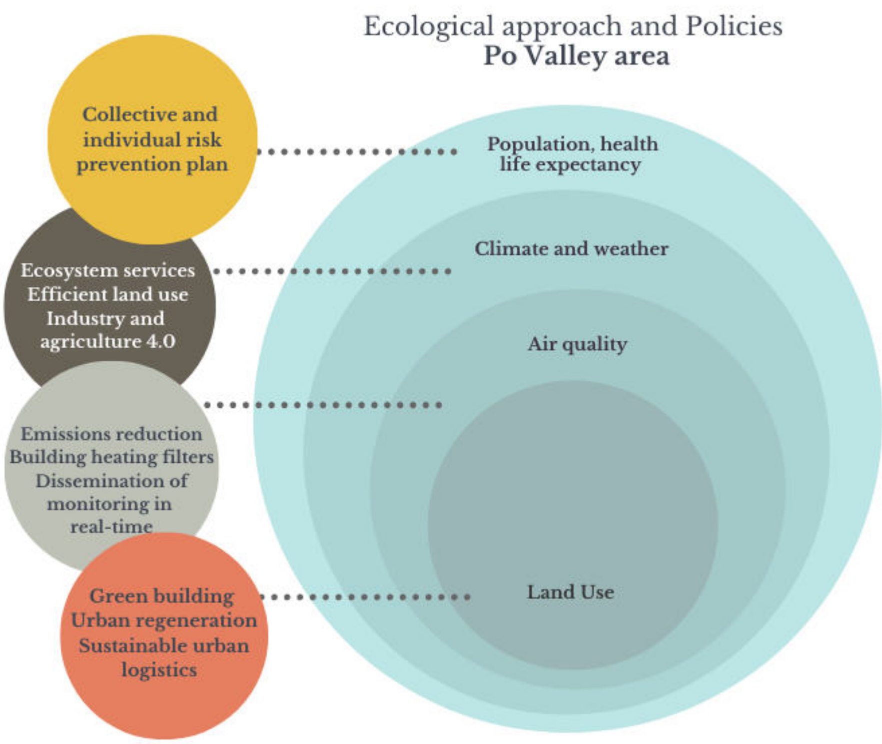


Fig.16 Ecological approach and Policies - Po Valley Area.

The health emergency has highlighted even more how in many cases the urban and territorial plans are old, very far from the current reality or based on old laws, which do not allow the production of tools to respond rapidly to current and immediate problems. The outcome is a scenario that leads to a consumption of resources greater than the planet's capacity. The result is that the main planning goals are very far from providing a serious response to the transformation demands that daily arise. This old system, based on vintage planning (Romano et al., 2018) or ghost planning (Scorza et al., 2020), can lead to a situation of potential peak and overshooting of the environmental carrying capacity (represented on left part of Fig.17).

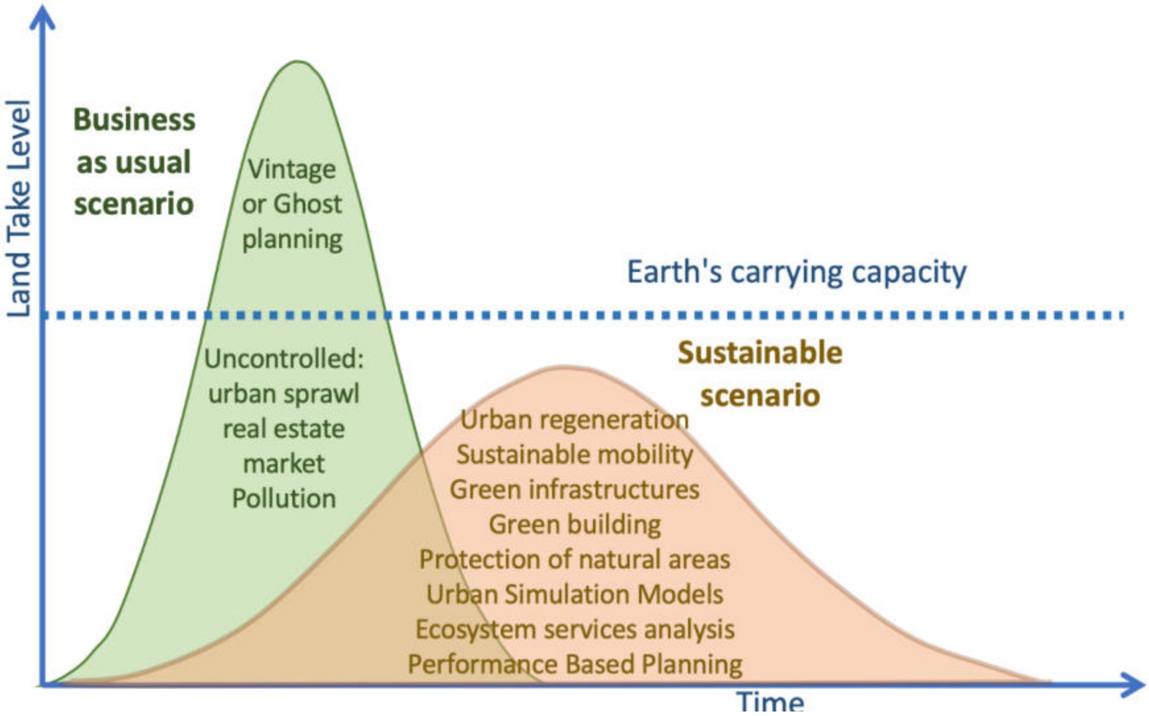


Fig.17 Ecological approach and Policies - Po Valley Area

As in the most dramatic moments of the Covid-19 outbreak a quest for flattening the curve was requested to avoid a peak and an extra stress over the national health systems, planning seem facing, now more than ever, the same risks and challenges. If, as said, ghost and vintage planning can barely allow tackling short run, ordinary solutions, for long run and extraordinary cases a change of pace is needed. An alternative to be pursued is an ecological approach based on simulations in assessing transformations impacts, that allows planners to take into account several land use scenarios, choosing the more suitable solutions for transformations. Such an approach to planning can also consider the possible losses of ecosystem services in simulations (Geneletti D., 2016; Gobattoni et al., 2016). The vast amount of data to date available, together with the vast array of instruments for modelling scenarios, as Multiagent Systems, Space Syntax, Geodesign (Cocco et al., 2020; Steinitz, 2012), etc. can take into account a lot of components in detailed simulations. A Performance Based Planning represents the summary and the container for all of these models and simulation tools. Such capacity of gathering and elaborating data to produce scenarios can help in meeting objectives of protecting natural areas and consequently of human health be more easily.

Furthermore, adopting urban policies based on urban regeneration, sustainable mobility (Battarra et al., 2018; Bonotti et al., 2015; Papa et al., 2018; Tira et al., 2018) and the creation of green infrastructures (Balletto et al., 2020; Lai et al., 2018; Ronchi et al., 2020) can create a more sustainable scenario able to flatten the curve under the Earth carrying capacity (Gargiulo & Russo, 2018; Maragno et al., 2020; Pietrapertosa et al., 2019).

5. Conclusions

In this paper we focused our attention on the Covid-19 outbreak in Italy and on the effect of the interaction among geographical, environmental and socio-economic characteristics. The occasion of the massive outbreak in the Po Valley area, which has been analyzed and compared in its main character with the Wuhan – Hubei Province in China in terms of some similarities, led us to consider a wide set of variables and analyze them by using spatial analytical methods. This was done to evaluate some relations and to provide with some suggestion in terms of integrated planning and policy actions. From a wide selection of variables we highlighted four big families, grouped for 'land use', 'air quality', 'climate and weather' and 'population, health and life expectancy'. These were related to mortality, expressed in terms of SMR – Standardized Mortality Ratio - examined in terms of spatial autocorrelation, and considered both from the spatial and attribute point of view. Geographically Weighted Regression - GWR - and Local Indicators of Spatial Autocorrelation LISA – Spatial analytical techniques as were performed and were useful in confirming a relation between a set of conditions and the spreading of the Covid-19. The analysis helped to understand more the relation between environmental conditions and health aspect, and on the need to introduce and systematize analytical tools to support spatial decisions, to plan in ordinary and extraordinary conditions.

Future developments will concern the systematization of medium and long-term policies in relation to health risk.

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