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Assessment of Social Vulnerability in Malaga Province, Spain: A Comparison of Indicator Standardization Techniques

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1. INTRODUCTION

Natural process or phenomena occurring in earth that may constitute a damaging event is known as natural hazard. Almost all countries of the world are affected by natural hazards in each and every year and most of them bring about some sort of natural disaster. Natural disasters are dependant not only on natural hazards, as they result from the interaction between these natural hazards and socio-economic conditions of a society; thus, the risk from natural disaster is defined as the probability of this interaction to occur in a particular place (Birkman *et al.,* 2013). In a broad sense, these socio-economic conditions are known as vulnerability.

Vulnerability assessment and mapping is an essential stage of natural risk management and it constitutes the research context of this particular study. The present study tries to assess social vulnerability for the province of Malaga, from a generic point of view, so it is not focused on a particular hazard. The study makes use of three simple standardization techniques for statistical data simplification in order to compare obtained results, and employs the 103 municipalities of this province as mapping units.

2. THEORETICAL BACKGROUND

Social vulnerability assessment is a process of identifying, quantifying, and analyzing the vulnerability factors in a particular area. In general terms, the assessment process consists of some basic phases (Beccari, 2016). As a first stage, (i) statistical data are gathered for these spatial units. Indicator selection could be driven according to the type of approach, namely hazard-specific, for those studies focused on a particular hazard (flood, earthquake etc.), or generic, for those others in which social variables are used to measure vulnerability to any

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hazard (Ran *et al.,* 2020). Other authors (Barrionuevo & Perles Roselló, 2017; Perles Roselló *et al.,* 2017) indicate the relevance to define the type of vulnerability, namely susceptibility/fragility (vulnerability to the hazard), or resilience (vulnerability to damage). In a second stage, (ii), some data treatments are carried out, including some sort of normalization, reduction, weighting or aggregation techniques. Finally, (iii) vulnerability mapping is accomplished through the classification of the same spatial units.

At regional scales, different spatial units can be found in vulnerability assessment; some examples are countries, as in the case of Latin America or Asia (CAF, 2014; Hoffmann & Blecha, 2020), NUTs, used in Europe (EEA, 2018), or river-basins, used in different world regions (Balica *et al*., 2009). Studies at national level show a great variety of spatial units according to the different administrative units that can be found in each country. In the classical study by Cutter et. al., (2003), Social Vulnerability Index (SoVI) was calculated for all the counties in the United States. In China, the province is frequently used in most of the national scope studies (Yang *et al*., 2014; Yan, X. & Li, X., 2016). National scale assessments in European countries usually employ municipalities or equivalent administrative sub national divisions, as in the case of Norway (Holand *et al*., 2011), Italy (Frigerio *et al.,* 2018), or Germany (Fekete, 2018). Below the national level, vulnerability assessments are usually carried out within these last mentioned spatial units (municipalities) or in urban environments (Diaz-Sarachaga & Jato-Espino, 2020). In the case of Spain, census district is a widely employed spatial unit for this type of studies (Morales *et al*., 2016; Navarro *et al*., 2020); however, some other more detailed studies have been accomplished, in which cadastral parcels have been used for social vulnerability assessment and mapping (Tascón-González *et al*., 2020).

3. MATERIAL AND METHODS

The study area is Malaga province which is located in the southern part of the Spain and on the northern coast of the Mediterranean Sea, and is under autonomous community of Andalusia. The area of the province is 7,308 square kilometers.

All the data have been collected from Instituto de Estadística y Cartografía de Andalucía (IECA,) Junta de Andalucía (2001 – 2018). For positive relationship, vulnerability of local people increases with the presence of indicator whereas for negative relationship, vulnerability decreases with increasing value of indicator (Table 1).

Table 1. Classifications of indicators.

Aspect	Indicators	Relationship with vulnerability	Reference
Locational	Distance from capital	Positive	Proposed in this research work
Demographic	Gender	Positive	Müller et al., 2011
	Child population (below 5 years)	Positive	Török, 2018
	Aged population (65 years and above)	Positive	Reid et al., 2009
	Dependency ratio	Positive	Kalaycıoğlu et al., 2006
	Single parent nuclei	Positive	Flanagan et al., 2011
	Median age	Negative	Burton et al., 2010
	Foreigners	Positive	Aksha et al., 2019
	Birth rate	Positive	Mavhura et al., 2017

Aspect	Indicators	Relationship with vulnerability	Reference
Social	Population density	Positive	Caliskan *et al.*, 2006
	Large household (5 or more)	Positive	Ge *et al.*, 2017
	Single and isolated living	Positive	Girasole *et al.*, 2017
	Literacy rate	Negative	Ahmad *et al.*, 2016
	Sport equipments/ 1000 population	Negative	de Oliveria Mendes, 2009
Economic	Renters	Positive	Armenakis *et al.*, 2017
	Employment rate	Negative	Dwyer *et al.*, 2004
	Population related to agriculture	Positive	Chen *et al.*, 2013
	Average net income (annual in euro)	Negative	Kirby, 2015
	Per capita income (annual in euro)	Negative	Emrich & Cutter, 2011
Health	Mortality rate	Positive	Lowe *et al.*, 2013
	Infant mortality rate	Positive	Gayen *et al.*, 2020
	Primary health care/1000 population	Negative	Fekete, 2009
	Number of pharmacy/1000 population	Negative	Guillard-Gonçalves *et al.*, 2014

Source: Own elaboration.

To calculate the indicators, data have been standardized by using three different methodologies (Table 2).

Table 2. Three standardization methodologies.

Methodology	Theory		Significance	References
	Positive relationship	Negative relationship		
Maximum value transformation	$x = \frac{x_i}{max}$	$x = 1 - \frac{x_i}{max}$	x_i= Actual value *max*= Maximum value	Wu *et al.*, 2002; Chakrabort *et. al.*, 2005
Z score transformation	$x= (q - \mu) / \sigma$ Final value adds with total value.	$x= (q - \mu) / \sigma$ Final value deducted from total value.	q= Actual value μ= Mean σ= Standard deviation	Zhang & Huang, 2013; Evans *et. al.*, 2014
Min-max rescaling transformation	$x = \frac{x_i - min}{max - min}$	$x = \frac{max - x_i}{max - min}$	x_i= Actual value *min*= Minimum value *max*= Maximum value	Tali *et al.*, 2016; Kablan *et al.*, 2017

Source: Own elaboration.

Social vulnerability index (SVI) or final value has been calculated by average of all indicators for each municipality for each standardization method.

4. RESULTS

Based on standard deviation score of each methodology adopted, SVI score are grouped into five different categories, hereafter called as vulnerable zones.

- Very low vulnerable zone (< -1.5 std. dev.)
- Low vulnerable zone (-1.5 – -0.50 std. dev.)

- Medium vulnerable zone (-0.50 – 0.50 std. dev.)
- High vulnerable zone (0.50 – 1.5 std. dev.)
- Very high vulnerable zone (> 1.5 std. dev.)

Atajate, Juzcar, Macharaviaya, Moclinejo, Rincon de la Victoria municipalities are common to each methodologies adopted and so categorized in very low vulnerable zone.

The top six municipalities with the highest vulnerability that has been identified in this study are Alcaucin, Benadalid, Cuevas del Becerro, Gaucin, Guaro, Istan.

Table 3. Pearson's correlation coefficient between three methodologies.

	Maximum value transformation	Z score transformation	Min–max rescaling transformation
Maximum value transformation	1	—	—
Z score transformation	0.89	1	—
Min–max rescaling transformation	0.93	0.98	1

Source: Own elaboration.

The result indicates that the strength between maximum value transformation and z score transformation (0.89) is strong. The values of the correlation coefficient are 0.93 (between maximum value transformation and min–max rescaling transformation) and 0.98 (between z score transformation and min–max rescaling transformation) which signify extremely strong relation.

5. DISCUSSION

Main causes of very high vulnerability are mainly low net income and low income/population, high female population, moderately high unemployment rate and high dependency ratio. In a broad sense, similar results are usually obtained by other studies in different contexts (Cutter *et al*., 2003; Morales *et al*., 2016; Navarro *et al*., 2020).

Municipalities show some advantages mainly related to data gathering, both on socio-economic and disaster damages data. Nevertheless, municipality extent should be very unsuitable if social vulnerability assessments and the resulted maps are to be used for subsequent risk studies by mean of integration of vulnerability and hazard maps. While an increasing spatial detail has been reached in hazard mapping (Muhadi *et al*., 2020), only some aspects of vulnerability related to characteristics of buildings, infrastructures or land-use patches (Papathoma-Köhle *et al*., 2019), or related to spatial indicators like accessibility (Barrionuevo & Perles Roselló, 2017), show comparable levels of spatial resolution. To overcome this gap among social vulnerability and hazard maps, indicators based social vulnerability assessment should look for other types of spatial units as census district or cadastral parcels and buildings (Navarro *et al.*, 2020; Tascón-González *et al.*, 2020).

6. CONCLUSION

Natural hazards cause great damages all over the world. Hazard maps can identify hazard prone areas but cannot able to measure the vulnerability of population in any region. Social vulnerability measures the susceptibility of social groups to the impacts of hazards and it is an important tool of hazard risk reduction system. This study also investigated spatial patterns of social vulnerability in Malaga province using three different standardization methods. The results obtained from these methodologies are almost same. So any

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of the methodologies used in this paper, could potentially be employed to identify vulnerable municipalities for another province. This study will help to build the distribution of vulnerable municipalities in Malaga province which is important for hazard management and thus to identify the socio-economically vulnerable community.