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Decennial comparison of changes in social vulnerability: A municipal analysis in support of risk management

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ABSTRACT

The concept of Social Vulnerability (SV) is characterized and distinguished by its complexity and multi-disciplinarity. This concept takes into account the specific characteristics of the individual and his social and economic relations, as well as the physical environment where he is inserted. These differentiating characteristics make Social Vulnerability (SV) an indispensable work tool in the process of characterizing and understanding the degree of exposure of communities, as well as evaluating their capacity for resilience and recovery from hazardous events.

This paper presents a comparison between the SV performed in 2008 with the results obtained in 2017 for the 278 municipalities of mainland Portugal. The methodology was based on the work developed by the Center for Social Studies of the University of Coimbra, which is distinguished by the fact that SV is composed of two components: Criticity and Support Capability. The analysis of SV and its components was done using Principal Components Analysis (PCA) starting from an initial set of 235 variables (90 for Criticality and 145 for Support Capability).

With respect to Criticality, the results point out the importance of factors related to the economic condition, employment and factors related to the disadvantaged population and risk groups. Support Capability is strongly influenced by the population density and the most relevant factors for the final results are those related to civil protection response, economic and environmental dynamism and logistic and service capacity. Regarding the SV spatial distribution, the highest values are located mainly in the central and northern parts of the country, with emphasis on the Douro river valley and surrounding municipalities; also a general decrease of SV was recorded in the southern regions from 2008 to 2017.

1. Introduction

There are multiple and distinct methods of measuring vulnerability [1–3]. The severity of impacts and the resilience to them are largely predicted by the cultural, institutional and social characteristics underlying the concept of vulnerability [4]. Vulnerability can be defined as the conditions determined by the physical, social, economic and environmental factors or processes that increase the susceptibility of a community to the impact of hazards [5].

The multi-faceted scope of the concept leads to the specific necessity of considering Social Vulnerability (SV) as a particular feature of vulnerability, and its measurement is also subject to distinct approaches [6–8]. SV is a multidimensional concept that allows us to characterize and understand the level of a given community's exposure to risks and to understand how it can respond and recover in post-disaster periods [9].

The concept of SV can then be characterized by its multi-dimensionality and complexity. It is related to the characteristics of the individual, but also his social and economic relations, as well as the physical and social environment where the individual is inserted [10]. The concept also involves a collective dimension, which considers the preexisting characteristics that influence the preparation, response and recovery from disasters [11]. These characteristics make SV an indispensable tool for the characterization and understanding of the degree of exposure of the communities, but also their capacity for resisting and recovering in face of hazardous events. The evaluation of SV as a tool

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for measuring risk management strategies has grown in recent decades and has been carried out in several contexts, for example, regarding the risk of floods [12], tsunami [13,14], environmental hazards [15] and climate change [16].

In Portugal SV was previously evaluated at the municipal level in order to better consider the interdependencies between environmental and societal structures [17]. Later, in the course of a research project coordinated by the Center for Social Studies of the University of Coimbra, a new methodological approach was introduced in which the SV assessment considers two dimensions – Criticality and Support Capability – using an inductive approach [18]. The concept of Criticality is understood as the set of characteristics and behaviors intrinsic to the individuals who may contribute to the disruption of the context where the individual is placed and the resources of the communities that allow them to deal with and respond to harmful events. Support Capability is understood as the set of territorial infrastructures that allows risk managers to react in case of disaster and could support the recovery. This conceptual development would better allow for the operationalization of the SV as a planning tool, supporting the implementation of a territorial model in which risk assessment and management would be more fully informed for decision making. Assessing the role of critical infrastructure in reducing vulnerability is essential for effective risk management policies. Not only the isolated function of such structures is to be considered as their interdependencies [19].

Having this context in mind, the mains objectives of the presented research are:

- Expression of the Social Vulnerability components in 2008;
- New analysis of the Social Vulnerability components in 2017;
- Comparision and discussion of the municipal Social Vulnerability evolution.

The present study focuses on the calculation of SV for the 278 municipalities of mainland Portugal (Fig. 1), with a total area of 89.089 km^2 and a 2011 resident population of 10.044.484 inhabitants [20]. In administrative terms Portugal is divided into three NUT's (Nomenclature of Territorial Units for Statistics) levels, defined according to population, administrative and geographical criteria, in accordance with Law-Decree 244/2002, changed in 2015 by Regulation n°868/2014. The present work is developed at the level of NUT III, which is composed of 23 territorial units, including 278 municipalities (Fig. 1).

With regard to socio-economic characterization, mainland of Portugal is characterized by a clear dichotomy between the coastal area, more densely populated, with a younger population, more industrialized and with greater economic dynamism, and the inland area, more rural and aged, less dynamic economically, where the territories of low density predominate. Fig. 1 presents three socio-economic variables (population density, percentage of employed population in the secondary sector, which includes manufacturing industry and construction, and percentage of purchasing power), which help to understand the national continental territory. As far as population density (Fig. 1a) is concerned, the highest values are located in coastal areas and in biggest cities and surrounding areas, as well as in district capitals. Regarding the sectors of activity, mainland Portugal also presents a clear dichotomy between the more industrialized coastline and the inland area where the tertiary sector and the areas related to the agricultural and forestry sector are most marked. The analysis of the output referring to the percentage of population employed in the secondary sector (Fig. 1b), shows that the highest values are concentrated in the northern and central coastal zone, with emphasis on the areas bordering the Metropolitan area of Oporto, central region, with emphasis on the industry linked to the automotive sector, wool and dairy products. Also noteworthy are the importance of the port of Sines and the mining complex of Aljustrel that stand out in the southern part of Portugal, more precisely in the Alentejo. In terms of quality and living conditions, the percentage of purchasing power (Fig. 1c) allows us to observe a higher purchasing power per capita in the coastal and south zone compared to the more inland areas. There is also a clear contrast between the innermost regions of the north, which have a lower purchasing power compared to the rest of the continental territory.

2. Methodology

2.1. Statistical procedures

The SV is assessed using PCA methodology advocated by Cutter et al. [15], Schmidtlein et al. [21], Mendes [17], Chen et al. [11], Guillard-Gonçalves et al. [22], de Loyola Hummell et al. [23] and Tavares et al. [24], with some adaptations made according to regional and local social and geographical specificities. For the PCA, SPSS® software, version 23 was used. The data that supports this evaluation were obtained from the 2011 Census [20] and PORDATA database [25]. The period of the data used varies between 2011 and 2016.

The Redundancy Analysis (RDA) is a multivariate, direct gradient analysis method in which individuals are presumed to have linear relationships to environmental gradients (i.e. linear species response curves), and it was conducted using the Canoco® software, version 5. This software is designed for multivariate statistical analysis using ordination methods in the field of ecology and several related fields [26]. As with the 2008 SV assessment, the 2017 updated analysis considered the components of Criticality and Support Capability introduced in Mendes et al. [18] as mention above.

Prior to the final running of PCA, redundant variables are eliminated (the same procedure was carried out in the 2008 analysis) based on the iterative and combined analysis of several indicators: Pearson correlation matrix; variance rate parameters, which should be greater than 60%; Kaiser-Meyer-Olkin (KMO) sample measurement, which should be greater than 0.6 [27]. After the definition of the final set of variables, PCA is carried out using normalized values to the *z-score*, Varimax rotation factor analysis. An analysis of the cardinality or sign interpretation of each principal component is done – identifying in the rotated matrix the variables that have a *loading* equal to or greater than the module of 0.5 – so the factors may be interpreted and, if needed, their respective scores multiplied by −1 [15,18]. This is justified by the fact that PCA cannot interpret the role of variables in increasing or decressing vulnerability. For example, a high % of persons with higher education may present a positive *loading*, thus requiring an inversion of scores so that a high % in that variable contributes to lower criticality.

After calculating Criticality and Support Capability, the Social Vulnerability composite index is calculated by combining the two components mentioned above. The calculation is made using the following equation:

$$\textbf{Social Vulnerability} = \textit{Criticality} \times (1 - \textit{Support Capability}) \quad (1)$$

The Eq. (1) is designed so that high values of Criticality and low values of Support Capability would represent a worse or higher Social Vulnerability composite index.

The results obtained are grouped into different classes that vary from very low to very high in accordance with the standard deviation (SD) and the following categories: “very low,” < 1 SD; “low,” [− 1, − 0.5 SD]; “moderate,” [− 0.5, + 0.5 SD]; “high,” [0.5, 1 SD]; “very high,” ≥ 1 SD [15].

2.2. Criticality, Support Capibility and Social Vulnerability in 2008

As mentioned before, the 2008 assessment of SV was conducted in the course of a research project coordinated by the Center for Social Studies of the University of Coimbra [18] and was based on principal component analysis (PCA) resulting in a total of 32 variables representative of 9 SV dimensions (Table 1). PCA was applied both to