A Spatial Statistical Approach for the Analysis of Urban Poverty

Paola Perchinunno[1](✉), Antonella Massari[1], Samuela L'Abbate[1], and Monica Carbonara[2]

[1] Department of Economics, Management and Business Law, University of Bari "Aldo Moro", Bari, Italy
{paola.perchinunno,antonella.massari,samuela.labbate}@uniba.it
[2] ISTAT, Rome, Italy
mocarbon@istat.it

Abstract. The paper analyses the concept of poverty through a multidimensional approach that uses multiple indicators to define a condition of poverty and allows to denote territorial areas and/or population subgroups characterized by situations of hardship or severe social exclusion. This study responds to need of defining and constructing indicators that are capable of estimating poverty in small areas. The complexity of the poverty phenomenon thus poses the need to identify analytical techniques that allow poverty to be framed in a broader context, to improve knowledge of the problem and deal with it through specific economic and social interventions. The data analysed in this paper allowed the construction of three sets of indicators referring to three areas of poverty: economic, social, and housing. The data refer to one Italian region: Apulia. Two methodologies were adopted to study the data. The first based on the Fuzzy approach that uses the technique of Fuzzy Sets to synthesize and measure the incidence of relative poverty in the considered population starting from the statistical information provided by a plurality of indicators. The second, based on a cluster analysis algorithm: the DBSCAN method for identifying dense areas from the fuzzy values processed by the first methodology.

Keywords: Statistical methods; poverty · Fuzzy · DBSCAN

1 Introduction

Poverty analysis is a topic of current interest in both the economic and social fields and is studied as a factor in the evolution and measurement of the level of well-being. In the last couple of years, the interdisciplinary debate on poverty has been growing again due to the adverse conditions in the health field and in the socio-political field, have been done multiple studies with a diversity of approaches. A fundamental prerequisite for a proper statistical analysis of this phenomenon is the need to share an unambiguous definition of the concept of poverty.

The contribution is the result of joint reflections by the authors, with the following contributions attributed to A. Massari (paragraphs 1 and 4), to P. Perchinunno (paragraph 3.2) and to S. L'Abbate (paragraphs 3.1, 3.3), to M. Carbonara (paragraph 2).

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2023
O. Gervasi et al. (Eds.): ICCSA 2023 Workshops, LNCS 14106, pp. 389–404, 2023.
https://doi.org/10.1007/978-3-031-37111-0_28

The profound economic and social transformations that have taken place in recent decades place the problem of poverty under a myriad of facets.

Having surpassed the identification of the poor with the person living on the margins of society (such as the homeless), the concept of poverty is extending toward that of economic hardship and social exclusion. This concept, especially in countries with advanced economies, has complex aspects and the theoretical landscape of reference is not unambiguously defined. There is no agreed definition of poverty in the literature. Usually, economic poverty is defined as an insufficiency of resources necessary to ensure a good level of well-being, compared to some predefined standard. In the general sense, assessing poverty means measuring the economic resources of each household and respective individuals against those possessed by other households.

In recent years, efforts have been made to study the problems of income distribution and poverty at the local level but having to deal with severe limitations in data availability and, therefore, resorting to alternative sources, with considerable problems of representativeness of the realities investigated.

2 Poverty Indicators

2.1 Data Sets and Indicators at the Regional Level

As the basis of analysis for the study of poverty, data from one Italian region, Apulia, were analysed focusing on data from "*A misura di comune*" a multi-source statistical information system in which sources of an experimental nature are enhanced alongside more established ones and is the result of the "Measures of well-being and planning at the municipal level" Project launched in 2016. In addition, "A misura di Comune" provides an articulated set of indicators useful for the planning, programming, and management tasks of Local Authorities. The available data provide an understanding of the social, economic, demographic, and environmental conditions of the regional territory, along with measures that reflect the levels achieved in terms of community well-being.

The data available on the "A misura di comune" website are updated to 2015 and the platform is currently being updated. There are 258 municipalities considered at the date of the survey in the Apulia region and they are divided as follows:

41 to the metropolitan city of Bari.
10 to the province of Barletta-Andria-Trani.
20 to the province of Brindisi.
61 to the province of Foggia.
97 to the province of Lecce.
29 to the province of Taranto.

Specifically, several poverty measures were constructed through the analysis of 9 indicators divided into 3 sets for each of the poverty areas identified: economic, social, and housing (Table 1). The indices were chosen to identify levels of economic, social, and housing hardship and were calculated so that high index values corresponded to high poverty levels.

Table 1. Sets of indicators

Set 1 - Indicators related to Economic Poverty
- **Gross disposable income per capita:** ratio of consumer households' gross disposable income to the total number of residents - **Single-income registered households with children under 6 years old:** registered households with at least one preschool child and one income earner per 100 single-income registered households - **Registered households with equivalent income below the social allowance amount**: registered households with equivalent income below the social allowance amount per 100 registered households
Set 2 - Indicators related to Social Poverty
- **Low work intensity of registered households:** registered households with work intensity below 20% of their potential per 100 registered households - **Low work intensity:** percentage of people living in households for which the ratio of the total number of months worked by household members during the income reference year (the one preceding the survey year) to the total number of months theoretically available for work activities is less than 0.20. For calculating this ratio, household members between the ages of 18 and 59 are considered, excluding students in the 18–24 age group. Households composed only of minors, students under the age of 25 and persons 60 years of age or older are not considered in the calculation of the indicator - **High school graduates 25–64 years of age enrolled in the registry:** registered 25–64-year-olds who have completed at least secondary school per 100 persons 25–64 years of age enrolled in the registry
Set 3 - Indicators related to Housing Poverty
- **Housing units reached by Ultra broadband 30 Mb**: housing units reached by Ultra broadband per 100 housing units - In**dex of availability of services in the dwelling: a**rithmetic mean of the individual percentage ratios between the number of occupied dwellings provided with (a) indoor drinking water services, (b) indoor toilet, (c) bathtub or shower and hot water and the total number of occupied dwellings

2.2 Analysis of Data at the Provincial and Municipal Levels

The data available for each municipality were merged at the provincial level in order to analyse them in each of the three identified sets.

Set 1 - Economic Poverty

The higher the value in Table 1 the more the province has a higher level of poverty as found in the provinces of BAT and Foggia for per capita gross disposable income; for single-income households with children under 6 years of age the percentage is higher for the provinces of BAT and Taranto, for the third indicator similarly as income the provinces of BAT and Foggia stand out. In general, for each of the three indicators the provinces of Bari, Brindisi and Lecce are least affected by poverty values.

Confirming what emerges from Table 2, per capita gross income ranges from a minimum of € 6,651.59 for the municipality of Zapponeta in the province of Foggia

to a maximum of € 14,899.06 for the municipality of Lecce for an average per capita gross income of € 997.69. While the percentage of single-income households ranges from a minimum value of 1.14 for the Municipality of Motta Montecorvino in the province of Foggia to a maximum value of 5.99 for the Municipality of Faggiano in the province of Taranto. Finally, the percentage of households with equivalent income below the allowance amount ranges from a minimum value of 10.78 for the Municipality of Sternatia in the province of Lecce to a maximum value of 32.69 for the Municipality of Celle di San Vito in the province of Foggia.

Table 2. Provincial-level indicator values for the first set: Economic Poverty

Provinces	Gross disposable income per capita (inverse with normalized values from 0 to 1)	Percentage of single-income households with children under 6 years of age	Percentage of Registered Families with Equivalent Gross Income below the amount of social allowance
Bari	0.51	3.82	15.98
BAT	0.71	4.30	20.42
Brindisi	0.58	3.40	17.58
Foggia	0.70	3.55	20.94
Lecce	0.60	3.10	18.81
Taranto	0.57	4.11	16.38
Apulia	**0.61**	**3.50**	**18.56**

Set 2: Social Poverty.
The percentage value of high school graduates is lower in the provinces of Bari and Lecce, i.e., those least affected by poverty-related hardships. The provinces with lower literacy are the same with a higher percentage value of unstable and low employment intensity. Thus, social poverty affects the area near Foggia and inland areas the most.

Confirming the findings of Table 3, the percentage of high school graduates varies from a minimum value of 27.95 for the municipality of Lecce in the province of Foggia to a maximum value of 69.05 for the municipality of Zapponeta, the same municipalities that had higher and lower per capita income.

While the percentage of non-stable employed varied from a minimum percentage value of 5.06 for the Municipality of Tremiti Islands to a maximum percentage value of 71.12 for the Municipality of Zapponeta in the province of Foggia.

Finally, the percentage of low employment intensity ranges from minimum value of 20.13 for the Municipality of Cellamare in the province of Bari to a maximum value of 45.31 for the Municipality of Celle di San Vito in the province of Foggia.

Set 3: Housing Poverty.
The percentage values of the index of availability of services in the home are almost

Table 3. Provincial-level indicator values for the second set: Social Poverty

Provinces	Percent High school graduates 25–64 years old enrolled in the registry (inverse)	Percentage Registry enrollees employed not stable in October	Percent Low work intensity of registry households
Bari	46.58	20.22	25.09
BAT	55.51	26.33	29.60
Brindisi	53.36	29.15	28.09
Foggia	52.77	27.01	32.20
Lecce	48.42	20.57	29.65
Taranto	54.26	24.94	28.57
Apulia	**50.47**	**23.42**	**29.28**

equal in all provinces and in any case are very low in all municipalities because all municipalities are reached by the essential services of hot water and sanitation in general. The case for the percentage value of housing units reached by broadband is different; the province of Foggia is always distinguished, which suffers from greater hardship, including housing, and the province of Bari, which, on the other hand, differs from the others in terms of better housing conditions, but also economic and social conditions (Table 4).

Table 4. Provincial-level indicator values for the third set: Housing Poverty

Provinces	Percentage Index of service availability in the home (inverse)	Percentage Housing Units Reached by Ultra Broadband 30 Mb (inverse)
Bari	0.01	8.10
BAT	0.01	12.73
Brindisi	0.01	15.92
Foggia	0.02	69.69
Lecce	0.01	55.68
Taranto	0.02	25.90
Apulia	**0.01**	**43.33**

3 Approaches and Methodologies for Poverty Analysis

3.1 Introduction

Since the 1970s, the various poverty studies have given rise to a variety of approaches, each of which has been matched by careful definition and conceptualization.

A first and more traditional approach is the unidimensional approach. It is essentially based on defining and measuring poverty from a single variable, whether income or consumption.

In most countries, poverty is often analysed using specific common indicators, such as:

– the use of economic variables (income or consumption expenditure);
– the determination of a poverty line, as a dividing line to classify individuals into poor and non-poor.

Thus, the economic connotation of poverty sees, in the first place, the level of consumption and current household income as privileged indicators.

Neither indicator is, however, able to fully exhaust the information needed to construct a measure of poverty, although consumption information is usually preferred because of both the greater reliability of the information collected and the greater stability of the series.

In this context, the many poverty concepts formulated can all be traced back to a traditional distinction between absolute and relative poverty [1, 2].

The approach based on the concept of absolute poverty starts from the definition of poverty as the failure to reach an objective minimum level of well-being and is therefore independent of the social and temporal context. Thus, reference is made to what is known in economic theory as the basic needs approach, according to which poverty is understood as failure to meet basic needs.

The relative poverty approach, on the other hand, is based on the assumption that the social condition of an individual, cannot be defined except from the environment in which he or she lives, i.e., individuals, families, population groups are considered poor when they live in a state of existence worse than the standard of the community to which they belong, i.e., they cannot attain the kinds of food, participate in activities and have those living conditions and comforts that are customary or at least widely encouraged and approved in the society to which they belong.

For the past few years, the subjective approach has been standing crosswise between the relative and absolute approaches. According to the subjective approach, individuals or families who declare themselves to be poor are considered poor in the comparison they themselves make in terms of their perceived well-being with members of the same society. The subjective approach starts, therefore, from the individual's perception of a state of social marginalization.

The presence of a varied range of definitions about poverty means that it is no longer necessary to resort to a single indicator but to a group of indicators useful for defining the living conditions of different subjects, [3–5].

As a result, scientific research options have moved toward the establishment of a multidimensional approach, sometimes abandoning dichotomous logic, and going as far as fuzzy classifications in which, each unit simultaneously belongs and does not belong to the category of poor.

A multidimensional index, which considers poverty as an overall condition of backwardness and deprivation and analyses relative poverty within the living standards of the target population, seems the most appropriate tool from the perspective of differential socioeconomic analysis of demographic phenomena.

The approaches used to arrive at synthesizing and measuring the incidence of relative poverty within the population under consideration are the Totally Fuzzy and Relative method and DBSCAN method. The first method uses the technique of Fuzzy Sets (Fuzzy Set) to obtain a measure of relative poverty incidence within a population from the statistical information provided by a plurality of indicators; the second is a method of clustering territorial units to obtain areas of high (or low) intensity of the phenomenon that allow the aggregation of contiguous spatial units homogeneous with respect to the phenomenon under study.

To overcome the limitations of the traditional approach, therefore, it is necessary to broaden the analysis to include a wide range of indicators of living conditions and at the same time to adopt mathematical tools to adequately account for the complexities and vague nature of poverty.

3.2 The Fuzzy Approach

The development of fuzzy theory initially stems from the work of Zadeh [3] and subsequently was conducted by Dubois and Prade [6]. The fuzzy theory develops starting from the assumption that each unit is not univocally associated with only one but simultaneously with all the categories identified based on links of different intensity (degrees of association).

The first measurement based on the fuzzy set theory, named TF (Totally Fuzzy), was suggested by Cerioli and Zani [7]. This logic can be applied to both continuous and ordinal variable cases. However, in the latter case, the maximum and minimum values can be determined by assuming the value of the lowest category as minimum and the highest as maximum.

Cheli and Lemmi [8] have proposed a generalization of this approach, called Totally Fuzzy and Relative (TFR). This method is also called "totally relative" because the value of the membership function is entirely determined by the relative position of the individual in the distribution of the population. The fuzzy TFR approach consists in defining the measurement of an individual's degree of belonging to the totality fuzzy, included in the interval between 0 (with an individual who does not demonstrate a clear belonging) and 1 (with an individual who demonstrates a clear belonging).

If we suppose to observe k indicators for each family, the function of belonging of the i-sima family to the blurred subset, can be defined as follows [8]:

$$f(x_{i.}) = \frac{\sum_{j=1}^{k} g(x_{ij}) \cdot w_j}{\sum_{j=1}^{k} w_j} \qquad i = 1, \ldots\ldots, n \tag{1}$$

where $w_1,\ldots,w_k$ represent a generic system of weights. The $f(x_{i.})$ is in practice a global poverty index, while $g(x_{ij})$ measures the specific deprivation of the i-sima unit according to the j-th indicator. Following the Totally Fuzzy and Relative Approach (TFR) proposed in [6] the function $g(x_{ij})$ is defined in terms of the partition function H (•) of the indicator X_j as follows:

$$g(x_{ij}) = \begin{cases} H(x_{ij}) & \text{if the risk of poverty increases with increasing of } x_j \\ 1 - H(x_{ij}) & \text{if the risk of poverty decreases with increasing of } x_j \end{cases}$$

The indices were chosen to identify different levels, related to aspects of poverty [9, 10]. The indices were grouped into three sets characterized by different situations in the different components considered: economic poverty, lack of basic services, lack of housing-related services.

The Totally Fuzzy and Relative method was applied on the data of all the Italian regions obtaining a value of the individual w_i weights, which varies according to the level of importance in determining the degree of quality of the situation.

The indicators were chosen to identify the different levels, related to the aspects of poverty, and grouped in the three described sets characterized by different situations in the different components considered: economic, social, and housing poverty. The Total Fuzzy and Relative method was applied on the data of all the Apulian municipalities obtaining a value of the individual w_i weights, which varies according to the level of importance in determining the degree of quality of the situation.

Minimum, maximum, and average values were calculated for each indicator of the different sets. For each set of indicators, the fuzzy value and its related values were calculated. As a result of the application, we classified the Apulian municipalities based on the fuzzy values obtaining the classification shown in Table 5. High values are significant of municipal situations of poverty, vice versa low values are significant of situations of no hardship.

Table 5. Absolute and percentage composition of municipalities by membership in fuzzy classes

Fuzzy values	Number of municipalities			%		
	SET 1 Economic hardship	SET 2 Social hardship	SET 3 Housing hardship	SET 1 Economic hardship	SET 2 Social hardship	SET 3 Housing hardship
0,0 ⊣ 0,2	0	14	127	0	5	49
0,2 ⊣ 0,4	29	48	72	11	19	28
0,4 ⊣ 0,6	84	40	22	33	16	9
0,6 ⊣ 0,8	139	91	8	54	35	3
0,8 ⊣ 1,0	6	65	29	2	25	11
Total	**258**	**258**	**258**	**100**	**100**	**100**

In particular, the percentage of municipalities with high economic hardship (fuzzy value between 0.8 and 1) appears to be smaller (2%) than the percentage representing social hardship (25%). Two of the largest percentage values (54%) and (35%) represent high economic and social hardship, respectively (fuzzy values between 0.6 and 0.8) compared to a percentage of 3 percent of municipalities with high housing poverty.

Going to graphically represent the different sets of indicators yields the following cartographies: darker colours refer to the highest values and thus to the municipalities with the greatest difficulties.

As for the set related to economic poverty indicators, the municipalities with high difficulties are only 6: Andria, Barletta, Bitonto, Lucera, Sannicandro di Bari and Trinitapoli (fuzzy values between 0.8 and 1), to which are added the 139 municipalities with high values (fuzzy values between 0.6 and 0.8) that are distributed in the area near Foggia, inland of Bari and Taranto (Fig. 1).

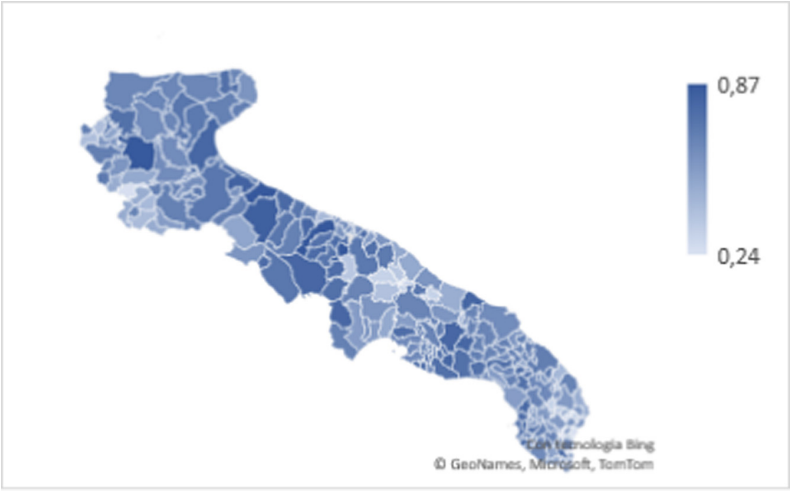

Fig. 1. Spatial Distribution-Economic Poverty (Fuzzy Values)

Relative to social hardship in high hardship (values between 0.8 and 1) and hih hardship (values between 0.6 and 0.8) there are 65 and 91 municipalities respectively distributed among the provinces of Foggia, BAT and Taranto. (Fig. 2).

Finally, regarding the lack of housing-related services (Fig. 3) there are 29 municipalities with problematic situations located mainly in the hinterland of Foggia and Brindisi (values between 0.8 and 1). Most Apulian municipalities do not experience housing problems at least in terms of the indicators considered because almost all homes are now reached by the essential services of drinking water, toilet, bathtub or shower and hot water, as well as Ultra Broadband.

3.3 The DBSCAN Approach

The fuzzy approach responds to the need to identify spatial areas and/or population subgroups characterized by situations of hardship or high social exclusion because it allows a measure to be defined of the degree to which they belong to the fuzzy set of the deprived. It is possible to employ methods of clustering territorial units to obtain areas of high (or low) intensity of the phenomenon by using clustering methods that allow the aggregation of contiguous spatial units homogeneous with respect to the phenomenon under study. Hence the need to supplement the fuzzy approach with one based on DBSCAN.

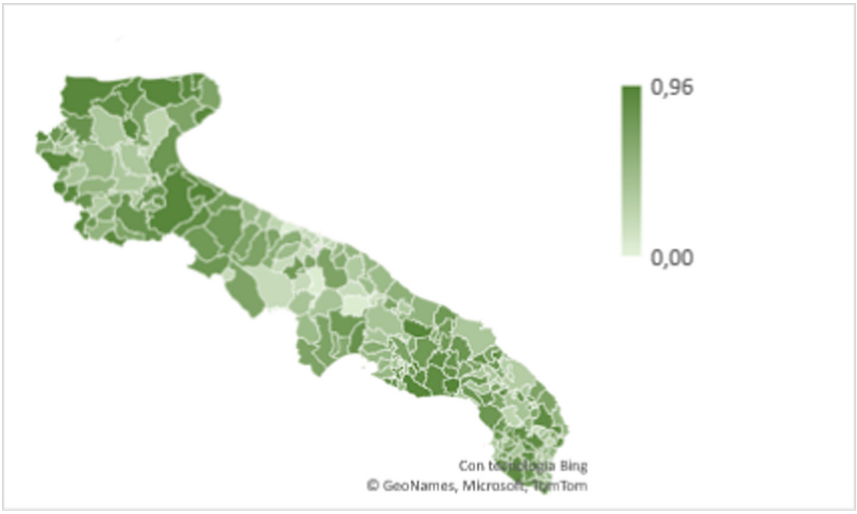

Fig. 2. Spatial Distribution-Social Poverty (Fuzzy Values)

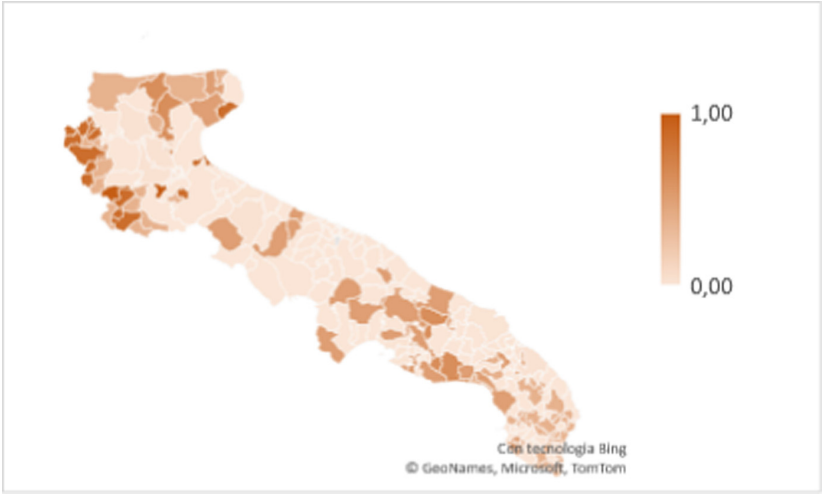

Fig. 3. Spatial Distribution-Housing Poverty (Fuzzy Values)

DBSCAN (Density Based Spatial Clustering of Application with Noise) [11], was the first clustering method based on spatial density. The basic idea is to define a new cluster or extend an existing cluster, the surroundings of a point of a given radius ε, must contain at least a minimum number of MinPts, i.e., the density of the points must exceed a certain threshold. DBSCAN as input needs the parameters ε and MinPts to be fixed. Their choice is crucial since they determine whether a group of points is a cluster or simply noise.

The authors in this regard provide a heuristic that they consider sufficiently valid. Let d denote the distance of a point p from its k -th nearest neighbour; within a distance d from p are then contained k + 1 points (barring special cases in which multiple points are at the same distance d from p). Having fixed k, we define a k -dist function, from the dataset D to the set of real numbers, that assigns to each point in D the distance to its k -th nearest neighbour. Then the points in the dataset are sorted in descending order with respect to k -dist, resulting in a graph called the sorted k -dist graph.

This graph provides information about the density distribution of the dataset: in particular, by choosing an arbitrary point p and fixing MinPts to k and ε to k -dist(p), all points having equal or lesser k -dist will be core points.

Having chosen a threshold point on the graph, to which corresponds a value of k -dist and hence ε, all patterns preceding it turn out to be noise while those following it will be assigned to clusters. The authors recommend choosing as a threshold the point at the first re-entrant that can be seen in the graph's trend; Such determination of ε has ambiguities within it since the graph does not have a sharp dip but often fluctuations are evident so the choice of ε is reduced to a trial-and-error choice of the most appropriate one.

The DBSCAN algorithm has been applied to municipalities to aggregate them even from different provinces to find spatially close and contiguous areas with similar characteristics to better organize spatial planning.

The municipalities were aggregated through the DBSCAN algorithm, based on the fuzzy value.

To define the optimal value of ε, the k nearest neighbour distances in a matrix of points were calculated. The idea was to calculate, the average of the distances of each point to its k nearest neighbours. The value of k was initialized equal to the same value of MinPts.

Next, these k-distances were plotted in ascending order, and the goal was to determine the inflection point corresponding to the optimal parameter. Figures 5, 7 and 9 show plots of the k-distances for each of the three sets of indicators, and the optimal value that was empirically chosen to assign to ε is highlighted. Increasing even slightly the value of ε concentrates the points into a single cluster, while decreasing the value of ε increases the noise points and increases the clusters.

The three cartographies in Figs. 4, 6 and 8 show in yellow the noise points, i.e., those not classified by the algorithm.

Specifically, the first cartography, Fig. 4, was processed by assigning the values obtained with the DBSCAN algorithm having assigned ε value 0.14, MinPts value 3 and using the fuzzy values of the first set of indicators related to economic poverty. Ten clusters highlighted with the various colours were obtained. The clusters formed by the municipalities with a higher fuzzy value and spatially close are those highlighted by the orange and yellow ochre colours and the blue corresponding to the areas of the provinces of Foggia and Taranto.

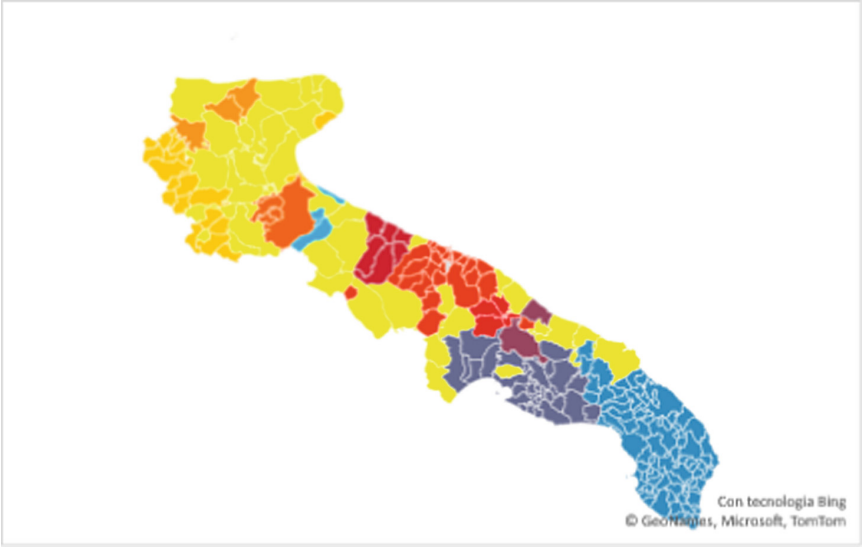

Fig. 4. Identification of dense areas with DBSCAN: Economic Poverty ($\varepsilon = 0, 14$ and MinPts = 3)

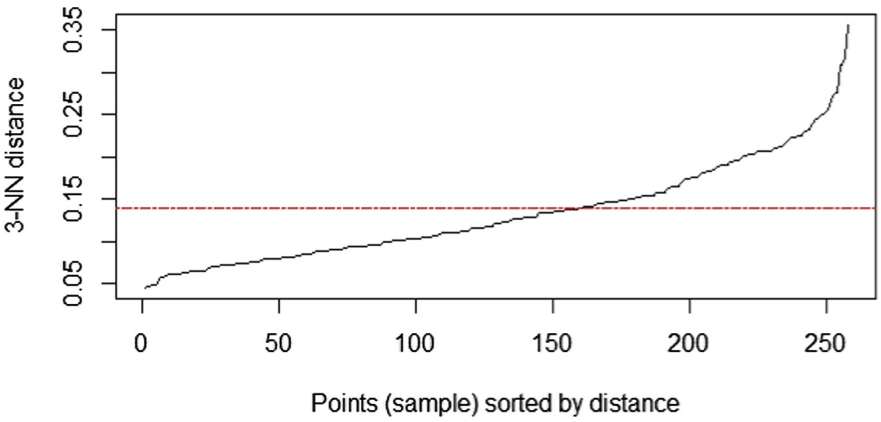

Fig. 5. Graph of k-distances for $\varepsilon = 0, 14$

The second cartography, Fig. 6, was processed by assigning the values obtained with the DBSCAN algorithm having assigned ε value 0.176, MinPts value 3 and using the fuzzy values of the second set of indicators related to social poverty. Thirteen clusters were obtained, those formed by municipalities with a higher fuzzy value and spatially close are highlighted by orange and the yellow ochre and the blue colors corresponding to the areas of Foggia, Brindisi and Taranto.

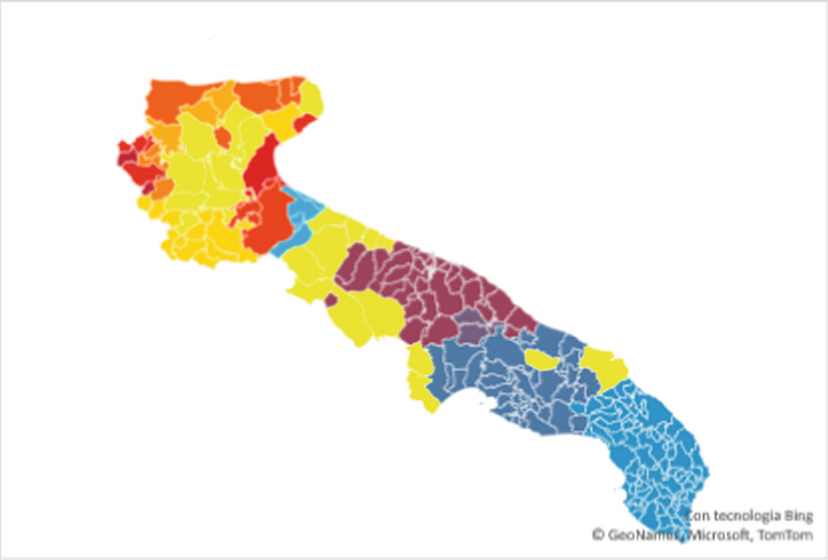

Fig. 6. Identification of dense areas with DBSCAN: Social Poverty ($\varepsilon = 0,176$ and MinPts $= 3$)

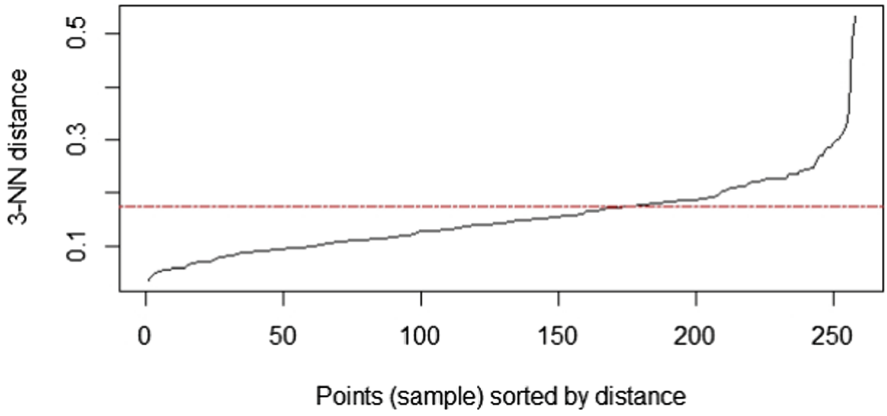

Fig. 7. Graph of k-distances for $\varepsilon = 0,176$

The third cartography, Fig. 8, was processed by assigning the values obtained with the DBSCAN algorithm having assigned ε value 0.17, MinPts value 3 and using the fuzzy values of the third set of indicators related to housing poverty. 11 clusters highlighted with the various colors were obtained, those formed by the municipalities with a higher fuzzy value and spatially close are those highlighted by the red and blue colors in the areas of Foggia and Brindisi respectively.

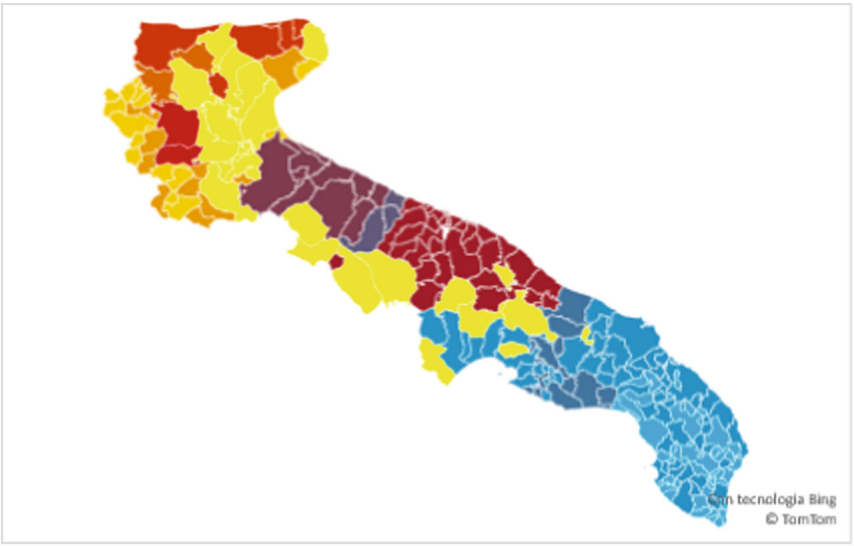

Fig. 8. Identification of dense areas with DBSCAN: Housing Poverty ($\varepsilon = 0,17$ and MinPts $=$ 3)

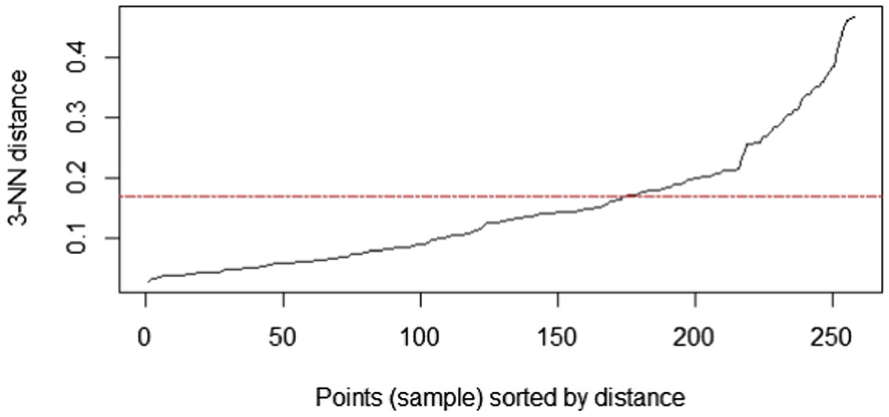

Fig. 9. Graph of k-distances for $\varepsilon = 0,17$

4 Conclusions

Poverty connotes a hardship that does not necessarily end in the lack of monetary resources but involves a plurality of dimensions of a social and cultural nature such as education, health, housing, and is embodied in the lack of equitable access to a plurality of essential goods and services.

In both academic literature and international scientific reports, however, the multidimensional nature of poverty is emphasized, implying the need to use not a single indicator but a group of indicators, which are useful in better delineating the living conditions of different individuals.

A first idea that emerges from this work is related to the ability to describe territorial phenomena through an integrated model, which starts from the construction of socioeconomic indicators, which are multidimensional in nature, and then adopts models capable of identifying areas at risk of hardship through statistical methods [12–14].

In this way, as with the data studied in this paper, it is possible to assess the problematic aspects that characterize households in a specific historical, geographical, and social context, as well as to assess socioeconomic distress, identify the profiles of new poverty and the impact of poverty on public institutions. In fact, the results presented in this paper from the fuzzy and DBSCAN approaches show that almost always the same are the provinces that need more attention from local policies. Targeted government action would be needed to support these areas. Certainly, to reduce poverty, it is necessary to ensure equal rights, access to economic and natural resources, technological resources, property, and basic services.

Future research developments may address other urban topics (such as real estate market and housing conditions) in order to highlight other useful issues through a spatial analysis of different sources of indicators as shown in [15, 16].

References

1. Analisi della povertà relativa Siqual, Istat 1997. http://siqual.istat.it/SIQual/visualizza.do?id=8888916&refresh=true&language=IT
2. La misura della povertà assoluta. Istat 2009. https://ebiblio.istat.it/digibib/Metodi%20e%20norme/MOD1546628Ed2009N39.pdf
3. Zadeh, L.A: Fuzzy sets. Inf. Control **8**(3), 338–353 (1965)
4. Poli, G., Muccio, E., Cerreta, M.: Circular, cultural and creative city index: a comparison of indicators-based methods with a machine-learning approach. Aestimum **81**, 53–70 (2022). https://doi.org/10.36253/aestim-13880
5. Cerreta, M., Panaro, S., Poli, G.: A knowledge-based approach for the implementation of a SDSS in the Partenio Regional Park (Italy). In: Gervasi, O., et al. (eds.) ICCSA 2016. LNCS, vol. 9789, pp. 111–124. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-42089-9_8
6. Dubois, D., Prade, H.: Fuzzy Sets and Systems. Academic Press, Boston, New York London (1980)
7. Cerioli, A., Zani, S.: A fuzzy approach to the measurement of poverty. In: Dagum, C., Zenga, M. (eds.) Income and Wealth Distribution, inequality and Poverty. Springer, Berlin (1990). https://doi.org/10.1007/978-3-642-84250-4_18
8. Cheli, B., Lemmi, A.A.: Totally fuzzy and relative approach to the multidimensional analysis of poverty. Econ. Notes **24**(1), 115–134 (1995)
9. Montrone, S., Perchinunno, P., Rotondo, F., Torre, C.M., Di Giuro, A.: Identification of hot spots of social and housing difficulty in urban areas: scan statistic for housing market and urban planning policies. In: Murgante, B., Borruso, G., Lapucci, A. (eds.) Geocomputation and Urban Planning, Studies in Computational Intelligence, Vol. 176, pp. 57–78. Springer, Heidelberg (2009). https://doi.org/10.1007/978-3-540-89930-3_4

10. Perchinunno, P., Rotondo, F., Torre, C.M.: A multivariate fuzzy analysis for the regeneration of urban poverty areas. In: Gervasi, O., Murgante, B., Laganà, A., Taniar, D., Mun, Y., Gavrilova, M.L. (eds.) ICCSA 2008. LNCS, vol. 5072, pp. 137–152. Springer, Heidelberg (2008). https://doi.org/10.1007/978-3-540-69839-5_11
11. Ester, M., Kriegel, H.-P., Sander, J., Xu, X.: A density-based algorithm for discovering clusters in large spatial databases with noise. In: Proceedings of the 2nd International Conference on Knowledge Discovery and Data Mining, Portland (1996)
12. Massari, A., L'Abbate, S., Mongelli, L., Perchinunno, P.: Spatial statistical model for the analysis of poverty in Italy according to sustainable development goals. In: Lecture Notes in Computer Science, vol. 13378 (2022). https://doi.org/10.1007/978-3-031-10562-3_45. ISBN: 978-3-031-10535-7
13. Perchinunno, P., Massari, A., L'Abbate, S., Mongelli, L.: Sustainable Development Goals per l'analisi statistica della povertà. Metodi e analisi statistiche, Dipartimento di Economia e Finanza, Università degli studi di Bari Aldo Moro., pp. 27–40 (2022). ISBN 978-88-6629-078-0
14. Perchinunno, P., Rotondo, F., Mongelli, L., L'Abbate, S.: Ecological transition and sustainable development integrated statistical indicators to support public policies. Sci. Rep. **12**, 18513 (2022). https://doi.org/10.1038/s41598-022-23085-0
15. Anelli, D., Tajani, F.: Spatial decision support systems for effective ex-ante risk evaluation: an innovative model for improving the real estate redevelopment processes. Land Use Policy **128**, 106595 (2023)
16. Anelli, D., Tajani, F., Ranieri, R.: Urban resilience against natural disasters: mapping the risk with an innovative indicators-based assessment approach. J. Clean. Prod. **371**, 133496 (2022)