International Journal of Disaster Risk Reduction 122 (2025) 105457

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdrr

The role of peripherality in the spread of pandemic: evidence from Basilicata (Southern Italy) during the first wave of COVID-19

Nadia Matarazzo [a], Rosa Coluzzi [b,c], Vito Imbrenda [b,c,*], Maria Lanfredi [b,c], Michele Galella [d], Dionisia Russo Krauss [a]

[a] Department of Economics and Statistics, University "Federico II", Naples, Italy
[b] Institute of Methodologies for Environmental Analysis, Italian National Research Council (IMAA-CNR), Tito, Italy
[c] National Biodiversity Future Center (NBFC), Palermo, 90133, Italy
[d] Department of Foreign Languages, Literatures and Cultures, University of Bergamo, Via Salvecchio, 19, Bergamo, 24129, Italy

ARTICLE INFO

Keywords:
Inner areas
Basilicata
Peripherality
Mobility
COVID-19

ABSTRACT

The first wave of COVID-19 arrived in Europe in February 2020, firstly impacting Italy, especially in the most economically advanced areas of the country, mainly located in the northern-central part of the peninsula. In general, the effects of pandemic in Italy outlined sharp differences across a latitudinal gradient. This paper focuses on Basilicata, an inner region of Southern Italy, connecting its peripherality, according to the SNAI (National Strategy for Inner Areas) classification, with its involvement in the first wave of the COVID-19 pandemic. Through the analysis of the number of infected people and deaths and the investigation of socio-economic and environmental data, we observed a low impact of the contagion in the first wave, supporting the thesis that some territorial and socio-economic features of this inner area (such as the specific settlement morphology and environmental conditions or the sparse infrastructural fabric, as well as the social model for the care of frail people) have somehow acted as a barrier for the spread of the virus. Our results suggest that the SNAI scheme could be overly rigid in certain cases due to the significance of highly local factors. Furthermore, while connectivity is valued in its own right, the observation of pandemic spread underscores the need to promote new territorial structures that not only foster environmental balance but also transform structural vulnerabilities into protective assets.

1. Introduction

The first wave of COVID-19 arrived in Europe in February 2020, firstly impacting Italy [1,2], especially in the most economically advanced areas of the country, mainly located in the northern-central part of the peninsula. In general, the effects of pandemic in Italy outlined sharp differences across a latitudinal gradient: COVID-19 impacted harder the regions crossed by the densest trade networks and mobility flows, *i.e.,* those playing the role of commuting corridors on a regional scale [3,4]. As in the case of Lombardy (Northern Italy), these areas are a sort of "urbanized countryside": spaces of original rural vocation which, located among various urban centres, became elements of connection and continuity between settlements [5]. Over time, they have become part of the urban landscape,

* Corresponding author. Institute of Methodologies for Environmental Analysis, Italian National Research Council (IMAA-CNR), Tito, Italy.
E-mail addresses: nadia.matarazzo@unina.it (N. Matarazzo), rosa.coluzzi@cnr.it (R. Coluzzi), vito.imbrenda@cnr.it (V. Imbrenda), maria.lanfredi@cnr.it (M. Lanfredi), michele.galella@unibg.it (M. Galella), dionisia@unina.it (D.R. Krauss).

https://doi.org/10.1016/j.ijdrr.2025.105457
Received 19 December 2024; Received in revised form 31 March 2025; Accepted 2 April 2025
Available online 3 April 2025

which has thus taken on the features of a sprawl city where the spread of the virus was very quick and difficult to counter [6].

In the South, on the contrary, the settlement morphology and territorial organization are still frequently marked by urban/countryside dualism, which often assumes spatially well-defined features [7,8]. In these contexts, the levels of peripherality are heterogeneous and the nodes of territorial interconnections are several, within environments characterized by scattered settlements, with urbanization rhythms that can be considered "slow", and by evident hierarchical mobility structures as opposed to the rhizomatic[1] pattern of the most advanced regions of central-northern Italy [9].

Just these spaces that were substantially "invisible" for decades, placed on the edge of development trajectories, seemed to re-emerge and start to acquire an increasingly important conceptual and political value in Italy. This occurred in the light of the deep rethinking promoted by the Italian SNAI, the National Strategy for Inner Areas [10,11]: a document written under the placed-based approach within the European cohesion policies that changed the vision of all those territories somehow marginalized by the dualisms North/South, urban/rural, pulp/bone [12]. They are the so-called inner areas, "a space of the remainder": what remained on the map of Italy once the large metropolitan areas and the urban systems of the plain were removed [10].

The crisis of cities with their urban model of development, the emergence of hydrogeological risk and land safety as a priority issue and the cultural metamorphosis connected to the global sustainability issues have contributed to a different perception of the inner areas, so they have begun to be no longer just a problem, but also an opportunity [10]. Although generally associated with abandonment (hydrogeological instability, degradation of agricultural landscapes and decaying buildings) and often disadvantaged by conditions of infrastructural and socio-economic weakness (as well as by demographic decline), these areas are rich in resources, natural capital and in specificities closely linked to the genius loci and cultural heritage [13–18]. They represent a potential of largely under-exploited environmental, tourist and productive resources to be valued within a coherent development and cohesion policy [19–22].

The concept of peripherality, as outlined by SNAI, is an attempt to revise the traditional definition of inner areas, identifying them based on their remoteness from essential services (education, health, mobility). From this point of view, "inner" are those areas characterized by a significant distance (more than 27.7 min is the travel time established by the most recent classification) from the main service provider centres. Overall – according to the new mapping carried out by ISTAT (the Italian National Institute of Statistics) for the 2021–2027 programming cycle – almost 60 % of the Italian national territory falls within the three clusters that identify the inner areas (intermediate, peripheral and ultraperipheral municipalities depending on the distance in minute from the "poles", for further details see https://opencoesione.gov.it/en/SNAI/), with 13.4 million inhabitants (or 22.7 % of the country's total population) distributed among 3834 municipalities (just under half of Italian municipalities), mostly small (up to 5000 inhabitants) and located in mountainous/hilly areas and far from the sea. About 45 % of these centres are located in one of the southern regions of the country; here, moreover, the relative weight of these areas is particularly significant (compared to the total number of municipalities in the South, intermediate, peripheral and ultraperipheral municipalities are more than 67 %), especially in regions such as Basilicata, Sicily, Molise and Sardinia (all with incidences above 70 %).

To properly illustrate the research proposed in this paper, the question of inner areas should be framed within the broader international, and particularly European, debate on inner peripheries, that is a recent concept based on peripherality and marginality features, thus far from the traditional geographical meaning of periphery [23]. Inner peripheries are in fact characterized by remoteness, poor accessibility to services of general interest, and they are associated with some peculiar socio-economic dynamics, such as negative demographic trends and population ageing, social exclusion and economic decline [24,25]. However, they are also places of unique endowments of a territorial capital that can shape the future potential and development alternatives.

It should also be noted that inner peripherality is a complex and multidimensional phenomenon which compounds the effects of various socio-economic processes that cause disconnection from external territories and networks. In this sense, location is not the only explanatory factor; as the final report of PROFECY project[2] highlights, distance to regional centres, agglomerations of population or economic activity, as well as access to services, may contribute to inner peripherality, but do not fully account for it. Non-spatial or "aspatial" components also affect these territories in such a way that they can contribute to their marginalization. In other words, a core aspect of inner peripherality is the capacity of a territory to "connect" with its environment; this is determined not only by geography, but also by relational connectedness (i.e., non-spatial factors and processes). That's why – given the multicausality of the processes and factors that intervene in each case and the different manifestations of peripherality they produce – this project has identified three possible types of inner peripheral areas: enclaves of low economic potential; areas with poor access to services of general interest; areas lacking relational proximity (experiencing aspatial peripheralization processes).

Ultimately, the Italian concept of inner areas is very close to the inner peripheries one [26]: they are conceived as areas subject to strong centrifugal forces that complicate the implementation of place-based development processes capitalising on local territorial resources to improve their competitiveness. They can be considered as a special type of inner peripheries, because they are characterized by poor accessibility to services of general interest [27]. We can thus also observe that the concept of peripherality, as outlined by SNAI, is an attempt to rethink the traditional definition of inner areas, identifying them based on their remoteness from essential

[1] The adjective *rhizomatic* – referring to the horizontal underground plant stem capable of producing the shoot and root systems of a new plant – figuratively refers to a reticular pattern composed of filaments that gradually intersect each other to form multi-directional linear thickenings [88].

[2] The PROFECY (*Processes, Features and Cycles of Inner Peripheries in Europe*) project – which intends to contribute to the development of strategies for inner peripheries at European level to overcome their marginalising effects – focuses on the understanding and empirical characterisation of "inner peripherality", covering the whole European space. The applied research activity was conducted within the framework of the ESPON 2020 Cooperation Programme, partly financed by the European Regional Development Fund.

services (education, health, mobility).

As for the effects of the pandemic, because literature is plenty of case studies focusing on the most impacted regions of Italy [28–30] showing that the urbanization degree, pollution, population density and human mobility had a significant relationship with COVID-19 infections [9,31–34], our aim is to investigate the case of a marginal region, such as Basilicata (Southern Italy), whose territory is almost entirely an inner area, with a high percentage of ultraperipheral municipalities. Starting from the necessity to examine the factors of territorial vulnerability that may have fostered and accelerated the spread of COVID-19 in the country, it puts emphasis specifically on the geographic features that determined lower contagion rates compared to the rest of the country during the first wave of pandemic (February 24, 2020–June 30, 2020).

In particular, the territorial configuration of Basilicata tends to highlight different forms and trajectories of spatial interaction compared to the examples of de-hierarchisation evident in the best-served districts of Italy. The latter areas experienced processes of urban-functional spread that have allowed many cities to widen and overcome their administrative boundaries thanks to mobility, horizontally distributing their functions over an inter-scalar spatial texture [35]. On the contrary, Basilicata is characterized by spatial relations organized in a traditional spatial hierarchy with functional centres and dependent peripheries.

Basilicata, therefore, gives the opportunity to observe the impact of the epidemiological phenomenon on a marginal region, a case little discussed in the literature. The research question of this paper deals with the hypothesis that the magnitude of the epidemic is correlated to the degree of centrality/peripherality of each territory with respect to the flows of spatial interaction [36].

First, we describe the main physical and socio-economic features of Basilicata, and then we consider the spread of COVID-19 from March till June 2020, analyzing its outbreaks and evolution, and dwelling also upon the role of the local network of hospitals and resting homes (RHs). The results will enable us to investigate the relationship between the positioning of a region like Basilicata in the networks of spatial interaction and the spread of COVID-19 during the first wave, confirming the idea that certain structural features of this inner area – its peripherality according to the SNAI classification and its "wide" spatial networks – somehow acted as a barrier to the spread of the virus at that stage.

1.1. The syndemic approach and the issue of inner areas in the time of the pandemic

In an era of multifactorial global crises, it is essential to take into consideration the interconnection between various types of risk (environmental, social, health, economic, geopolitical) to properly characterize geosystemic phenomena. In this regard, we speak of "syndemic", a term which combines the words "synergy", "epidemic", "pandemic" and "endemic", and means the set of pandemic pathologies not only health-related, but also social, economic, psychological, cultural, connected to lifestyle and human relations, exacerbated by conditions of morbidity concomitant with particular socio-economic and environmental conditions. This innovative approach to public health, which originates from the studies of the American medical anthropologist Singer, invites us to broaden our gaze to identify the barriers and territorial circumstances that cause, facilitate or in any case aggravate pathological conditions or that, on the contrary, represent a barrier [37,38].

The syndemic approach therefore considers the health status of a population as the result of a wide range of factors: on the one hand, genetic and biological, on the other hand, environmental, social, political and economic. It interprets diseases as multifactorial and multiscalar events, on which social inequalities and territorial imbalances have a strong influence, since the vulnerability to harmful conditions changes in space and in relation to socio-environmental factors [39]. This is a holistic vision of public health that, also on the basis of recent geographical studies [1,9,40,41], contributes to recognizing the centrality of territorial analysis in addressing the challenges of the Anthropocene and, secondly, as far as the present reflection is concerned, stimulates innovative readings of territories that the mainstream tends to dismiss as fragile and marginal.

In this context, it is useful to note that some studies have examined the impact of the pandemic on peripheral areas around the world. Diop et al. [42] found that sparsely populated rural areas in Africa may help slow the spread of the epidemic. As a result, rural regions may experience staggered peaks, which carries significant implications for decision-makers who may need to manage two distinct waves.

By examining the impact of COVID-19 on people living in the rural American West, Mueller et al. [43] demonstrated that many of the dramatic effects observed in urban areas and at the national level were equally significant in this geographically sparse region of the United States. Similarly, in the USA, an analysis conducted in Ohio by Cuadros et al. [44] revealed significant spatial variation in disease spread, with distinct differences in infection rates across localized areas. Some highly connected and urbanized regions experienced higher COVID-19 attack rates, which could heavily strain their healthcare systems despite their potentially greater capacity compared to more rural and less connected areas.

Turning to Italy, we see that in complex landscapes that include both highly connected urbanized areas and predominantly rural regions—such as the Marche region in Central Italy (see Ref. [45])—the latter may have intrinsically prevented or slowed the spread of COVID-19. The Italian region of Irpinia (Southern Italy) is particularly well-suited to this dynamic, as it is a remote inland area with limited accessibility. This makes it prone to a two-stage paradoxical process: (1) its low accessibility initially prevents or slows the spread of COVID-19, but (2) if the virus does manage to spread despite these barriers, the same inaccessibility may hinder healthcare services, potentially leading to a dangerous peak in cases.

These two political paradoxes have underscored pre-existing gaps and vulnerabilities in the region [46].

2. Materials and methods

2.1. Study area

Basilicata is one of the 20 NUTS-2 (Nomenclature of Territorial Units for Statistics) regions of Italy, bordering to the West with Campania and to the East with Apulia.

The landscape of Basilicata is morphologically very varied, divided almost equally between mountains and hills (47 % and 45 % respectively) with flat areas reaching just 8 % of the overall surface (https://www.istat.it/it/archivio/137001). The land cover is highly heterogeneous, with a peculiar arrangement that roughly reflects the orography. Agricultural surfaces cover 57 % of the regional extent, forest and semi-natural areas occupy 41 %, artificial areas just correspond to about 1.6 %, while wetlands and internal water bodies do not reach 0.5 % (Figg 1a and 1b, data extracted from the Copernicus Corine Land Cover 2018; [47].

Generally, forest and natural covers dominate high-altitude areas, mainly corresponding to the slopes of the Lucanian Apennines and the Pollino Massif (located in the south-western part of the region) and representing valuable zones of conservation interest (Natura 2000 network, see Ref. [49]). Anthropic land uses extensively characterize flat and low-hilly areas. The north-eastern part of

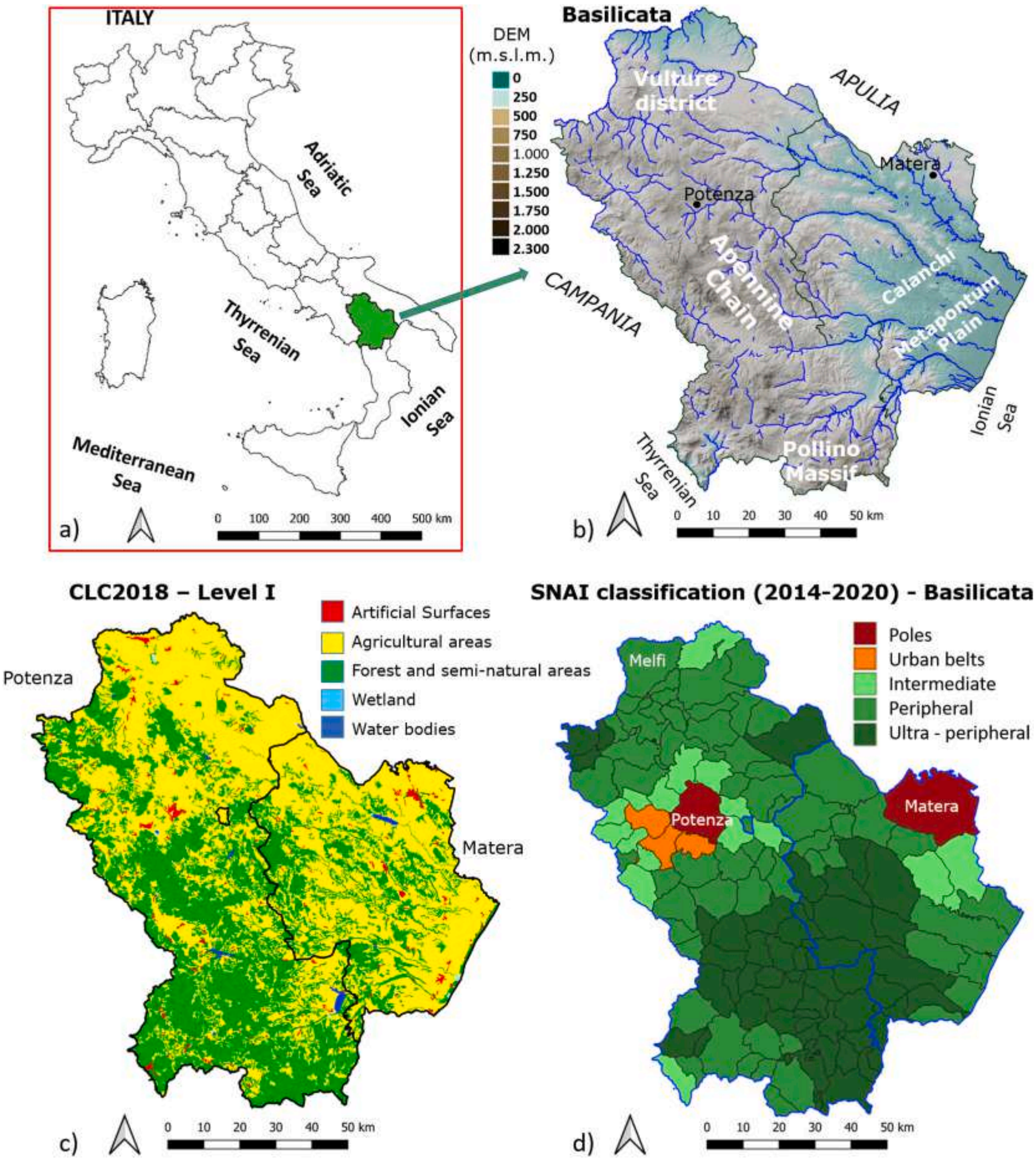

Fig. 1. Location of Basilicata within Italy (a) with its main features: morphology [48] (b); land use from the CLC2018 and subdivision in provinces (Potenza and Matera) (c); SNAI classification (2014–2020) of its municipalities (d).

Basilicata, on the border with Apulia, is characterized by flat areas where cereal crops prevail, while in the volcanic basin of the Vulture, the traditional cultivations of vineyards and olives groves shape the landscapes configuring typical Mediterranean eco-mosaics [50,51]. The central-eastern part of the region includes low-hilly lands where the profiles of the *calanchi* (i.e., rill formations) emerge, as symbols of a rugged territory where bare soil and sparse vegetation prevail, often affected by degradation phenomena [52]. Along the Apennine chain and the western part of Basilicata, the thermoregulatory effect of the sea is negligible [53], featuring a continental climate, while along the coasts the climate is typically Mediterranean, with dry periods coinciding with the hottest months of the year [54,55].

Essentially, the western and eastern parts of the region can ideally be separated from many points of view: climate, physiography, land use and ecosystems are different, as effectively represented by the Italian map classifying municipalities according to ecoregions [56]; https://www.istat.it/it/archivio/224780).

2.2. Procedure and limitations

Selecting the appropriate methodological approach to unravel the dynamics underlying the spread of the virus in Basilicata was the most challenging phase of this research. The collected data reveal clear discontinuous patterns, with the two main cities, Potenza and Matera, distinctly separated from the rest of the region (see Section 3), where the pandemic did not reach most areas. Data do not suggest the existence of a unique connection structure that extends across the entire region and can explain territorial differences. Instead, it appears that connectivity is fundamentally a local issue. While multivariate analysis typically relies on correlation estimates to uncover underlying patterns, in our case, standard correlation could mask significant local differences and heterogeneities in connectivity patterns.

The strategy we used in data analysis took into consideration this lack of continuity in the spatial, economic and social contexts. Unlike correlation, which assumes linear relationships between variables across the entire datasets, we chose to use clustering, which identifies natural groupings or patterns within the COVID-19 spread for a more nuanced understanding of complex or heterogeneous structures. Such a clustering, applied to the number of infected, enables to define spread classes to investigate the link between different groups and proxy indicators of the level of urbanization, accessibility and demographic structure. We used K-means [57], which is a simple and popular unsupervised clustering algorithm, to divide a dataset into a predefined number of clusters (denoted as K) based on similarity. The goal is to minimize the variance within each cluster while maximizing the variance between clusters; the Elbow method was used to determine the best K [58]. The proposed methodological approach can be adapted to similar cases, when local scale heterogeneity prevails. Instead, some limitations can arise from the count of infected.

The identification of individuals infected with COVID-19 in Italy was carried out through various methods, which changed over time based on the spread of the virus and the available resources. These methods included molecular testing, rapid antigen testing, serological testing, contact tracing, and self-diagnosis with possible reporting to health authorities. However, there can be a significant discrepancy between the number of officially confirmed cases and the actual number of infected individuals. This gap is due to several factors: underdiagnosis (not all patients with mild or asymptomatic cases underwent testing); accessibility to testing; unreported self-testing; undetected asymptomatic cases; errors in data collection systems.

Numerous studies and statistical analyses suggest that the actual number of infected individuals was significantly higher than the official data. For example, a serological survey conducted by ISTAT and the Ministry of Health revealed a virus spread greater than what was reported in official bulletins [59]. Additionally, an analysis by the Institute for International Political Studies [60] estimated that, at a certain point, the actual number of positive cases in Italy could have been around 530,000, compared to the approximately 55,000 officially recorded active cases (Institute for International Political Studies, 2020).

2.3. Indicators: calculation and rationale

To characterize at municipal level the clusters obtained through the K-means, we used different demographic and environmental indicators. Data on population structure were used to derive the ageing index, a demographic indicator measuring the ratio of the elderly population (generally aged 65 and over) to the younger population (under 15 years of age). It is computed as the number of people aged 65 and older per 100 individuals under the age of 15 [61]. Higher values of this index mean a greater proportion of elderly people in comparison with the youth population, reflecting an aging population structure.

To estimate the level of land fragmentation (the process responsible for reducing the continuity of ecosystems, habitats, and landscape due to urban expansion and infrastructure development, see Refs. [62,63] we chose the S_{eff} (Effective mesh-density) estimating the barrier to movement represented by artificial fragmenting elements present in the analyzed area. This index represents the density of land patches (number of meshes per 1000 km^2), computed by adopting the effective mesh size (m_{eff}) methodology [64]. The S_{eff} index is definitively related to the possibility that two randomly chosen points within a given area are located within the same continuous patch. The higher the index value, the greater the fragmentation of the landscape caused by urban elements.

Soil consumption was assessed at the municipal scale by estimating the extent of sealed land, i.e., areas covered by artificial land classes relative to the total area of municipality [65].

The density of the municipal road network is expressed in relation to the total area of the municipality (km/km^2). Thanks to the use of the Overpass Turbo (https://overpass-turbo.eu/) we extracted specific information from the large OpenStreetMap (OSM) database using customised queries in Overpass QL (Query Language), a powerful tool for querying and searching data within OSM. The road density index can be interpreted as a proxy of accessibility to the municipal area.

The Geographical Information System (GIS) environment adopted for the collection, processing and analysis of all the used layers is

Quantum GIS (QGIS) version 3.16.11 (http://qgis.osgeo.org). Through this software we produced many thematic maps to depict different patterns characterizing Basilicata from an environmental, socio-economic, and infrastructural point of view.

We adopted the provincial scale to describe and analyze the spread of contagion during the first wave, while data at municipal scale (cumulative value of infected) were analyzed through the boxplot analysis [66], i.e., the well-known visual tool used to show the distribution of a given dataset. It provides a summary of key data features (median, quartiles, outliers), where the box portion of the plot represents the interquartile range (IQR), starting from the first quartile (Q1) to the third quartile (Q3) and including the central 50 % of the data. A line within the box indicates a crucial statistics: the median, i.e., the middle value of the dataset. After showing the statistical distribution of infected in Basilicata, we used these data to cluster the municipalities into similar classes. Finally, we used the above-mentioned indicators to show the significant difference in terms of socio-economic structure and level of urbanization between the identified clusters.

2.4. Data sources

In order to illustrate the main drivers of the COVID-19 diffusion acting in Basilicata during the period February–June 2020, we took into account different typologies of data from various sources.

- Data on population structure collected from ISTAT (accessible at http://dati.istat.it/index.aspx?queryid=18564);
- Official data of the number of infected people and deaths (at provincial scale), to track the evolution of the contagion, acquired from the database issued by the Civil Protection Department – Presidency of the Council of Ministers (accessible at http://opendatadpc.maps.arcgis.com/apps/opsdashboard/index.html#/b0c68bce2cce478eaac82fe38d4 138b1);
- Official data of the number of infected people at municipal scale made available on demand by the Department of Health, Personal Policies and PNRR - Basilicata Region;
- Data on deaths registered in the period 2015–2019 (the five years preceding the pandemic event) and population structure collected from ISTAT (see respectively www.istat.it/it/files/2020/03/nota-decessi-22-ottobre2020.pdf and http://dati.istat.it/index.aspx?queryid=18564);

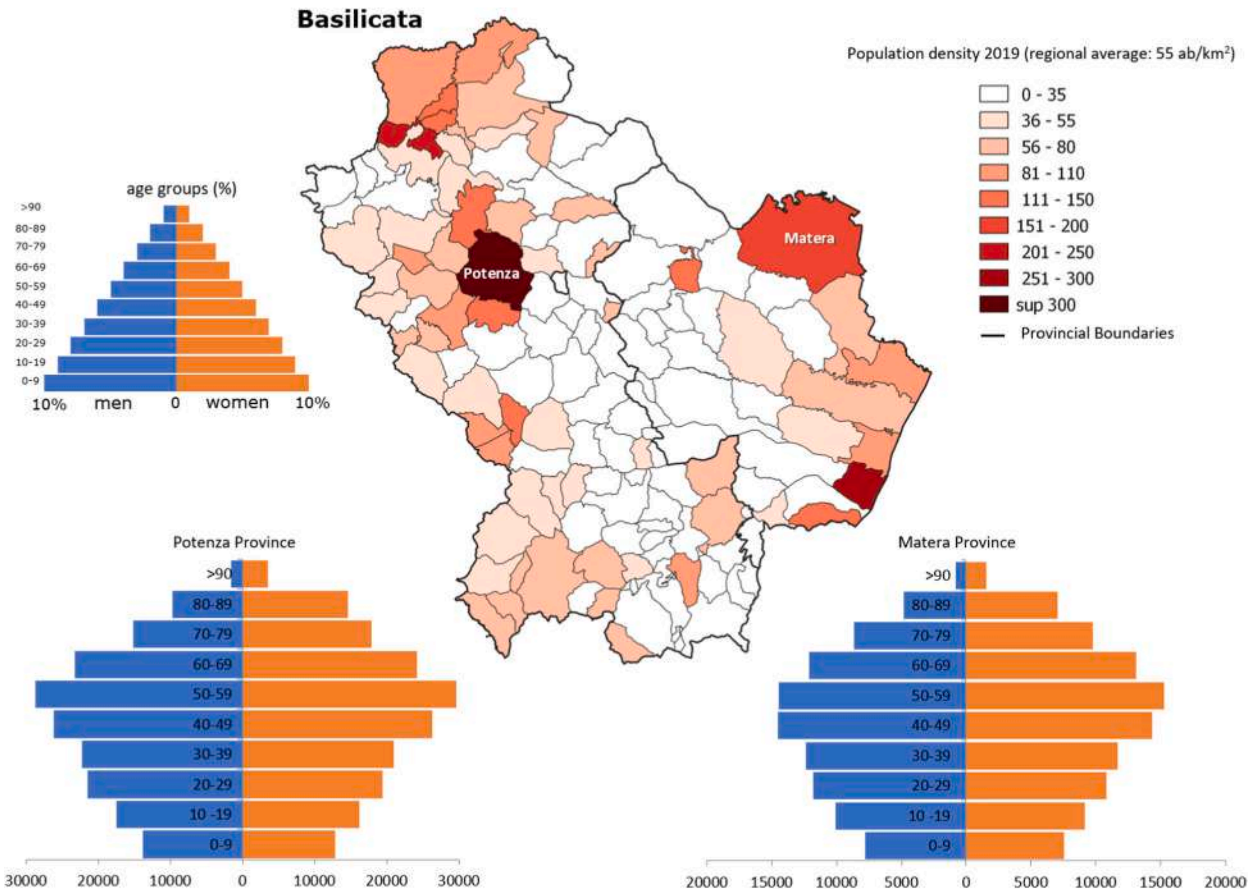

Fig. 2. Population 2019 and age structure per province, represented with a population pyramid. Black lines indicate the boundaries of the two provinces (http://dati.istat.it/Index.aspx?QueryId=18564).

- Data on the health care system acquired from the Health and Personal Policies Department of the Basilicata Region (see https://www.regione.basilicata.it/giunta/site/giunta/department.jsp?dep=100061&area=535764&level=1);
- Data on the mobility collected from ISTAT and the Regional School Office of Basilicata (see https://www.istat.it/it/archivio/139381 and http://www.basilicata.istruzione.it);
- Data on land fragmentation (S_{eff} - Effective mesh-density) and soil consumption at municipal scale acquired from ISPRA (Italian Institute for Environmental Protection and Research) (see respectively https://indicatoriambientali.isprambiente.it/it/pon/linea-2-linea-3/indice-di-frammentazione and https://www.isprambiente.gov.it/it/attivita/suolo-e-territorio/suolo/il-consumo-di-suolo/i-dati-sul-consumo-di-suolo);
- Data on road density acquired from OpenStreetMap (OSM, see https://www.openstreetmap.org/).

3. Results and discussion

3.1. Characterization of Basilicata in terms of demography, economy, mobility, workforce and healthcare system

3.1.1. Population structure

The peculiar demographic dimension of Basilicata is a key information to understand the dynamics of the epidemic. The region is third to last in Italy (only Valle d'Aosta and Molise host a smaller population) with a total population of 553,254 inhabitants (december 31, 2019, see https://www.istat.it/comunicato-territoriale/il-censimento-permanente-della-popolazione-in-basilicata/), of which 364,960 residents in the province (administrative boundary corresponding to the level of NUTS-3) of Potenza (Capital City of Basilicata) and 197,909 in the province of Matera. This figure is continuing its downward trend: the population on January 1, 2024 is 533,636 (https://www.istat.it/wp-content/uploads/2024/05/17Basilicata_Focus2022_Testo_def.pdf). Following the SNAI criteria for the period 2014–2020, only two municipalities out of the total 131 in Basilicata were considered poles: the province capitals of Potenza and Matera, accompanied by only three urban belts municipalities falling in the vicinity of Potenza [11]; Fig. 1c).

All the remaining municipalities (approximately 96%) are classified into the other categories (intermediate, peripheral, ultra-peripheral), clearly showing that almost the overall territory is prevalently rural and suffers from structural gaps in terms of school, health structures and transport facilities [67].

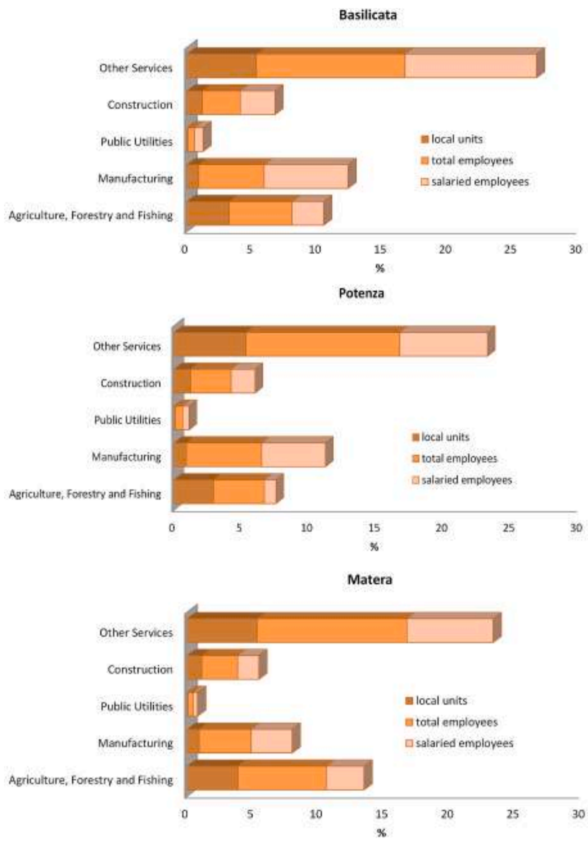

Fig. 3. Sectors of economic activity: local units, total employees and salaried employees normalized to the total regional and provincial population (Basilicata, Potenza, Matera, data updated to 2012, see http://basilicatadati.regione.basilicata.it/xwiki/bin/view/annuario_statistico_2013/Imprese_e_Occupati_tav1).

This pattern is partially driven by the morphology of Basilicata, contributing also to the emergence of many geo-economic processes that have shaped the region's population distribution and demographic structure. Today, the population does not exert a heavy pressure on landscapes, since the urban mesh is rather large, with population mostly concentrated in the two province capitals, around the city of Melfi (hosting the former FIAT-SATA, now Stellantis, automotive plant in the north-western part of the region) and along the Ionian coast, i.e., the main productive areas corresponding to the most urbanized districts of the region.

The population density of Basilicata in 2019 was about 55 persons per square kilometer (562,869 inhabitants over a surface of about 10,000 km^2), placing the region well below the national average (about 197 persons per square kilometer), with only few municipalities exceeding this threshold (Fig. 2).

This figure also includes those non-resident students and workers who, despite having moved elsewhere, keep their residence in the municipality of origin: this is a crucial aspect for analysing the population of Basilicata, since the lack of services, especially the public ones, and the scarce dynamism of the labour market have influenced the temporary or permanent emigration phenomena. On the contrary, immigration flows here are still of marginal relevance, considering that the incidence of foreign residents does not exceed 4%, compared to a national average equal to more than double (http://dati.istat.it/Index.aspx?QueryId=19120).

The demographic structure re-proposes the prevailing scenario of the inner areas of Italy, affected by aging and low birth rates, as phenomena partially linked to a history of negative migration balances [68].

Almost a quarter of the population of Basilicata is over 65 (Fig. 2), and this certainly affects – as regards the territorial aspects here investigated – the demand for infrastructure and mobility, considering that a large part of local communities, and especially the ultra-peripheral ones, have rural lifestyles and low levels of innovation compared to urban areas [69].

3.1.2. Patterns of economy, mobility and commuting

Although Basilicata is one of the less dynamic regions in Italy, due to the harshness of the physical geography and a history of marginalization with respect to the major investment programs, its economy has recorded in recent years the lowest unemployment rates in Southern Italy [70]. Although agriculture is no longer predominant today, primary sector activities are still a mainstay of the regional economy (*ibidem*). In fact, thanks to the reclamation and irrigation works started with the Land Reform of the 1950s, with the contextual allocation of plots and scattered houses to labourers, agriculture has strengthened, diversified and somehow better distributed [71,72].

After the 2008 crisis, the Basilicata production framework was recovering because it was mainly driven by industrial activities, thanks to the supply chain of oil extraction and automotive sectors, concentrated respectively in the Agri and Basento valleys and in the Stellantis plant located in the municipality of Melfi. However, in recent years, there has been an expansion of services. The activities concerning tourism are mainly due to the presence of a hub such as Matera, which has become European Capital of Culture 2019, while the services of the building industry have benefited from the good performance of the residential and public works' sectors [70].

As shown in Fig. 3, in the economic structure of Basilicata the tertiary sector prevails over the other economic activities with almost 50 %, a share common to both the provinces of Potenza and Matera.

The two provinces show different rates in the primary and the manufacturing sectors, with the former more rooted in the Matera province (27% of total workers compared to 15% in Potenza), while the latter is more rooted in the Potenza province (23% compared to 16%) as a result of the industrial concentration near the Stellantis plant of Melfi [73].

The geography of productive activities follows that of settlements; as shown in Fig. 4, the map of the employees' number draws a triangular structure of the industrial concentration, whose vertices are, also in this case, Potenza, Matera and Melfi with their

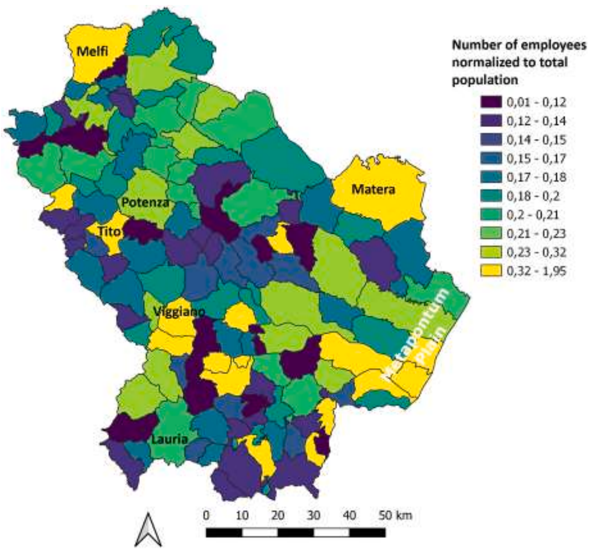

Fig. 4. Distribution of the workforce across the manufacturing and service sectors, normalized to the total municipal population [74].

hinterlands and the area of Metapontum Plain and the city of Viggiano (Agri Valley), home to the oil center.

As regard to the mobility revolving around these three cities (Potenza, Matera and Melfi) (Fig. 5), it is evident a collective behaviour consisting in daily flows mostly involving commuters from other municipalities of the region towards these hubs, because they host the largest concentration of schools, hospitals, industrial zones and also the two university sites (Matera and Potenza).

Furthermore, if we consider that students of high schools are the principal users of public transport, it is relevant to point out that these schools are present in only 31 % of the municipalities of Basilicata and the southern-central part of the region is the most poorly served (Fig. 6).

Except for Matera, the share of commuters reaching Basilicata from neighboring regions is negligible, although all three centres are located rather close to the regional boundaries. Commuting flows are also extremely fragmented: a small number of workers and students commute daily to the main centres from a multitude of municipalities.

This way, it is evident that the mobility does not take a diffuse and rhizomatic form, but it tends to be rather unbalanced on these same poles, i.e., it predominantly connects them to each other, to the detriment of other areas, indicating one of the main deficiencies of this region: the lack of infrastructural endowment.

Regional mobility is founded on road transports because of the extreme scarcity of railway infrastructure and the functional dependence on Apulia and Campania in terms of airport connections. Consequently, Basilicata is among the least endowed regions with transport infrastructures in Italy: poorly interconnected internally and crossed by commuter flows whose magnitude is greatly reduced, on the one hand, by the extreme fragmentation of the travel trajectories, on the other hand, by the preponderance of road transport (mainly cars).

It is the effect of what Stanzione [75] defined as “the tyranny of peripheral geographical location”, with respect to the centralization of production and service functions occurred between the 1950s and 1960s. It was responsible for a significant infrastructural deficit in large areas of Southern Italy that have been affected by depopulation and marginality over time.

3.1.3. Healthcare system

Starting from the early 2000s, as a result of the reforms of the National Health System and the 1998–2000 National Health Plan [76], there has been a rationalization of the regional hospital network, which led to the closure of three of the five pre-existing local health authorities in Basilicata and their unification into the two provincial structures of Potenza and Matera (Fig. 7). Although the aim was to strengthen the forms of territorial assistance, both the provincial structures recorded a reduction in the ratio between the number of beds and inhabitants of over 15 % in 2010 compared to 2005, while the national average was about 3 %. The supply of healthcare personnel, on the contrary, has significantly increased in the same period, with evidence on the regional health economics [77].

Moreover, the overall hospital network of Basilicata, largely managed by public services, consistently records a very limited surgical admissions alongside a high number of medical admissions among the older population groups. This fact, together with the small number of hospitalizations for rehabilitation and long-term care, indicates that the quality of the hospital service is rather inadequate. This conclusion is also supported by the flows of outbound healthcare mobility that persist over time, due to the consolidated migration to extra-regional structures for highly complex services and, in general, for surgical operations [78–80].

This aspect partially explains the limited availability of RHs, to which healthcare mobility contributes because users who migrate to other regions to receive surgical services, requiring subsequent rehabilitation or long-term hospitalization, are likely to stay elsewhere for the post-operative time.

The list of accredited facilities available in Basilicata includes many RHs with a total of 726 authorized beds (Fig. 8), evenly distributed between the provinces of Potenza and Matera, primarily specialized in elderly care: a provision that offers an average coverage of 0.6 % of the population over sixty-five at the regional level, slightly higher in the province of Matera (http://dati.regione.basilicata.it/catalog/dataset/elenco-strutture-sanitarie-accreditate/resource/399cdc74-561f-49a3- ae44-02d61194ae05).

In addition to healthcare emigration, along with income factors, another element explaining the under-provision of RHs is linked to the cultural profile of local communities in Basilicata, where elderly care is primarily entrusted to homecare professionals or, where possible, to the family. It is evident that, in the context under examination, this kind of habit can be considered among the factors that

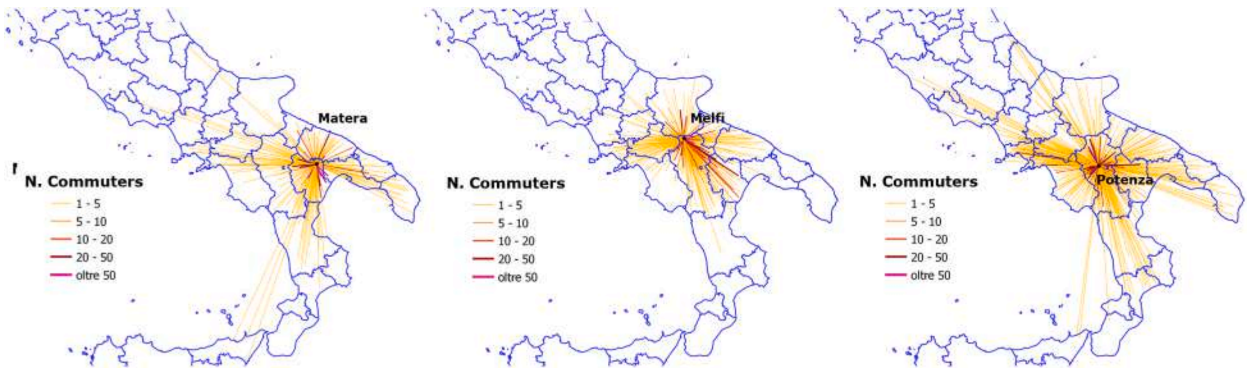

Fig. 5. Commuting flows to Potenza, Matera and Melfi (data updated to 2011, see https://www.istat.it/it/archivio/139381).

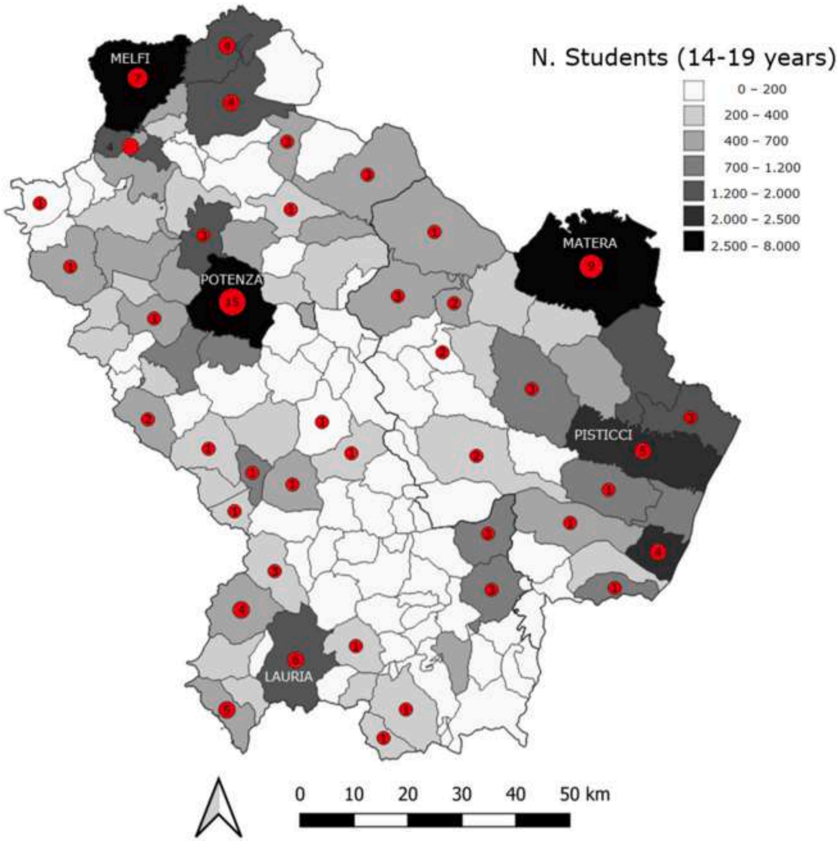

Fig. 6. School age population (14–19 years) and number of high schools (in the red circle) by municipality (Data updated as of 2019, see http://dati.istat.it/index.aspx?queryid=18564 and http://www.basilicata.istruzione.it/).

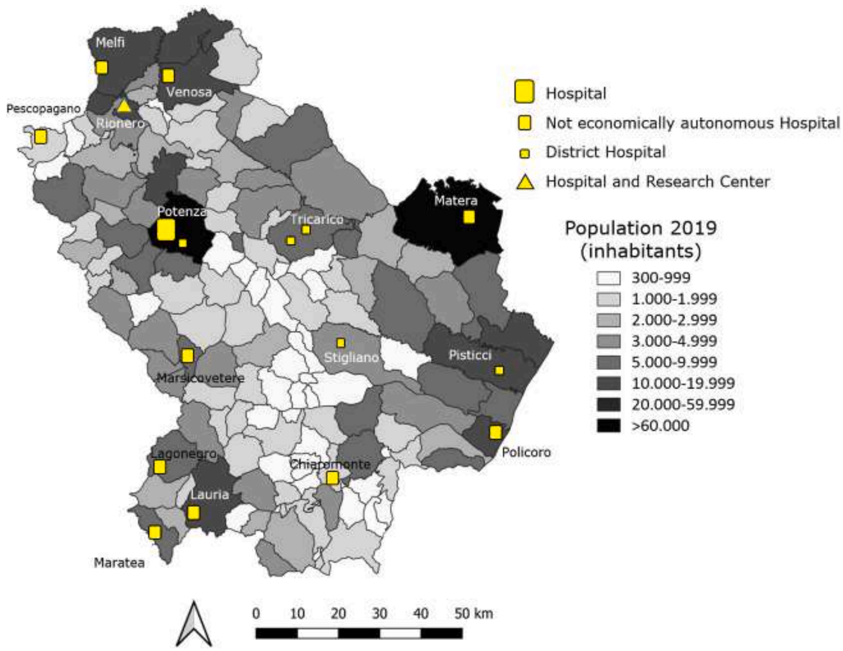

Fig. 7. The hospital network of Basilicata (data updated as of 2019).

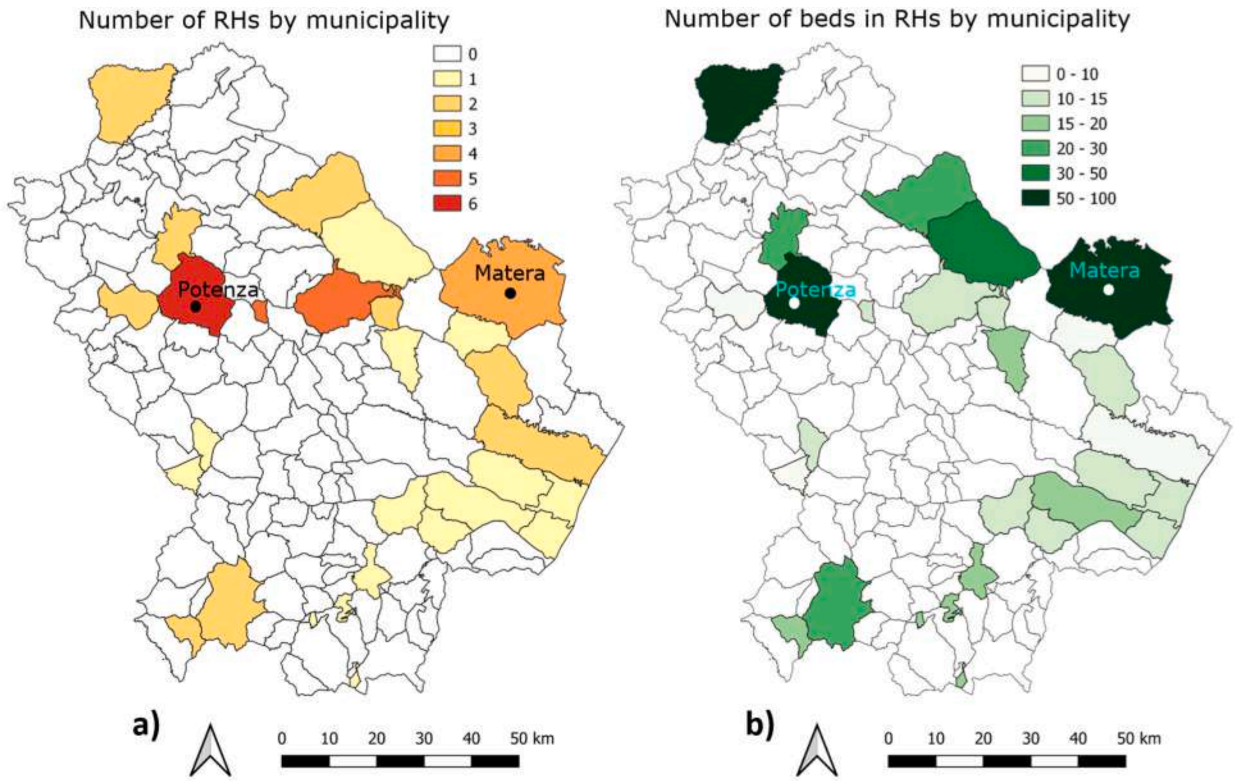

Fig. 8. Number of RHs by municipality (a) and relative availability of beds (b) (data updated as of 2020, see https://www.regione.basilicata.it/giunta/site/giunta/department.jsp?dep=100061&area=535764&level=1).

have contributed to limiting the scope of the contagion, given the specific vulnerability that RHs have dramatically shown in other regions of the country [81].

3.2. The spread of COVID-19 at provincial scale during the first wave (Feb–Jun 2020)

In Basilicata the so-called "first wave" began on March 3, 2020, when the first COVID-19 positive test was registered in the province

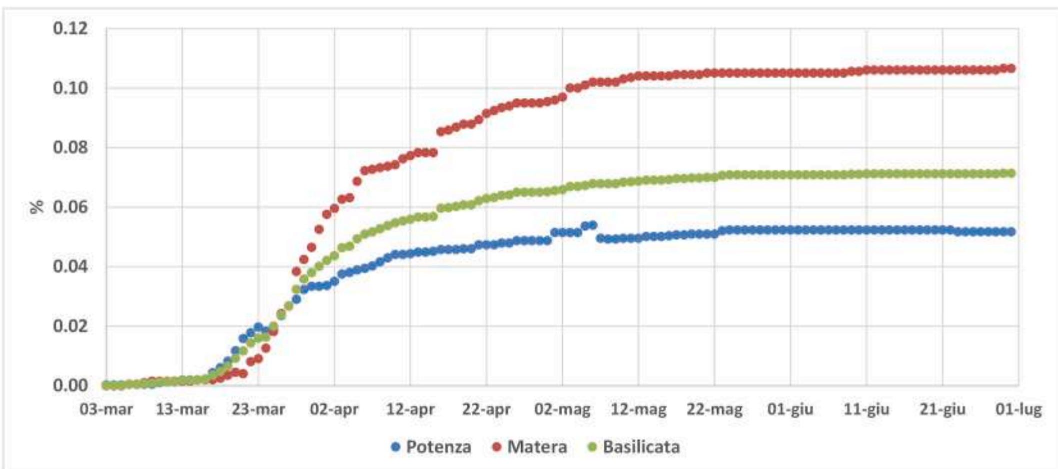

Fig. 9. Temporal evolution of the COVID-19 infected normalized to the total provincial or regional population during the first wave (March–June 2020). Different colors indicate trends for the whole region and the provinces of Potenza and Matera.
(Source: elaboration of data provided by the Civil Protection Department - Presidency of the Council of Ministers at http://opendatadpc.maps.arcgis.com/apps/opsdashboard/index.html#/b0c68bce2cce478eaac82fe38d4 138b1).

of Potenza (the first positive test in Italy was registered in Codogno – Lombardy, on February 20, 2020): since that date the total of daily positives up to June 30, 2020 had never exceeded the incidence of 0,08 % on the total residents in the province of Potenza and in Basilicata and barely reaching 0.1 % in the province of Matera.

As Figg 9 and 10 show, the epidemic curve in the time frame investigated indicates a growing trend since mid-March until the end of April, with daily absolute increases of a few units in the first period and more consistent (a few dozen) in the week between the two months, corresponding to approximately 0.1 % of the ratio between infected individuals and population. If until mid-April the province of Potenza was the most affected, in the following weeks the province of Matera overcame it. This is more relevant if we consider the smaller demographic size of the province of Matera. During the period from May to June, the epidemiological trend was almost unchanged, except for a few days when negative values of the new infected were recorded. This is likely due to the transfer of individuals who had contracted the virus in Basilicata and were subsequently hospitalized or detained there, but later relocated outside the region.

As far as mortality, Fig. 11 shows how the mortality curve trend reaches 7% around mid-April, confirming that the epidemic peak occurred in the second week of April. The total deaths from COVID-19 up to June 30, 2020 is 6.7% of the infected by the same date. Furthermore, Fig. 12 shows how the first wave of pandemic has affected the increase in mortality in the northern regions of Italy, where there were increases of 94% and 74% in the March–April period compared to the five-year average 2015–2019 (Lombardy has a decisive role in this regard). On the contrary, in other areas of Italy, such as in southern regions, the trend was similar to the previous five-year period. Moreover, it is remarkable that Basilicata during March to June 2020 even recorded a decrease (respectively of 5% and 6%) compared to the same months of the period 2015–2019 [82]. This certifies that during the first wave Basilicata was affected by the pandemic no more than minimally.

3.3. The spread of COVID-19 at municipal scale during the first wave (Mar–Jun 2020)

In Fig. 13 is reported the cumulative distribution of infected at municipal scale during the first wave of pandemic. The figure shows a predominance of municipalities with either no infected individuals or at most one. Only a few municipalities exhibit an appreciable number of infected. Matera leads with 70 cases, followed by Potenza (58) and a few other municipalities, including those where ad hoc measures were implemented to establish the so-called 'red zones': between March and April 2020, the municipalities of Moliterno in the province of Potenza, and Irsina, Tricarico, and part of Grassano in the province of Matera, were subjected to a total lockdown with restrictions more stringent than those applied in the rest of the region (Regional decrees no. 7 of March 17, 2020, regarding the municipality of Moliterno, and no. 12 of March 27, 2020, regarding the municipalities of Tricarico, Irsina, and Grassano).

Looking at these values through the lens of statistics, we observe that the distribution of the number of infected is extremely

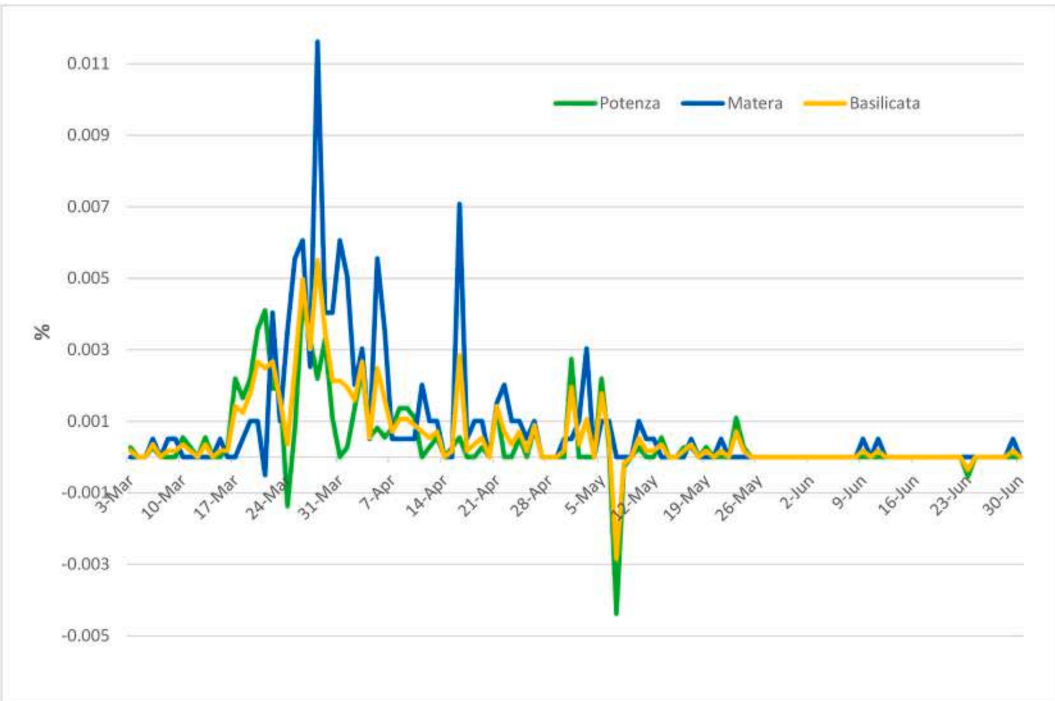

Fig. 10. Daily increase in infected people normalized to the total provincial or regional population during the first wave (March–June 2020). Different colors indicate trends for the whole region and the provinces of Potenza and Matera.
(Source: https://www.istat.it/it/files/2020/03/nota-decessi-22-ottobre2020.pdf).

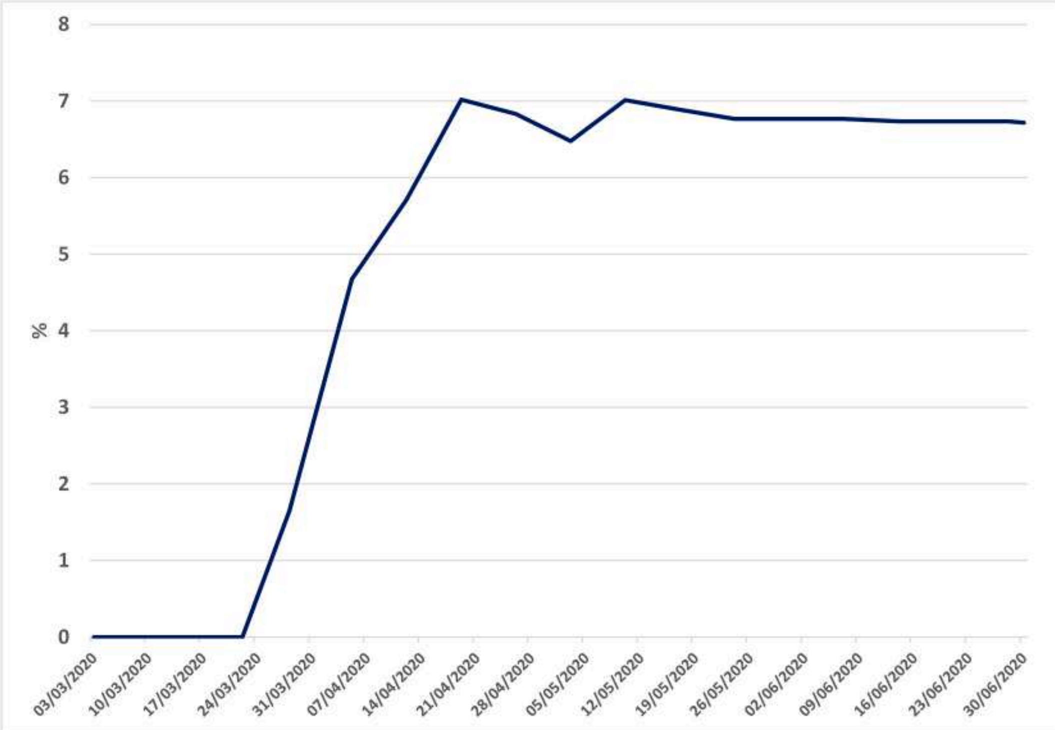

Fig. 11. Total deaths on total infected in Basilicata during the first wave (March–June 2020).
Source: elaboration of data provided by the Civil Protection Department - Presidency of the Council of Ministers at http://opendatadpc.maps.arcgis.com/apps/opsdashboard/index.html#/b0c68bce2cce478eaac82fe38d4 138b1).

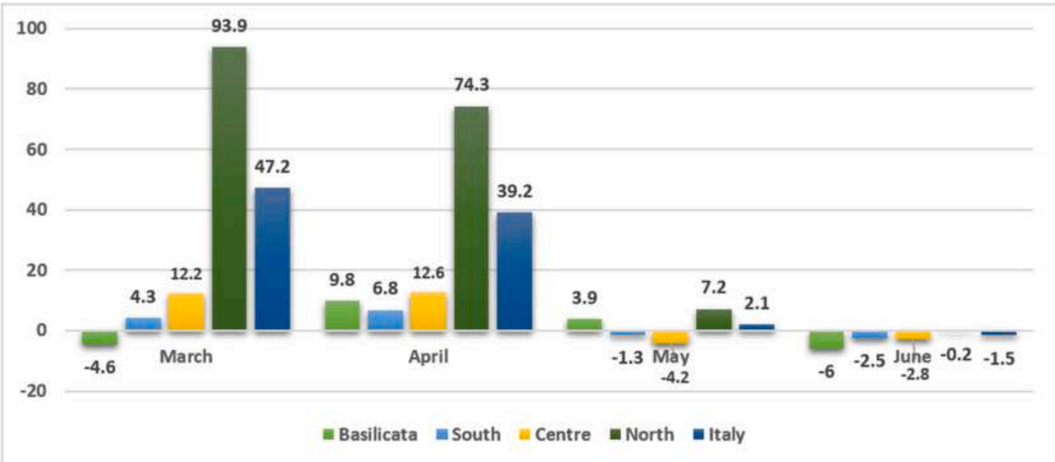

Fig. 12. Variation of deaths (%) in 2020 compared to the 2015–2019 average by geographical area and month.
(Source: https://www.istat.it/it/files/2020/03/nota-decessi-22-ottobre2020.pdf).

skewed, showing a pronounced right tail (see the boxplot in Fig. 14). The median number of cases is 0, with 75% of values falling between 0 and 2. Based on this distribution, any count above 5 infected per municipality has to be considered as an outlier thereby testifying the marginal impact from the pandemic on the region as a whole.

Subsequently, we applied *K*-means to cluster the number of infected. The Elbow method identified $K = 3$ as the optimal number of clusters, with K-means categorizing the data into three distinct classes that can be easily labelled according to statistics: Cluster 1 (inliers), Cluster 2 (outliers), and Cluster 3 (poles). An evident feature emerges from the visual inspection of the clusters in Fig. 15. The areas surrounding the poles in Cluster 3 are either in Cluster 2 or Cluster 1 thereby showing that the contiguity to center hubs is not determinant for the contagion geography. As an example, only one of the seven municipalities bordering Potenza was in Cluster 2; the

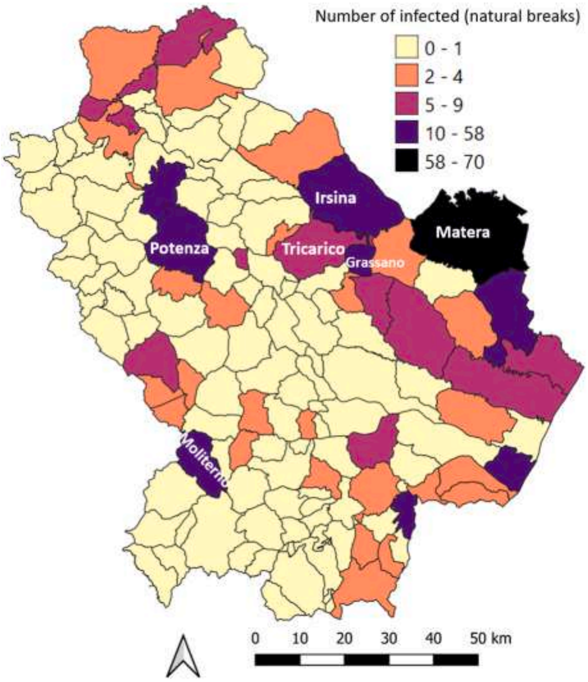

Fig. 13. Total number of confirmed infected registered at the municipal level in Basilicata during the first wave of pandemic (March–June 2020). (Source: Department of Health, Personal Policies and PNRR - Basilicata Region).

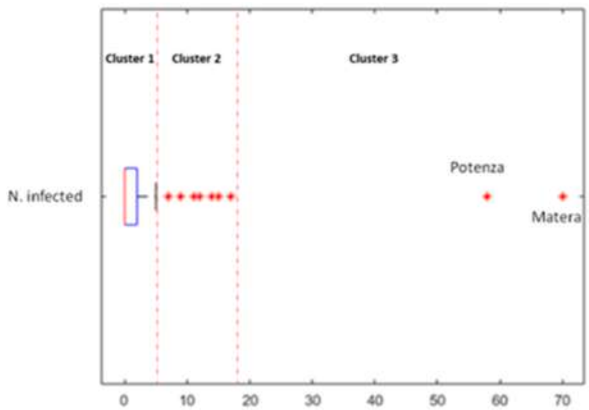

Fig. 14. Boxplot of number of infected during the first wave of pandemic (municipal scale – Basilicata). The red continuous line indicates the median value, while the red stars represent the outliers. Red discontinuous lines separate the three clusters identified by K-means.

number of infected drops to less than 6 cases in the other municipalities and we do not observe the isotropic distribution that is typical of spatial variables that depend on the distance from a center.

Cluster 1 includes the large mass of small municipalities that primarily rely on local socio-economic activities for their livelihood, without significant exchanges fueling the pandemic. More interestingly, Cluster 2 mainly includes medium-size population municipalities, where contagion was presumably favored by strict contacts with the poles Potenza and Matera (representing the Cluster 3). Cluster 2 is mainly concentrated in a large area encompassing the neighboring of the city of Matera and the Metapontum Plain. This cluster is characterized by a strong agricultural vocation and a significant presence of manufacturing activities, especially along the Basento Valley (see also Fig. 4 representing the number of employees in the manufacturing and service sectors). In particular, the Metapontum Agro-Food District of Quality (recognized by the Basilicata Region with the Decree of the Regional Executive n.1256 of May 24, 2004) is characterized by a high concentration of medium-sized and small enterprises, the presence of certified or protected productions and a strong internal 'network' organization: internal subcontracting networks, supply chain links, trade/production agreements and common service centres [83]. This very intense exchange of labour and goods continued during the first pandemic wave leading up to the first lock-down (March 10, 2020), also because of the need to guarantee essential crop productions. The

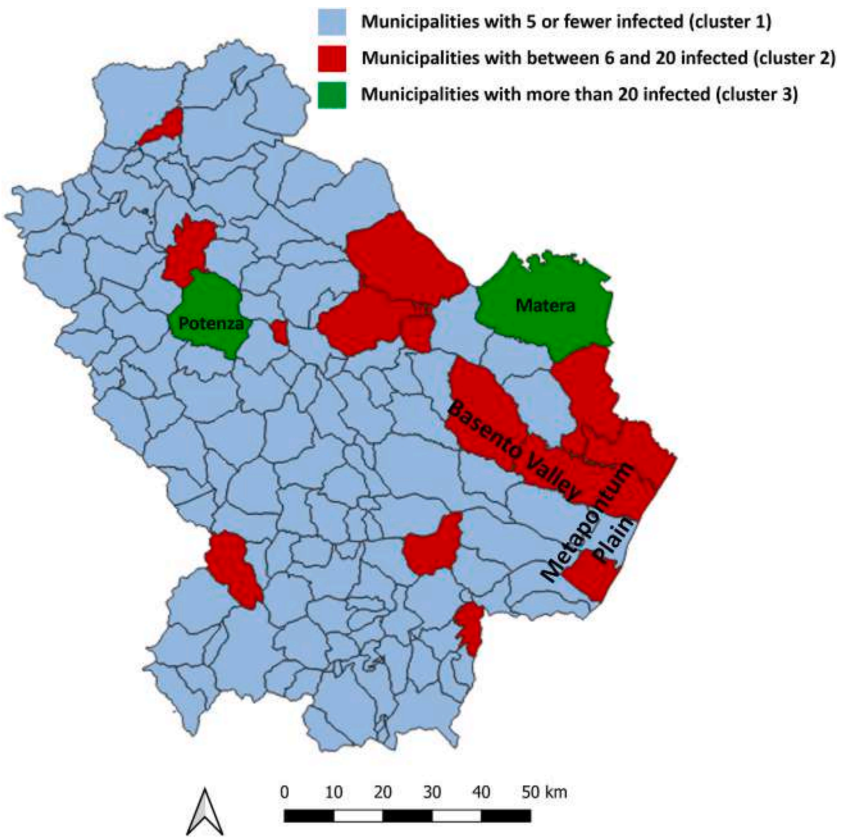

Fig. 15. Geographical profile of the three identified clusters: municipalities with more than 20 infected (green colored, poles – cluster 3) municipalities with between 6 and 20 infected (red colored, medium-size municipalities – cluster 2) and municipalities with less than 5 infected (blue pastel colored – small municipalities – cluster 1).

promotion of tourism flows in Matera during the first months of 2020 [84], ascribable to its role of the European Capital of Culture for the year 2019, presumably contributed to the high number of infected in the city (70 infected). Altogether, shared productive interests likely contributed to separate this municipalities group from the essentially unaffected areas.

In conclusion, the first wave of pandemic affected Basilicata only marginally, first of all because of the considerable distance between this region and the heart of the most impacted Italian districts (e.g., Lombardy). The creation of mini-outbreaks (such as those found in the municipalities of Irsina, Moliterno, Tricarico and Grassano) is a process probably triggered by sporadic travels. The only areas where a relatively appreciable number of infected occurred during the first wave are the Metapontum Plain and the Basento Valley with the nearby city of Matera, due to the frequent interchanges and the relative contiguity and connectivity of these districts with respect to the other areas of Basilicata, in line with the works of d'Andrea et al. [85] and Ascani et al. [86]. The former suggests that the spread of COVID-19 was mainly driven by contacts occurring within a single municipality or through short-distance travels, especially in the period when many restrictions on physical distancing were promoted (beginning of March 2020). The latter asserts that areas specializing in certain economic activities and characterized by high geographic concentration could experience relatively higher infection rates due to the physical interactions associated with the agglomeration advantages inherent in these industrial

Table 1
Comparison of socio-environmental indicators for the three identified clusters.

Indicators	Municipalities with 5 or fewer infected (cluster 1)	Municipalities with between 6 and 20 infected (cluster 2)	Municipalities with more than 20 infected (cluster 3)
S_{eff} (N. of meshes per 1000 km^2)	3.23	3.39	3.84
Land consumption 2020 (%)	3.03	3.38	8.18
Road density (km/km^2)	1.11	1.12	1.77
Population density (inh./km^2)	43.17	85.74	267.33
Ageing index (%)	299.46	223.97	193.85

activities, especially if they are manufacturing in nature, rather than belonging to the service category.

To support this theory, proxy indicators of the level of urbanization, accessibility and demographic structure were calculated for the three clusters as average municipal values. The results confirm our interpretation (Table 1): the municipalities of the Cluster 3 (poles) show the highest level of land fragmentation (S_{eff} indicator) indicating a denser presence of artificial elements as signs of an extensive urban/industrial network that break the continuity of the agricultural-natural fabric, the highest values of sealed soil (land consumption), a better accessibility (higher values of road density), the highest concentrations of people (population density) and the lowest incidence of older people (aged 65 years and over, see the ageing index) with respect to the overall population. This last indicator means a prevalence of younger age groups with a greater propensity to travel and thus to act as vector of contagion. Values above 100 indicate a higher presence of elderly people compared to very young ones. Cluster 1 exhibits conditions opposite to those reported for Cluster 3, while Cluster 2 shows intermediate values but closer to those of Cluster 1, supporting the idea that Potenza and Matera are clearly distinguished from the rest of the study area.

4. Conclusions: towards a new approach to peripherality

The analysis of the first wave of COVID-19 in Basilicata provides very useful insights for the right understanding of the geography of pandemic in Italy. While subsequent waves affected the region more severely mainly due to the reshuffling processes generated by restored interregional mobility flows, the first wave describes the trigger phase and vividly shows which regions were directly exposed to the pandemic. Patterns of contagion in this period allow us therefore to identify the territorial factors responsible for risk and, conversely, those that provide protection. As suggested by Casti and Riggio [40]; the complex characteristics of Italy, both physical and territorial, contributed to a marked epidemic differentiation. The distribution and regional evolution of the contagion in relation to relevant factors such as population, mobility, pollution, number of hospitals and rest homes provides a composite picture and a solid ground for a correct interpretation of the epidemic dynamics.

On the whole, the area analyzed in this study exhibits a socially and economically vulnerable territorial architecture. Distances from national-level hotspots of contagion (Lombardy and Veneto regions in northern Italy) and underdevelopment aspects were likely at the origin of the limited spread of the COVID-19 pandemic in Basilicata. The mobility network that characterises the interconnection between high-intensity productive areas in the region clearly shows a tri-polar distribution around Potenza, Melfi, and Matera. These poles are well-connected between them but are less effectively connected to other municipalities of the region and extra-regional hubs. The only super-municipal clustering of spread identified by our analyses is located in the Metapontum Plain/Basento Valley, where agricultural and manufacturing activities could have triggered contagion before the lockdown. Low demand for interconnection and mobility compared to other regions with younger population, low-income problems, and cultural models that prefer family-based elder care so limiting the concentration of fragile people in RHs [87], acted as protection factors, as in similar rural districts of Italy [45].

The results of this study suggest a new interpretation of some characteristics that define life in the inner areas of southern Italy, such as Basilicata, that are not necessarily mobile, not predominantly urbanized, not universally interconnected. The hierarchical classification of Italian municipalities in belt, intermediate, peripheral and ultra-peripheral municipalities (SNAI) seems to be overly rigid in certain cases. Our infection clusters often transcend these classifications, as connectivity is frequently shaped by distinctly local factors, beyond mere proximity to urban centres providing essential services. The need to re-signify local aspects stems precisely from the observation of protective factors in the epidemiological trends during the first wave in areas with similar characteristics. In agreement with the assumption that the spread of COVID-19 was empowered by mobility and subsequently conveyed by proximity [35], our results suggest to recognize the value of the geographies of "slow life" and connective discontinuity when rethinking settlement styles. The core of this new approach to territorial planning should be the reinforcement of these models through policies aimed at equipping disadvantaged areas with better services, removing their functional dependence on overcrowded main centres and decreasing the anthropic pressure on urban ecosystems, all while promoting territorial architectures that foster environmental balance.

CRediT authorship contribution statement

Nadia Matarazzo: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Rosa Coluzzi:** Software, Methodology, Data curation. **Vito Imbrenda:** Writing – original draft, Methodology, Investigation, Data curation. **Maria Lanfredi:** Writing – original draft, Supervision, Methodology. **Michele Galella:** Validation, Software. **Dionisia Russo Krauss:** Writing – original draft, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

[1] B. Murgante, G. Borruso, G. Balletto, P. Castiglia, M. Dettori, Why Italy first? Health, geographical and planning aspects of the COVID-19 outbreak, Sustainability 12 (12) (2020) 5064, https://doi.org/10.3390/su12125064.

[2] T. Boschi, J. Di Iorio, L. Testa, M.A. Cremona, F. Chiaromonte, Functional data analysis characterizes the shapes of the first COVID-19 epidemic wave in Italy, Sci. Rep. 11 (1) (2021) 17054, https://doi.org/10.1038/s41598-021-95866-y.

[3] E. De Angelis, S. Renzetti, M. Volta, F. Donato, S. Calza, D. Placidi, R. Lucchini, M. Rota, COVID-19 incidence and mortality in Lombardy, Italy: an ecological study on the role of air pollution, meteorological factors, demographic and socioeconomic variables, Environ. Res. 195 (2021) 110777, https://doi.org/10.1016/j.envres.2021.110777.

[4] A. Cartenì, L. Di Francesco, M. Martino, How mobility habits influenced the spread of the COVID-19 pandemic: results from the Italian case study, Sci. Total Environ. 741 (2020) 140489, https://doi.org/10.1016/j.scitotenv.2020.140489.

[5] M. Fior, V. Mpampatsikos, COVID-19 and estimates of actual deaths in Italy. Scenarios for urban planning in Lombardy, J. Urban Manag. 10 (3) (2021) 275–301, https://doi.org/10.1016/j.jum.2021.06.008.

[6] N. Matarazzo, La pandemia di Covid-19 in un'area interna della Campania: perifericità, densità abitativa e diffusione del contagio nella provincia di Avellino, Documenti Geografici 1 (2020) 753–765, https://doi.org/10.19246/DOCUGEO2281-7549/202001_48.

[7] L. Viganoni, Il Mezzogiorno delle città: tra Europa e Mediterraneo, F. Angeli, Milano, 2007.

[8] C. Muscarà, G. Scaramellini, I. Talia (Eds.), Tante Italie Una Italia, Dinamiche Territoriali e Identitarie. Franco Angeli, Milano, Italy, 2011.

[9] E. Casti, F. Adobati, I. Negri (Eds.), Mapping the Epidemic. A Systemic Geography of Covid-19 in Italy, Elsevier, Amsterdam, 2021.

[10] A. De Rossi, Introduzione. L'inversione dello sguardo. Per una nuova rappresentazione territoriale del Paese Italia, in: A. De Rossi (Ed.), Riabitare l'Italia, Le aree interne tra abbandoni e riconquiste. Roma: Donzelli, 2018, pp. 3–17.

[11] F. Barca, P. Casavola, S. Lucatelli (Eds.), *Strategia Nazionale per le Aree Interne: definizione, obiettivi, strumenti e governance*. Roma: UVAL – Dipartimento per lo Sviluppo e la Coesione Economica, 2014.

[12] D. Cersosimo, A.R. Ferrara, R. Nisticó, L'Italia dei pieni e dei vuoti, in: A. De Rossi (Ed.), Riabitare l'Italia. Le aree interne tra abbandoni e riconquiste, Donzelli, Roma, 2018, pp. 21–50.

[13] V. Imbrenda, R. Coluzzi, V. Di Stefano, G. Egidi, L. Salvati, C. Samela, T. Simoniello, M. Lanfredi, Modeling spatio-temporal divergence in land vulnerability to desertification with local regressions, Sustainability 14 (17) (2022) 10906.

[14] A. Perrone, Lessons learned by 10 years of geophysical measurements with Civil Protection in Basilicata (Italy) landslide areas, Landslides 18 (4) (2021) 1499–1508.

[15] V. Santarsiero, A. Lanorte, G. Nolè, G. Cillis, B. Tucci, B. Murgante, Analysis of the effect of soil erosion in abandoned agricultural areas: the case of NE area of Basilicata region (southern Italy), Land 12 (3) (2023) 645.

[16] L. Curatella, G. Fortunato, A. Pilogallo, L. Saganeiti, V. Santarsiero, A. Bonifazi, F. Scorza, Polycentrism and effective territorial structures: basilicata region case study, in: New Metropolitan Perspectives: Knowledge Dynamics and Innovation-Driven Policies towards Urban and Regional Transition, vol. 2, Springer International Publishing, 2021, pp. 1689–1696.

[17] A. Pilogallo, F. Scorza, Regulation and maintenance ecosystem services (ReMES): a spatial assessment in the Basilicata Region (Southern Italy), in: Computational Science and its Applications–ICCSA 2021: 21st International Conference, Cagliari, Italy, September 13–16, 2021, Proceedings, Part VII, vol. 21, Springer International Publishing, 2021, pp. 703–716.

[18] L. Pace, R. Coluzzi, V. Imbrenda, M. D'Emilio, A. Falcone, V. Nuzzo, M. Lanfredi, Combining multi-source data to map vineyards in a specialized district of Basilicata (Southern Italy), J. Maps 20 (1) (2024) 2327859.

[19] E. Lemmi, M. Siena Tangheroni, Il geoitinerario come espressione del turismo postmoderno, in: E. Lemmi (Ed.), Turismo e management dei territori: i geoitinerari, fra valori e progettazione turistica, Pàtron, Bologna, 2015, pp. 15–25.

[20] M. Marchetti, S. Panunzi, R. Pazzagli (Eds.), Aree interne. Per una rinascita dei territori rurali e montani, Soveria Mannelli, 2017. Rubbettino.

[21] R. Sommella, Una strategia per le aree interne italiane, Geotemas 55 (2017) 76–79.

[22] M. Ragosta, G. Daniele, V. Imbrenda, R. Coluzzi, M. D'Emilio, M. Lanfredi, N. Matarazzo, Land transformations in Irpinia (Southern Italy): a tale on the socio-economic dynamics acting in a marginal area of the mediterranean Europe, Sustainability 16 (19) (2024) 8724.

[23] M. Kühn, Peripheralization: theoretical concepts explaining socio-spatial inequalities, Eur. Plan. Stud. 23 (2) (2014) 367–378, https://doi.org/10.1080/09654313.2013.862518.

[24] A. Copus, F. Mantino, J. Noguera, Inner Peripheries: an oxymoron or a real challenge for territorial cohesion? Ital. J. Plann. Pract. 7 (1) (2017) 24–49.

[25] A. De Toni, M. Vizzarri, M. Di Febbraro, B. Lasserre, J. Noguera, P. Di Martino, Aligning Inner Peripheries with rural development in Italy: territorial evidence to support policy contextualization, Land Use Policy 100 (2021) 104899, https://doi.org/10.1016/j.landusepol.2020.104899.

[26] J. Noguera, A. Copus, Inner Peripheries: what are they? What policies do they need? Agriregionieuropa 12 (45) (2016).

[27] J. Noguera, M. Ortega-Reig, H. del Alcázar, A. Copus, A. Berlina, J. Moodie, F. Mantino, B. Forcina, S. Weck, S. Beißwenger, N. Hans, G. Tagai, B. Koós, K. Kovács, A. Uzzoli, T. Dax, I. Machold, C. Schürmann, P. Tobiasz-Lis, K. Dmochowska-Dudek, M. Wójcik, Processes, Features and Cycles of Inner Peripheries in Europe – PROFECY (ESPON Project, Final Report), 2017 available at: https://www.espon.eu/inner-peripheries.

[28] D. Tosi, M. Chiappa, Understanding the geographical spread of COVID-19 in relation with goods regional routes and governmental Decrees: the Lombardy region case study, SN Comput. Sci. 2 (3) (2021) 203.

[29] E. Consolandi, M. Rodeschini, Contagion and local fragilities in Bergamo and the Seriana valley, in: Modern Cartography Series, vol. 9, Academic Press, 2021, pp. 51–61.

[30] R. Troisi, G. Alfano, Is regional emergency management key to containing COVID-19? A comparison between the regional Italian models of Emilia-Romagna and Veneto, Int. J. Public Sect. Manag. 35 (2) (2022) 195–210.

[31] M. Coccia, The effects of atmospheric stability with low wind speed and of air pollution on the accelerated transmission dynamics of COVID-19, J. N. Y. Bar Assoc.: Int. J. Environ. Stud. 78 (1) (2021) 1–27, https://doi.org/10.1080/00207233.2020.1802937.

[32] M. Coccia, How do low wind speeds and high levels of air pollution support the spread of COVID-19? Atmos. Pollut. Res. 12 (1) (2021) 437–445, https://doi.org/10.1016/j.apr.2020.10.002.

[33] V. Vandelli, L. Palandri, P. Coratza, C. Rizzi, A. Ghinoi, E. Righi, M. Soldati, Conditioning factors in the spreading of Covid-19–Does geography matter? Heliyon 10 (3) (2024) e25810 https://doi.org/10.1016/j.heliyon.2024.e25810.

[34] S.A. Sarkodie, P.A. Owusu, Impact of meteorological factors on COVID-19 pandemic: evidence from top 20 countries with confirmed cases, Environ. Res. 191 (2020) 110101.

[35] E. Casti, F. Adobati (Eds.), Mapping riflessivo sul contagio Covid-19. Dalla localizzazione del fenomeno all'importanza della sua dimensione territoriale, II Rapporto di ricerca, Università degli Studi di Bergamo, CST-DiathesisLab, Bergamo, 2020.

[36] E. Casti, F. Adobati (Eds.), Mapping riflessivo sul contagio Covid-19. Dalla localizzazione del fenomeno all'importanza della sua dimensione territoriale, I Rapporto di ricerca. Bergamo: Università degli Studi di Bergamo, CST-DiathesisLab, 2020.

[37] M. Singer, Introduction to Syndemics: a Systems Approach to Public and Community Health, Jossey-Bass, San Francisco, 2009.

[38] M. Singer, F. Valentín, H. e Jia Z. Baer, Why does Juan García have a drinking problem? The perspective of critical medical anthropology, Med. Anthropol. 14 (1) (1992) 77–108.

[39] J. Cortes, M. Pacheco, I. Fronteira, Essential factors on effective Response at the onset of the Covid-19 pandemic. Comment on "experiences and implications of the firse wave of the Covid-19 emergency in Italy: a social science perspective", Int. J. Health Pol. Manag. 13 (1) (2024) 1–4.

[40] E. Casti, A. Riggio (Eds.), Atlante Covid-19. Geografie del contagio in Italia. Roma: A.Ge.I, 2022.

[41] J. Lévy, L'humanité habite le Covid-19, AOC. Analyse, Opinion, Critique (2020) October 2020 from https://aoc.media/analyse/2020/03/25/lhumanite-habite-le-covid-19/.

[42] B.Z. Diop, M. Ngom, C.P. Biyong, J.N.P. Biyong, The relatively young and rural population may limit the spread and severity of COVID-19 in Africa: a modelling study, BMJ Glob. Health 5 (5) (2020) e002699.
[43] J.T. Mueller, K. McConnell, P.B. Burow, K. Pofahl, A.A. Merdjanoff, J. Farrell, Impacts of the COVID-19 pandemic on rural America, in: Proceedings of the National Academy of Sciences, vol. 118, 2021 2019378118, 1.
[44] D.F. Cuadros, Y. Xiao, Z. Mukandavire, E. Correa-Agudelo, A. Hernández, H. Kim, N.J. MacKinnon, Spatiotemporal transmission dynamics of the COVID-19 pandemic and its impact on critical healthcare capacity, Health Place 64 (2020) 102404.
[45] E. Gioia, A. Colocci, C. Casareale, N. Marchetti, F. Marincioni, The role of the socio-economic context in the spread of the first wave of COVID-19 in the Marche Region (central Italy), Int. J. Disaster Risk Reduct. 82 (2022) 103324.
[46] S. De Falco, G. Fiorentino, Geographical scattering in Italian inner areas, politics and COVID-19, AIMS Geosci 8 (2022) 137–158.
[47] G. Büttner, B. Kosztra, *CLC2018 Technical Guidelines*. 25 October 2017, European Environment Agency, Wien, 2017.
[48] S. Tarquini, L. Nannipieri, The 10 m-resolution TINITALY DEM as a trans-disciplinary basis for the analysis of the Italian territory: current trends and new perspectives, Geomorphology 281 (2017) 108–115, https://doi.org/10.1016/j.geomorph.2016.12.022.
[49] V. Imbrenda, M. Lanfredi, R. Coluzzi, T. Simoniello, A smart procedure for assessing the health status of terrestrial habitats in protected areas: the case of the natura 2000 ecological network in Basilicata (Southern Italy), Remote Sens. 14 (11) (2022) 2699, https://doi.org/10.3390/rs14112699.
[50] T. Simoniello, R. Coluzzi, M. D'Emilio, V. Imbrenda, L. Salvati, R. Sinisi, V. Summa, Going conservative or conventional? Investigating farm management strategies in between economic and environmental sustainability in southern Italy, Agronomy 12 (3) (2022) 1–22, https://doi.org/10.3390/agronomy12030597, 597.
[51] S. Russo, R. Carella, Basilicata, in: M. Agnoletti (Ed.), Italian Historical Rural Landscapes. Cultural Values for the Environment and Rural Development, Dordrecht: Springer, Netherlands, 2012, pp. 453–465.
[52] C. Samela, V. Imbrenda, R. Coluzzi, L. Pace, T. Simoniello, M. Lanfredi, Multi-decadal assessment of soil loss in a Mediterranean region characterized by contrasting local climates, Land 11 (7) (2022) 1010, https://doi.org/10.3390/land11071010.
[53] M. Lanfredi, R. Coppola, M. D'Emilio, V. Imbrenda, M. Macchiato, T. Simoniello, A geostatistics-assisted approach to the deterministic approximation of climate data, Environ. Model. Software 66 (2015) 69–77, https://doi.org/10.1016/j.envsoft.2014.12.009.
[54] M. Lanfredi, R. Coluzzi, V. Imbrenda, M. Macchiato, T. Simoniello, Analyzing space–time coherence in precipitation seasonality across different European climates, Remote Sens. 12 (1) (2020) 1–15, https://doi.org/10.3390/rs12010171, 171.
[55] M. Piccarreta, A. Pasini, D. Capolongo, M. Lazzari, Changes in daily precipitation extremes in the Mediterranean from 1951 to 2010: the Basilicata region, southern Italy, Int. J. Climatol. 33 (2013) 3229–3248, https://doi.org/10.1002/joc.3670.
[56] C. Blasi, G. Capotorti, R. Copiz, D. Guida, B. Mollo, D. Smiraglia, L. Zavattero, Classification and mapping of the ecoregions of Italy, Plant Biosyst. 148 (6) (2014) 1255–1345, https://doi.org/10.1080/11263504.2014.985756.
[57] J. MacQueen, Some methods for classification and analysis of multivariate observations, in: Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability, vol. 5, University of California press, 1967, January, pp. 281–298, 1: Statistics.
[58] D.J. Ketchen, C.L. Shook, The application of cluster analysis in strategic management research: an analysis and critique, Strateg. Manag. J. 17 (6) (1996) 441–458.
[59] Istat & Ministero della Salute, Primi risultati dell'indagine di sieroprevalenza sul SARS-CoV-2, Istituto Nazionale di Statistica, 2020. https://www.istat.it/it/files/2020/08/ReportPrimiRisultatiIndagineSiero.pdf.
[60] Istituto per gli Studi di Politica Internazionale (ISPI), Coronavirus: la letalità in Italia tra apparenza e realtà. ISPI. https://www.ispionline.it/it/pubblicazione/coronavirus-la-letalita-italia-tra-apparenza-e-realta-25563, 2020.
[61] UN, Department of economic and social affairs, population division. World Population Prospects 2019: Highlights (ST/ESA/SER.A/423), 2019.
[62] A. De Montis, B. Martín, E. Ortega, A. Ledda, V. Serra, Landscape fragmentation in Mediterranean Europe: a comparative approach, Land Use Policy 64 (2017) 83–94.
[63] D. Smiraglia, I. Tombolini, L. Canfora, S. Bajocco, L. Perini, L. Salvati, The latent relationship between soil vulnerability to degradation and land fragmentation: a statistical analysis of landscape metrics in Italy, 1960–2010, Environ. Manag. 64 (2019) 154–165.
[64] J.A. Jaeger, Landscape division, splitting index, and effective mesh size: new measures of landscape fragmentation, Landsc. Ecol. 15 (2000) 115–130.
[65] A. Strollo, D. Smiraglia, R. Bruno, F. Assennato, L. Congedo, P. De Fioravante, C. Giuliani, I. Marinosci, N. Riitano, M. Munafò, Land consumption in Italy, J. Maps 16 (1) (2020) 113–123.
[66] S.M. Ross, Introduction to Probability Models, Academic Press, Cambridge, MA, USA, 2014.
[67] V. Cattivelli, Delimiting rural areas: evidence from the application of different methods elaborated by Italian scholars, Land 11 (10) (2022) 1–21, https://doi.org/10.3390/land11101674.
[68] D. Russo Krauss, N. Matarazzo, Migrazioni e nuove geografie del popolamento nelle aree interne del Mezzogiorno d'Italia: il caso della Campania, Geotemas 61 (4) (2019) 82–89.
[69] P. Bevilacqua, L'Italia dell'«osso». Uno sguardo di lungo periodo, in: A. De Rossi (Ed.), *Le aree interne tra abbandoni e riconquiste*. Verona: Donzelli, 2018, pp. 111–122.
[70] M. Lozzi, et al., L'economia Della Basilicata. Economie Regionali, vol. 17, Banca d'Italia, Roma, 2020.
[71] A. Riggio, Basilicata, in: M.G. Grillotti Di Giacomo (Ed.), The Italian Rural Systems Atlas, Brigati, Genova, 2005, pp. 227–231.
[72] S. Margiotta, C. Manera, C. Sivolella, D. Fabrizio, Evolution of the Metaponto district, Southern Italy: from land reform to new sustainable scenarios, Landsc. Res. 40 (2015) 174–191, https://doi.org/10.1080/01426397.2013.787405.
[73] SMAIL, Dossier imprese e occupazione in Basilicata. Potenza: Regione Basilicata e Unioncamere Basilicata, 2012 available at: https://www.regione.basilicata.it/giunta/files/docs/DOCUMENT_FILE_596429.pdf.
[74] ISTAT, Censimento industria e servizi 2011, ISTAT, Roma, 2011 available at: http://dati-censimentoindustriaeservizi.istat.it/Index.aspx.
[75] L. Stanzione (Ed.), *Le vie interne allo sviluppo del Mezzogiorno*. Napoli, IUO, 2001.
[76] V. Mapelli, Il Sistema Sanitario Italiano, il Mulino, Bologna, 2012.
[77] C. Alato, L'offerta socio-sanitaria del SSR della Basilicata: rete strutturale e dotazioni organiche, in: A. D'Adamo, B. Polistena (Eds.), Il Sistema Sanitario Della Basilicata Nel 2010-2011. Ammalarsi Meno, Curarsi Meglio, McGraw-Hill, Milano, 2012, pp. 41–59.
[78] A. Riggio, L'emigrazione sanitaria in Basilicata, in: C. Palagiano, M.C. Cardillo (Eds.), Geografia medica. Quinto seminario internazionale "Le strutture sanitarie tra pubblico e privato, 1995, pp. 555–567. Perugia: Rux.
[79] Regione Basilicata, Rapporto regionale sulla mobilità attiva e passiva 2013-2017, Dipartimento delle Politiche della Persona, Potenza, 2019.
[80] P. Sciattella, L'assistenza ospedaliera nella Regione Basilicata: spesa e performance, in: A. D'Adamo, B. Polistena (Eds.), Il Sistema Sanitario Della Basilicata Nel 2010-2011, McGraw-Hill, Milano, 2012, pp. 61–112.
[81] C. Terranova, O. Terranova, COVID-19 and the death of older people in Italy's rest homes. Is a judicial turmoil the answer? Lancet Psychiatry 7 (7) (2020) E46, https://doi.org/10.1016/S2215-0366(20)30227-3.
[82] ISTAT, Nota sui decessi per il complesso delle cause. Periodo Gennaio-Agosto 2020, ISTAT, Roma, 2020 available at: https://www.istat.it/it/files/2020/03/nota-decessi-22-ottobre2020.pdf.
[83] F. Contò, P. La Sala, P. Papapietro, The metapontum agro-food district of quality: an innovative model of governance for local development through informatics, in: Agricultural and Environmental Informatics, Governance and Management: Emerging Research Applications, IGI Global, 2011, pp. 122–151.
[84] C. Delio, P. Angela, The impact of European capital of culture on tourism and local involvement: Matera 2019 case study, in: Cultural and Tourism Innovation in the Digital Era: Sixth International IACuDiT Conference, Athens 2019, Springer International Publishing, 2020, pp. 79–88.
[85] V. d'Andrea, F. Trentini, V. Marziano, A. Zardini, M. Manica, G. Guzzetta, S. Merler, Spatial spread of COVID-19 during the early pandemic phase in Italy, BMC Infect. Dis. 24 (1) (2024) 450.

[86] A. Ascani, A. Faggian, S. Montresor, The geography of COVID-19 and the structure of local economies: the case of Italy, J. Reg. Sci. 61 (2) (2021) 407–441.
[87] A. Cepparulo, L. Giuriato, The residential healthcare for the elderly in Italy: some considerations for post-COVID-19 policies, Eur. J. Health Econ. 23 (4) (2022) 671–685.
[88] M. Torres, Nuovi Modelli di Città. Agglomerazioni, infrastrutture, luoghi centrali e pianificazione urbanistica, Franco Angeli, Milano, 2008.