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Agriculture and Agricultural Science Procedia 8 (2016) 499 – 508

Agriculture and Agricultural Science Procedia

Florence "Sustainability of Well-Being International Forum". 2015: Food for Sustainability and not just food, FlorenceSWIF2015

A geostatistical multicriteria approach to rural area classification: from the European perspective to the local implementation

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Abstract

The rurality index has been explored using Spatial Statistical Techniques, Multicriteria Decision Support System and Cluster Analysis to obtain areas with homogenous characteristics. The profile outlined is an effective tool to support decision-makers in defining actions aimed to the development of rural areas, in view of a global rationalization and optimization of resources.To check the consistency of results, the model was tested within Basilicata region, which is well-known to the authors and which has been extensively investigated with regard to its levels of rurality. The results show eight homogeneous areas, classified in relation to the Rural Index. The results obtained enable locating resources based on specific needs.

Peer-review under responsibility of Fondazione Simone Cesaretti

Keywords: composite index; rurality index; PCA weighted; spatial cluster.

1. Introduction

The European Union and all world governments have long been committed to overcoming the existing inequalities between urban and rural areas by social and political measures well suited to the diversified socio-economic and site-specific conditions.

Through the European Agricultural Fund for Rural Development (EAFRD 2014/2020), the EU has allocated 95.6 billion Euros for all member States (annex 1 to Regulation (EU) No 1305/2013) with a view to promoting the

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Peer-review under responsibility of Fondazione Simone Cesaretti
doi:10.1016/j.aaspro.2016.02.055

development of rural areas. The above Fund allocates to Italy a budget of 10.4 billion Euros, which add to 18.6 billion Euros of national co-financing (which confirms that Italy has also invested to promote rural development) for a total overall budget of 29 billion € for the 2014/2020 seven-year period, i.e. about 6% more compared to the past programme period (EAFRD 2007/2013).

Identifying the rural areas that need greater targeted investments – on the basis of the degree of rurality - is not easy, since this concept has not a univocal and objective definition (European Commission, 1997). This difficulty is intrinsically connected to the profound social, economic and cultural changes that populations have experienced throughout their history; these changes cannot obviously be considered as being uniformly distributed in the space. In this regard Blanc (1997) states that: *the concept of rurality is still undefined, due to the multiple factors that contribute to classify a space as rural; this pertains to the many ways space heterogeneity may be perceived*. Since 1950 till now, three main definitions of rurality have prevailed in the Italian scenario, corresponding to three historical periods of major social, economic and cultural changes. Firstly, the definition of *agricultural rurality (1950-1960),* where the concept of rural is identified in the rural-urban dualism and rurality is meant as unease and poverty in contrast with urban, meant as ease and richness; secondly, the notion of *industrial rurality (1960-1990),* characterized by the growth of an economic system focused on small and medium enterprises mutually related to the rural system. Lastly, in the concept of *post-industrial rurality (from 1990 to date),* rurality is meant to express high environmental and life quality (Saraceno 1994; Sotte et al. 2012).

In the latter phase, the primary sector has been fundamental to the notion of rural and a new expression has been coined, i.e. sustainable agriculture that involves farming systems, which are environmentally-friendly, economically viable and healthy, in terms of food quality and safety. On this basis, rural areas are called to play a major role in the conservation and recovery of traditional techniques, aimed at the preservation of landscape and local culture.

This makes clear that the territorial dimension is intended as an element of typicality[†], in the sense of diversity and distinctiveness, thus becoming a strength that involves original traditions and socio-economic features typical to each community-based area. Following this new approach, the notion of rurality is closely related to the local area and is largely affected by the scale of observation taken as reference. It follows that a regional-based approach seems reasonably correct.

Despite the above considerations and the criticisms expressed by the scientific community, the EU still continues to apply the OECD methodology (1994)[‡] for the identification of rural areas on the European scale. The procedure for determining the degree of national and local rurality necessitates, however, further distinctive traits that characterize the area concerned. In Italy, accurate classifications have been proposed by the main national statistical services, such as ISTAT (1986) and INSOR (1992, 1994). Nevertheless, we do not yet have an appropriate general framework to harmonize data from localized information.

Considering that areas with similar characteristics may have a different class of rurality if they are found in areas far from each other (in spatial terms as well as in their socio-economic context), the aim of the present work is to define an appropriate general methodology to identify portions of land that need targeted political-economic measures.

This methodology, based on a *Spatial Decision Support System* (S-DSS,Viccaro et al. 2014) applied to Basilicata region, has involved the use of a geographical multicriterion model (Cozzi et al. 2014; Malczewski 2004; Romano et al.2013) correlated to geostatistical and spatial analysis techniques, which have enabled the definition of a rurality index closely related to the area concerned, on the basis of some identified variables that would best describe the

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[†] The above considerations are confirmed by the 1988 reform of structural Funds and the launch of a significant territorial policy (Fanfani 1998)

[‡] This methodology is based on population density: local units are considered as rural if their population density is below 150 inhab./km². Therefore the regions fall within one of the three following categories:

1. Mainly Rural Areas (PR): over 50% of the population live in rural local units;
2. Intermediate regions: 15% to 50% of the population live in rural local units;

Mainly Urban Areas (PU): less than 15% of the population lives in rural local units.

degree of rurality. The above index has finally been explored using spatial statistical techniques so as to obtain cluster areas with homogenous characteristics.

2. Materials and Methods

The concept of “endogenous development” (ED) currently dominates the socio-economic element of the European Rural Development Policy (RP). The ED is sometimes used synonymously with “locally-based” (Martin and Sunley 1996) or “localised” or “place-based” development, and refers to approaches that emphasise the need for integrated planning in a territorial approach (Vázquez-Barquero 2006) and the relevance of soft factors such as “leadership” and “entrepreneurship” for development (Garofoli 2002; Stimson 2009;Stough and Salazar 2009;Margarin2013).

In this context, the proposed approaches lead to bottom-up management models, where the place-based features and the local preferences are the guiding principles of regional policy decisions (Stimson and Stough 2009; Vázquez-Barquero 2006).

The identification of rural areas at the regional level can be an effective tool to support decision-makers in defining measures aimed at their development, in view of a global rationalisation and optimisation of resources. Based on this understanding, this paper aims to identify a method applicable to different contexts and able to point out the single peculiarities of these areas, for the purpose of setting up homogeneous units. Given the territorial scale of the issue, the research proposes an S-DSS system and the implementation of geostatistical and clustering analysis techniques.

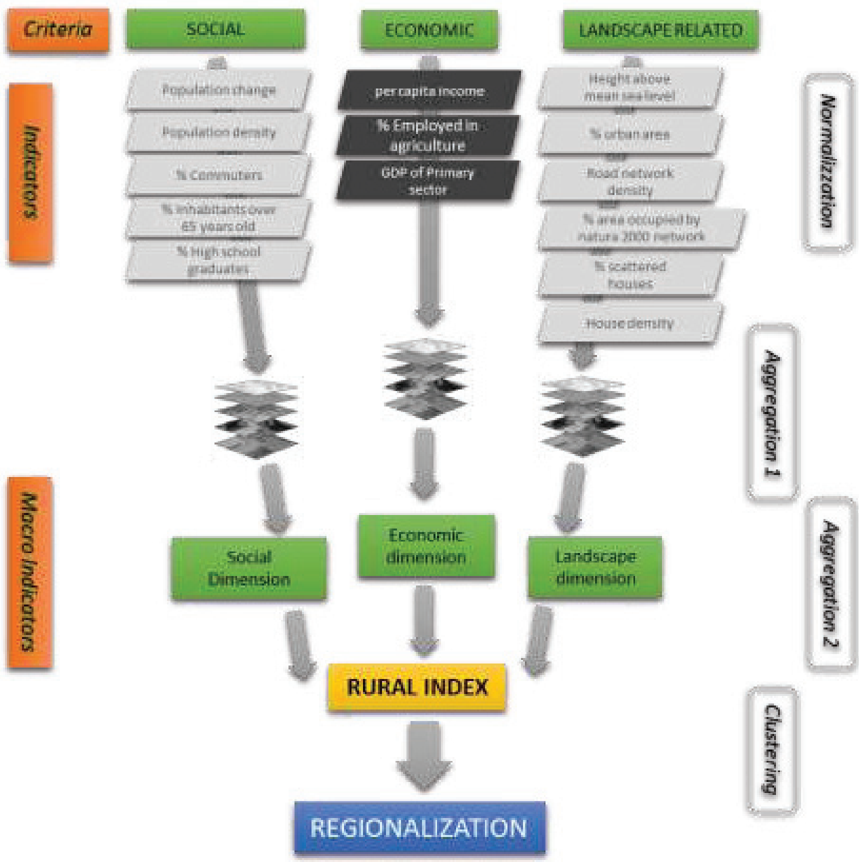

Fig 1. Simplification scheme of the model adopted

The whole model is based on a C**omposite Index (CI)** approach **(**Michalek and Zarnekow 2012). The expected advantages from using a composite index to policy analysis include: fullness, multi-dimensionality and the ability to reduce empirical sets of the hundreds of available indicators to a one, or more, synthetic measure (Saisana and Tarantola, 2002; OECD 2005; Michalek and Zarnekow 2012). A good **Rural Index** (RI) should be able to aggregate the indicators using objective and statistically verifiable weights. RI should also fulfil a number of general conditions (Hagerty et al. 2001; OECD 2005), e.g. it should be based on a sound theoretical framework; the selection of variables should take into consideration their relevance, analytical soundness, accessibility, geo-localization, etc.

The literature review on the subject reveals that numbers of applications have been carried out on the construction of the CI, including (Deutsch et al. 2001; Henderson and Black 1999; Rahman et al. 2005; Kaufmann et al. 2007. The resulting structure is as follows:

- Selection of appropriate variables/coefficients
- Weighting the variables/indicators according to their relative importance
- Application of unbiased aggregation techniques
- Making the index useful for policy purposes.

The analysis model applied to Basilicata region follows this logical pathway (Figure 1). From the identification and standardization of the most appropriate indicators to define the concept of rurality (see 2.1), the above model identifies three macroindicators (Social, Economic, Landscape[§]-related) that are then aggregated (see 2.2) leading to the Rural Index (RI). The final result of the model is the identification, via clustering techniques (see 2.3), of the existing rural areas in the region concerned.

2.1 Characterizations and treatment of indices

The first step for the definition of rural areas was the choice of indicators (tab. 1). It was based on an accurate reinterpretation of the existing literature (ISTAT1986; INSOR 1992, 1994; OECD 1994) and on the assessments of the possible descriptions of the concept of rural, which may be influenced by the political, social and economic needs of different territorial contexts, added to which the application of the OEDC methodology tends to flatten different situations (Zolin 2012). Another major aspect in the choice of other indicators has been the availability of data for disaggregation that was helpful to the implemented work (it has thus been possible to spatialise data using *spatial join* techniques, in order to obtain maps characterizing the area for each variable considered).

Given the need to aggregate the maps obtained for the three indices considered, the method has required their standardisation to make them numerically comparable (Riberio et al. 2014), by combining geographical multicriteria procedures using fuzzy methods (Zadeh 1965).

Fuzzy logic is an extension of the classical binary valued logic (0/1; true/false; clear/dark) that can best describe the characteristics of real-life phenomena, often characterised by vagueness and uncertainty. So if in the crisp logic an element is well-defined (as could be the case of the boundary of a protected area that distinguishes clearly the included area from the excluded area), in the fuzzy logic a membership function (*fa*) is identified in a range between 0 and 1. This function represents the degree to which each element belongs to a given well-defined interval. This methodology is largely suitable for coping with uncertainty, although it has some difficulties in the application, mostly due to the need to identify the appropriate membership functions.

In the standardisation of criteria, the present paper has made use of *spatial fuzzy functions*, selected on the basis of the kind of treated data and the uncertainty associated with it (Table 1). Once variables are identified, the analysis

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[§] Landscape means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors (Council of Europe, 2000) continues through the implementation of an appropriate rule of aggregation, so as to express for each single portion of land the weighted sum of the factors that contribute to express the concept of rurality.

Table 1. Macroindicators, Variables and Fuzzy functions applied.

Macroindicators	Variable	Fuzzy function					Criterion weights (W_J)	
			Control point					
			a	b	c	d		
Social	Population density	*Decreasing linearly*			10	394	0.2019	0.3854
	% high school graduates				14	43	0.2106	
	% Population change				-26	22	0.2142	
	% Inhabitants over 65	*Increasing linearly*	12	41			0.1870	
	% Commuters		9.5	77			0.1864	
Economic	% Employed in agriculture	*Increasing linearly*	2	35			0.3429	0.2371
	Per capita income	*Decreasing linearly*			5047	17002	0.3442	
	GDP of Primary sector				33	2632	0.3130	
Landscape related	Height above mean sea level	*Increasing linearly*	19	1237			0.1358	0.3775
	% Scattered houses		0	48			0.1714	
	% area occupied by natura 2000 network		0	51			0.1547	
	House density	*Decreasing linearly*			6	154	0.1670	
	Road network density				1118	7076	0.1852	
	% Urban area				0	8	0.1861	

2.2. Weighted Linear Combination

One of the most largely used aggregation techniques is the *Weighted Linear Combination* (WLC, Malczewski, 2004; Massam, 1988). The WLC is a rule of aggregation that may be represented by the following equation:

$$S = \sum_i w_i x_i$$

where*S* (suitability) is the land suitability for a given use;

wi the level of importance/weight attributed to the *i-th* factor;

xi the standardised value of the *i-th* factor.

The WLC method is connected with the class of compensatory methods in the sense that the low value of a criterion may be compensated by the high value of another criterion.

In order to assign to each variable a level of importance/weight in an objective manner, the PCA has been applied in this work (Cozzi et al. 2015; Eastman 1997). The PCA is a multivariate statistical technique that enables the analysis of relationships between different quantitative variables. It first calculates a matrix of correlation between the variables: high correlation coefficients point out variables highly correlated with each other and thus redundant. Therefore, the cumulative contribution of eigenvectors to the principal components was calculated for each variable. The result is multiplied by the eigenvalue referred to each component, so that the PCA measures the relative importance of variables (weights) that are not excluded from the model (Alleva G. et al. 2009; Sanguansat 2012).

2.3. Regionalization: SKATER method

The regionalization is a classification procedure applied to spatial objects through an area-based representation, which groups them in homogenous neighboring regions (Assunçãoet al.2006).

In literature there are different examples of clustering methods (Bersimisa 2015; Desjeux 2015; Yurui L. 2015): the most suitable for the peculiarities of our analysis is the SKATER algorithm (*Spatial 'K'luster Analysis by TreeEdgeRemoval*) that was chosen on the grounds of a careful literature review and based on trials conducted on different clustering algorithms. The quality of the outcome has also been assessed by the authors, drawing on the knowledge of the test area.

To identify adjacency conditions the SKATER procedure makes use of the connectivity graph in which each object (in our case the objects are the municipalities) is connected with an edge (corresponding to the barycentre of the municipality), each of which is linked to the neighboring vertices.

The cost of each edge is proportional to the dissimilarity between the linked objects; this diversity is given by the attributes associated to the objects (in this case the rurality index) and the weighted distance that exists between them (Assunçãoet al.2006). To limit the complexity of the obtained graph, the highly dissimilar edges are “cut out” until you obtain a “Minimum Spanning Tree” (MST) that enables the connection between all objects having a minimum weighted distance (Pettie 2002). Lastly, cutting out progressively the MST and removing the residual branches with the highest dissimilarity, you obtain separate objects, characterised by the maximum potential internal homogeneity and the highest possible heterogeneity between the agglomerates obtained (Bernetti 2010). For further insight on the construction of MSTs and their cutting out, readers are referred to Assunção et al. (2006).

3. Results

Rurality indicators were standardised using fuzzy functions [0-1], where 0 and 1 represent, respectively, the minimum and maximum ability to describe the degree of rurality. The indicators obtained, grouped as Social (by selecting all appropriate variables to describe the social conditions of municipalities), Economic and Landscape-related, have then been aggregated via WLC, once weights were assigned by means of the PCA, with a view to obtaining three maps representing the degree of rurality for the three macroindicators concerned (Figure 2).

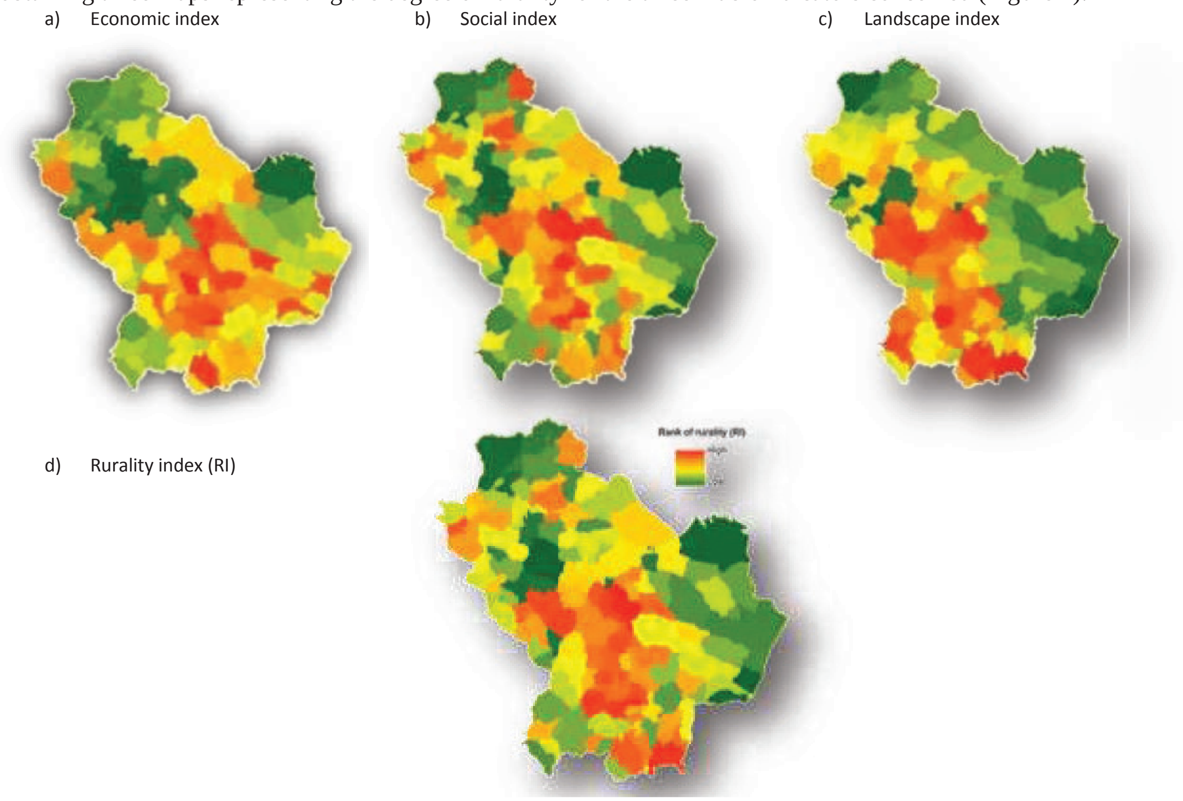

Fig 2. Macroindicator (a, b, c) and Rurality Index (d)

The above maps were then weighted by means of the PCA and aggregated via the WLC, thus obtaining a single map of the rurality index (RI) for Basilicata region (Fig 2).

However, given the need to identify portions of land that might be defined in relation to the degree of rurality, the SKATER procedure was applied: it was disaggregated at the municipal level and clustered in eight areas of homogeneous rurality (Fig3.).

Figure 3 shows clearly that the area of highest rurality (zone 1) is located along the ridges of Apennines, in the central part of the region, whereas less rural areas are those that surround the areas of highest population density in the region, where services and industry are the driving sectors. Zone 1 includes 37 municipalities and extends over about 2,203 Km², accounting for 22 % of the regional surface area, with a residential population of about 48,000 inhabitants, i.e. only 8.3% of the total residential population of the region. On the other hand, zone 4 is the area with the lowest rurality index; it covers 9 municipalities, including the regional capital, and extends over a surface area of 584 Km², accounting for 6% of the total regional area; the residential population includes about 104,970 people (18% of the regional population).

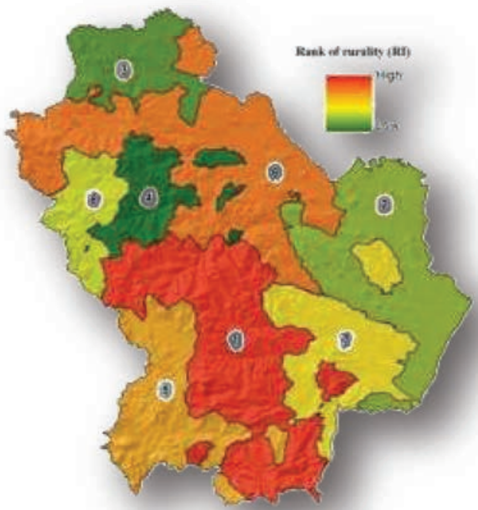

Fig 3. Result of Cluster SKATER analysis

To make this information easily available, the three variables have been plotted on a graph (figure 4) that displays the deficits of the eight areas compared to the means of the three macroindicators within the area under study.

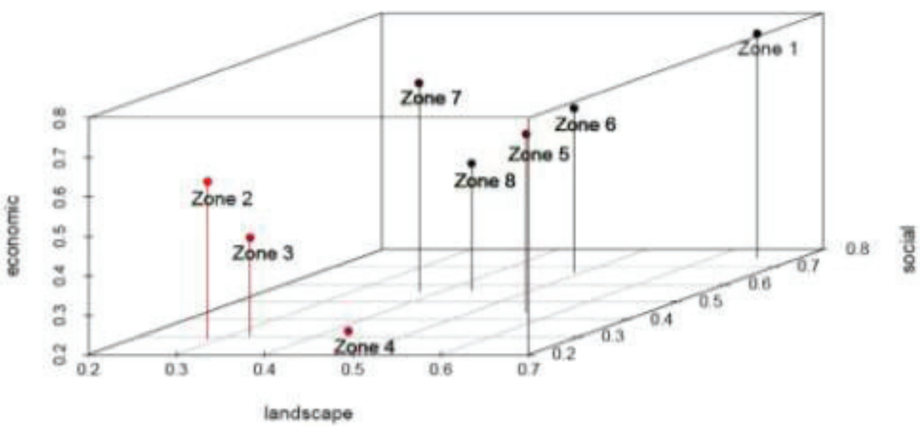

Fig 4. 3-D scatter plot of macroindicators

The graph shows, for example, that zone 7, which is a moderately rural area, has a territorial index of 0.38, well below the regional average, which is around 0.44, but it has – at the same time - a high economic index of 0.73, compared to the regional average of 0.57. This means that it has high potential at the landscape level, in terms of infrastructures and flat soils, but it would deserve special attention and targeted policies for increasing income opportunities; this outline seems to match the priorities identified in the rural development plan for the 2014-2020 period[**].

As a matter of fact, zone 7 would be suitable for the measures included in Priority 6 "Operating for social cohesion, poverty reduction and economic development in rural areas". This example shows that it would be possible to improve the potential of the areas concerned with measures, while optimizing the economic resources made available by the competent bodies.

4. Conclusions

There is a growing emphasis laid by the EU on rural areas and their development, as proved by the increased availability of EU funds aimed to overcome the existing inequalities between rural and urban areas. EU incentives are directed towards the diversification of economic activities within rural areas and multifunctionality of agriculture. The identification of a methodology aimed at identifying the areas of high rurality is an issue that has long been explored by scientists committed to finding a complete solution; this article proposes a new methodology, which is well suited to the varying scales of investigation of rurality. Besides supplying decision-makers with a sufficient set of knowledge for the rationalization and optimisation of resources, it might also become an effective tool to assess the past policies and better orient future choices.

Despite the good outcome ensured by the proposed model, which has been applied to a testing area that is well-known to the authors of this work, further improvements of the methodology could be envisaged to obtain increasingly reliable results; for example, it would be useful to consider not only the variables already assessed in this study but also their variation over time, with a view to identifying the growing/declining trends of different identified areas. Moreover, the proposed model does not consider the political-economic measures taken in the identified areas nor how those areas have reacted to them.

Another important remark is that national statistical services provide a growing deal of usable information, so that in future new variables will certainly be identified to better describe the concept of "rurality" and recognise the areas that match this definition. However the profile outlined proves to be an effective tool to support decision-makers in defining actions aimed to the development of rural areas, in view of a global rationalization and optimization of resources.

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