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Fragility and its dimensions: an analysis methodology in support of local development policies

Le dimensioni della fragilità: una metodologia di analisi a servizio delle politiche di sviluppo territoriale

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ABSTRACT AND KEYWORDS

Fragility and its dimensions
The research explores different aspects of spatial fragility. It develops a GIS-based methodology that aims to synthesize fragility indicators implemented in order to build analytical validation and support tools for planning at different administrative levels. Three main themes concerning environmental, socioeconomic and relational issues are considered in order to integrate fragility assessment into planning practices. Thus, an alternative to approaches often based on one-dimensional criteria is proposed. By relating different datasets, the study constructs composite indicators through a non-compensatory synthetic index, enabling a multidimensional understanding of spatial dynamics. The research does not focus on classifying areas, but rather on understanding the nuances of fragility and how it manifests itself at the spatial scale. The attempt is thus to theorize an analytical tool useful in identifying spatial homogeneities and differences, enhancing the understanding of fragility by promoting integrated planning strategies.

Keywords: fragility, analysis, indicators, evaluation, knowledge

Le dimensioni della fragilità
La ricerca esplora diversi aspetti della fragilità territoriale. Sviluppa una metodologia basata su sistemi GIS che ha l'obiettivo di sintetizzare indicatori di fragilità implementati al fine di costruire strumenti analitici di validazione e di supporto per la pianificazione a diversi livelli amministrativi. Si considerano tre tematiche principali riguandanti temi ambientali, socioeconomici e relazionali al fine di integrare la valutazione delle fragilità nelle prassi pianificatorie. Si propone quindi un'alternativa ad approcci spesso basati su criteri monodimensionali. Mettendo in relazione diversi set di dati, lo studio costruisce indicatori compositi attraverso un indice sintetico non compensativo, consentendo una comprensione multidimensionale delle dinamiche territoriali. La ricerca non si concentra sulla classificazione delle aree, ma piuttosto sulla comprensione delle sfumature della fragilità e di come questa si manifesta a scala territoriale. Il tentativo è quindi quello di teorizzare uno strumento analitico utile a identificare le omogeneità e le differenze territoriali, migliorando la comprensione della fragilità promuovendo strategie di pianificazione integrate.

Parole chiave: fragilità, analisi, indicatori, valutazione, conoscenza

1. Introduction

The research presented in this article aims to investigate the concept of fragility and its declinations in contemporary times, in territories that change as fast as the societies that inhabit them. There are multiple studies on the topic in many fields of reference from the academic to the programmatic at different scales. This research is part of the theoretical-applicative context concerning new forms and tools of urban and territorial planning, which aspire to relate concretely with the phenomenologies taking place in the contemporary world. It tries to relate with the needs of the society that inhabits them and establish a possible role that knowledge can have in practices related to the study and definition of development strategies. In this sense, the theme of fragility is approached by trying to grasp its nuances by interpreting its connotations through the information available in the territories where it manifests itself. Therefore, it seems useful, in the first instance, to ask a question: does the concept of fragile area or territory coincide with the physical dimension of peripherality? There is a precise reason in the formulation of this question. In the cultural and scientific landscape, there is a large body of literature from which it appears that this link is strongly established. “Inland areas” are spoken of as the ‘bone territories’ as opposed to the ‘pulp territories’ (De Rossi, 2020), thus defining the fragility of mountain territories about their geographical position thus emphasizing a contrast with service centres. Strongly explored are the concepts of “margin” (Rimondi, 2022; Tarpino, 2016) and “fragility” (Butelli, 2019; Galderisi, 2020, Lai, 2015). This is true especially in a strand of research, in the disciplinary fields of sociology and urban geography, related to one of the most well-known and discussed development-oriented programming experiences of the last decade: the National Strategy for Inner Areas, SNAI (Opencoesione, 2022; Lucatelli, 2018). Now in its second cycle of national planning, which began in one for 2014-2020 and has been renewed for 2021-2027, SNAI provides for the definition at the territorial scale of clusters of municipalities that share a distance from essential services, especially concerning health. Although the criteria have recently been updated (Presidency of the Council of Ministers, 2022), the evaluation parameter that is considered for this classification to which municipalities have been subjected is the alert-target time for ambulances (Carrosio, 2019). This means that the longer the time to reach the municipality, the more peripheral the area will be. Reference is also made to one of the measures of the much more recently conceived National Recovery and Resilience Plan (MC13 - investment 2.1) (Italia Domani, 2023). Here, to fund actions related to improving the attractiveness of villages (Ministry of Culture, 2022), an open selection of municipalities with fewer than 5,000 residents is called for. In both programming experiences, which are above all economically a benchmark to be considered since about 2 billion were allocated for the former and 800 million euros for the latter, the logic of selection refers to only one indicator (physical distance in the former and demographics in the latter). All this, however, fits into a national context in which the demographic decline for areas considered precisely inland, and therefore the subject of funding, in 10 years was 12.5 percent, compared to 5.6 percent for the national average (ISTAT, 2024). This phenomenon is exacerbated in the centre, south and islands where the figure rises to 15 percent. A critical issue that seems to emerge thus concerns the selection criteria for this substantial distribution of wealth on a pseudo-local scale. These programmes should help put in place forward-looking and wide-ranging actions capable of fostering collective dynamics related to environmental issues (Sargolini, 2023) and reverse the current demographic trend (MIUR, 2013). Similar reasoning can be traced in studies designed to rethink the classification of inland and peripheral areas by proposing

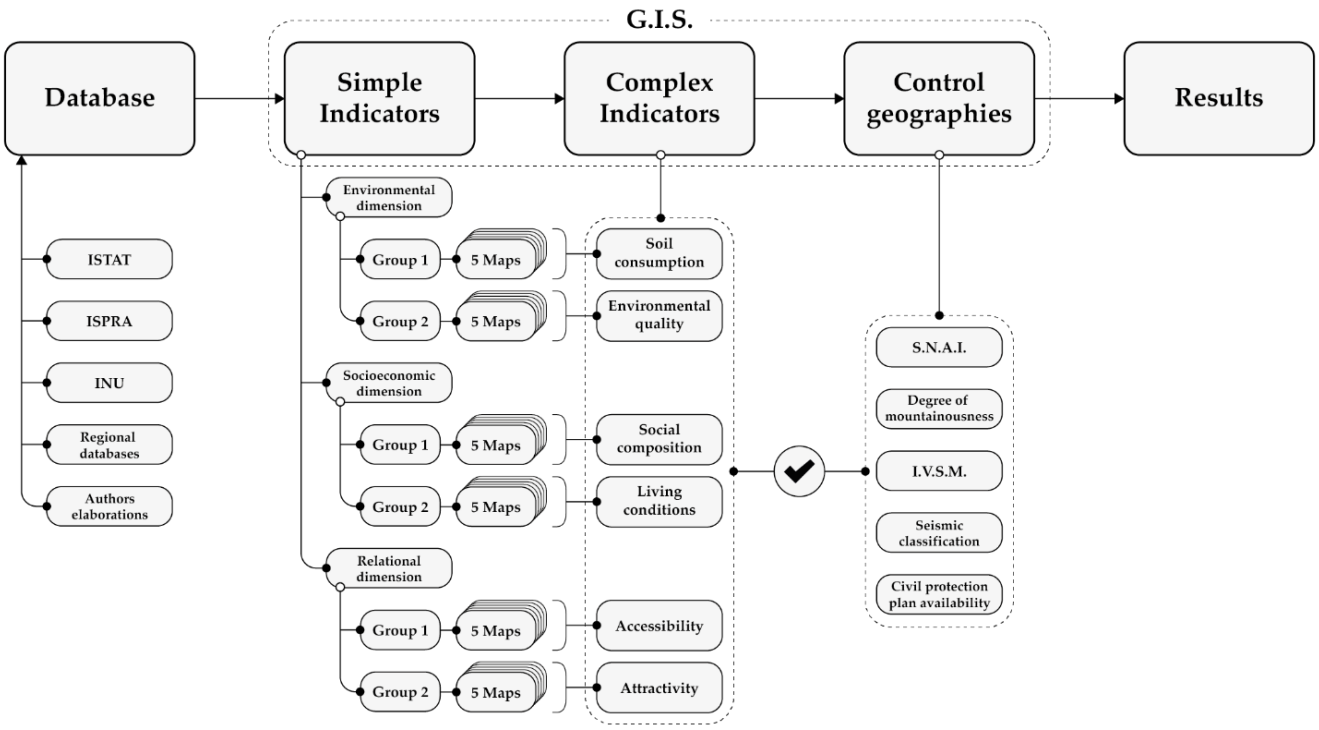
baskets of indicators on the themes of transportation, economy, tourism, culture, environment, and human and social capital (Scrofani, Accordino, 2023) as levers of analysis and thus of development paths. Experiences that associate such proposals with indicator-based cartographic representations concern new paradigms for the construction of geographies of marginal areas (Vendemmia et al., 2022; Kerçuku et al., 2024; Dezio, 2024; Chioni, 2024; Pucci et al., 2021) based on cross-cutting and multidisciplinary analyses suitable for the construction of shared policies for inland areas (Colavitti, 2024). Evolving logics in project area selection practices are associated with practices for evaluating and monitoring them, especially the macroregional strategies recommended by the European Union (European Commission, 2017). In this regard, it is considered useful to mention the study experiences related to integrated strategic planning (Stanganelli, 2020) and performance-based monitoring of territories (Caselli et al., 2020; Marucci et al., 2020; Adobati, 2023). These experiences stress the role of indicators and quantitative analysis is in the foreground precisely as a tool to support policy, validating its practices and forecasting and application choices. Knowledge, built with information that is verified and updated according to its availability, thus constitutes an axis that holds the task of guiding and inspiring choices capable of affecting the development of territories. Reasoning of this kind has theoretical and methodological roots that date back to the late 1900s, especially in the vast panorama of multi-criteria analyses at the service of sustainable development planning (Nijkamp, Van Delft, 1977; Nijkamp, Voogd, 1983; Nijkamp, Ouwersloot, 1997). They have subsequently inspired programs such as ESPON that aims to create relationships between researchers and entities to inspire policy-making through spatial evidence (ESPON, 2024). It is precisely the latter, on the topics that are the subject of this article, that has produced several studies over the years (ESPON, 2014, 2017) in which it becomes clear, among other things, how the scale of analysis plays a key role for the mentioned objectives. Indeed, from the latter, the LAU 2 (Local Administrative Units) level, is the one through which it is best possible to understand the dynamics at work in the territories without incurring coarse approximations due to lower granularity. Recently, the Italian National Institute of Statistics (ISTAT) has published two studies that take up these challenges in which the process of indicator selection was guided by two needs: i) identify measures capable of describing the most relevant components of the significance of the phenomenon and ii) ensure the accuracy, consistency and comparability of the data available at the municipal level (ISTAT, 2020, 2024). Reference is made to the Index of Social and Material Vulnerability (IVSM) and the Index of Fragility of Municipalities (IFC). In both cases, indicators have been synthesized based on a vast cognitive apparatus capable of interpreting different themes and making innovative geographies. Factors about physic (areas exposed to various types of environmental risk, ecosystem services), social (employment rate, level of education, population dependency index) and economic (density of local industrial and service units, percentage incidence of employees in local units with low nominal labour productivity for industry and services) aspects were considered in these studies. While this level of deepening and articulation of studies on the topic can build a vast theoretical-scientific apparatus of reference, there seems to be a lack of a common umbrella under which a multidisciplinary debate can be built. This could be based on common factors and methodologies capable of making the results and variables involved comparable, accommodating different instances and interpretations in such a way that they can dialogue with each other with a common language. Hence the research question is the following: is it sufficient to reason about this issue discussing on a single

variable, or do phenomena such as this, which have been discussed for decades, need a broader and more careful look capable of analyzing and understanding the pulviscular and stratified nature of contemporaneity? The second line of inquiry, closely related to the first, concerns its quantitative representation of the dimensions of fragility and how they manifest and emerge in territories. If the topic is often associated with the word "geography," the role of cartographic representation is relegated to mere infographics without considering its dialogic and informational potential in which communication is part of the process of sharing towards society information about the state of places and the processes manifested there. Given these boundary conditions, the article goes on to explain the constructed methodological proposal by detailing its phases, cognitive, operational and monitoring apparatus. In the last instance, the application of two case studies on the territory of the Lazio Region and the results of this first experimentation are presented. In conclusion, finally, the possible evolutionary potential of the research is reasoned, also about other academic experiences in which the working group is involved. The methodology proposed in the following section aims to investigate the concept of fragility and understand in what forms, and in what territorial dimensions, it manifests itself.

2. Methodology

Given this theoretical and cultural approach, fragility is understood as a multidimensional and complex phenomenon. It relates to aspects that are not limited to issues linked to geographical location and, more specifically, to the physical distance of inland territories from service centres. The methodology is organized according to the scheme in Figure 1.

Figure 1. Methodology diagram



Source: Authors' elaboration

With these premises, it is therefore based on a large, purpose-built database containing 393 simple indicators of a spatial type at the LAU-2 (Local Administrative Units, municipal scale) level. Those were identified by ESPON[1] as the most appropriate at which to make local-scale assessments, faithfully descriptive of the multidimensional phenomenology at work. The sources drawn on are all verified as coming from the main institutes that carry out statistical analysis on the Italian territory (ISTAT, ISPRA), cultural institutions such as the National Institute of Urban Planning (INU) and regional databases. There are also original elaborations by the authors that are, however, based on verified institutional sources, as set forth extensively below. To explore the multiple dimensions of fragility, and thus make an attempt at a disconnect from the single-issue spatial analyses in the bibliography cited in the previous section, three phenomenological dimensions are defined: i) environmental, ii) socioeconomic, iii) relational. The first was used to investigate issues closely related to the environment, anthropized and non-anthropized, concerning land consumption, hazards, atmospheric emissions, and landscape. The second, the socioeconomic one, focused on human resources in their different declinations, between residents and employees who reside, work, and use the territories. Thus, issues related to income, depopulation, residents' exposure to natural hazards, employment and housing porosity are explored. Finally, the relational dimension is expressed through two groups of different but closely related declinations. One to be understood as more related to the infrastructure of the area and the presence of services, the other of a more social nature, focused on the themes of tourism, associationism and knowledge. Each of these dimensions was divided into two groups for which five simple indicators were selected from the database that could describe the theme. These, subsequently, were combined through statistical procedures discussed extensively below in order to construct six compound indicators capable of expressing numerically the themes belonging to each dimension and aspire to describe the main dimensions of the phenomenon under analysis. At the methodological level, it is also considered useful to compare the results of the analysis of the indicators at the municipal scale with the elaborations belonging to other programmatic experiences taking place in Italy. To this end, five control geographies are defined. Further investigation is carried out because it is considered useful to extend, on the one hand, the cognitive apparatus concerning the analyzed territories at the different scales. Secondly, to carry out a further horizontal check among the results proposed in the study, exploring experiences based on which planning and programmatic considerations are already being made at the national level. The 36 indicators (30 simple and 6 composite) and 6 control geographies thus allow quantifying and measuring phenomena of a multidimensional nature in a comparative form by considering individually or combining data on potential environmental, demographic, social and economic fragilities. As mentioned earlier, the indicators, constructed to provide a measure of the level of potentiality and fragility of a municipal reality, are synthesized to express with a single value the different facets of phenomena taking place in the contemporary period at the local and territorial level. Thus, the values obtained provide useful elements for identifying potential areas of criticality. These data were not only analyzed numerically. Indeed, an important part of the work, especially to what is described in the previous section, is the representation, both cartographically and infographically. The methodology is to be considered open, updatable and scalable in that those analyzed are only some of the possible dimensions of fragility. Its open nature is made manifest both from the point of view of data sources (all public and institutional) and from the procedural one, taking inspiration on the technical side of

processing from well-known experiences in the national and international scene. On the other hand, it is scalable since, although as will be seen below in this case 2 municipalities are considered as study areas, a maximum of LAUs that can be compared at the same time is not considered. The dimensions analyzed are described in detail below. Finally, a table encapsulating each indicator considered and the structure of the sheets made to represent the phenomena are given.

2.1 Environmental dimension

The first cluster of environmental indicators focuses on the issue of land consumption, a phenomenon related to settlement and infrastructural dynamics, mainly due to the construction of new buildings, buildings and settlement complexes, expansion of cities, densification or conversion of soils within an urban area, and in general the infrastructure and "mineralisation" of land (ISPRA, 2022). In this sense, the environmental dimension is explored with a first cluster of indicators that investigate the issue of land consumption, and its effects related to seismic and hydro-geological hazards. The prevailing reference is the indicators attached to the ISPRA report on land consumption (2022). The second investigates some of the characteristics that contribute directly and indirectly to residents' living standards. The data used come from different sources. The first two (the ratio of areas of high to low urbanization density and the percentage of soil consumed within areas under landscape protection) were extracted from the ISPRA Land Consumption Report (2022). The annual averages of PM10 and NO2 are extracted from regional databases while the data regarding separate waste collection come from ISPRA's Special Waste Report 2023. This difference in the provenance of information may trigger some attention on the issue by the relevant bodies, especially regional ones. From an analysis of regional open-source information systems in Italy, it is possible to verify that the availability of data at the municipal level related to environmental issues (especially regarding air quality) is very poor except for regional capitals (however, processed at the national level by ISTAT).

2.2 Socioeconomic dimension

The first cluster of indicators concerning socioeconomic reality focuses on the social composition of the resident population. The selected indicators describe the different population groups in the area in such a way as to establish relationships between groups, trying to investigate commonalities and diversities. They investigate, in fact, such issues as the percentage of foreign population in total residents, taxable income, the rate of employed people in the total labour force, the population with secondary or higher education in total residents, and the old-age index. The second group deals with issues related to housing conditions in the territories. On the one hand, an attempt is made to explore the "physical" components of the socioeconomic dimension by analyzing data regarding the percentage of unoccupied housing and the at-risk population residing in areas of high (and very high, in the specific case of landslide hazard) hazard. On the other hand, components related to places are investigated, understood as realities of which the signifier is not only substantiated in punctual outcomes but also as the result of long-term processes triggered, as in the case of depopulation, several decades ago. Along these lines, the trend of municipal planning is also considered, the updating of which is regarded as an index of social and programmatic dynamism with a view to the development of territories.

2.3 Relational dimension

The indicators of the first cluster focus on the topic of accessibility. The latter is investigated under various aspects, thus trying to emphasise the multidimensional nature of the phenomenon. The containment of systematic travel for study and work purposes in each municipality is analysed (indicating a greater or lesser need to travel to neighbouring municipalities). Further data concern the accessibility of service centres offering intermodal transport and the main regional commercial poles. The density of provincial and state roads on the regional surface was then measured (taking a cue from the work carried out to create the web atlas of post-metropolitan territories, https://www.postmetropoli.it/atlante/). Finally, the accessibility to the national health system was assessed, thanks to some elaborations carried out using the national list of health facilities of the Ministry of Health concerning the Lazio Region. The second group focuses on the attractiveness of the municipal poles with indicators mainly related to tourism. Theu were analysed thanks to the databases made available by ISTAT in 2022 in which it is described according to the intensity and characteristics of tourism supply and demand and the economic activities connected to it. Finally, thanks to a further survey carried out by interrogating regional databases, the number of schools of all levels present in the municipal territory was calculated (also to establish a relationship with the number of journeys for study and work purposes, already investigated in the first group of indicators of the same dimension). The same procedure had been adopted for the number of associations present in the municipal territory. Concerning the latter, no distinction is made based on the type of associations (cultural, social promotion, voluntary, etc.) present in the area, but all of them are considered.

2.4 Fragility indicators

After a detailed analysis of each dimension and group of indicators, these are listed in the Table 1, indicating for each the reference year and source.

Table 1. Fragility indicators list

Dimension	Complex indicator	Simple indicator	Year	Source
Environmental	Soil consumption	1. Increase in soil consumption (Increase in land consumed compared to 2021 [ha])	2022	ISPRA
		2. Municipal consumed soil (Percentage of land consumed over administrative area [%])	2022	ISPRA
		3. Soil consumption in seismic risk areas (Percentage of land consumed in areas of high and very high seismic hazard [%])	2022	ISPRA
		4. Soil consumption in flood risk areas (Percentage of land consumed in areas of high hydraulic hazard [%])	2022	ISPRA
		5. Soil consumption in landslide risk areas (Percentage of land consumed in high and very high landslide hazard areas [%])	2022	ISPRA

	Environ-mental quality	1. Dispersion index (Ratio of high-density urbanization areas to high-density and low-density areas [%])	2022	ISPRA
		2. Soil consumption in protected areas (Soil consumed within areas subject to paessaggistic protection under Legislative Decree 42/2004 (art. 136, art. 142 c.1 a, b, c, d, l))	2022	ISPRA
		3. PM10 annual mean (PM10 annual average (µg/m3) MAX)	2021	Reg. database
		4. NO2 annual mean (NO2 annual average (µg/m3) MAX)	2021	Reg. database
		5. Recycling (% of waste sorted from total waste collected)	2021	ISPRA
Socioeconomic	Social composi-tion	1. Income of natural people (IRPEF income)	2020	ISTAT
		2. Professional condition (Percentage of employed people out of total in labor force)	2021	ISTAT
		3. Old-age index (Old age (index of): ratio of population aged 65 years and older to population aged 0-14 years, multiplied by 100)	2022	ISTAT
		4. Presence of foreigners (Percentage of foreign population to total residents)	2022	ISTAT
		5. Instruction degree (Percentage of population with secondary or higher education certificates out of the total)	2021	ISTAT
	Living conditions	1. Residents in landslide risk areas (Resident population at risk in very high and high PAI landslide hazard areas - P4+P3)	2020	ISTAT
		2. Residents in flood risk areas (Resident population at risk in areas of High Hydraulic Hazard - P3)	2020	ISTAT
		3. Unoccupied dwellings (% Unoccupied dwellings out of total dwellings)	2021	ISTAT
		4. Municipal urban planning update (Status of municipal planning update (no plan, pre 1995, 1995-2010, 2011-2018, post 2018))	2022	INU
		5. Variation of population (% change in resident population in the decade 2011-2021)	2021	ISTAT

	Relational	Accessibi-lity	1. Everyday commuting for work and study (Moving for work and study outside the municipality of residence)	2019	ISTAT
			2. Accessibility index to commercial centers (The index is calculated using a sampling function of the isochrones in which the centroid of the municipality falls. From all isochrones, the one corresponding to the shortest travel time is selected: 0 = average travel time greater than 60 minutes 1 = average travel time between 45 and 60 minutes 2 = average travel time between 30 and 45 minutes 3 = average travel time between 15 and 30 minutes 4 = average travel time less than 15 minutes)	2013	ISTAT
			3. Density of regional and provincial road network (Calculated as the ratio, expressed in km/square kilometers, of the total length of provincial and state roads that pass through the municipality (km) to the total municipal area (sq. km). Indicates the degree of supra-municipal road endowment with the exclusion of highway sections passing through the municipality)	Author's processing	
			4. Accessibility index to railway stations (The index is calculated using a sampling function of the isochrones in which the centroid of the municipality falls. From all isochrones, the one corresponding to the shortest travel time is selected: 0 = average travel time greater than 60 minutes 1 = average travel time between 45 and 60 minutes 2 = average travel time between 30 and 45 minutes 3 = average travel time between 15 and 30 minutes 4 = average travel time less than 15 minutes)	2013	ISTAT
			5. Accessibility index to national sanitary service (The index is calculated similarly to the previous one but using the timelines developed by the LEAs by the Ministry of Health)	Author's processing	

		1. Number of 1st and 2nd degree schools (number of educational institutions by municipality)	2020/ 21	Reg. database
	Attracti-vity	2. Synthetic index of intensity and characteristics of the tourism offer (D1=Very low (1st quintile), D2=Low (2nd quintile), D3=Medium (3rd quintile), D4=High (4th quintile), D5=Very high (5th quintile))	2021	ISTAT
		3. Synthetic index of tourist demand intensity and characteristics (P1=Very low (1st quintile), P2=Low (2nd quintile), P3=Medium (3rd quintile), P4=High (4th quintile), P5=Very high (5th quintile))	2021	ISTAT
		4. Summary index of tourism-related economic activities (T1=Very low (1st quintile), T2=Low (2nd quintile), T3=Medium (3rd quintile), T4=High (4th quintile), T5=Very high (5th quintile))	2021	ISTAT
		5. Associations in the municipality territory (Number of associations on the regional register)	2023	Reg. database

Source: Authors' elaboration

2.5 Statistical processing

Each of these dimensions, and their groups, quantitatively explores one aspect of territorial fragility. Thus, from a statistical point of view, ten elementary indicators (five for each group) are selected for each dimension. The methodology is based on the hypothesis of non 'substitutability' of the different components. This makes it possible to produce a non-compensatory synthetic index that is comparable over time in 'absolute' terms (Adjusted Mazziotta - Pareto Index - AMPI+/-). The same methodology was used by ISTAT to synthesise the Social and Material Vulnerability Index (ISTAT, 2020) and the Fragility Index of Municipalities (ISTAT, 2024), already mentioned in the previous paragraph. The elementary indicators were thus freed from their unit of measurement and stripped of their variability. This last aspect is particularly important because it makes it possible to avoid the elementary indicators with a higher variability weighing more heavily on the construction of the index, thus influencing the outcomes more. The results obtained in this way make it possible to assign a comparable index value to each municipality. The municipal distribution of the index, ordered in descending order, is divided into five classes. Municipalities falling in the critical area identified by the first or fifth quintile, and coinciding with the high, or low, part of the ranking (high index values and low rank values, and vice versa) were classified as 'in potentially severe fragility'. For the complete penalty method by coefficient of variation, with formulas and statistical procedures (also relating to compensation methods) reference is made to the work of Mazziotta and Pareto (2020).

2.6 Control geographies

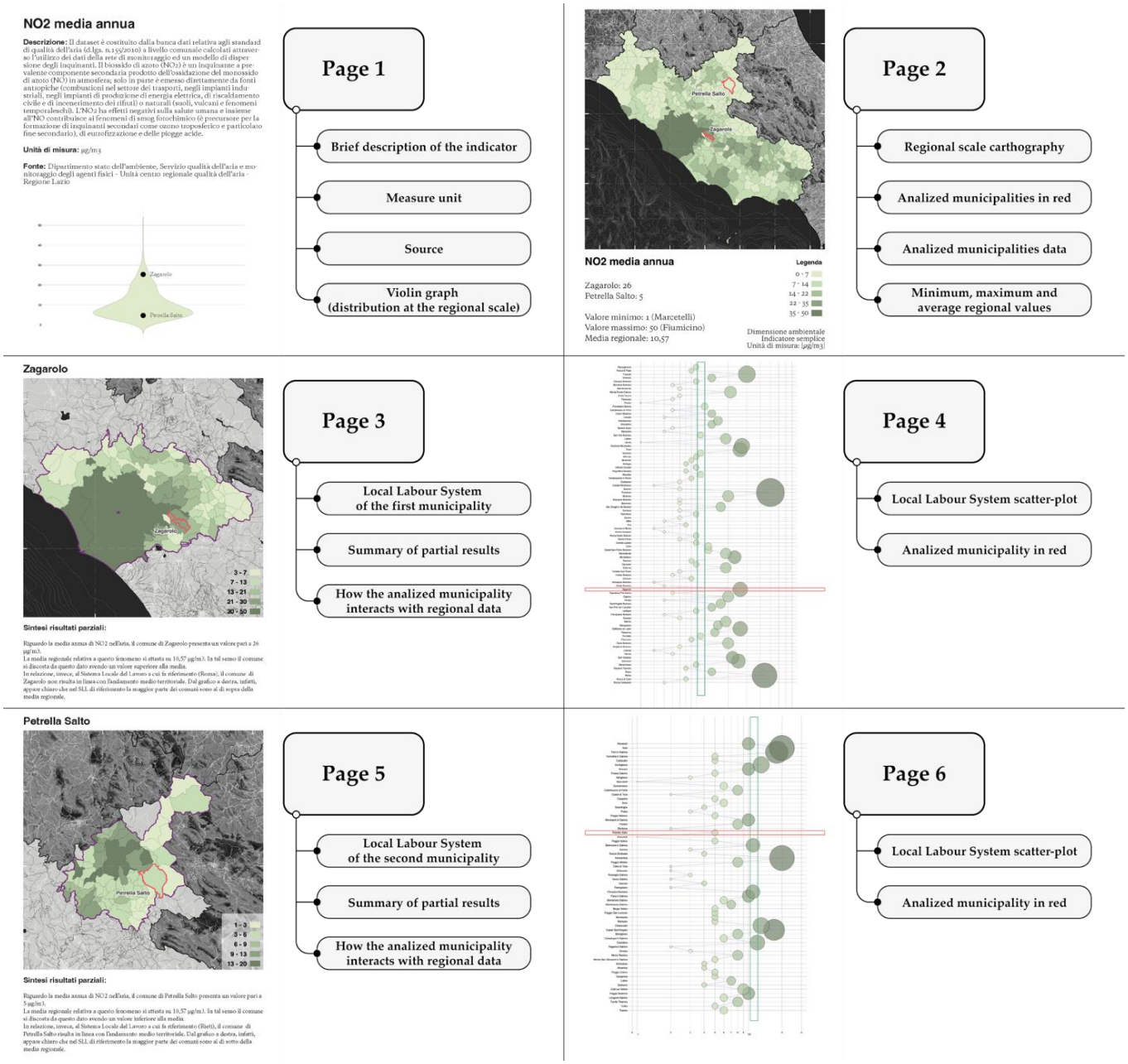
Once the diagnostics had been carried out at a regional level thanks to the zooms on the Local Employment Systems to which the municipalities under study refer, a further analytical step was carried out. This has been done going on to investigate classifications and assessments already carried out by the relevant bodies and by ISTAT (already discussed at length in the second paragraph) concerning the same territorial dimensions used so far. To this end, the following classification and research strategies were used: i) S.N.A.I. (National Strategy of Inner Areas) classification, ii) degree of mountainousness, iii) Index of Social and Material Vulnerability (I.V.S.M.), iv) Seismic classification of the municipality, v) Availability of the Civil Protection Plan.

2.7 Thematic boards

Different data representation techniques are used for each of the 36 indicators (as for the 5 control geographies). Violin and scatter plots and thematic cartographies are used, which represent, at the municipal level, a snapshot of the state of the administrative unit, relative to the theme being analysed from time to time. Since the research tends to investigate the multidimensional nature of the 'fragility' phenomenon at a territorial scale, it is considered useful to specify that the three themes, declined according to the 30 simple and compound indicators, are not described only with the municipalities under study. As functional areas of comparison, the ISTAT Local Labour Systems (SLL) are considered. They represent a territorial grid whose boundaries, regardless of the administrative articulation of the territory, are defined using the flows of systematic daily home/work movements (commuting) recorded during the general Population and Housing Censuses. Each local system is both the place where the population resides and works and the context in which social and economic relations evolve and thus home/work travel is used as a proxy for existing relations in the area (ISTAT, 2011). The structure of the sheets, each consisting of 6 pages, is shown in Figure 2. The topic described by the indicator is introduced with a brief description in which the reference context is set, the sources are cited, and the unit of measurement is specified. Subsequently, a violin graph is used to represent the development of the theme's values on a regional scale. Where the graph shows a bulge, the density of values is higher. The second sheet presents a further cartographic framing of the theme at the regional level. It also shows the values for the selected indicator for the municipalities under study, followed by the minimum, maximum and average values on a regional scale.

The next two sheets represent a fixed scheme that can therefore be repeated according to the number of analyzed municipalities for which the comparison is to be made. The first contains a further cartographic representation of the subject matter by framing the analyzed municipality in its local labour system. A summary of the partial results follows. The opposite tab contains the representation of a scatter graph, relative to the SLL, in which the analysed municipality is highlighted in red and the regional average in green.

Figure 2. Thematic boards organization

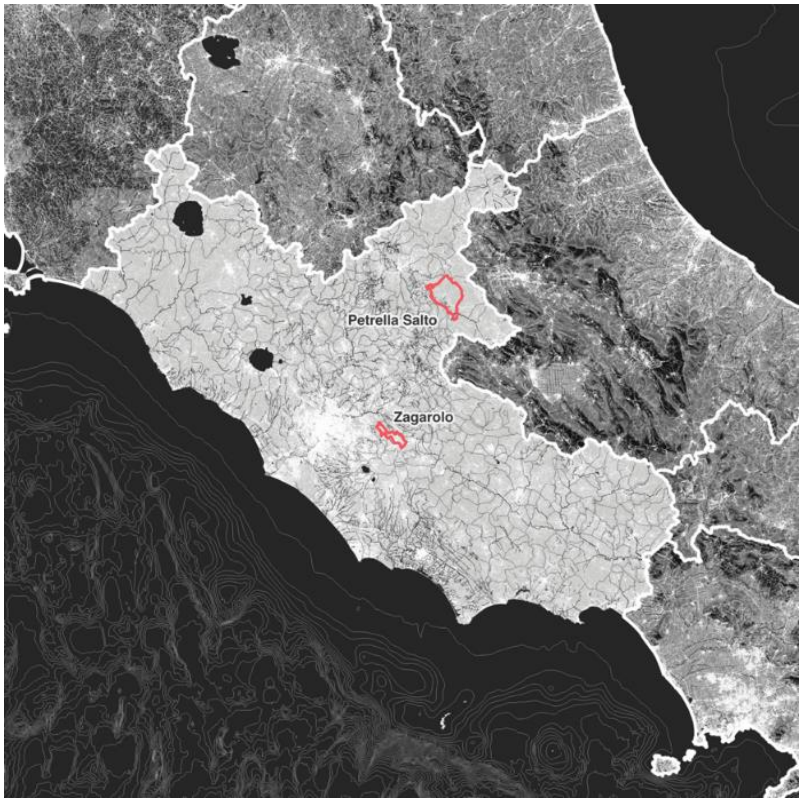


Source: Authors' elaboration

3. Case-study and results

The proposed methodology was tested as part of a larger research project called 'VaGARe', which won the '2020 Research Group Projects' call for proposals with POR FESR Lazio 2014-2020 funds. The project is promoted by the interdepartmental research centre Fo.Cu.S., Formazione Cultura Storia of 'Sapienza' University of Rome (https://www.progettovagare.it/). In this context, as external collaborators, the authors investigated the concept of fragility in the municipalities of the Lazio region, including Petrella Salto (RI) and Zagarolo (RM) with the aim of understanding under what forms, and in what territorial dimensions, already chosen by the project committee, it manifests itself. Figure 3 shows a territorial framework on a regional scale of the two municipalities.

Figure 3. Municipalities at the regional scale



Source: Authors' elaboration

The two areas differ in terms of environmental, social and economic conditions found throughout the regional territory and can be traced to the two macro-categories:

- areas subject to high anthropic pressure as they are close to metropolitan areas (Zagarolo)
- areas with low density and high settlement dispersion (Petrella Salto).

Zagarolo lies in the Roman countryside, on the extreme southern slopes of the Tiburtini mountains, north-east of the Alban Hills, about 36 km from Rome. The municipality has a surface area of 28.03 km2, 18,483 residents (ISTAT data updated on 01/01/2023), and a population density of 659.40 inhabitants/km2. The municipality belongs to the Local Employment System of Rome.

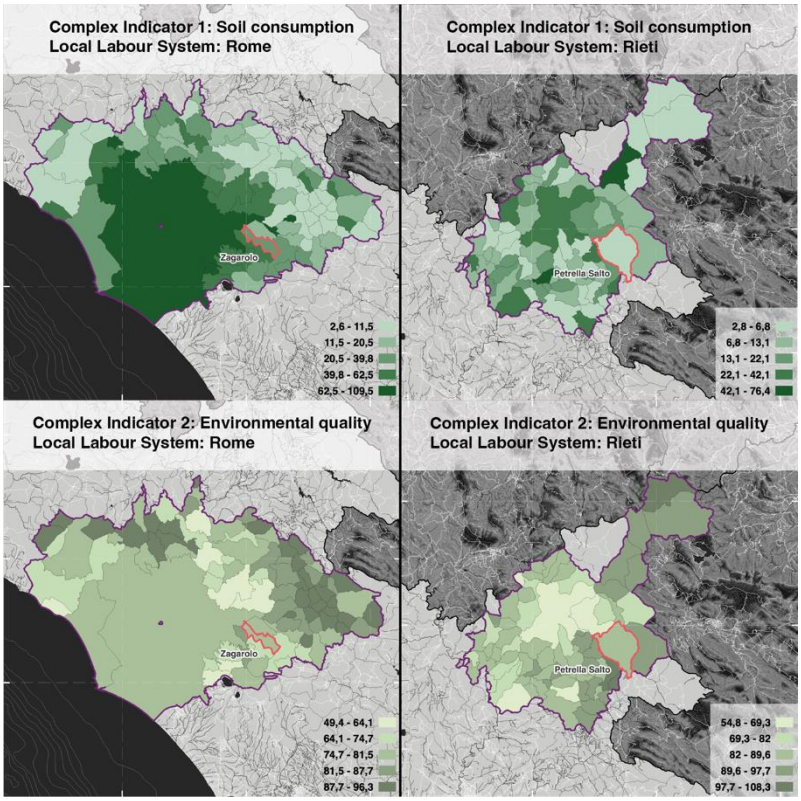
Petrella Salto, on the other hand, is a municipality in the province of Rieti that stands on a hill overlooking the Salto valley with the lake of the same name and the Cicolano mountains to the east. The municipality has 1,026 residents (ISTAT data updated to 01/01/2023), belongs to the Rieti Local Employment System, a surface area of 102.93 km2 and a population density of 9.97 inhabitants/km2.

The results of the comparative analysis of the two municipalities carried out according to the methodology described above makes it possible to construct a multidimensional portrait of fragility and its components in the two municipalities analysed. The maps describing the six composite indicators are shown as an example in Figure 3: i) land consumption, ii) environmental characteristics, iii) social composition, iv) housing conditions, v) accessibility, vi) attractiveness.

It is therefore possible to highlight and assess specific characteristics, conditions, criticalities, and potentialities relating to the two municipalities analysed. This is possible also thanks to the individual analyses carried out for each simple indicator and subsequently from the quantitative comparison between the complex indicators.

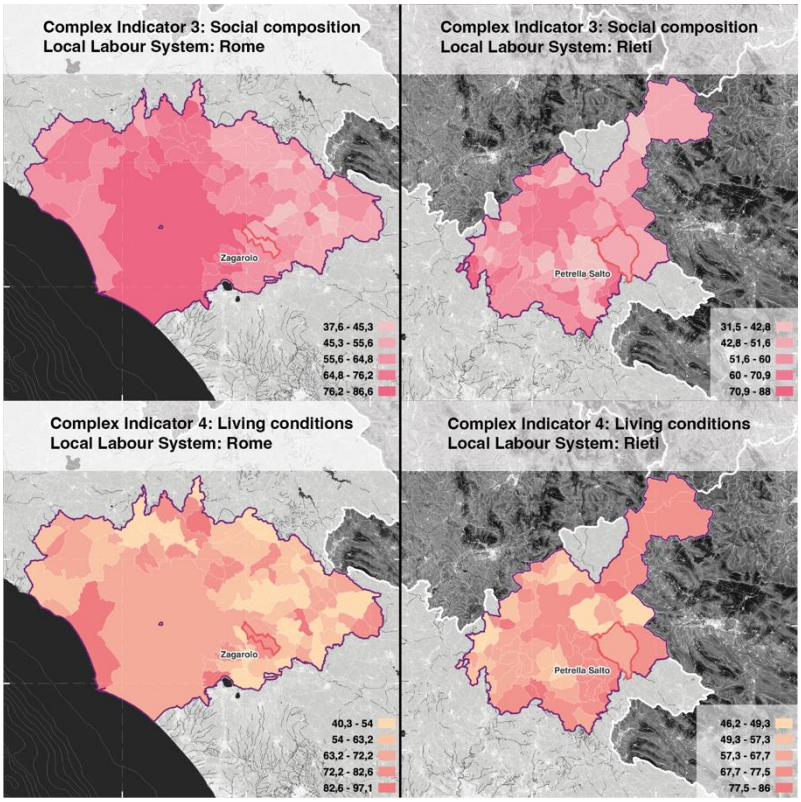
Results are shown in Figure 3-5 representing each complex indicator for each municipality in the scope of its Local Labour System.

Figure 3. Complex indicators – Environmental dimension



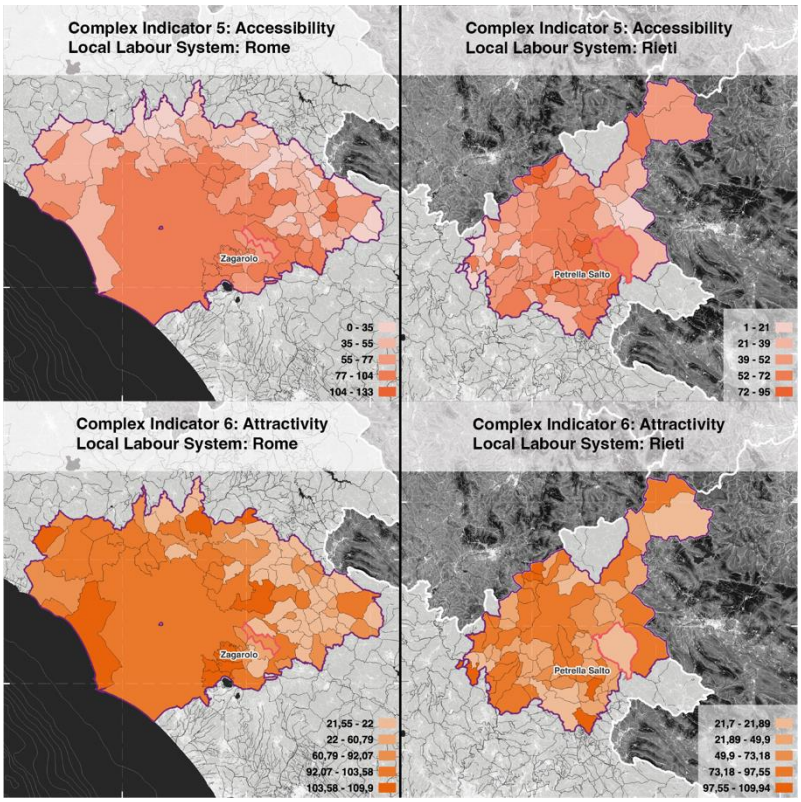
Source: Authors' elaboration

Figure 4. Complex indicators – Socioeconomic dimension



Source: Authors' elaboration

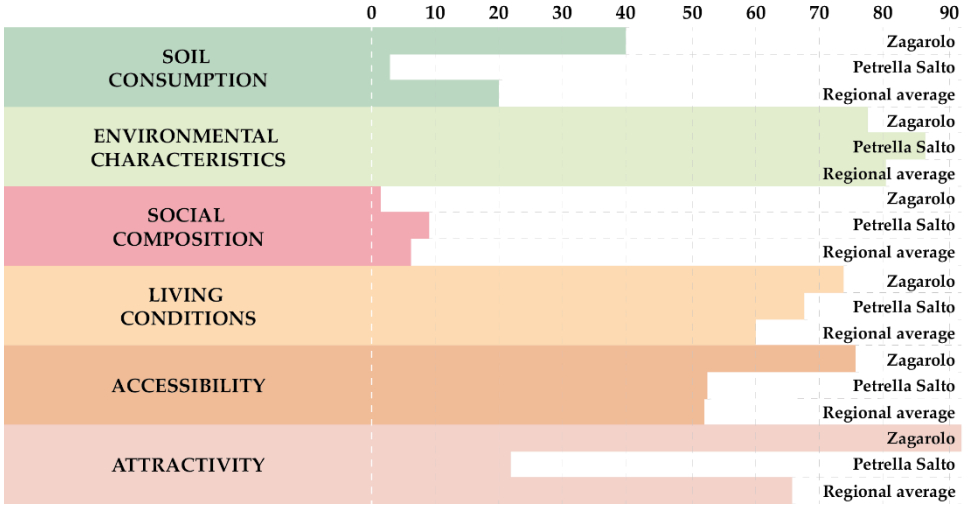
Figure 5. Complex indicators – Relational dimension



Source: Authors' elaboration

The quantitative nature of the analyses allows a numerical comparison between the calculated indicators. The results of this further comparison are shown in Figure 6.

Figure 6. Complex indicators



Source: Authors' elaboration on ISTAT, ISPRA, Lazio Region and INU data

Results shown in Figures 3-6 can be summarized as follows:

– the municipality of Petrella Salto has a higher environmental quality than Zagarolo, with large areas of its territory falling within protected areas;
– in the municipality of Zagarolo there is a high percentage of anthropised surfaces (consumed soil) in areas of high and very high seismic and/or landslide hazard;
– unoccupied dwellings in Petrella Salto are much lower than the regional average,

an average compared to which Zagarolo's unoccupied dwellings are a few percentage points above;
- between 2011-2021 the population of Zagarolo increased, while that of Petrella Salto decreased by about 13%;
- a younger and more active population resides in Zagarolo than in Petrella Salto, but the latter has a higher percentage of foreign population;
- in both municipalities the Urban Plan is not recent: Zagarolo's plan was systematically updated in 2007 while Petrella Salto's dates back to 1984;
- travel for work and study purposes is much higher in Petrella Salto than in Zagarolo: this phenomenon is related to the lack of schools, production activity centres and other private and public services in the municipality of Rieti;
- the municipality of Zagarolo is more accessible than Petrella Salto, a characteristic that is linked to the quality of its infrastructures and its proximity to the pole of attraction in Rome;
- the accessibility index to the national health system is very high in Zagarolo compared to Petrella Salto and exceeds the regional average;
- from the point of view of economic and tourist activities, Zagarolo has a much higher vocation than Petrella Salto, a municipality, the latter, which cannot pursue an integrated enhancement and management of its cultural and natural heritage.

4. Conclusions

The research question posed at the beginning of the article is: is it sufficient to reason about territorial fragility discussing a single variable, or do phenomena such as this need a broader and more careful look capable of analyzing and understanding the multiscalar and stratified nature of contemporaneity? A first attempt to answer this question is represented, in this research, by the exploration of the multidimensional nature of fragility. On one hand, the experiences already present in the literature with practices and programmes in action on the Italian and European scene are aligned. Each of them, some with more fruitful results than others as already pointed out in the introduction, uses single indicator-based logic. On the other hand, following an evolutionary perspective, an attempt is made to propose a methodology that in this context may represent an open contribution in form and repeatable given the type and nature of the information used as it is freely accessible to all. In the fourth paragraph, the results of an initial methodology experimentation are presented concerning two municipalities in the Lazio Region (Zagarolo and Petrella Salto) which present different traits. A comparison was made between the two, which is certainly not to be understood as a mere classification based on performance but rather as a support tool, in the decision-making phases of plans and programmes. These results show how complex and stratified phenomena dealing with fragility can be at the territorial level. For example, the municipality of Zagarolo, so close to a very multicultural and highly densely populated area like the Metropolitan City of Rome, presents lower values of foreign residents than Petrella Salto, very far from the main centres of services. Zagarolo presents soil consumption percentages much higher than the regional average, higher attractivity and accessibility values that can be linked with an overall higher quality of life. Following the same logic, in Petrella Salto high values of environmental characteristics are linked with soil consumption values much lower than the regional average. This procedure may enable decision-makers and policymakers to read and interpret the fragilities and potentialities of the territories transversally and in a multidisciplinary manner based on territorial

evidence. Given the nature of the information, such knowledge can help to move away from different logics. While on the one hand local administrators are very aware of what is happening and developing in the territories as they are known to those who inhabit and use them, on the other hand, they might suffer from the lack of an overall, external and therefore impartial vision of the dynamics at work at the different scales and how they relate to each other. Main outcomes of this study are not traced into the quantitative results themselves but mainly on the proposal of a new methodology capable of covering different topics having different fields of research under the same umbrella. The inhomogeneity of information, especially in its temporal dimension, is a limitation of the methodology. While it is updatable, modifiable and open, it needs data produced by third-party institutions that carry out continuous monitoring. In this sense, also to outline perspectives for the next steps, already underway, research, reference is made to the possible role of computerised territorial platforms for territorial development (Eugeni et al., 2022). Thanks to their ability to process and manage real-time information from alternative sources (which, however, require technological infrastructures specifically designed to be managed), they could play an important role in the new forms of antifragile spatial planning (Di Ludovico et al., 2019, 2020) (Blecic, Cecchini, 2015). Another line is linked to the issue of climate change, which is considered in the environmental dimension in the proposed methodology, for example, thanks to the presence in the Lazio Region of data on emissions by pollutants (not available homogeneously throughout the country). Further experimentation of the methodology will concern the comparison with the classification based on ecoregions (ISTAT, 2023; Fabbro, 2023) as possible geography of control to understand its potential and implications in new forms of territorial governance.

Notes

1. Acronym for the European Spatial Planning Observatory Network, ESPON is a European Union cooperation programme aimed at supporting the growth of territorial cohesion policies and the harmonious development of the European territory (https://www.espon.eu/).

Author Contributions

This paper is the result of the joint research of the authors. Federico Eugeni worked on the following aspects: Conceptualization, Methodology, Software, Data Curation, Writing - Original draft preparation, Visualization, Writing - Review & Editing. Luana Di Lodovico worked on the following aspects: Supervision, and Validation.

Conflicts of Interest

The authors declare no conflict of interest.

Originality

The authors declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere, in English or any other language. The manuscript has been read and approved by all named authors and there are no other persons who satisfied the criteria for authorship but are not listed. The authors also declare to have obtained the permission to reproduce in this manuscript any text, illustrations, charts, tables, photographs, or other material from previously published sources (journals, books, websites, etc).

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