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Towards sustainable and inclusive communities: an integrated approach to assess sustainability in rural areas

Sustainable development is a priority in EU rural development strategies. Due to the multidimensionality of the sustainability issue, this paper presents a Spatial Decision Support System to assess territorial sustainability and help decision-makers in rural planning process. Four globally valid sustainability dimensions were considered (long-term ecological sustainability, satisfaction of basic human needs, promotion of intragenerational and intergenerational equity), measured by a set of socio-cultural-political-environmental indicators by using the Mazziotta and Pareto method.
The results of the S-DSS, implemented and verified in Basilicata region (southern Italy), provide the maps of sustainability values for each dimension at municipalities level, showing the usefulness of the tool to identify and monitor rural areas that require priority interventions and resources, in order to foster sustainable rural development.

1. Introduction

"If you don't know where you're going, you end up somewhere else." (Yogi Berra)

In this historical phase, the severity of some social costs, the excessive use of natural resources and the spread of pollution, have led to redefine community preferences and needs, paying attention not only to economic growth but also to social development and environmental protection with a view to sustainability (Böhringer and Jochem, 2007; Hàk et al., 2016; Salvati and Carlucci, 2014).

The concept of sustainable development was launched with the publication *Our Common Future*, commonly known as the Brundtland Report (WCED, 1987). Three decades passed since its definition, and achieving sustainable development is still a priority in the international and national agendas (Viccaro and Caniani,

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2019). However, sustainability is a really complex issue, as well as its assessment, and it is widely believed that public institutions cannot develop a strategy for sustainable development without a quantitative knowledge of overarching goals to reach and the state of the "system" in order to measure progress toward them (Costanza et al., 2016; Ronchi et al., 2002). In 2015, all UN Member States adopted the 17 Sustainable Development Goals (SDGs), representing a universal call to reach socio-economic and environmental sustainability by 2030. To that, the United Nations Statistical Commission established the Inter-Agency Expert Group on SDGs to identify a shared statistical information framework, based on a set of over 200 indicators, as a tool for monitoring and evaluating progress towards the SDGs.

Since that, multiple initiatives have helped to advance the "science of sustainability measurement", developing new indicators and models to help decision-makers in sustainable development policies at different scales. In particular, great progress has been made in the use of sustainability indicators at the national level and, while authors highlight the necessity to develop indicators of planetary sustainability (Costanza et al., 2016; Dahl, 2012; Holden et al., 2014), new approaches have been applied for integrating (and measuring) sustainability into regional development policy and planning (Boggia and Cortina 2010; Boggia et al., 2014, 2018; Ferretti et al., 2020; Palmisano et al., 2016; Paolotti et al., 2019; Péti, 2012; Salvati and Carlucci, 2014; Zolin et al., 2017). In Europe, these new approaches are stimulated by the European development idea of 'territorial cohesion'. Camagni (EEA, 2010, p. 43) claims that "*territorial cohesion has been defined as being the spatial representation of sustainability (which is time-oriented), since both territorial cohesion and sustainability represent an integration of people, planet and profit*". Territorial cohesion represents an opportunity to capitalise on the strengths of each territory so they can best contribute to the sustainable and balanced development of the EU.

In this context, promoting rural development is fundamental for the European Union: as pointed out in the Cork 2.0 declaration "*rural areas and communities play a key role in the implementation of the SDGs*" (EU, 2016) and it is, therefore, important to maintain high levels of life satisfaction in rural areas, as an indispensable condition to foster sustainable development (Boggia and Cortina, 2010; Ravetz, 2000). For a better application of programmes regarding rural development, such as the Rural Development Programmes (RDPs), it is very important to analyse and understand local opportunities and territorial characteristics. In this way, it is possible to guide and manage rural development. Different studies have largely demonstrated that RDP expenditure tends to be concentrated more on richer regions (or municipalities) than on ones that are lagging behind, causing territorial imbalances (Camaioni et al., 2019; Kiryluk-Dryjska et al., 2020). So, assessing the level of rural sustainable development in specific areas and finding explanations for the different levels is important in rural planning processes in order to increase the efficiency of rural development expenditures. This can help to maintain and improve both the level of development and the level of sustainability in rural areas (Boggia et al., 2014).

However, measuring sustainability in rural areas is not easy: rural areas present very different elements contributing to sustainable development (different environments, economic activities, social and cultural traditions), a concept in itself already complex. Thus, developing decision support systems based on spatial analysis of composite indicators is necessary to explore latent spatial patterns and trends of the main factors affecting sustainability in rural areas, providing an objective procedure able to estimate the importance of different drivers of sustainable development (Salvati and Carlucci, 2014). As pointed out by Palmisano et al. (2016), the integration of a Decision Support Systems (DSS) and of a Geographic Information System (GIS), known as Spatial Decision Support Systems (S-DSS), can provide different benefits in spatial planning processes, such as (i) the possibility to structure and evaluate the decision problem based on multiple evaluation criteria that have quantitative priority according to a specific decision rule, (ii) classify a series of alternatives based on their relative importance in meeting the analysis objective and (iii) identify the rural sustainable development potentialities of rural municipalities. Lastly, by the use of GIS, an S-DSS helps the parties to reach consensus in some types of conflicts by using a visual language that is easily explained and understood (Jelokhani-Niaraki and Malczewski, 2015).

Therefore, in the search for the "integrated and dynamic vision" of sustainability, the objective of the proposed study is to develop an S-DSS able to monitor rural sustainable development at a local scale. The model was build going beyond the popular ''triple bottom line'' model focusing on the balance between environmental, social, and economic issues (Holden et al., 2014). Starting from the Brundtland report and SDGs of 2030 Agenda, four key dimensions globally valid were identified to measure the sustainability (Holdel et al., 2014; Viccaro and Caniani, 2019), modelling a set of indicators according to the socio-cultural-political-environmental context (Casini et al., 2019; Péti, 2012) by applying the non-compensatory method proposed by Mazziotta and Pareto (De Muro et al., 2011). The Basilicata region was chosen as a case study, a rural region in Southern Italy. The analysis was carried out at the municipality level, sharing the idea that sustainable development could be achievable if it originates at the local level (Ferretti et al., 2020) and also to assess sub-regional disparities. A reduction in local disparities may favour an increase in regional performance compared to other regions (and to the national context). Confirming this, Lukovics (2008) points out that regional disparities are widening because the growth of the more developed sub-regions is increasing while the less favoured sub-regions are lagging behind. Consequently, rural analyses must devote increasing attention to the study of sub-regions. The results of the analysis will offer some reflections and discussion on the possible future developments of the planning tools.

The paper has the following structure: after a brief overview of the state of the art and of the contribution of our paper in growing the research on sustainability assessment (Section 2), the study area and materials and methods are presented in Section 3. The main results are discussed in Section 4 and concluding remarks, as well as discussion about future developments, are presented in Section 5.

2. Sustainability assessment: a brief overview and a step forward

As sustainability is a multidimensional concept, the appropriate instrument for analysing it according to a multidimensional representation is a suitable set of indicators that must be an integral part of an assessment methodology (Paolotti et al., 2019). The purpose of indicators is to provide a tool for guidance in sustainability policies, including monitoring of measures and their results, and communication to the public at large (Spangenberg et al., 2002).

Sustainability indicators generally differ in their characters, scales and ranges, and are usually aggregated into composite indexes of sustainable development mainly used at a global or national scale. In Italy, for example, the National Institute of Statistics (ISTAT) is engaged in the production of statistical measures for monitoring progress towards SDGs, based on the indicators defined by the UN Expert Group together with some specific national context data (ISTAT, 2019e). They represented the inputs for the definition of the Italian Sustainable Development Strategy, presented to the Council of Ministers in October 2017. All UN member States go in the same direction to evaluate their own progress towards sustainability. Global indexes are instead used to understand where the overall society is going, motivating and guiding the process of global societal change. Examples are reported in Costanza et al. (2016) and Holden et al. (2014).

However, the evaluation cannot be solely at a national level, although it is perhaps the most significant one and the most applied in international fora. Boggia et al. (2018) and Paolotti et al. (2019) evaluated regional sustainable development and its disparity among regions in three EU Member States (Malta, Spain and Italy), in order to support EU regional policy strategies. These studies have shown that, even within a small geographic area, spatial differences at regional levels identify the need for sustainability strategies that are not homogenous across a single territory at a national scale and that, therefore, sustainability assessment at a local scale is fundamental. Examples of studies conducted at municipality level are reported in Boggia et al. (2010) and Salvati and Carlucci et al. (2014), with a focus on rural areas in Boggia et al. (2014), Palmisano et al. (2016), Zolin et al. (2017), and more recently in Ferretti et al. (2020).

The common denominator of the studies conducted at a local scale mentioned above is the use of Multiple Criteria Decision Aiding (MCDA) techniques integrated with Geographic Information System (GIS). Known as Multiple Criteria Spatial Decision Support Systems (MC-SDSS), this integration has widely been used in many research fields over the last twenty years (Malczewski, 2006), such as agriculture (Riccioli et al., 2019), bioenergy (Romano et al. 2013), wildlife management (Cozzi et al., 2015b, 2019), rural evaluation (Cozzi et al., 2015a), wastewater management (Viccaro et al., 2017) and so on. MC-SDSS link concepts and methods of GIS and MCDA, providing new ways to face decision problems (Malczewski and Rinner, 2015) and, since spatial decision problems in rural development require a large number of alternatives to be evaluated based on multiple criteria, MC-SDSS represents the most suitable tool to evaluate a multidimensional concept like sustainable development. The methodology appears consolidated so much that it was proposed in form of plugin “GEOUmbriaSUITE” (Boggia et al. 2014; Palmisano et al., 2016; Paolotti et al., 2019) working in the open-source GIS software QuantumGIS (QGIS.org, 2020).

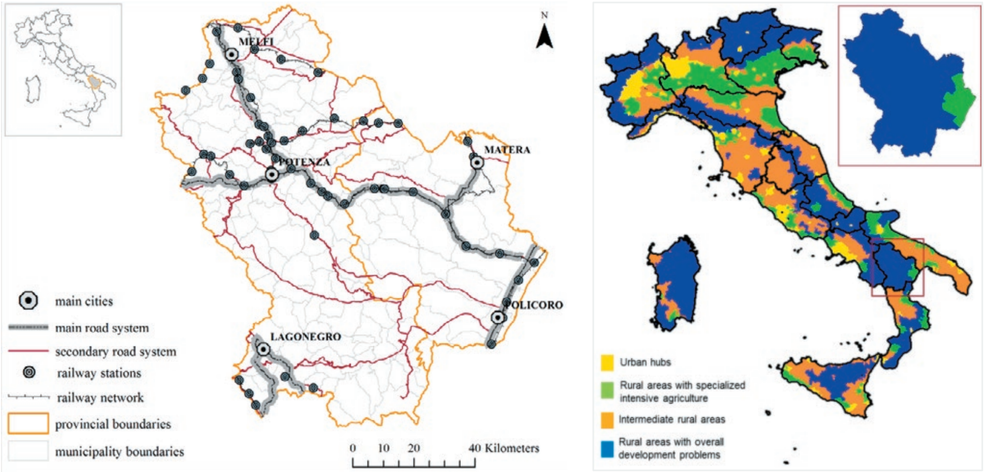
Despite progress in sustainability measure, with our work, we want to highlight two fundamental aspects underlying the concept of sustainable development not considered in the mentioned studies. To date, sustainable development has been evaluated according to the 'triple bottom line' (TBL) concept, originally served as an accounting framework that included environmental and social dimensions within the conventional finance-centric business performance model (Elkington, 1994). However, Holden et al. (2014), in the paper "Sustainable development: Our Common Future revisited", underline the necessity to reconsider the dimensions of sustainable development returning to its original definition used in the Brundtland Report, suggesting four primary dimensions: (i) safeguarding long-term ecological sustainability, (ii) satisfying basic needs, and promoting (iii) intragenerational and (iv) intergenerational equity. They argue that "*economic growth is a potential means to facilitate the fulfilment of the four primary dimensions and not a primary dimension in its own right*" (Holden et al, 2014: p.131). Moreover, the authors highlight that the proposed dimensions are all equally important and non-negotiable, what Daly (2007, p. 47) refers to as "*fundamental objective values, not subjective individual preferences*." Based on that, we argue that, in defining composite indexes for the sustainability dimensions, also the indicators used should be all equally important. So, the decision rules based on compensatory methods, used in the proposed MC-SDSS, appear inadequate. The above considerations represent the novelty of our work, "a step forward" towards sustainability assessment at a local scale.

3. Materials and method

3.1 Study area

The empirical analysis focuses on the Basilicata region (NUTS II) (Fig. 1a), one of the twenty regions of Italy, located in the south of the country (40° 30′ 1′′ North, 16° 6′ 50′′ East). The study area is characterized by a high geomorphological diversity (46.8% of the area is mountainous, 45.2% is hilly and only 8% is flat) and a wide altitude range, between 0 and 2,267 m a.s.l. With an area of 9,992 km^2, the Basilicata region is divided into two administrative provinces and 131 municipalities: two main hubs (Potenza and Matera) and a high diffusion of small rural municipalities (with less than 2,000 residents, which affect the 48% of the total number), with limited population density (61 inhabitants per km^2) compared to the rest of Italy and Europe. The study area, disadvantaged by its morphological constitution and largely devoid of important communication routes, is one of the regions with the greatest delay in the development of the country, which is associated with all the problems related to depopulation and population ageing. Indeed, the study area is identified in the EU programming as a predominantly rural territory (OECD, 2010), so that rural development programs concern substantially the whole area (National rural network 2014-2020) (Fig. 1b). The agri-food sector plays an important role in the regional economy (Viccaro et al., 2018). According to the latest data of the agricultural census (ISTAT, 2019b), the percentage of employed in agriculture equal to 8.36%, is above the data of the comparative divisions: South = 6.73%; Italy = 3.90%; EU 27 = 4.6%, confirming the strong ag-

Figure 1. Maps of the study area: Basilicata region (a) and National rural network 2014-2020 (b).



a) Basilicata region b) National rural network 2014-2020

ricultural and rural character of the region. A significant component that reflects the marked natural and rural character of the study area is represented also by the tourism sector, a progressive growth sector; however, it suffers the distance from the main metropolitan areas.

3.2 Theoretical framework

The theoretical structure that defines the concept of sustainability in our study is based on four key dimensions: 1) long-term ecological sustainability, 2) satisfaction of basic human needs, 3) promotion of intragenerational equity and 4) promotion of intergenerational equity.

The four dimensions, closely connected with the SDGs, can be described as follows:

- Long-Term Ecological Sustainability (LTES): *"At a minimum, sustainable development must not endanger the natural systems that support life on Earth: the atmosphere, the waters, the soils, and the living beings"* (WCED, 1987, p. 44). Therefore, it measures the main elements of pressure on natural capital assets, such as water, air, soil, vegetation. In particular, (a) the water consumption (SDG 6), (b) the soil consumption (SDG 11), (c) the protection of natural and semi-natural ecosystems and biodiversity (SDG 15) and (d) the incidence of pollutants in the atmosphere for the fight against climate change (SDG 9, SDG 13).
- Satisfaction of Basic Human Needs (SBHN): *"It [sustainable development] contains […] the concept of 'needs,' in particular the essential needs of the world's poor, to which overriding priority should be given"* (WCED, 1987, p. 43). In a developed society it measures the level of achievement of a series of basic elements, that is (a) the level of achievement of certain income standards and employment levels (SDG

1, SDG 2, SDG 8), (b) ensuring adequate conditions of health care (SDG 3), (c) providing quality education and learning opportunities for all (SDG 4) and (d) making adequate settlements and resilient communities (SDG 11).
- Promotion of Intragenerational Equity (PIntraE): the Brundtland report states that social equity between generations *"must logically be extended to equity within each generation"* (WCED, 1987, p. 43). Therefore, it measures intra-generational inequalities in the (a) distribution of wealth (SDG 10), (b) in education (SDG 4), (c) in work (SDG 8). In addition, great importance was given to (d) monitoring gender equality in work and politics (SDG 5).
- Promotion of Intergenerational Equity (PInterE): *"We act as we do because we can get away with it: future generations do not vote; they have no political or financial power; they cannot challenge our decisions"* (WCED, 1987, p. 8). Therefore, it measures the sustainability of land development through (a) the level of sustainable forest management (SDG 15), (b) monitoring the sustainable use of water resources (SDG 6), (c) the possibility of making cities and human settlements sustainable, favouring the reuse of waste (SDG 12) and the use of renewable energy sources, preserving the cultural and natural heritage (e.g. fires) (SDG 7, SDG 11, SDG 13, SDG 15) (WCED, 1987, p. 8).

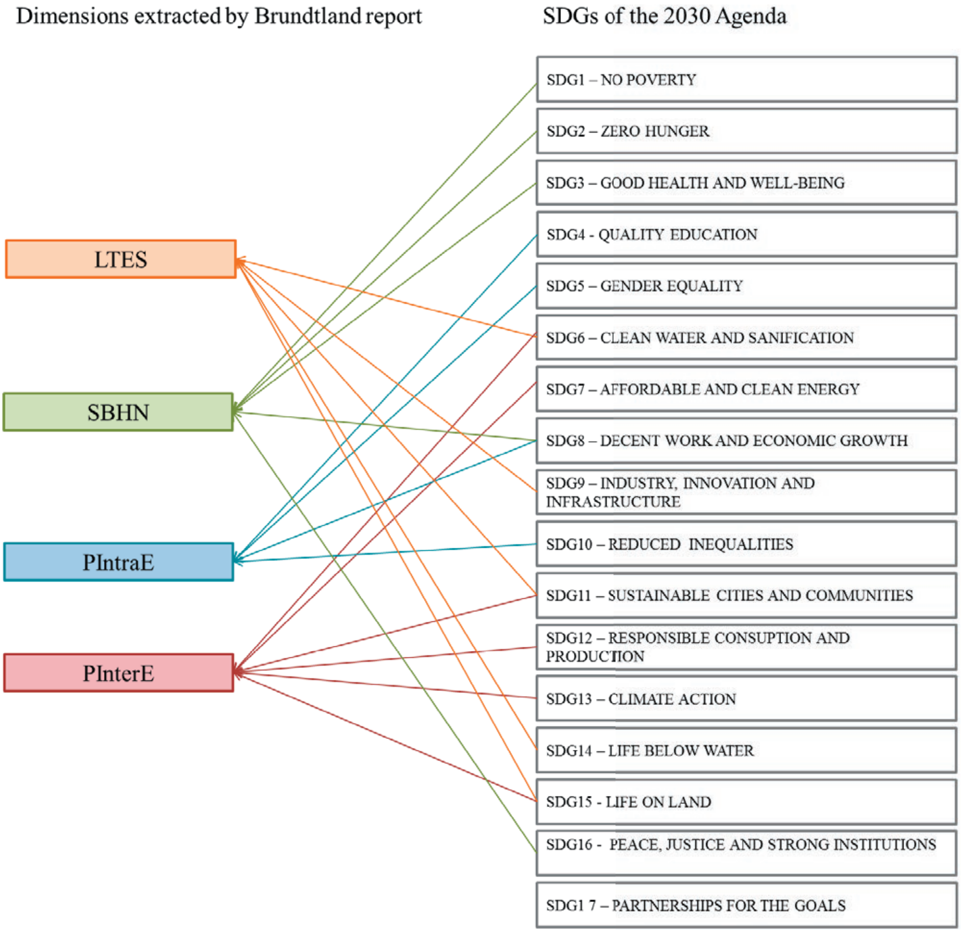
This structuring departs from the popular triple bottom line model, focused on the balance between environmental, social and economic issues (Elkington, 1994), which currently dominates politics and to some extent the academic debate on sustainable development (Ferretti et al., 2020; Rogers et al., 2008; UN, 2012).

In the following scheme, it is possible to highlight how the SDGs are placed within each dimension. Some goals can also fit into multiple dimensions (see Fig. 2).

3.3 Identification and selection of elementary indicators

The study of literature (Ferretti et al., 2020; Lior et al., 2018; Salvati and Carlucci, 2014) and the regulatory framework on the topic, led to identify a set of indicators representing the four key dimensions of sustainability (Table 1). The indicators capable of guaranteeing, analytical stability, measurability, territorial and temporal coverage have been selected (Maggino, 2014; OECD, 1993). The set of indicators was also chosen according to the context, focusing our attention on the indicators which, as regards rural areas, proved to be relevant for highlighting sub-regional differentials, or relative sustainability, which is the specific object of our analysis (Casini et al., 2019). For the analysis, different sources were used to collect data at the municipality level. The principal source was the Italian National Institute for Statistics. Statistics were also collected from GSE, INEMAR, ACI, Ministry of the Interior, ISPRA, Ministry of the Environment and Protection of the Territory and the Sea, etc. In some cases, proxy variables to compensate for the lack of data and spatial analyses in the GIS environment (e.g. the hospital facilities accessibility and quality - SBHN3, see Table 1) were used. The indicators were analysed through descriptive statistics and Pearson correlation analysis (Dowdy et al., 1983), to evaluate the presence of correlation (cause-effect relationships) and to screen the polarity with respect to the objective. For direct correlation (and

Figure 2. Relationship between dimensions and SDGs.



similarly for the inverse one), we distinguish a weak correlation for the interval $0 < \rho_{x,y} < 0.3$, a moderate correlation for the interval $0.3 < \rho_{x,y} < 0.7$ and a strong correlation for $\rho_{x,y} > 0.7$.

The preliminary study led to identify 24 indicators, 6 for each dimension (see Table 1). The selected indicators refer to a variable period between 2011 and 2018 depending on data availability. The temporal range could be considered acceptable since the growth process at a local scale in very low.

3.4 Integrated evaluation of the indicators

The choice of aggregating elementary indicators into composite indicators (or indexes) stems from the need to have synthetic information with respect to com-

Table 1. Dimensions and indicators used in the case study, meanings and sources.

Dimension/Indicator	Description	Reference unit	Source and reference year
Long-Term Ecological Sustainability (LTES)			
LTES1 – Greenhouse-gas emissions from productive activities	Greenhouse gas emission coefficients (represented by GHRO) per Annual Labour Unit (ALU) for the different productive activities in the national context have been estimated, starting from National Accounts Matrix including Environmental Accounts, subsequently multiplied by the ALU of the productive activities in each municipality	$TonCO_2eq$	ISTAT (2011)
LTES2 - Water consumption	Water introduced into municipal drinking water distribution systems	Thousands of cubic meters per inhabitant	ISTAT (2015)
LTES3 - Soil consumption	Variation from 1989 to 2017 of the percentage ratios between artificial areas and municipal areas	%	School of Engineering - Unibas (2017)
LTES4 – Potential greenhouse-gas emissions from vehicles	Potential greenhouse-gas emissions from vehicles have been estimated by multiplying vehicle fleet with an emission factor according to the category, related to the population aged 18-80 years for each municipality	kgCO2eq/km per capita (18-80 years)	ACI (2017) and -INEMAR (2014)
LTES5 - Incidence of protected areas	Percentage ratio between protected areas (Official List of Protected Areas and the Natura 2000 network) and municipal area	%	Ministry of the Environment and Protection of the Territory and the Sea (2018)
LTES6 – Incidence of organic agriculture	Percentage variation between organic UAA[1] 2018/UAA 2010 and organic UAA 2010/UAA 2010	%	Istat (2010); and Phytosanitary office of Basilicata Region (2018)
Satisfaction of Basic Human Needs (SBHN)			
SBHN1 - Average per capita income	Data relating to the declarations on the taxable income of individuals for the additional personal income tax	Euro	Ministry of Economy and Finance (MEF) (2017)

Dimension/Indicator	Description	Reference unit	Source and reference year
SBHN2 - Employment rate	Percentage ratio between employed people aged 15 and over and the resident population aged 15 and over	%	Urbistat (2017)
SBHN3 - Hospital facilities accessibility and quality	Evaluation of the hospital service quality (beds, number of departments, equipment), weighted according to the time needed to reach the facility using the isochronous method by Network Analysis (Wang et al., 2012)	Adimensional (range 0-6.50)	Regional technical map (2013), and Ministry of Health (2013)
SBHN4 - High schools' accessibility and differentiation	Evaluation high schools offer, normalized based on the time to reach the structure from each municipality	Adimensional (range 0-10)	Regional technical map (2013)
SBHN5 - Quality of housing	Average of basic services available in the home[2] and buildings in good condition[3]	Adimensional (range 0-1)	ISTAT (2011)
SBHN6 - Social and material vulnerability index	Aggregation of: 1) percentage of 25-64-year-old illiterate and literate population with no educational qualification; 2) percentage incidence of families with potential economic hardship; 3) percentage incidence of families with potential care difficulties; 4) percentage incidence of the population in serious crowding; 5) percentage incidence of families with 6 and more members; 6) percentage incidence of young and adult single-parent families; 7) percentage incidence of non-active 15-29-year-olds and non-students[4]	Adimensional (70-130)	ISTAT (2011)
Promotion of Intragenerational Equity (PIntraE)			
PIntraE1 - Income inequality index	Gini concentration index to measure inequality in income distribution	(range 0-1)	MEF (2017)
PIntraE2 - Unemployment rate	Percentage ratio between the resident population aged 15 and overlooking for employment and resident population aged 15 and over	%	Urbistat (2017)

Dimension/Indicator	Description	Reference unit	Source and reference year
PIntraE3 - Incidence of adults with diplomas or degrees	Percentage ratio between the resident population aged 25-64 with a high school diploma or university degree and the resident population aged 25-64	%	ISTAT (2011)
PIntraE4 - Gender inequality in the labour market	The ratio between the male employment rate and the female employment rate	Adimensional (range 0-3)	ISTAT (2011)
PIntraE5 - Women and political representation at the local level	Percentage ratio between elected women and the total elected officials in municipal administrations	%	Ministry of the Interior (2018)
PIntraE6 - Employment turnover index	Percentage ratio between those aged 45 and over and those aged 15-29	%	ISTAT (2011)
Promotion of Intergenerational Equity (PInterE)			
PInterE1 – Incidence of sustainable forest management	Percentage ratio between managed wooded forest area and total forest area	%	Forest management plans (2018)
PInterE2 - Dispersion of water from the distribution system	Total water losses in municipal drinking water distribution systems (percentage value on the total volume introduced into the system) (mc)	%	ISTAT (2015)
PInterE3 - Separate collection of municipal waste	Percentage of municipal waste subject to separate collection out of the total amount of municipal waste collected	%	ISPRA (2018)
PInterE4 - Production of energy from renewable energy sources	Production of energy (electric and thermal installed power) from renewable sources (MW) compared to the population	MW per capita	Energy Services Operator (GSE) (2018)
PInterE5 - Public expenditure for the protection and enhancement of cultural goods and activities	Municipal public expenditure for the protection and enhancement of cultural goods and activities concerning total expenditure	%	Ministry of the Interior (2015-2017)
PInterE6 - Impact of forest fires	Percentage ratio between forest area covered by fire and total forest area	%	Ex-State Corps of Foresters(2011-2013)

[1] Utilised Agricultural Area (UAA).

[2] Internal drinking water services, b) internal toilet, c) bath or shower and hot water.

[3] Physical conditions, both internal and external, in "excellent or good" state of conservation.

[4] http://ottomilacensus.istat.it/fileadmin/download/Indice_di_vulnerabilit%C3%A0_sociale_e_materiale.pdf

plex realities, expressed in ways that are easily understood by a large number of people and to promote an integrated approach in the decision-making process. Several authors (e.g. Boggia et al., 2014; Ding et al., 2014; Liu, 2007; Paolotti et al., 2019) have proposed integrated methodologies for assessing and monitoring sustainability, in order to help decision-makers.

Therefore, to allow an integrated assessment of the dimensions considered, measured operationally by the selected indicators, different aggregation methods were studied. There are several classification schemes for aggregation methods. They include those based on the semantics of the aggregation (Beliakov et al., 2007; Grabisch et al., 2009) and those based on the authorization degree of the compensation (OECD, 2008). In particular, according to the latter scheme, the most widely used aggregation methods include additive aggregation methods (e.g. arithmetic mean), multiplicative aggregation methods (e.g. geometric mean) and non-compensatory aggregation methods (e.g. multicriteria analysis).

In the specific case, assuming that the elementary indicators cannot be replaced with each other, attention was paid to non-compensatory aggregation methods (Mazziotta and Pareto, 2016, 2018). We have chosen the method of penalty for variation coefficient, proposed by Mazziotta and Pareto (De Muro et al., 2011). It is a non-compensatory method, which allows the construction of a synthetic measure for each territorial unit (x_i). This method was also chosen because it is applicable in the presence of null values; moreover, compared to methods based on geometric mean (Diewert, 1995) this method is more robust and not very sensitive to the elimination of a single elementary indicator.

The method provides for the standardization of the indicators by means of a transformation criterion that frees them both from the unit of measurement and their variability (Delvecchio, 1995). Therefore, the elementary indicators have been re-proportioned, in such a way as to oscillate all within the same standardized scale, with an average 100 and an average square deviation 10: the values obtained are included in a range (70-130).

Given the matrix $X=\{x_{ij}\}$ of n rows (territorial units) and m columns (elementary indicators), it is possible to calculate the normalized matrix $Z=\{z_{ij}\}$ in the following way:

$$z_{ij} = 100 \pm \frac{\left(x_{ij} - M_{x_j}\right)}{S_{x_j}} 10 \tag{1}$$

where $M_{x_j} = \frac{\sum_{i=1}^{n} x_{ij}}{n}$ and $S_{x_j} = \sqrt{\frac{\sum_{i=1}^{n}\left(x_{ij} - M_{x_j}\right)^2}{n}}$ are, respectively, the mean and the standard deviation of the j indicator, while the ± sign represents its polarity.

Indicating with M_{Zi}, S_{Zi} and cv_{Zi}, respectively, the mean, the standard deviation and the variation coefficient of the normalized values for the statistical unit i, the composite index of Mazziotta and Pareto (MPI, Mazziotta and Pareto Index) is defined as follows:

$$MPI_i^{\pm} = M_{z_i} \pm S_{z_i} cv_{z_i} \tag{2}$$

The arithmetic mean of the normalized indicators is therefore corrected by a quantity (the product $S_{Zi}cv_{Zi}$) proportional to the mean square deviation and a direct function of the coefficient of variation. This variability, measured through the coefficient of variation (cv_{Zi}), makes it possible to penalize the score of the units which present a greater imbalance between the values of indicators. The use of normalized standard deviation (S_{Zi}) allows to build a robust measure that is not very sensitive to the elimination of a single elementary indicator (Mazziotta et al., 2010).

Ultimately, if the regional average represents the reference value, we are able to make relative comparisons between the different municipalities and evaluate the degree and the distribution of sub-regional disparities for each dimension.

4. Results and discussion

The application of methodology (as described in the Section 3) allowed us to obtain a map for each dimension. Figure 3 shows municipalities in advantage conditions (value of MPI>105) and municipalities in disadvantaged conditions (value of MPI<95) compared to the average (regional) value (95≤MPI≤105), respectively represented in shades of green and red. First of all, a greater negative imbalance for all dimensions was detected.

More in detail, advantaged clusters were identified for the SBHN and PIntraE dimensions in the crown areas of large urban centres and commercial attractions (see Fig. 3b, c). In these areas, however, worse ecological sustainability (LTES) insists (see Fig. 3a): this is due to a) greater concentration of productive activities and/or the presence of point sources[1] with high emissions (LTES1); b) higher water consumption (LTES2) (the central-eastern portion of Basilicata, the Val D'Agri area); c) higher land consumption (LTES3) linked to urban fragmentation processes (e.g. municipality of Potenza), which is quite high for the study area (88% compared to a national average of 84%) (Saganeiti et al., 2018). It is, indeed, a phenomenon of considerable importance due to the progressive abandonment, depopulation and disuse of historic city centres in favour of new land consumption in peripheral and peri-urban areas. This affects ordinary urban management: higher energy costs both in the public and private sectors, heavy technical-economic-organizational commitments in any kind of services provision (due to the distances among residential areas and the very low population density of the same) with consequences also on the quality of landscapes and ecosystems.

Large disadvantaged clusters were observed for the SBHN dimension in the central (on the border between the two provinces) and in the south part of the study area (see Fig. 3b). In these areas, in addition to lower incomes (SBHN1) and lower employment (SBHN2), lower quality of housing (SBHN5) was found. Indeed, 3.1% of the population lives in houses without basic services (compared to

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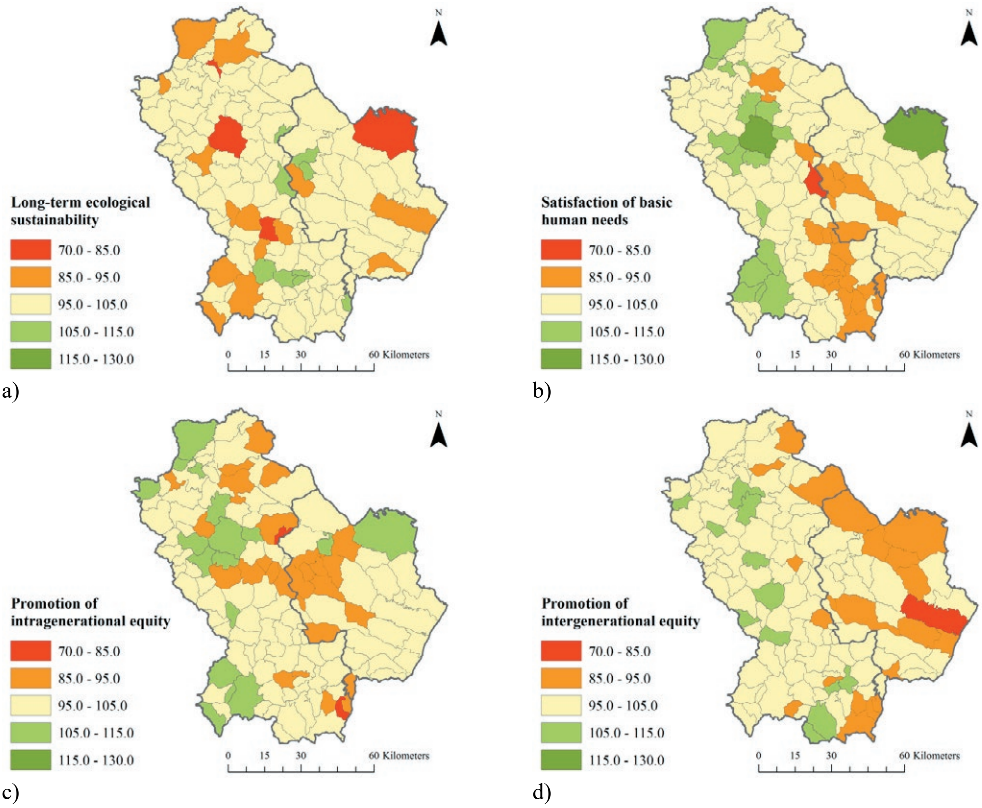
[1] Twenty-point sources were detected within the Atmospheric Emissions Inventory of 2015 produced by the Basilicata Environmental Observatory Foundation - FARBAS.

Figure 3. Sustainability indices for the four dimensions: a) Long-term ecological sustainability (LTES), b) Satisfaction of Basic Human Needs (SBHN), c) Promotion of Intragenerational Equity (PIntraE), d) Promotion of Intergenerational Equity (PInterE).



a regional average of 1.6%) and 35.3% of the population lives in poor condition buildings (compared to a regional average of 23.1%). Added to also lower accessibility to hospitals (SBHN3) and secondary schools (SBHN4) (journey times > 60 minutes) was found.

The PIntraE dimension is characterized by a condition generally falling within the average, with clusters both above and below the average (see Fig. 3c). The disadvantages clusters are concentrated in the central portion of the study area. This is mainly due to a lower education rate (diploma or degree) (PIntraE3) and a greater inequality in the distribution of income among the population (PIntraE1). Overall, the recent dynamics, despite an employment improvement in the study area, do not allow to prefigure a territorial balance of the labour market, characterized by gender differentials (PIntraE4) (male-female ratio greater than 2:1) in many municipalities of the Matera province and a generalized low employment turnover (PIntra6). The female representation in politics at a local level (PIntraE5), following the law 23 November 2012 n. 215, has doubled (from 14% to 28% in the period 2001-2018), but is still below the Gender balance zone (percentage between 40% and 60%) (EIGE, 2016).

Within the PInterE dimension, few virtuous municipalities above the average, scattered in the province of Potenza, were observed (see Fig. 3d). They are mainly characterized by sustainable forest management (PInterE1)[2], more sustainable waste management (PInterE3) and higher production of energy from renewable sources (PInterE4). The negative values are concentrated mainly in the province of Matera, mainly linked to the impact of forest fires (PInterE6) (being these areas more vulnerable); they constitute one of the main factors of environmental change in a wide range of agricultural and forest ecosystems (FAO, 2007). A second cluster of negative values is concentrated in the south-east of the study area, mainly linked to management shortcomings, including the management of water resources (PInterE2) and urban waste (PInterE3). Actually, the water dispersion from distribution system (attributable to breakages in pipes, pipelines or fittings, obsolescence of materials), represents a generalized problem in the region, going from 32.7% in 2012 to 55.9% in 2015 (92 municipalities with losses greater than 50% compared to the national average of 41.4%). As regards the waste collection, from 2010 to 2017, a marked increase in the percentage of separate collection was found, going from 10.7% to 41.7% (compared to the Italian average of 55.5%). During this period, many municipalities in the province of Matera took action for more sustainable waste management. It affected positively a form of aggregate management among municipalities, that allowed waste separate collection percentages above 65%. Indeed, often the scarce local autonomy (lower spending capacity) in such contexts determines the inability of self-regulation with respect to intergenerational equity (sustainable forms of management, such as separate waste collection, water loss control and management of local resources). This denotes how the Union among municipalities (Legislative Decree No. 267 of 2000) could represent also a virtuous attempt towards new ways of self-regulation of sustainable development at a local level.

In general, a low interaction was detected among the four dimensions. However, by analysing the relationships among them, a (weak) negative correlation between the LTES and SBHN dimensions (64% - 84 out of 131 municipalities appears to have an imbalance between the two dimensions) was found. This means that the study area is positioned in the growing portion of the environmental Kuznets curve, which has an inverted U shape (Hanley et al., 2001). This position is typical of developing economies, where an increase in economic well-being implies an increase in environmental pressure. Indeed, only in few municipalities (9% - 12 out of 131 municipalities), better economic well-being is accompanied by better ecological sustainability. To move towards the decreasing part of the environmental Kuznetz curve, typical of mature economies, it would be necessary an increase in

[2] The percentage of managed forest area is increased in the last 20 years (55 plans drawn up in 2006-2015); however, many of the plans drawn up in the past have expired, so as of 2018 there is again a contraction of the actively managed area.

the elasticity of demanded environmental goods quantity with respect to income, and an increase in the capacity of policymakers to accept and incorporate stakeholder's opinions in the choices, encouraging technological innovation and structural changes.

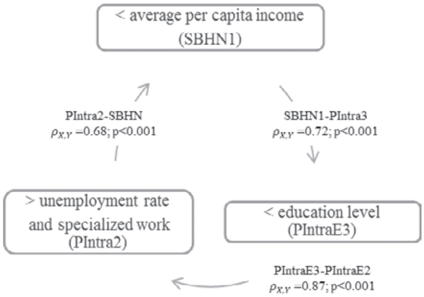
The remaining share of municipalities (27% – 35 out of 131 municipalities) is characterized both from low LTES and SBHN values. An example of this relationship is the greater potential greenhouse gas emissions from vehicles in areas with less access to essential services and/or without the railway network (in the south of the study area). This can be confirmed by lower mobility rates by public transport (less than 10%) respect to the areas covered by the railway network (between 18% and 27%) (ISTAT, 2019a). A negative self-reinforcement process was generated, i.e. an increase in private mobility due to a progressive contraction of public transport, which was itself determined by a contraction of users. This led to an increase in potential greenhouse gas emissions from vehicles (LTES4) from 2002 to 2017 despite a reduction in the population aged 18-80 years. In this sense, as also underlined by Ferretti et al. (2020), public intervention is needed to generate better infrastructure, extend the railway or upgrade public transport systems at peak times, bearing in mind that the creation of new transport infrastructure or the strengthening of existing infrastructure must not cause environmental damage. Furthermore, very often the most marginal areas, which show negative growth dynamics, have natural resources (e.g. they are part of regional and national parks) not fully valorised. Thus, the results highlight the need of variables to facilitate the introduction of natural capital concepts into decision-making processes (Bernetti et al., 2013).

Another element of interest concerns a (moderate) positive relationship between SBHN and PIntraE dimensions; indeed, 75% of municipalities (98 out of 131 municipalities) had a negative or positive balance between the two dimensions; more precisely, a low SBHN level corresponded to a low PIntraE level for 44% of the municipalities (58 out of 131 municipalities). This result is in agreement with Wilkinson and Pickett (2009), who found that health and social problems - which prevent societies from meeting the basic needs of their inhabitants - are more common in countries with high levels of inequality. Furthermore, the relationship between high social and health problems and high levels of inequality is such that the latter causes the former. Therefore, reducing the level of inequality (thus increasing intra-generational equity) would consequently lead to an improvement in the ability of a community to meet the basic needs of its inhabitants.

Furthermore, our results show that a lower per capita income (SBHN1) led to a lower level of education (PIntraE3) ($\rho_{x,y}$=0.72, p<0,001) and therefore a higher unemployment rate and less specialized work. (PIntra2) ($\rho_{x,y}$=0.87, p<0,001), which consequently led to a lower per capita income (SBHN1) ($\rho_{x,y}$=0.68, p<0,001) (see Fig. 4). It triggered what the economist Nurske calls the vicious circle of poverty (Nurkse, 1971).

The relationship between development and education has been emphasized in a wide range of studies (Becker, 1994; Psachoropoulos and Patrinos, 2004). Amartya Sen, in her fundamental study Development as Freedom, argued that a gen-

Figure 4. Vicious circle of poverty.



eral expansion of education and literacy can facilitate social change and help to improve the economic progress that others also benefit from (Sen, 1999, p.129). Moreover, Liu et al. (1986) supported the hypothesis that investments in human resources, especially through the improvement of education (elementary and secondary), would enhance social mobility, which in turn would enhance the productivity of labour and capital. Therefore, it would be appropriate to act through redistributive policies and an increase in the quality of education.

5. Conclusions

The proposed approach to measuring territorial sustainability was structured through four independent dimensions derived from the global framework on sustainable development (according to a top-down approach), consisting of an integrated system of indicators adapted to the context (according to a bottom-up approach).

The results obtained allow us to read the distribution of the composite indicators (dimensions) on the territory and to analyse which components and/or correlations between components are the cause of the positive and/or negative phenomena.

To promote an integrated decision-making approach of sustainable development, it is necessary to foster a territorial balance in the territory for each of the four dimensions. However, the simultaneous improvement of all dimensions raises a complex problem on how we can reach a certain level for one dimension without simultaneously reducing the possibility of it being reached for another dimension. The key to solving this problem is to decouple existing unwanted correlations between negative dimensions and cause-effect relationships and promote positive ones; this is one of the challenges presented to decision-makers with this study.

More specifically, the larger (urban) municipalities are characterized by greater sustainability in terms of essential needs and intra-generation equity but also less ecological sustainability; however, the smaller and more rural municipalities (central and southern regions) are not only characterized by lower levels as regards the fulfilment of essential needs and intra-generational equity, but this also implies repercussions in the ecological sustainability and inter-generational equity.

Finally, the satisfaction of basic needs and the intragenerational equity, acting synergistically, generated clusters affected by the socio-economic exclusion.

The proposed framework represents, in the current political context, a useful support tool in identifying and monitoring the areas that require priority actions and resources, with a view to efficient resource management, and in promoting sectoral decision-making processes in a global strategy.

More specifically, in a rural context, this implies an overall rural development perspective that considers sustainability as an essential precondition for any possible development of these areas. Indeed, in many realities, rural development programmes focused on funding sectoral actions and did not partner with other structural funds and local resources.

This study represents a first step in developing tools helpful to monitor sustainable development at a local scale going beyond the "triple bottom line" approach. The strength of the proposed approach consists in the simplicity and transparency of the four dimensions, considered non-negotiable and equally important, based on the common definition of Sustainable Development. However, still much to be done. Future developments will be oriented towards improving the representativeness of indicators, choosing a set of standard indicators making the model replicable in other contexts, as well as the choice of the aggregation method. In fact, despite the method used in this study is a consolidate method in constructing composite indices, it gives a picture of the phenomena based on the mean values of indicators considered, but it does not allow to consider the distance from the "best solution" or "ideal point", that is usually required in evaluating some indicators (e.g. greenhouse gas emissions).

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