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Ecosystem Health Assessment in urban contexts: a proposal for the Metropolitan Area of Naples (Italy)

The concept of urban resilience describes the capacity of a system to recover its functionality after a disturbance. Considering that every city is unique, the aim of the paper is to apply the concept of ecosystem health to the Metropolitan Area of Naples (Italy), classifying the territory according to its urban health. Three different perspectives have been considered: "vigour", "organisation" and "resilience" and according to this framework, a system of indicators has been developed, identifying their territorial distribution. The application provides a subdivision of the Metropolitan Area in different zones with various degrees of resistance to risks and vulnerabilities. The evaluation has been carried out integrating Geographic Information System and Multi-Criteria Decision Analysis.

1. Introduction: from urban resilience to urban ecosystem health

The consequences of climate change are leading to the prediction of a significant increase in surface temperatures, generating so-called global warming. In this problematic context, cities become suitable places wherein to experience practices of mitigation, adaptation and urban regeneration based on the concept of urban resilience. Resilience can be defined as "the ability of a system, community, or society exposed to hazards to resist, absorb, accommodate, and recover from the effects of a hazard promptly and efficiently" (Jha et al., 2013, p. 9). The concept of resilience applied to urban systems can be formed by: 1) metabolic flows, such as production, supply and consumption chains; 2) governance networks; for example, institutional structures; 3) social dynamics; i.e. human capital; 4) built environment, such as ecosystem services in urban landscape. Resilience was born in the ecological field (Holling, 1973), where it represents the ability of a system to remain stationary; that is, to maintain its structure in case of external perturbations, recovering its organisation and ensuring systemic stability. Therefore, according to the flow of available energy and to its context, over time, the system tends to maintain its self-organisational processes, unless it is not subject to external shocks, which, if they reach critical levels (or threshold levels), determine a different self-organising ability or they cancel it, changing the morphogenesis of the same system or otherwise producing reactions that lead to bifurcations (Fusco Girard and Nijkamp, 1997).

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In addition, resilience is characterised by some components, such as "robustness", which is the capacity of the elements to withstand the levels of stresses without causing a loss of function; "adaptability", which is the ability of a system to adapt itself to the consequences of a given perturbation and "transformability", which is the ability of a system to transform a problem into an opportunity, creating new and different conditions, often more desirable than those preceding.

Furthermore, a system proves to be resilient when it is subjected to a perturbation (defined "stressor") that can be caused by human activities; for example, an increase in pollution or by natural events such as an earthquake. These "stressors" are able to affect the variable and the performance of the system and they can be chronic: for this reason, they could also be predicted in some way but at the same time, acute "stressors" are unpredictable and can cause serious consequences (Juan-García et al., 2017).

Considering cities as adaptive systems, resilience assessment is able to connect landscape, society and land use with adaptive capacities, providing an important advantage (Ahern, 2011) and "quantifying resilience is particularly motivated by the need to support design and decision making" (Tran et al., 2017, p. 73).

In general, many studies based on resilience assessment focus on some specific aspects, giving up the multidimensionality characterising resilience in a general sense. These are indeed examples of resilience assessment in relation to the problem of floods or typhoons (Kotzee and Reyers, 2016; Wang et al., 2012); other examples refer to the evaluation of microclimate resilience linked to the problem of urban heat islands (Toparlar et al., 2015), the management of water resources (Li et al., 2106; Grafakos, 2015) or resilience related to single buildings (Lomas and Ji, 2009). There are still analyses focusing on the integrated concept of vulnerability and resilience (Angeon and Bates, 2015; Graziano and Rizzi, 2016), while others are interested in resilience assessment according to infrastructures (Reed et al., 2009). In the urban context, resilience determines a new paradigm of urbanisation, influencing the way of understanding and managing hazards as well as urban planning, determining the necessity of incorporating disasters and climate risk management into urban policies (Jha et al., 2013). Anthropic and natural risk factors give rise to pressures on the landscape, determining the intensification of the vulnerability of the heritage. When the level of resilience is low, a system becomes vulnerable, losing its ability to resist under pressure and being exposed to the risk of negative impacts, altering the economic, social and environmental development as a consequence (Biancamano, 2016). There have been many studies and tools developed in order to evaluate resilience and cities are beginning to progress some specific plans and resilience targets with the aim of reducing risks and vulnerabilities to climate change (McPhearson et al., 2015), although an integrated approach is still missing.

The aim of the paper is to enlarge the concept of resilience, taking into account other components and, in particular, the starting point is the concept of ecosystem health (Costanza, 1992, 2012). According to this concept, ecosystem health is formed by three components:

- the "vigour" of a system is a measure of its activity, metabolism or primary productivity;

- the "organisation" of a system refers to the number and diversity of interactions between its components;
- the "resilience" of a system refers to its ability to maintain its structure and pattern of behaviour in the presence of stress.

As far as benefits to the human community are concerned, "a healthy ecosystem is one that provides the ecosystem services supportive of the human community, such as food, fibre, the capacity for assimilating and recycling wastes, potable water, clean air, and so on" (Costanza, 2012, p. 2).

In particular, the present paper aims to transfer this concept from the ecological to the urban perspective, taking into consideration some recent experiments where this type of research has already been conducted, especially because of the high level of environmental degradation.

Indeed one of these studies, applied to the cities of Beijing and Shangai, considers that "a healthy urban ecosystem is the basic requirement of a strong economy, healthy environment and harmonious sustainable development for human society" (Li and Li, 2014, p. 155) and the urban ecosystem is divided into three components:

- "vigour", which means a city's vitality and metabolic activity, reflecting also the productivity;
- "structure", which means the diversity of configuration and the channels, reflecting the economic, social and natural structure of relationship;
- "resilience", which means the function of an urban ecosystem; keeping the structure usability and making a long-term and sustainable development, reflecting a kind of systematic self-regulation.

A second research that has been taken into account uses Shenzen City as a case study area and aims to assess the ecosystem health of urban landscapes based on ecosystem services, considering a subdivision of the territory in areas according to the level of ecosystem health in different periods of time (Peng et al., 2015).

Therefore, the main topic of the present paper is represented by urban ecosystems; i.e. dynamic ecosystems that are a hybrid of both natural and anthropic components, whose interactions are affected not only by the natural environment but also by culture, politics, economics and social organisations. These ecosystems have not been adequately incorporated within the various forms of urban governance and planning approaches aimed to increase resilience (McPhearson et al., 2015). They are dynamic and complex and the greater vulnerability to climate change that interacts with the existing urban problems and at the same time determines new perturbations is concentrated here (Sharifi and Yamagata, 2014). In these areas, the risks resulting from climate change will greatly intensify, but adaptation policies are still poorly developed (Araos et al., 2016) and the greatest vulnerability manifests itself in a variable way, depending on the physical and socio-economic characteristics and, therefore, action is needed in order to improve the adaptive capacity and the level of resilience.

In the present paper we try to find an approach by which to evaluate urban ecosystem health. According to Tran et al. (2017), an important factor to be considered is related to the temporal aspect: that is the necessity to consider the ability of the system to adapt itself over time, considering the evolution of its characteristics and the stressors over its entire life. Starting from this aspect, the proposed application aims to analyse the urban ecosystem health according to the actual state, providing an informative base from which it will be possible to shape future scenarios, taking informed decisions, ensuring a sustainable future urban development and acting in a specific manner where the level of urban ecosystem health is lower.

The paper presents an application of this model in order to provide a classification of the Metropolitan Area of Naples (Italy), according to the level of health it may offer and to identify the factors that contribute to its capacity of recover. Indeed "building resilience in cities relies on investment decisions that prioritise spending on activities that offer alternatives that perform well in different scenarios" (Jha et al., 2013, p. 3).

The paper is organised as follows: Section 2 provides a description of the applied methodology. In particular, Section 2.1 describes the study area and Section 2.3 provides a description of the application, focusing on the indicators of urban health and the principal component analysis. Results of the assessment are presented in Section 3 and finally Sections 4 and 5 present some discussion and conclusions.

2. Method

2.1 Study area

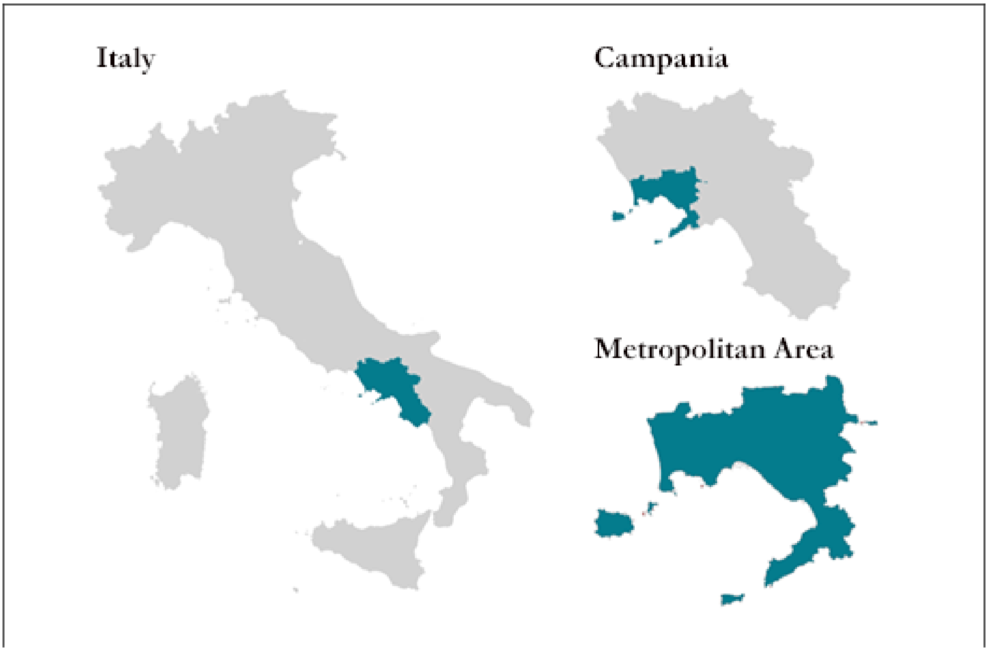
The study area is represented by the Metropolitan Area of Naples (Fig. 1), located in the Campania Region and formed by 92 municipalities: it represents the third most populated metropolitan area in Italy, with more than 3.5 million inhabitants. It is characterised by an unregulated urban development and during the last two decades, the different municipalities have welded together, creating undifferentiated suburbs, characterised by socio-economic and environmental disorder.

Metropolitan areas are particularly vulnerable to climatic hazards because of a high agglomeration of population, economic activities and an improper urban development (Kirshen et al., 2008). Furthermore, "a wide range of climate change and hazard impacts are particularly acute in metropolitan areas where there is a dynamic and complex interaction of natural and socioeconomic systems under highly heterogeneous contexts […] however, metropolitan authorities rarely use resilience approach to frame climate adaptation strategies and land use policies" (Hung et al., 2016, p. 49).

Anyway, despite the problematic context of the present case study, there is also great potential for development, thanks to the territorial variety, the presence of high quality landscapes and many economic, cultural and environmental resources.

The integration of the Geographic Information System (GIS) with Multi-Criteria Decision Analysis (MCDA) renders the decision-making phase transparent

Figure 1. Metropolitan Area of Naples (Italy).



and explicit, also considering that GIS can be used as a tool to identify hazards, mapping spatial attributes and understanding resilience. This tool can enhance knowledge of the influencing factors for local resilience and its spatial vulnerability (Wang et al., 2012).

Furthermore, the metropolitan areas require suitable planning instruments because their environmental conditions are more critical due to energy consumption and greenhouse gas emissions and their many negative impacts. For these reasons, we propose the construction of a Spatial Decision Support System (SDSS) through integrating GIS and MCDA to support the new metropolitan planning choices.

2.2 Ecosystem health indicators and Principal Component Analysis

A healthy ecosystem can balance the three components of "vigour", "organisation" and "resilience" (Costanza, 2012). It can be noted that resilience is only one of the evaluation factors that, together with the components of vigour and organisation, can qualify the health of an ecosystem in a comprehensive and exhaustive manner. Furthermore, a system is healthy and free from danger when it is stable and sustainable: this happens when it is active and maintains its organisation and autonomy over time, proving to be resilient despite perturbations. The concepts of ecosystem health and sustainability are closely interdependent, because the term sustainability is also an indication that a system is able to maintain its structure (organisation), its function (vigour) and its ability to recover (resilience) in the presence of external perturbations while the lack of these factors indicates an ecosystem in crisis (Costanza, 1992).

Translating these parameters from an environmental to an urban sphere, a healthy urban ecosystem is the fundamental prerequisite for a strong economy, a healthy environment and a harmonious sustainable development for human society (Li and Li, 2014). Based on these concepts, a set of drivers was associated to each of the three urban health categories in question and according to this reference framework, a system of indicators has been developed with the aim of identifying their territorial distribution (Tables 1-3). A "positive direction" has been established for each indicator, because according to the kind of data, some (negative) indicators must be minimised, while others must be maximised, in order to improve the degree of health of the urban ecosystem. Indicators, that are vital elements in developing awareness of urban problems (Stanners and Bourdeaux, 1995), have been spatially represented through maps using GIS. Some of these maps refer to the 92 municipalities in the metropolitan area, while others refer to the census areas, according to the kind of data available: some examples are reported (Fig. 2 and Fig. 3). Numerical data derives from Census (2011) and from some Regional and Sectorial plans, together with reports and previous studies (Carone et al., 2017). These indicators have been normalised and rasterised to make them comparable. In order to obtain a smaller number of variables and to avoid redundancy, a Principal Component Analysis (PCA) has been carried out: this analysis, suitable for quantitative variables, represents a variable reduction procedure appropriate when measures have been obtained on a consistent number of observed variables.

This kind of technique replaces the original variables by a smaller number of derived variables, called "principal components", formed by linear combinations of the originals (Joliffe, 2014): therefore, they represent a weighted sum that combines different variables in a single construct. In particular, PCA is a method for multivariate analysis that transforms a set of m correlated variables into a new set of m uncorrelated variables that can be called "components". In the form of linear combinations, these allow a better understanding of data (Harris et al., 2015). In addition, the smaller number of constructs are independent, then orthogonal to one another in space and are sorted in ascending order of variance. PCA is able to balance the aim of the synthesis with that of minimising the loss of information and the number of principal components is equal to the number of the observed variables. In addition, the total variance, i.e. the sum of the variances, is kept in the transition from the observed variables to the principal components. PCA is suitable for quantitative variables and it has been applied in different fields of research related to human and physical geography and with different objectives (Sanders et al., 2015; Sabokbar et al., 2014; Comber et al., 2016; Lloyd, 2010) but also in relation with geology (Yang and Cheng, 2015) or oceanography (Moskalik et al., 2014).

Therefore, PCA allows representation of the multivariate nature of data, identifying their structure using a relatively smaller number of dimensions. Consider-

Table 1. Indicators for Vigour.

Dimensions	Drivers	Indicators	Positive direction
Vigour	Economy and tourism	Employment rate	MAX
		Unemployment rate	min
		Number of local units compared to inhabitants (15-64 years old)	MAX
		Number of employees in local units compared to inhabitants (15-64 years old)	MAX
		Average taxable income per capita	MAX
		Number of beds in hotels	MAX
		Number of other forms of accommodation	MAX
	Agriculture	Percentage of total agricultural surface compared to territorial surface	MAX
		Percentage of used agricultural surface compared to total agricultural surface	MAX
		Percentage of irrigated surface compared to used agricultural surface	MAX
		Percentage of irrigable surface compared to used agricultural surface	MAX
		Number of farms compared to used agricultural surface	MAX
		Number of farmhouses compared to used agricultural surface	MAX
		Surface percentage use by biological farms compared to used agricultural surface	MAX
		Surface percentage used by farms with typical local productions compared to used agricultural surface	MAX
	Landscape and cultural heritage	Percentage of areas of historical, cultural and environmental interest compared to total surface	MAX
		Average monthly number of visitors in museums, monuments and state archaeological areas	MAX

ing too many principal components or including a low number of them can determine a wrong interpretation of results. It is important, then, to know which variables contribute more to the definition of the principal components, obtaining a reduction of the problem dimensionality and optimising results. An example related to agriculture is reported: in detail, the driver is formed by 8 indicators representing the original variables. The analysis has been carried out in GIS and the components correspond to the 8 input layers. The results are formed by a covariance matrix between the layers (Table 4), a correlation matrix (Table 5) and a table of eigenvalues and eigenvectors (Table 6).

Table 2. Indicators for Organisation.

Dimensions	Drivers	Indicators	Positive direction
Organisation	Population	Old age index	min
		Number of families compared to inhabitants	MAX
		Percentage of households in home ownership compared to total resident households	MAX
		Percentage of apartments with 6 or more inhabitants	MAX
		Number of foreigners per 100 inhabitants	MAX
		Population density	min
	Built heritage	Percentage of used buildings compared to total	MAX
		Percentage of buildings built before 1945	MAX
		Percentage buildings built between 1945 and 2000	MAX
		Percentage of buildings built after 2000	MAX
		Percentage of buildings with bearing walls	MAX
		Percentage of buildings made of reinforced concrete	MAX
		Percentage of buildings in other materials (wood, steel, etc.)	MAX
	Mobility and transports	Percentage of people who travel daily outside the municipality of residence compared to total	min
		Number of buses per 10,000 inhabitants	MAX
		Number of railway stations on 100 Km^2	MAX
		Number of stops of underground lines, funiculars, cable cars and hydrofoils over surface of 100 Km^2	MAX
	Society	Number of non profit institutions per 10,000 inhabitants	MAX
		Percentage of inhabitants engaged in voluntary activities in non-profit institutions compared to total	MAX
		Number of social, cultural and recreational association per 10,000 inhabitants	MAX
		Number of groups and joint purchasing networks for 10,000 inhabitants	MAX
		Number of associations of social assistance, health and social emergency relief per 10,000 people	MAX
		Percentage of graduated inhabitants compared to total population	MAX

We can observe that for the present application, we have attested to a value of cumulative variance of about 80% (Table 7; Fig. 4). In fact, it is necessary to obtain a reduced number of principal components compared to the original indicators but at the same time, able to significantly represent the considered phenom-

Table 3. Indicators for Resilience.

Dimensions	Drivers	Indicators	Positive direction
Resilience	Atmosphere	Annual diffuse emissions of SOx per capita	min
		Annual diffuse emissions of NOx per capita	min
		Annual diffuse emissions of CO per capita	min
		Annual diffuse emissions of COV per capita	min
		Annual diffuse emissions of PM10 per capita	min
	Hydrosphere	Coverage of aqueduct	MAX
		Annual consumption of drinking water per person	min
		Coverage of sewerage network	MAX
		Coverage of purification	MAX
		Annual load of BOD5 spilled per capita	min
		Annual load of nitrogen (N) spilled per capita	min
		Annual load of phosphorous (P) spilled per capita	min
	Biosphere	Percentage of the Site of SCIs compared to total surface	MAX
		Percentage of the SPAs compared to total surface	MAX
		Percentage of areas belonging to natural parks compared to total surface	MAX
		Percentage of forest area compared to total surface	MAX
	Geosphere	Percentage of areas of urban consolidation and environmental rehabilitation compared to total surface	MAX
		Percentage of degraded areas subject to recovery and environmental redevelopment compared to total surface	MAX
		Percentage of soil used for urban uses compared to total surface	min
		Percentage of areas for services and public facilities and/or public interest compared to total surface	MAX
		Number of historic parks and gardens open to the population for 10,000 inhabitants	MAX
		Proportion of spaces for the community compared to residential surfaces	MAX
		Percentage of buildings used for productive, commercial, office/service, industry, tourism/hospitality services compared to total number of buildings	MAX
	Environmental certification	Percentage of companies certified EMAS compared to total	MAX
		Percentage of organisations/companies certified UNI EN ISO 14001 compared to total	MAX
		Percentage of INES factories compared to total	min

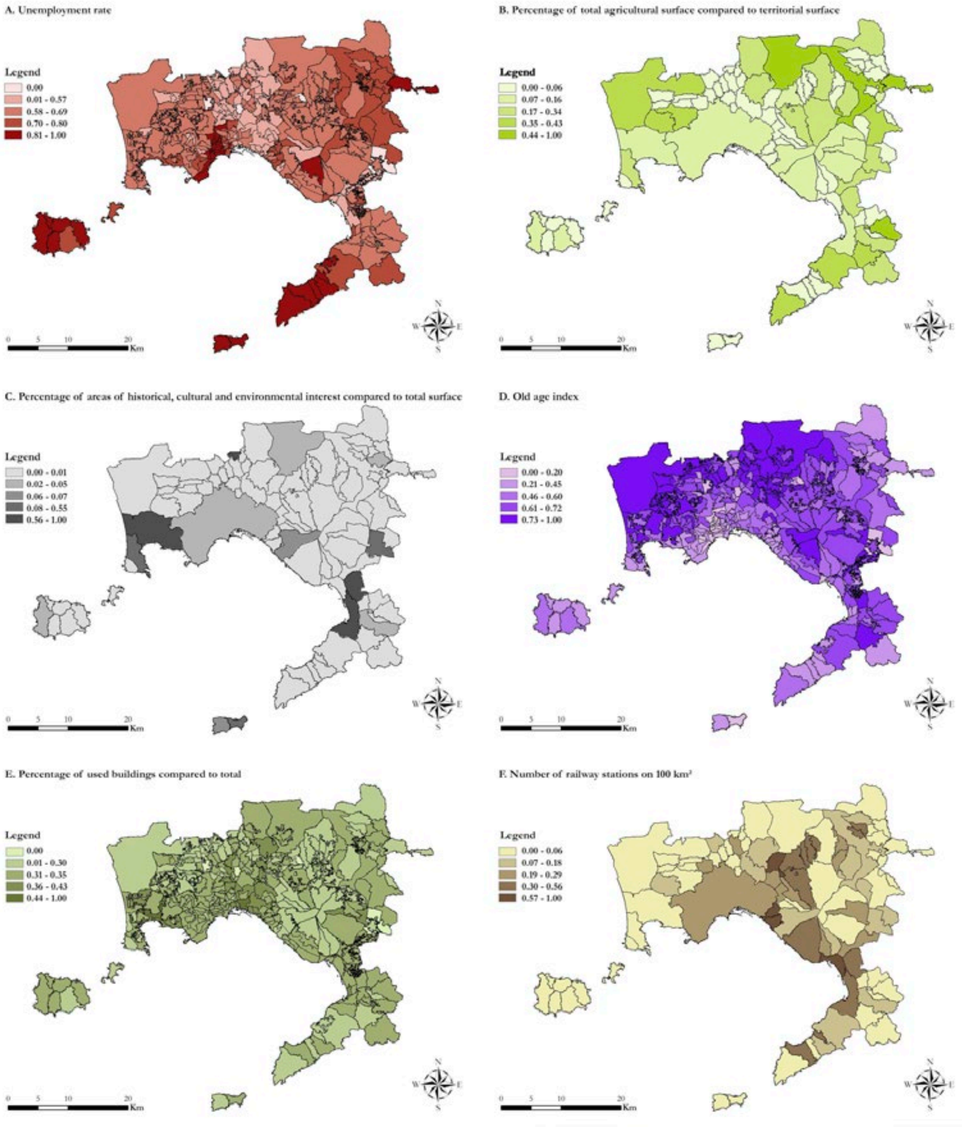
Dimensions	Drivers	Indicators	Positive direction
	Waste	Annual per capita production of municipal solid waste	min
		Percentage of separate collection of total municipal solid waste	MAX
		Number of incinerators	min
		Number of installations for waste treatment	MAX
	Natural and anthropogenic hazards	Volcanic risk exposure (high, medium and low risk)	min
		Exposure to air pollution (areas of renovation, observation and maintenance)	min
		Number of establishments at risk of major accident	min
		Number of contaminated sites	min
		Number of potentially contaminated sites	min
		Percentage of areas crossed by fire compared to total	min
	Safety and human health	Number of enterprises registered or requesting registration to the list of enterprises not subject to criminal attempt of infiltration compared to total number of enterprises	MAX
		Number of criminal organizations compared to total number of inhabitants	min
		Number of road deaths per 100 accidents	min
		Number of cancer deaths per 10,000 inhabitants	min
		Number of hospitalisations per 10,000 inhabitants	min

ena. For this aim, among the criteria used for the selection of the principal components, we have chosen the method according to which only the components that represent the 80-90% of the total variability have to be considered, in order to include the right number of variables. Another advantage of this approach has been to consider linearly independent variables for subsequent processing.

3. Results: Ecosystem Health Assessment of the Metropolitan Area of Naples

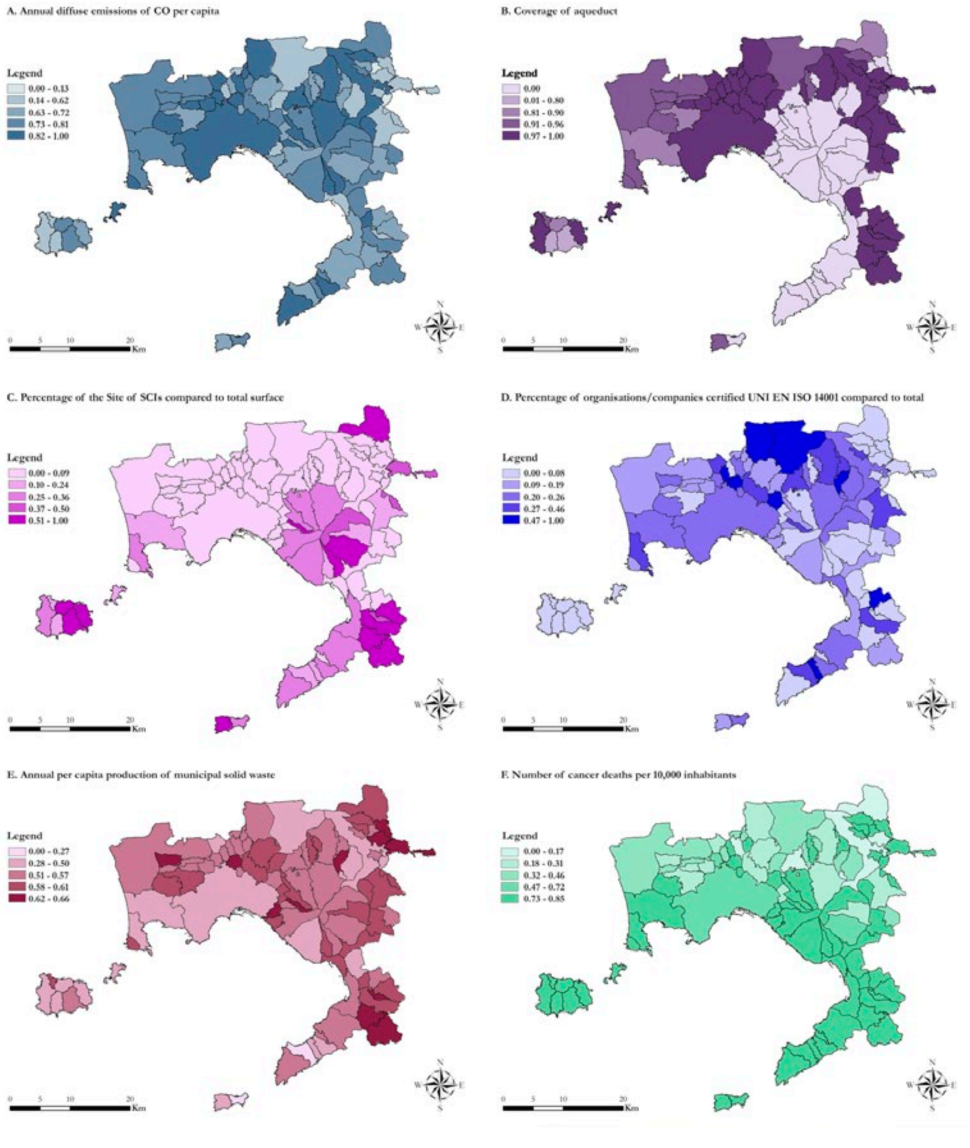
After the selection of data, we have assigned weights, considering equal weights both for the drivers and for the principal components. The evaluation has been carried out using VectorMCDA (Rocchi et al., 2015) associated to geoTOPSIS, as a plugin of QGIS. In general, the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method (Hwang and Yoon, 1981) assumes as a basic concept that the preferable option should have the "minor distance" from the

Figure 2. Spatial representation of urban health ecosystem indicators.



"ideal solution" and the "maximum distance" from the "non-ideal solution". This method uses the geometrical interpretation of distance, referring to the Euclidean distance, and it is possible to rank the options with reference to the ideal and non-ideal. The final ranking of options is obtained through comparison among relative distances. In particular, VectorMCDA assumes that each geographical object is a single geo-alternative and geoTOPSIS implements the ideal point algorithms,

Figure 3. Spatial representation of urban health ecosystem indicators.



based on the TOPSIS model, and returns a map showing the arrangement of the various geographical alternatives. The weights assignment can be made either directly or by calculation, using the Analytic Hierarchy Process method (AHP) (Saaty, 1980). The ideal point, on which the model is based, identifies the target value assigned to a particular criterion, representing the optimal value at which the decision maker would tend. In general, for a given problem, its ideal solution

Table 4. Principal component analysis related to agriculture driver: covariance matrix.

	Covariance Matrix							
Layer	1	2	3	4	5	6	7	8
1	1,025070e-002	2,507881e-005	4,159372e-003	2,697214e-003	-4,946195e-003	-4,713255e-004	-2,830477e-004	-3,761803e-003
2	2,507881e-005	4,218607e-003	4,913194e-003	4,708464e-003	-3,821828e-003	-1,309377e-003	8,405030e-005	-2,771580e-003
3	4,159372e-003	4,913194e-003	2,500272e-002	2,325620e-002	-9,291456e-003	-2,023934e-003	-7,486715e-004	-9,533971e-003
4	2,697214e-003	4,708464e-003	2,325620e-002	2,796302e-002	-6,208651e-003	-2,282532e-003	-1,003767e-003	-9,950546e-003
5	-4,946195e-003	-3,821828e-003	-9,291456e-003	-6,208651e-003	1,481656e-002	1,485170e-003	-4,349429e-005	6,697409e-003
6	-4,713255e-004	-1,309377e-003	-2,023934e-003	-2,282532e-003	1,485170e-003	2,419281e-003	4,914788e-004	1,126295e-003
7	-2,830477e-004	8,405030e-005	-7,486715e-004	-1,003767e-003	-4,349429e-005	4,914788e-004	1,567495e-003	6,071999e-004
8	-3,761803e-003	-2,771580e-003	-9,533971e-003	-9,950546e-003	6,697409e-003	1,126295e-003	6,071999e-004	1,489303e-002

Table 5. Principal component analysis related to agriculture driver: correlation matrix.

	Correlation Matrix							
Layer	1	2	3	4	5	6	7	8
1	1,00000	0,00381	0,25981	0,15931	-0,40135	-0,09465	-0,07061	-0,30446
2	0,00381	1,00000	0,47839	0,43351	-0,48341	-0,40986	0,03269	-0,34966
3	0,25981	0,47839	1,00000	0,87953	-0,48274	-0,26023	-0,11959	-0,49407
4	0,15931	0,43351	0,87953	1,00000	-0,30502	-0,27751	-0,15161	-0,48760
5	-0,40135	-0,48341	-0,48274	-0,30502	1,00000	0,24806	-0,00903	0,45086
6	-0,09465	-0,40986	-0,26023	-0,27751	0,24806	1,00000	0,25238	0,18764
7	-0,07061	0,03269	-0,11959	-0,15161	-0,00903	0,25238	1,00000	0,12567
8	-0,30446	-0,34966	-0,49407	-0,48760	0,45086	0,18764	0,12567	1,00000

Table 6. Principal component analysis related to agriculture driver: eigenvalues and eigenvectors.

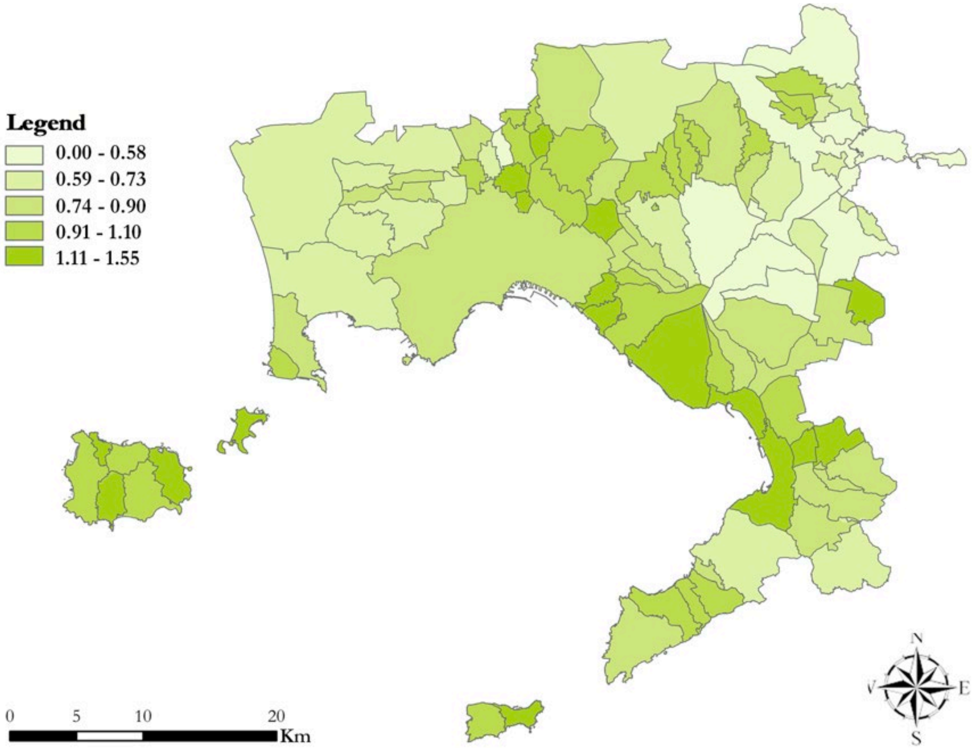
Eigenvalues and Eigenvectors								
Number of Input Layers: 8					Number of Principal Component Layers: 8			
PC Layer	1	2	3	4	5	6	7	8
Eigenvalues								
	0,06061	0,01591	0,00844	0,00777	0,00302	0,00233	0,00194	0,00111
Eigenvectors								
Input Layer								
1	0,13743	-0,47548	0,12640	0,81705	0,20934	0,06381	0,14718	0,04386
2	0,14262	-0,05424	0,07903	-0,35085	0,55231	0,39743	0,50732	0,35639
3	0,61159	0,16621	0,25443	0,04085	-0,3928	0,59058	-0,15904	-0,05897
4	0,62694	0,43885	-0,03385	0,11450	0,23636	-0,57147	0,13129	0,02023
5	-0,28580	0,65056	-0,41108	0,41585	0,11462	0,36247	0,09296	-0,00024
6	-0,06401	0,02343	-0,03634	0,08340	-0,63083	-0,15880	0,50385	0,55683
7	-0,02256	-0,01643	0,04895	-0,05104	-0,15259	0,00815	0,64480	-0,74505
8	-0,32768	0,35596	0,85977	0,10981	0,08085	-0,07705	0,01299	0,04488

Table 7. Principal component analysis for the agriculture driver.

Layers	Eigenvalues	Percentage	Cumulative variance
1	0,06061	59,93276	59,93
2	0,01591	15,73223	75,66
3	0,00844	8,34569	84,01
4	0,00777	7,68318	91,69
5	0,00302	2,98626	94,68
6	0,00233	2,30397	96,98
7	0,00194	1,91832	98,90
8	0,00111	1,09760	100,00
TOT	0,10113	100,00000	

that represents the best score for each criterion is calculated according to its minimisation and maximisation (Munier, 2011). The paper aims to test a methodology that can be re-proposed in different decision-making contexts. For this reason, by way of example, equal weights are assigned to the various criteria, reserving the possibility of assigning different weights according to the specific priorities of the application context. The same is true for the definition of the ideal point, which is

Figure 4. Principal component analysis results according to the percentage of used agricultural surface compared to total.

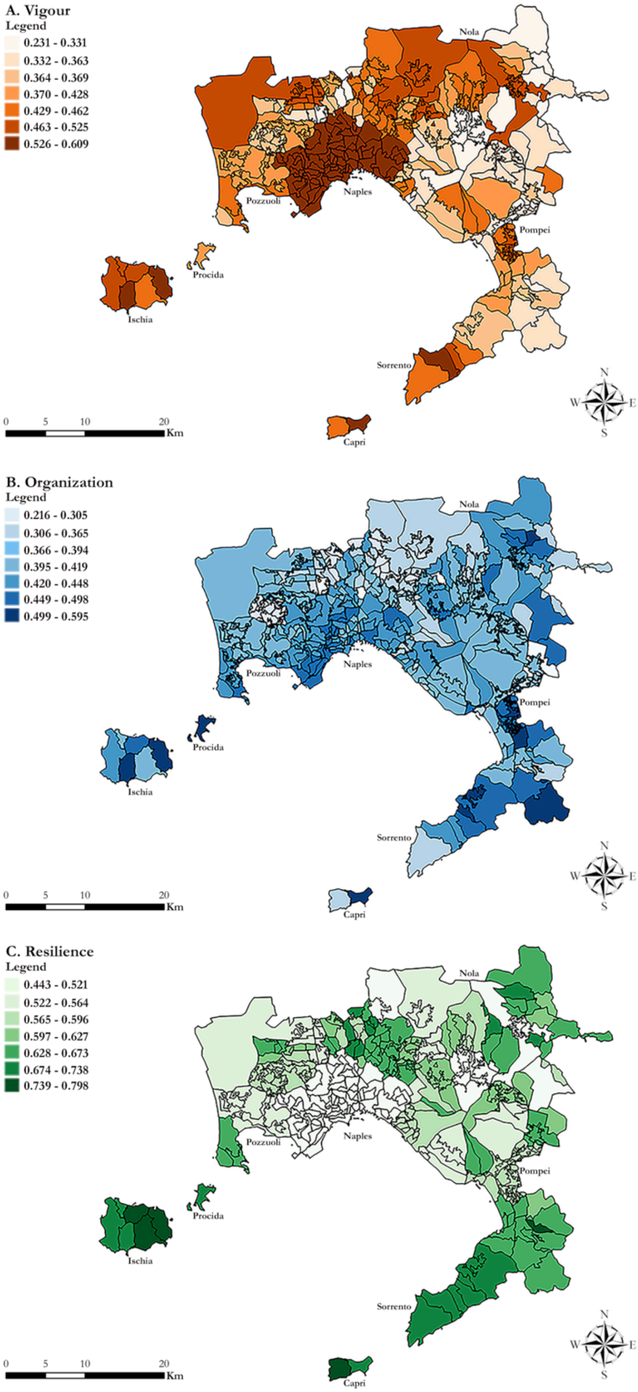


strictly linked to the decision-making sphere in question and to its ideal solution and could be defined by decision-makers according to some specific targets, such as urban standards, etc.

In the cartographic representation of the results obtained (Fig. 5), it is possible to observe the choice of using 7 classes, generated by the model, that represents the different level of "vigour", "organisation" and "resilience", from "very low" to "very high" with some intermediate values, to diversify the results also according to the variety of urban landscapes that characterise the metropolitan area.

The results do not represent an absolute value, but can vary according to the available indicators, the weights assignment, the drivers selected and the purposes of the evaluation. Furthermore, they do not present a ranking between the various municipalities, but represent a comparative method, in order to highlight both positive and negative aspects related to the territorial configuration. Analysing the results, it is possible to observe the territorial distribution of the components of urban health that have been taken into account. In particular, it is possible make some reflections; for example, the component of "vigour" is mainly concentrated in Naples, Ischia island, Capri island, Sorrento and Pompei, mainly because of

Figure 5. Results according to the geoTOPSIS method.



tourism and partially in Nola due also to the presence of some enterprises. The component of "organisation" shows a more fragmented territorial distribution, taking into account diversified aspects, such as population, transport and built heritage. Finally, "resilience", that is formed especially by environmental indicators, is concentrated mainly in the islands of Ischia, Capri, Procida and also in Sorrento, while Naples shows a very low level of resilience because of the high concentration of pollution.

4. Discussion

When we refer to the decision-making processes for urban planning and design, "evaluation can be considered a relevant tool to build choices, to recognise values, interests and needs, and to explore the different aspects that can influence decisions" (Cerreta and De Toro, 2012, p. 77). An important potentiality of the present application is represented by the integration of MCDA with GIS that creates the basis for the development of a Spatial Decision Support System (SDSS), integrating geospatial data with decision makers' preferences and producing information for decision making (Malczewski, 1999). In this way, "a variety of territorial information (social, economic and environmental) may be easily combined and related to the characteristics of the different options of territorial use, facilitating the construction of appropriate indicators and improving impacts forecasting, leading up to a preference priority list of the various options" (Cerreta and De Toro, 2012, p. 81). The use of GIS is due to the clear spatial definition of the selected indicators and the necessity to spatially visualise the distribution of the three components of urban health, especially taking into account the difference in intensity according to the municipalities of the metropolitan area and the territorial distribution of the values. Furthermore, MCDA allows inclusion of the multiple dimensions of planning for climate change and environmental problems, ensuring transparency and proving to be the most appropriate instrument (UNEP, 2009). Combining the potentialities of these two instruments, it is possible to create an ideal platform for analysis, the structuring and the resolution of problems related to the environmental and territorial management (Geneletti, 2000), developing win-win solutions. The advantage of the integrated evaluation is the possibility of holding together a broader set of components of the same question (Parson, 1994) as it happens in the present application, considering that each of the three components includes an extensive set of drivers and indicators and each aspect helps to define the general connotation of ecosystem health.

As far as results of the application are concerned, it is possible to notice that "resilience assessment" can be integrated with "vigour assessment", representing the urban system's level of activity, "organization assessment", representing the structure of population and the way in which society manages its daily activities. These three components, if declined and interpreted properly, are able to capture all the components that contribute to the functioning and the connotation of the urban system. The peculiarity of the present application lies in the importance of analysing the current condition of the urban ecosystem, because only by carefully evaluating the status quo will it be possible to think about the planning and management of the future development of the metropolitan area.

In future developments, it could be possible to integrate the proposed numeric criteria and indicators with perceptual examples that could derive from stakeholders' interviews (Hung et al., 2016) in order to have a complete set of hard, as well as soft, information.

Indeed, from a first analysis of the results, it is possible to observe the necessity of intervening in the municipality of Naples that, because of its low level of resilience, could be in need of a better calibration of green and blue infrastructures, improving air quality and hydrosphere, or reducing soil consumption and improving waste management, acting definitely on the drivers belonging to the category of resilience. Another reflection on the results could be the necessity of improving the economic component in the municipalities characterised by a lower level of vigour, exporting the business and touristic models that make Naples and the islands richer from this perspective. These are only some general examples of actions that could be implemented using this informative base to make the decision-making phase transparent and aware.

Therefore, evaluation is a strategic activity at all levels and in different phases; in the present case, evaluation "ex ante" is a very useful instrument to analyse all the components before starting the planning activity. In a second phase, evaluation "ex post" could be used to examine how a development scenario is able meet the goal of minimising or maximising the selected indicators, assessing the quality of the process and introducing the necessary corrective actions. Indeed, in order to ensure an effective planning process, there is a need to measure all the variables, defining adequate quantitative and qualitative indicators.

Defining an integrated evaluation framework that, in a multidimensional perspective, takes into account the environmental, social, economic and cultural aspects, can implement the evaluation phase connected to planning for climate change and environmental problems, reacting to the lack of an evaluation phase linked to this problematic context.

Considering the importance of the decision-making process as a key element, a future development of the present application could be that of carrying out the assessment at different scales, selecting a particular territory of the metropolitan area and analysing its processes in terms of ecosystem health and resources consumption. In this type of analysis, indeed, multi-scaling is a key prerogative. This is because it is highly important to deepen the analysis of certain other problematic contexts, to identify the significant phenomena and spatial processes that need to be decoded, increasing the level of awareness in the decision-making process. Moreover, a step further could be that of including the component of Urban Ecosystem Services (UES) in the assessment, that could increase urban resilience in general, understanding the way in which they interact with the urban ecosystem and ensuring a resilient supply in the long term (Calderón-Contreras and Quiroz-Rosas, 2017).

5. Conclusions

The present paper presents an urban ecosystem health assessment method that aims to translate the concept of ecosystem health from the ecological sphere to the urban version, identifying a suitable set of indicators associated with the usual categories of vigour, organisation and resilience that characterise the concept of ecosystem health. Starting from the analysis of the disturbance factors associated with the problem of climate change and considering the possibility of putting the problem at different scales, it builds a decision support system through the integration of MCDA and GIS, by specifically applying the geoTOPSIS method. Therefore, the evaluation criteria are associated with geographical entities and are represented by maps, providing an important support to the question analysed, thanks to the quantification and visualisation of decision criteria (De Toro and Iodice, 2016). Furthermore, it uses the method of the principal components in order to reduce the initial number of indicators, showing that with the use of an appropriate evaluation method, these data, applied to the Metropolitan Area of Naples, provide a classification of the territory that proves and confirms that the economically strongest areas are supported mainly by tourism phenomena and partly by the presence of enterprises. Organisation, referring to components such as population and transport, presents a fragmented spatial territorial distribution. Finally, resilience, embracing mainly environmental components, is more concentrated in the less industrialised areas such as Ischia, Capri, Sorrento, showing, meantime, very low levels in Naples. This analysis then allows a solid knowledge base that can support the various stages of decision-making at the metropolitan level, in order to exploit and enhance the capabilities already present and at the same time, act on the weaknesses, creating win-win solutions from the economic, ecological and social perspective, regarding sustainable development. Therefore, having focused on implementing the proposed research on urban ecosystem health, applied within that framework, a substantial difference compared to the already proposed models consists of considering "vigour", "organisation" and "resilience" not as indicators but as macro-dimensions within which to understand the drivers to which the appropriate reference indicators correspond, including social, economic, ecological, environmental and institutional aspects (Michael et al., 2014).

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