Spatial analysis for territorial marginality mapping. GIS-based application to the case of Southern and Insular Italy [†]

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Abstract: The authors defined a methodology based on geo-statistical analysis techniques implemented in a GIS environment that measures and maps the territorial gaps at the sub-regional level. The measurement activity is based on the construction of a system of quantitative indicators sampled at the municipal level. The mapping activity is based on the calculation of the Moran correlation index and the elaboration of LISA cluster maps. The proposed presentation shows the results of the application of the methodology to the regions of Southern and Insular Italy (Abruzzo, Basilicata, Calabria, Campania, Molise, Puglia, Sicily and Sardinia).

Keywords: spatial planning; GIS; territorial marginality

1. Introduction

The research focuses on territorial marginality. This is a development gap that affects the quality of life and, more generally, the well-being of people [1–4]. Two reflections are necessary to place the study in a broad context of literature. Firstly, the issue of marginality must be theoretically contextualized in the European panorama with reference to the goal of territorial cohesion [5–7]. Secondly, we must refer to the Italian National Strategy for Inner Areas (called SNAI) that identifies them as areas with important geographical or demographic disadvantages and distant from centres equipped with the essential services [8–10].

However, the issue of territorial marginality cannot be traced back to the centre-periphery model alone, since geographical distance is only one of the elements that can generate marginality. The aim of this work is to respond to the need to identify marginal areas by considering further and specific aspects of territorial marginality through the definition of a new methodology of spatial analysis. Its significance is related to two aspects. The first is the measurement activity. It is based on the construction of a system of quantitative indicators sampled at the municipal level. The second is the mapping activity. It is based on the calculation of the Moran correlation index and the elaboration of LISA cluster maps.

This paper is organized as follow. Section 2 describes the proposed methodology based on geo-statistical analysis techniques and implemented in a GIS environment that measures and maps the territorial gaps at the sub-regional level. Section 3 shows the main results of the application of the methodology to the Regions of Southern and Insular Italy (Abruzzo, Basilicata, Calabria, Campania, Molise, Puglia, Sicily, and Sardinia). Section 4 discusses the results obtained by comparing them with the mapping of the project areas proposed by the SNAI to highlight the points of contact and mutual divergence and concludes.

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2. Materials and Methods

Spatial analysis can be carried out using various techniques with the help of statistics and Geographical Information Systems (GISs) [11]. GISs allow georeferencing of data that facilitate spatial exploration and are provided with geo-statistical techniques [12].

As part of this study, we analyzed the geographical distribution of a dataset of 35 gap indicators. They are sampled at the municipal level to analyze the spatial spread of territorial marginality. We visualized their spatial autocorrelation by processing the Local Indicators of Spatial Association (LISA) cluster maps to verify the existence of any clusters.

The indicators were standardized and aggregated into a composite non-compensatory index (MP_{CVi}). MP_{CVi} summarizes a set of indicators that are assumed not substitutable. It is based on a non-linear function, which starts from the arithmetic mean and introduces a penalty for the units with unbalanced indicators values [16]. The thematic indicator relating to the territorial unit (*i*) is obtained as follows:

$$MP_{CVi} = M_{zi} \pm S_{zi} CV_{zi}, \quad (1)$$

where M_{zi} and S_{zi} are, respectively, the mean and standard deviation of the standardized values of the territorial unit (*i*), CV_{zi} is the coefficient of variation for the territorial unit (*i*) and the sign $\pm$ depends on the indicator polarity. Through this procedure the total number of 35 indicators was reduced to 5 thematic indicators. They refer to 5 aspects that are natural environment, housing stock, social capital, economic dynamism, and accessibility.

The spatial localization of the high autocorrelation values (Moran index) among the thematic indicators is provided by the LISA cluster maps, which allow to evaluate the similarity between the territorial unit and the elements that surround it for each thematic indicator. Clusters are neighboring municipalities with similar gap conditions with respect to considered thematic indicator and coincide, according to the proposed methodology, with the so-called hot spots. Hot spots are territorial units with high values of the thematic indicator and high levels of similarity with the neighborhood (High-High).

All data were analyzed using Quantum GIS (QGIS) version 3.10.14 and GeoDA version 1.18. QGIS is a package created by the QGIS Development Team in 2002 [13]. GeoDA [14] performs spatial analysis functions. It is programmed in C++ language and uses the MapObjects ActiveX control (ESRI), which allows to use the Shapefiles (.shp) of the aforementioned company [15].

3. Results

The methodology was applied to the regions of Southern and Insular Italy (Table 1).

Table 1. Main information relating to the eight regions considered

Region	Area (kmq)	Inhabitants	Number of Provinces	Number of Municipalities	SNAI Class A	SNAI Class B	SNAI Class C	SNAI Class D	SNAI Class E	SNAI Class F
Sardinia	24 099.45	1 598 225	5	377	6	0	53	93	159	66
Sicily	25 832.55	4 840 876	9	390	10	4	85	121	136	34
Abruzzo	10 831.50	1 285 256	4	305	6	4	65	115	84	31
Basilicata	10 073.11	547 579	2	131	2	0	3	16	59	51
Calabria	15 221.61	1 877 728	5	409 *	8	3	71	152	142	33
Campania	13 670.60	5 679 759	5	551 *	15	25	241	161	106	3
Molise	4 460.44	296 547	2	136	3	0	24	39	61	9
Puglia	19 540.52	3 926 931	6	258 *	14	7	97	78	57	5

* Currently there are 404 municipalities in Calabria, 550 in Campania and 257 in Puglia. In this study we referred to the administrative subdivisions for which it is possible to sample the selected indicators

Figure 1 shows the main results presented in this paper that are the LISA Cluster Maps compared with the SNAI project areas.

Figure 1. LISA cluster maps indicating significant local spatial correlations. In red color is the category High-High and positive spatial correlation based on Moran based test ($p < 0,05$)

4. Discussion and Conclusions

In this paper we described the methodology based on geo-statistical analysis techniques implemented in GIS environment. It measures and maps the territorial gaps at the sub-regional level. We showed the results of the application of the methodology to the regions of Southern and Insular Italy (Abruzzo, Basilicata, Calabria, Campania, Molise, Puglia, Sicily and Sardinia). With reference to these regions, the results show that:

- in Sardinia region, 129 Municipalities are identified in territorial gap condition (34% of administrative units) and 4 additional clusters to SNAI project areas.

- in Sicily region, 140 Municipalities are identified in territorial gap condition (36% of administrative units) and 4 additional clusters to SNAI project areas.
- in Abruzzo region, 158 Municipalities are identified in territorial gap condition (52% of administrative units) and 3 additional clusters to SNAI project areas.
- in Basilicata region, 65 Municipalities are identified in territorial gap condition (50% of administrative units) and 2 additional clusters to SNAI project areas.
- in Calabria region, 103 Municipalities are identified in territorial gap condition (25% of administrative units) and 3 additional clusters to SNAI project areas.
- in Campania region, 331 Municipalities are identified in territorial gap condition (60% of administrative units) and 5 additional clusters to SNAI project areas.
- in Molise region, 55 Municipalities are identified in territorial gap condition (40% of administrative units) and 1 additional cluster to SNAI project areas.
- in Puglia region, 167 Municipalities are identified in territorial gap condition (65% of administrative units) and 3 additional clusters to SNAI project areas.

In conclusion, the proposed methodology helps to affirm the importance of spatial analysis for the purposes of territorial planning. The results of the case study are reported in a very concise form. Although, they are sufficient to demonstrate how geostatistical analysis techniques can enable the construction of spatial and strategic frameworks aimed at reducing gaps and improving the quality of life.

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