

# Is There a Relationship Between Climate, Morphology and Urbanization and COVID19? Preliminary Analysis of Environmental and Pandemic Data in the Lombardy Region (Northern Italy)

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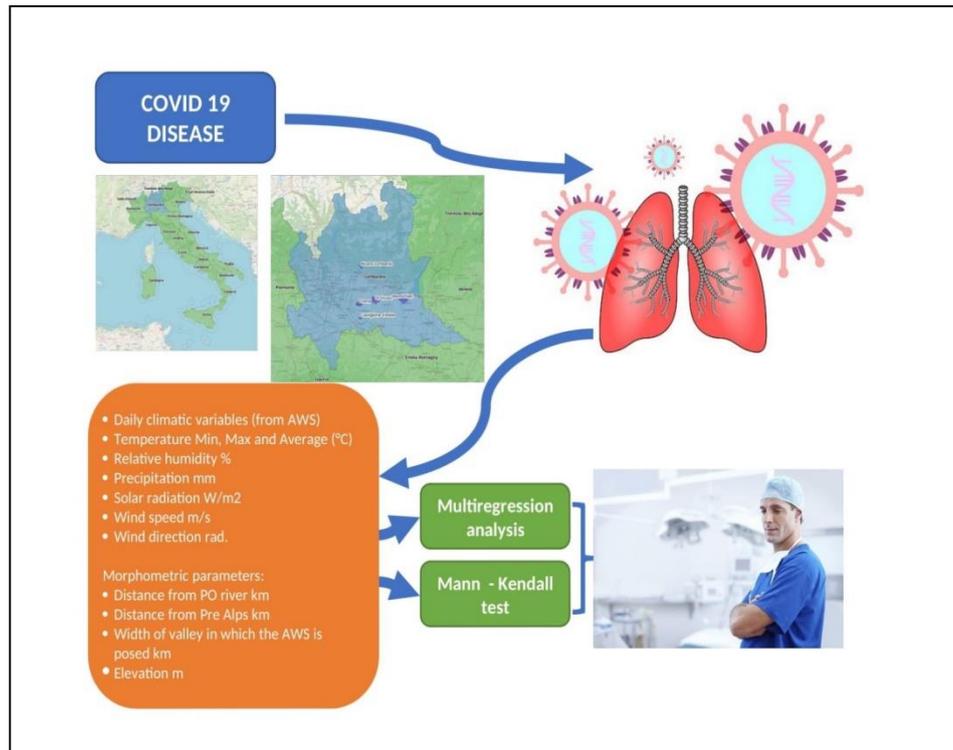
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**Abstract** The coronavirus disease 2019 (COVID-19) pandemic is the defining global health and socioeconomic crisis of our time and represents the greatest challenge faced by the world since the end of the Second World War. The academic literature indicates that climatic features, specifically the temperature and absolute humidity, are very important factors affecting infectious pulmonary disease epidemics (e.g., SARS, MERS); however, the influence of climatic parameters on COVID-19 remains extremely controversial. The goal of this study is to quantify the existing relationship between several daily climate parameters (temperature, relative humidity, accumulated precipitation, solar radiation, wind direction and intensity, and evaporation), local morphological parameters, and new daily positive swabs for COVID-19, which represents the only parameter that can be statistically used to quantify the pandemic. The daily deaths parameter was not considered because it is not reliable due to frequent administrative errors. Daily data on meteorological conditions and new cases of COVID-19 were collected for the Lombardy area from March 1, 2020, to April 20, 2020. This region in Italy exhibited the largest number of official deaths in the world per million inhabitants, with a value of approximately 1700 per million on June 30, 2020. Moreover, the apparent lethality was approximately 17% in this area, mainly due to the considerable housing density and the extensive presence of industrial and craft areas. The Mann-Kendall test and multivariate statistical analysis showed that none of the considered climatic variables exhibited statistically significant relationships with the epidemiological evolution of COVID-19, at least in the spring months in temperate subcontinental climate areas, with the exception of solar radiation, which was directly related and showed an otherwise low explained variability of approximately 20%. Furthermore, the average temperatures of two highly representative meteorological stations of Molise and Lucania, the most weakly affected by the pandemic. The temperatures at these stations were approximately 1.5°C lower than that in the cities in Lombardy of Bergamo and Brescia, again confirming that a significant relationship between the increase in temperature and decrease in virology from COVID-19 was not evident, at least in the Italian peninsula.

**Keywords:** Coronavirus disease 2019 (COVID-19); temperate sub-continental climate; Lombardy; temperature; solar radiation

## Graphical Abstract.



## 1. Introduction

In the second part of December 2019, the World Health Organization (WHO) reportedly received information about an epidemic with unidentified ethology from Wuhan, Hubei, China. On February 11, 2020, this epidemic was officially named COVID-19 and was acknowledged as an infectious disease resulting in a public health emergency, as it quickly spread within China and to 24 additional countries throughout the world [1,2].

The SARS-CoV-2 or COVID-19 pandemic has become a major global health threat. The last time the world responded to a global emerging disease epidemic of the scale of the current COVID-19 pandemic with no access to vaccines was the 1918-19 H1N1 “Spanish” influenza pandemic. While our understanding of infectious diseases and their prevention is now very different than that in 1918, most of the countries across the world face the same challenge today with COVID-19, a virus with comparable lethality to H1N1 influenza in 1918-19.

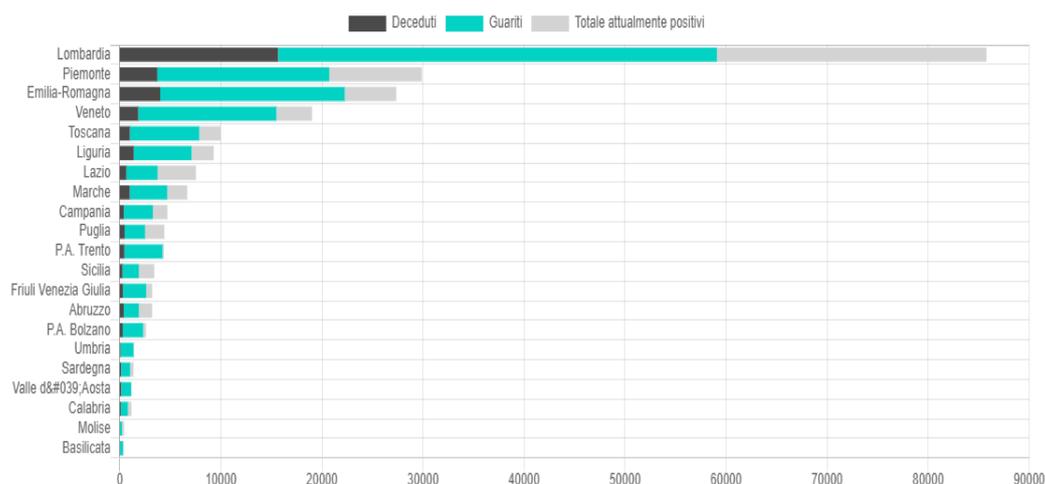
Coronavirus is a specific type of virus that affects the respiratory tract. The virus causes several illnesses, ranging from colds and pneumonia to severe acute respiratory syndrome (SARS) [3]. The outbreak of COVID-19, as the newest coronavirus discovered, started in the city of Wuhan, China, at the end of December 2019. On March 11, 2020, the World Health Organization officially declared the novel coronavirus a pandemic, as the virus spread to more than one hundred countries, causing over thousands of deaths.

On the night of February 20, 2020, the first case of novel coronavirus disease (COVID-19) was confirmed in Codogno in the Lombardy Region, Italy. In the week that followed, Lombardy experienced a very rapid increase in the number of cases. At the time of detection of the first COVID-19 case, the epidemic had already spread in most municipalities of southern Lombardy[4].

During the early stages of the COVID-19 epidemic in Lombardy, we observed the formation of three major clusters identified around the cities of Codogno, Bergamo, and Cremona. Later, the epidemic started to widely spread throughout the region and subsequently throughout Italy within a short time, albeit with a minor spread due to the lockdown that occurred earlier in the south than

in the northern regions. Similar quick spread of COVID-19 in France, Germany, Spain, USA, and South Korea led to the WHO declaring it as a pandemic [5].

After entering Italy, coronavirus quickly spread. As of May 31, 2020, the total number of cases reported by the authorities reached 233 K, and approximately 32 K of these cases resulted in death. The north of the country was mostly hit, and the region with the highest number of cases was Lombardy, which registered approximately 88 K of the cases, with 0,86% of the infected population and 15,3 K dead (fig. 1). The neighbouring regions of Piedmont and Emilia-Romagna followed in the list of the regions with the most cases. The virus mostly impacted individuals older than 50 years in Italy. As of May 20th, Italy had the sixth-highest number of coronavirus cases after the United States, Russia, Brazil, the United Kingdom, and Spain [6,7,8].



**Figure 1.** – Regional distribution of COVID-19 on June 30th - : deceduti: dead; guariti: healed, totale attualmente positivi: total currently positive (source: national civic protection).

## 2. Geography and climatology of Lombardy

Lombardy is one of the twenty administrative regions of Italy and is located in the northwest of the country, with an area of 23,844 square kilometers (9,206 sq mi). Approximately 10,5 million people live in Lombardy, representing more than one-sixth of Italy's population, and 18% of Italy's GDP is produced in the region, making it the most populous, richest, and most productive region in the country. Lombardy is also one of the top regions in Europe according to the same criteria.

Milan's metropolitan area is the third largest in Italy after Naples and Rome and the third most populated functional urban area in the EU. Lombardy has a wide array of climates due to local variances in elevation, proximity to large inland water, and large metropolitan areas (e.g., Milan).

The climate of the region is mainly humid subtropical (Cf according to Köppen and Geiger, 1954 – fig. 2, [9]), but the climate is truly humid subcontinental, especially in the Po plains and the most extended valley floor. However, these regions exhibit significant variations to the Köppen model, especially regarding the winter season, which is normally long, damp, and rather cold in Lombardy, with several days without daytime thaw.

In addition, there are high seasonal temperature variations (in Milan for the 1981-2010 timespan, the average January temperature was 2.7 °C (36.9 °F) and 24.5 °C (77 °F) in July). The annual average temperature (AAT) is 13.1 °C (55.5 °F, Air Force Meteorological Service, 2006). A peculiarity of the regional climate is the thick fog and consequently the smog that frequently covers the Po plains between October and February.

In the Alpine foothills, which are characterized by an oceanic climate (Köppen Cfb), numerous lake basins (Maggiore, Como, Lugano, Iseo, and Garda) exercise a mitigating local influence - just to 15°C of the AAT (annual average temperature) along their coasts - allowing the cultivation of typical Mediterranean crops (olives, orange, and citrus fruit). In the medium-high hills and mountains, the climate is humid continental, with cold winters and mild – fresh summers (Köppen Dfb).

In the valleys, the climate is relatively mild but with frequent thermal inversion, while it can be severely cold above 1,500 m, with abundant snowfall (Passo Tonale, 1883 m a.s.l. – 627 cm/season of fresh snow). Above 3,000 m, extended glaciers are present in the Adamello-Presanella, Ortles-Cevedale, and Bernina massifs.

Precipitation is more abundant in the pre-alpine area, reaching 1,500 to 2,200 mm (59.1 to 80.7 in) annually but is also abundant in the plains and alpine zones, with an average of 600 to 850 mm (23.6 to 33.5 in) annually. Approximately 1013 mm | 39.9 inches of precipitation falls annually in Milan. (Air Force Meteorological Service, 2008).

The total annual rainfall in the region is on average 853 mm. The pluviometric regime is “padan” type [10] in the lower Po plain, slightly bimodal, with an absolute minimum in winter, which is common to all regional pluviometric regimes; the second lowest values occur in July, and two maxima occur in November and April.

In the high plains area, in the hills, pre-alpine, and the Orobic Alps, the regime becomes pre-alpine-subalpine, with two similar maxima in spring and autumn and two moderate minima in the solstice seasons. Along the Alpine chain, the system becomes subcontinental and continental, unimodal, with a summer maximum and a moderate snowy minimum in winter.

## Köppen climate types of Italy



**Figure 2.** Climate map of Italy (Köppen-Geiger, 1954) with evidenced Lombardy.

### 2.1. Meteorological analysis for the period March 1st – April 20th

From the meteorological point of view, the period under study showed a clear discontinuity with respect to the first two months of the year, which were dominated by prevailing anticyclone conditions and with an extremely mild thermal climate - up to 4°C above the climatic average. In particular, in the first part of March in northern Italy, four fronts passed through the Atlantic in rapid succession, which brought significant rainfall. The most intense of these fronts occurred between March 2nd and 3rd, accompanied by intense atmospheric phenomena and abundant snowfall even below 1000 meters. Temperatures fell below the average climate conditions of approximately 2 °C. The middle of March, between days 11 and 21, was characterized by more stable meteorological conditions due to the increased presence of the Azores anticyclone. In this phase with dry and mild weather, the passage of a single perturbation was distinguished, with modest effects on day 14. In its wake, however, there was a significant thermal decrease due to the cold continental polar currents that occurred in the Po Valley.

This cold phase coincides with the period of maximum epidemiological expansion of coronavirus in Lombardy. The last part of March began with a late burst of Arctic sea air over the country. Between March 22nd and 23rd, the development of a blocking configuration in northern Europe favored the transport of north-eastern currents up to the Mediterranean, with a sharp and generalized decrease in temperatures, even in the presence of very low rainfall, with snow up to high plains (approximately 300 m). In the following days, the weather remained variable and significantly improved between March 28th and 29th due to the weakening of the low pressure over the Mediterranean, while the passage of a new Atlantic cold front characterized the last two days of the month, with abundant rainfall on the 30th day.

The first two weeks of April were characterized by a long phase of stable and dry conditions, with very mild temperatures of 1-2°C above the climate average due to the persistent presence of a subtropical anticyclone that extended over a large part of southern Europe. The long phase dominated by weather stability was temporarily interrupted only on the 14th, when Lombardy was rapidly crossed by a cold front coming from northern Europe that caused weak rains. Cold currents descending from northern Europe also favored a sharp thermal decline that covered much of the country. Between April 15th and 18th, a new phase of fair weather occurred due to a high-pressure system that elongated from North Africa to the Alps. On the 19th, the approach of low pressure from the western Mediterranean caused the first modest worsening of the weather, resulting in significant precipitation accumulations on the 20th. Despite the worsening of the weather, due to the lukewarm air mass following the disturbance, the temperatures remained mild and higher than the average climate.

### 3. Material and methods

This preliminary study considers only climatological parameters, even if they have extremely short temporal steps (hourly data) in the first phase of the research. Parameters related to air quality were also considered, and the response of the epidemiology was analyzed with respect to some important parameters, such as sulphur dioxides, nitrogen dioxides, ozone, and total particulate matter. However, after discussion with atmospheric physicists, it was evident that these parameters vary extremely rapidly as they move away from their main production sources, and therefore, the results could have been misleading. The period analyzed by the study was forcibly extended from March 1st to April 20th because the provincial ATS provided daily epidemiological data for each municipality during only this time span. The analysis of temperatures and precipitation extended to only April 30th, while the study is still in progress for the city of Brescia, as daily data from the Poliambulanza Foundation Hospital, the second largest in the city, are available for this city. The daily municipal epidemiological parameters used for the analysis were provided by the provincial ATS (territorial health company), while the meteorological and climatic parameters - minimum and maximum temperature (°C), average relative humidity (%), diurnal solar radiation sum (W/m<sup>2</sup>), wind direction and speed (azimuth angle and m/s) and evaporation (mm) - were provided by automatic weather stations (AWS) by the ARPA LOMBARDIA regional meteorological service.

Table 1 and Figure 3 show the geographical characteristics of the considered AWS that were highly representative of the most important pandemic outbreaks.

Some morphological and morphometric features were also considered in the analysis at each AWT - distance from the Pre-Alps, width, and main direction of the valley sector in which the AWT is located, distance from the Po River, elevation - and quantified using the ESRI-GIS platform.

AWS	LAT	LONG	ELEV M.
BERGAMO GOISIS	5062736	1553648	290
BRESCIA ZIZIOLA	5040857	1595198	70
CEVO	5103942	1606557	1128
CODOGNO	5001213	1556680	68
CREMONA	4999335	1582095	43
LIMONE DEL GARDA	5075036	1639229	76
MANERBA DEL GARDA	5044652	1622289	74
SARNICO	5056956	1574749	197
SONCINO	5027700	1569706	87

**Table 1.** – Geographical features of the meteorological stations analyzed.



**Figure 3.** – Map of Lombardy - northern Italy, with focus on the outbreak area: the weather stations used for the analysis are highlighted in blue, and the main epidemic outbreaks are highlighted in grey.

Since the studied area is very homogeneous from the climatological point of view (fig. 4; tab. 2), a daily average was calculated for each of the climatic variables considered for the purpose of statistical analysis.

To determine the relationship between the evolution of the pandemic and climate characteristics at the mesoscale, all the available epidemiological parameters—number of swabs performed, number of hospitalizations in the emergency room, number of hospitalizations in the COVID-19 area, number of hospitalizations in intensive care and deaths—were considered. However, the only epidemiological parameter that was less impacted by significant daily mistakes due to administrative and legal reasons is the ratio between the first positive swabs and the total number of swabs collected per day (fig. 4), and this parameter was considered for analysis purposes.

TEMPERATURES °C AND PRECIPITATIONS MM										
MARCH	BERGAMO	BRESCIA	CEVO	CODOGNO	CREMONA	LIMONE D.G.	MANERBA D.G.	SARNICO	SONCINO	
AverageT	8,5	9,1	4,1	9,2	8,7	10,2	9,5	9	9,3	9,3
AVtmin	4,3	4,8	0,9	4,6	3,5	7	6,8	5,3	4,5	4,5
AVtmax	13,4	13,5	8,2	14,1	13,8	14,5	12,4	13,4	14,1	14,1
Prec.	88,4	43,8	103,8	47,8	31,4	63,2	58	85,4	50,4	50,4
APRIL	BERGAMO	BRESCIA	CEVO	CODOGNO	CREMONA	LIMONE D.G.	MANERBA D.G.	SARNICO	SONCINO	
AverageT	13,5	14,6	9,4	14	13,8	15,3	14,1	14,2	14,7	14,7
AVtmin	7,5	8,6	5,3	7,6	6,7	10,7	10,4	9,2	7,8	7,8
AVtmax	19,5	20,5	14,6	20,7	20,8	21,2	18,7	20,5	21,2	21,2
Prec.	43,6	32,4	41	19,4	21,2	32	43	54,8	20,2	20,2

OTHER CLIMATIC VARIABLES										
MARCH	BERGAMO	BRESCIA	CEVO	CODOGNO	CREMONA	LIMONE D.G.	MANERBA D.G.	SARNICO	SONCINO	
RH%	65	67	68	70	73	71	70	72	65	65
Wind m/s	1,8	1,7	3	1,4	1,5	3	2,3	2,1	1,6	1,6
Solar rad. w/mq	503	498				511				
evap. mm	3	4	0	5	4	6	5	5	6	6
APRIL	BERGAMO	BRESCIA	CEVO	CODOGNO	CREMONA	LIMONE D.G.	MANERBA D.G.	SARNICO	SONCINO	
RH%	51	53	66	58	56	67	68	63	59	59
Wind m/s	2	2,2	3,1	1,9	2	4,2	3,3	3,1	2	2
Solar rad w/mq	347	352				333				
evap. mm	11	13	6	12	12	14	13	13	13	13

Table 2. - Average climatological values for March and April 2020.

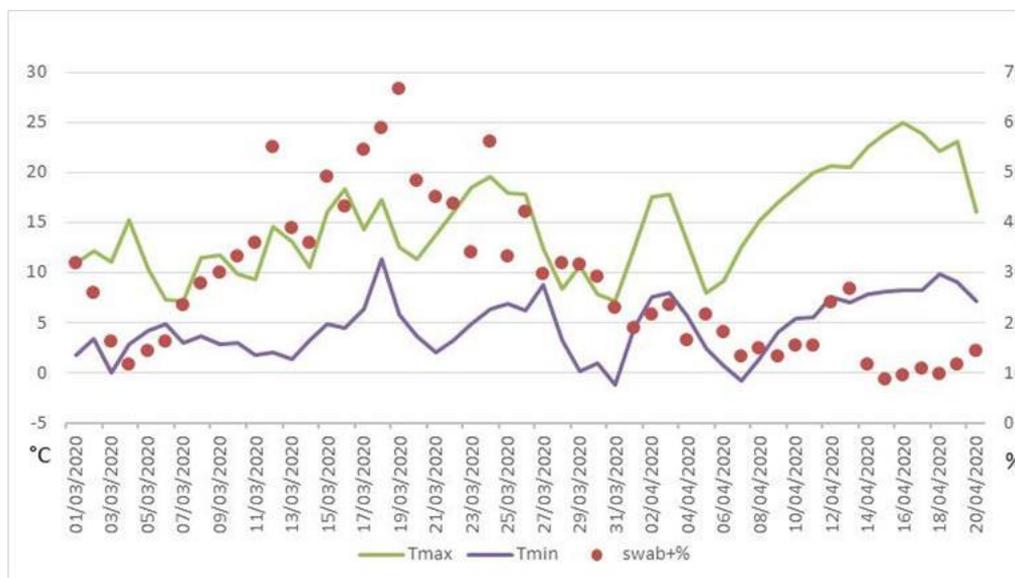


Figure 4. Temporal evolution of minimum and maximum temperatures and of first positive swabs (March 1<sup>st</sup> – April 20<sup>th</sup>).

In accordance with the scientific literature (ISS), an average incubation period of 5,3 days was considered, so for example, if the number of first positive swabs was reported on 15 April, the meteorological data from 10 April were considered for statistical analysis.

As the data were not normally distributed, Mann-Kendall rank correlation and with multi-regression analysis and stepwise forward analysis were utilized to examine the possible correlation between variables.

#### 4. Results

The Mann-Kendall test results show in a peremptory manner that there is no climate variable that is correlated with the temporal evolution of the pandemic, with the exception of relative humidity - RH % (value - 0.548) for all levels of significance 1, 5 and 10% (99, 95 and 90% confidence intervals). The output of the stepwise forward multiple linear regression analysis [11] showed that, considering the variables that explain at least 3% of the total variability, only three of them—the relative humidity (RH%), solar radiation (Sol Rad) (directly related) and the maximum temperature (Tmax) (inversely correlated)—cover approximately 60.5% of the explained variability, with values of 35.9, 21 and 3.6%, respectively.

The multiple linear regression equation is:

$$Y(\text{first positive swabs}) = 0,503RH\% + 0,03 \text{ Sol. Rad.} - 0,0582T_{\text{max}}$$

The percentages of the explained variability are considered satisfactory for the relative humidity and solar radiation - and in this case, they show that the spread of the pandemic is favored by increased sunshine and high relative humidity - while the statistical contribution provided by the maximum temperature is practically close to zero and therefore not significant.

#### 5. Discussion

Several previous studies showed results confirming the relationship between the pandemic and relative and absolute humidity, as well as maximum temperature, while it appears that no author has yet researched the relationship between the pandemic and solar radiation.

Araújo and Naimi, 2020 [12] calculated an evident decrease in the epidemiology of COVID-19 throughout the world as the temperature increased to over 29°C and relative humidity decreased to below 40%.

Scafetta, 2020 [13] highlighted that the 2020 winter season in the Wuhan region was extraordinarily similar to that in the northern Italian provinces of Milan, Brescia and Bergamo, where the pandemic was devastating in March. This similarity indicates that this pandemic is worsening in the presence of temperatures between 4 °C and 11 °C. In the same area of China,

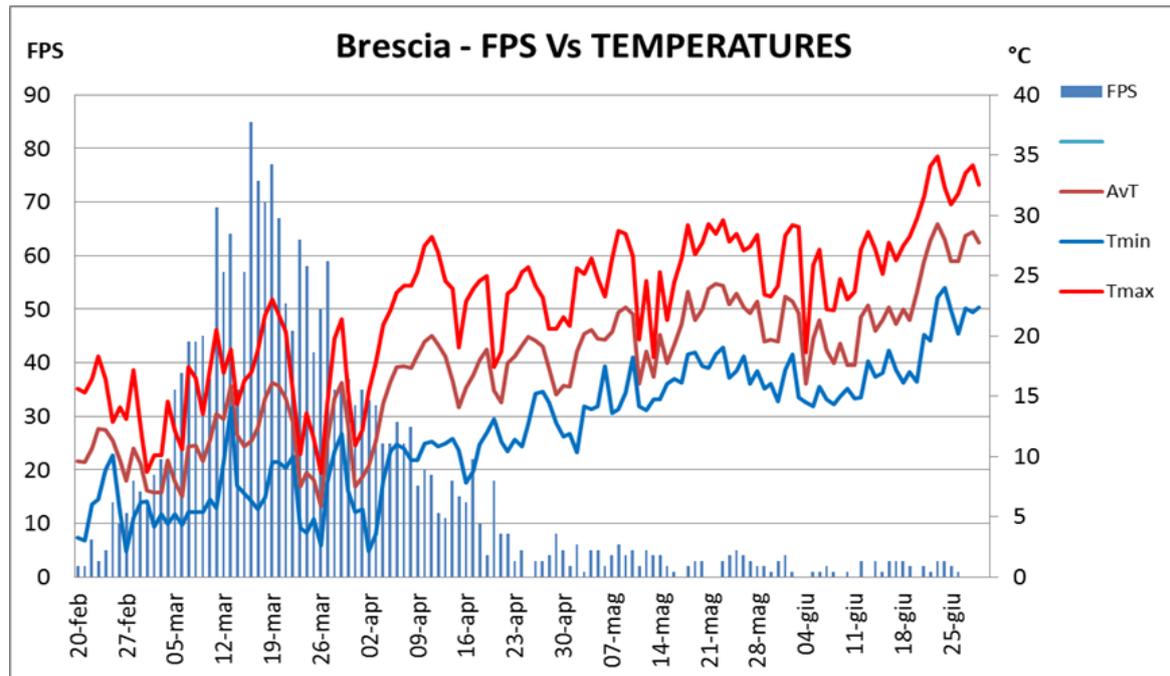
Ma et al., 2020 [14] and Liu et al, 2020 [15] showed that the absolute humidity was negatively associated with the daily death counts of COVID-19. In China, Wang et al. (2020a) [16] found that high values of relative humidity exhibited a strong influence on the R-value, with a significance level of 1% for both. The specific and absolute humidity finally exhibited a significant and consistent distribution with the seasonal behaviour of respiratory viruses at latitudes between 30°N and 50°N [17] (Sajadi et al., 2020). This result almost coincides quantitatively with that calculated by Sahin M., 2020 [18] and Sahin A.M. et al. 2020 [19] for the Anatolian Peninsula, which has an average spring climate that is overall very similar to that of Lombardy.

Some authors did not detect any statistically significant relationship between the aforementioned climatic variables and COVID-19. Tosepu et al. (2020) [20] posited that the average temperature was significantly correlated with COVID-19. However, it was claimed that minimum and maximum temperature, rainfall, and humidity were not significantly correlated with the COVID-19 signal. Bashir et al., 2020 [21] showed that the average and minimum temperatures in New York City exhibited poor significance in the COVID-19 epidemic.

Prata et al., 2020 [22] suggested that there is no evidence supporting that case counts of COVID-19 could decline when the weather becomes warmer if temperatures are above 25.8°C.

Finally, Cheval et al (2020) [23] point out that local weather conditions of lowered temperature, mild diurnal temperature range and low humidity may favor the transmission, other studies claim there is no evidence that warmer weather can determine the decline of the case counts of COVID-19. Maybe, the most important cause of the impact of the pandemic in Northern Italy is that a high concentration of particulate matter (PM, including PM10 and PM2.5) makes the respiratory system more susceptible to infection and complications of the coronavirus disease.

The study relating only to the situation that occurred in Brescia, extended temporally until 30 June (fig. 5) shows that actually with the increase in average temperatures and above all the maximum temperatures, there has been a gradual decrease in virulence but it is also evident that after April 20, the signal has become statistically unreliable, because it derives from the fact that a "house – to-house" serological tests have started in the city, with the identification of many situations with virus positivity but clinically asymptomatic. On the other hand, in the first part of July, in many areas with pronounced thermal seasonality (USA, Russia, Balkans and with a very hot climate, e.g. arabian Peninsula s.l.), the pandemic is reaching its peak, thus highlighting a statistically inverse relationship with temperatures, however, extending into the respective large cities or metropolises (source WHO).



**Figure 5.** - characterization of the thermal values and those relating to the first positive buffers relating to the Poliambulanza institute of Brescia for the period 1 April - 30 June.

## 6. The role of human activity in the spread of COVID 19

If the map of population density, industrial activities (secondary) and services (tertiary) overlapped with that of the spatial distribution of COVID 19 in Lombardy, it would seem to be an extremely high correlation between the variables and therefore it would be obvious to look at them to look for the root cause of the exceptional numbers that characterized the pandemic in this region. As a result, the data made available by ISTAT [25] on the number of activities belonging to the secondary and tertiary sectors were analyzed. for the provinces of Milan, Bergamo and Brescia (table 3 and figures 5 and 6). This data was compared with those relating to the province of Naples the only in Italy to have the same anthropogenic and industrial quantitative characteristics just mentioned in the Lombardy

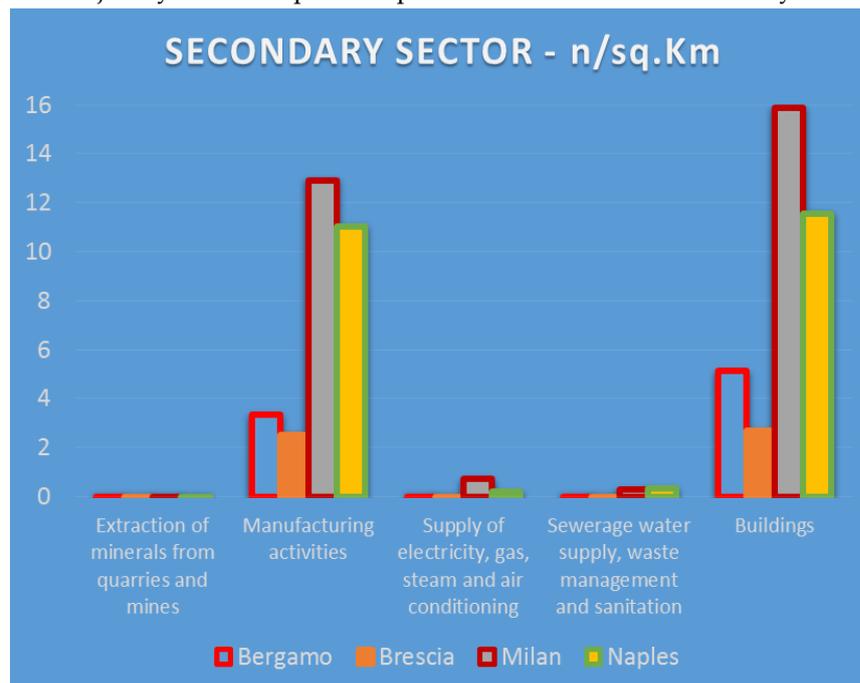
Province	Area in sq. km	inhabitants mln	covid 19 positive	cov19+/inhab. %
Bergamo	2755	1,11	14100	1,27
Brescia	4785	1,26	15560	1,23
Milan	1575	2,35	24080	1,02
Naples	1171	3,11	2654	0,09

**Table 3.** - main anthropic and pandemic features of some provinces analyzed.

From the analysis of the data, it is very evident that the population density is decidedly higher in the province of Naples than in the Lombardy provinces but the ratio between covid 19 cases and the number of inhabitants - and secondly population density is extremely lower in this last province (about 0.09 Vs about1) – tab.3

If we then go to observe the density per square kilometer of the most important secondary sectors that most favor human contacts (fig. 5), it can be observed that in the province of Naples manufacturing activities have a density slightly lower than that of the province of Milan but they are much more widespread than in the territories of the provinces of Bergamo and Brescia

With regard to the tertiary sector (fig. 6); a similar signal is observed with regard to retail and wholesale activities. So it would be clear that even the activities that promote close potential contact between people do not justify the widespread expansion of the virus in Lombardy



**Figure 5.** –presence of secondary sector in the four province examined.

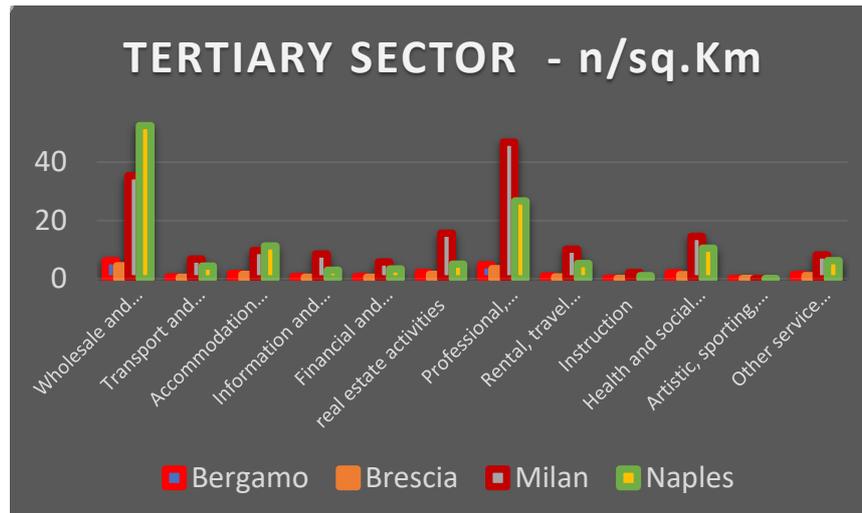


Figure 6. - presence of tertiary sector in the four province examined.

## 7. Conclusion

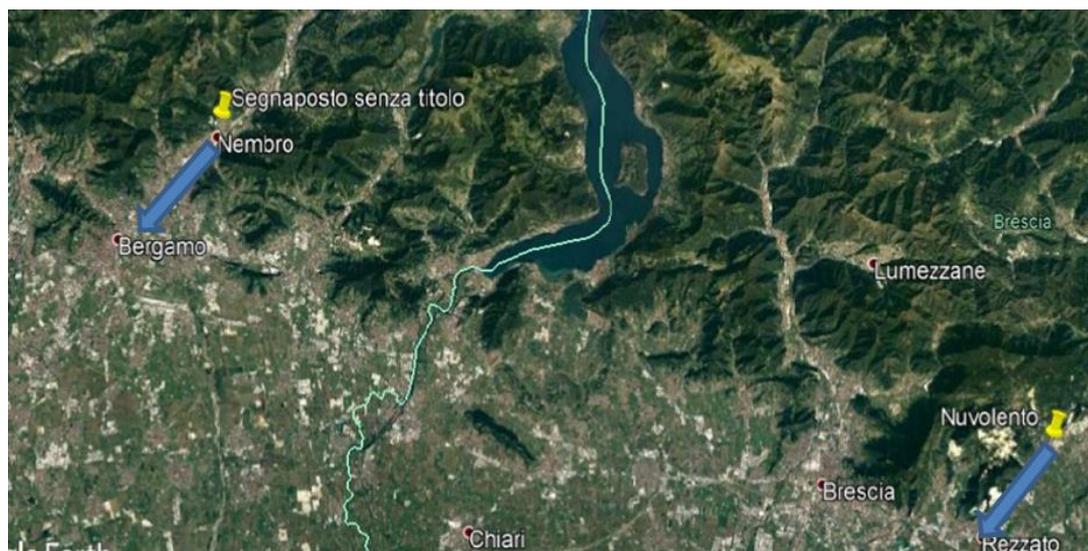
A comparison between the maximum and average temperatures for the months of March and April between the cities in Lombardy most affected by COVID-19 (Bergamo and Brescia) and two locations representative of the thermal climate of the southern regions - Molise and Basilicata - that were least affected by the pandemic confirms the absence of statistical relationships between these two variables. In the AWS of Campochiaro (Molise) and Potenza (Basilicata), the temperatures were on average lower than those in the cities in Lombardy by approximately 1.5 °C, and therefore, there should have been an increase in the percentage of the population with positive swabs.

In the city of Brescia, the study, currently active, shows that very high maximum temperature values - above 29 °C do not correspond to a drastic drop in the number of first positive swabs but rather a moderate, not statistically significant oscillation of the parameter that has shown from April 20, a general trend towards a gradual, slow decline

As further evidence that high temperatures do not seem to favour the decrease in COVID-19 cases, there was a peremptory increase in the pandemic diffusion maxima after 10 May and just to the first days of July in areas with a cold temperate climate (Köppen Df) such as Sweden, Denmark, where temperatures have become decidedly mild. The same epidemiological signal was also observed in areas with equatorial or monsoonal climates, where the thermal seasonality is absent or reduced, such as in the Indian and Nepalese territories (Köppen Am), the Amazon and Peru (Köppen Af). The pre-monsoon period in these regions is notoriously the hottest of the year, with temperatures reaching 47 °C in the second half of May. Finally, in June and July, the pandemic reached the prolonged maximum in west and south USA, in Russia and Balkan and also in the equatorial part of Brasil.

Finally, the states with the highest percentage of positive people compared to the total population were those that extend over the Persian Gulf notoriously characterized by a desert climate Köppen (BH), with extremely high spring and summer thermal values - up to 52 °C - but with extremely low relative humidity - with Qatar which at the end of June reached a percentage of infected people of around 3.65%

At the same time, the mesoscale morphologic analysis did not clarify the spatial distribution of the pandemic. For example, the lower Val Seriana (Nembro) in the Bergamo area, which had the highest number of deaths in the world in relation to the population, and the lower Chiese valley (Nuvolento) in the Brescia area, which was least affected by the pandemic of the two provinces of Bergamo and Brescia, are arranged almost parallel to each other at the outlet in the Po Valley. These areas are limited by reliefs with the same altitudes and are finally similar distances of approximately 10 km from the respective provincial chief towns (fig.7)



**Figure 7.** Ubication of Val Seriana (Nembro) and Chiese valley (Nuvolento). Segnaposto senza titolo identifies the town of Nembro – source Google Earth.

Therefore, the high number of COVID-19 cases in Lombardy are most likely caused by the very high mobility of the people deriving from the large number of secondary and tertiary activities that occur in all the "outbreak" areas of the epidemic. The population density is also very high - approximately 430 inhabitants per km<sup>2</sup> and up to 2200 inhabitants per km<sup>2</sup> in the areas of Milan and Brescia, which allows for the fast transmission of COVID-19. However, a comparison with the same parameters calculated in the province of Naples - where pandemic was extremely less virulent, would show that even these parameters do not justify the presence of the large Lombard outbreak.

Other fundamental parameters, such as vehicular traffic, the use of *personal protective equipment* (PPE), and the most basic hygiene rules are impossible to quantify for statistical analysis.

Finally, it would be essential to understand whether there is a possible relationship between the temporal "rhythmicity" of coronavirus epidemics and the newly established global climate changes that are currently underway.

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