Spatial flood vulnerability assessment. Decision makers' challenges.

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Abstract

Floods are one of the main disasters that frequently occur in several parts of the world leading to lives and property losses. Vulnerability, as an important part of the risk assessment, has become a foremost matter to decision makers so they can take efficient measures, either if it is needed for immediate reaction following an event or it is needed for long term planning. For both circumstances we discuss, for the first time, the appropriateness of two, extensively used in literature, vulnerability assessment approaches. Multicriteria decision analysis, which allows for several scenarios can be considered more adequate to long term planning, on the other hand, principal component analysis which conveys one single result, exhibit its potentialities in the responsiveness to a close event.

Keywords: Decision; Flood; Vulnerability.

1 Introduction

From 2001 to 2010, hydrological disasters in Europe took the largest share of total disaster victims (55.1%) and millions of Euros on damages [1]. Currently, understanding the vulnerability for flood risk assessment is an important issue because climate models project an increase in rainfall intensity in warmer climates [2, 3, 4] that will lead to an increase in the frequency of flood events [4]. Vulnerability assessment is thus of paramount importance as a tool to ensure people and property protection.

There are four dimensions that need to be considered in vulnerability assessment: (1) the physical dimension that represents the potential of the hazard impact on the built infrastructures; (2) the economic dimension that accounts for the potential impacts of hazards on economic assets; (3) the social dimension that relates to the presence of human beings, individuals or communities, and their capacity to cope, resist and recover from hazards impacts and (4) the environmental dimension that refers to potential impacts on natural environment and the ability of ecosystems to cope and recover from hazards impacts.

Combining all these aspects on a flood vulnerability index presents a great challenge due to several conceptual and methodological problems. The main challenges already dealt with are related with data, spatial and time scale, aggregation methods, indicator weighting, subjectivity in the statistical methods and in the vulnerability concept, transparency, perception and decision makers [5].

The need for validation of the results with field survey, can be considered a drawback in the vulnerability assessment and may be the reason why we lack on literature reviews that compare different methods.

In this paper we intend to discuss which methodological approach is more suitable to decision makers in different situations, either immediate response to an event or long term management. Our discussion will not be about the results obtained by different indices approaches but about how each approach is more suitable to towards different decision maker's challenges. We compare two flood vulnerability indexes, one based on Multicriteria Decision Analysis (GIS-MCDA) and the other based on Principal Component Analysis (PCA).

2 Data and Methods

2.1 Study area

The flood vulnerability was assessed for the municipality of Vila Nova de Gaia, Northern Portugal, where several flood

events occurred. Between 1865 and 2010, 57 floods have been reported in Vila Nova de Gaia municipality which account for a total of four deaths, 123 evacuated and 2930 displaced. The municipality is located in the fourth place on the Portuguese ranking of flood disasters. This municipality is the third most populous in Portugal, with 302,295 inhabitants in 2011, approximately 180,000 of which are urban residents.

The vulnerability indices were designed according several variables or characteristics such as: building density, number of floors, construction period, building structure, housing occupancy, gender, education level, age, unemployment, household composition, economic activity sector, land use, and urban growth. Every single variable is comprehensively described in terms of resilience and recovery capacity.

2.2 Multicriteria decision analysis

The combination of GIS with MCDA methods creates a powerful tool for spatial planning. GIS-MCDA is a process that transforms and combines spatial data and value judgments into a resultant decision [6]. It provides a spatial analysis of flood vulnerability and allows for a better understanding of their multidimensional aspects. The relative weight of the vulnerability criterion is estimated by the Analytic Hierarchy Process (AHP) and ordered weighted averaging (OWA) is used to map social vulnerability.

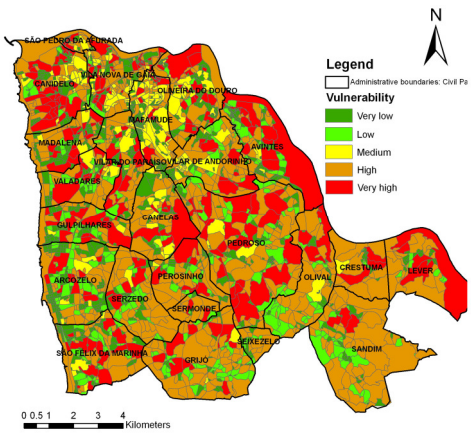
The methodological process for assessing vulnerability follows the next steps: (1) hierarchical structure of the social vulnerability model, (2) standardization of the criteria, (3) criteria weighting, and (4) decision rules and the mapping of social vulnerability scenarios [8].

Several scenarios can be defined by the position of the OWA on the continuum decision strategic space that can be identified by specifying the degree of ORness or ANDness [7] that express optimistic or pessimistic risk perception. This method can be greatly improved if the different stakeholders are engaged in the weighting process and several scenarios are studied in the OWA strategic decision space.

2.3 Principal component analysis

The PCA was applied to reduce the number of variables in order to derive some components that summarize different vulnerability characteristics. Those components scores have then to be combined into a single score using an aggregation method. The aggregation methods are another uncertainty source and weight the component scores in a different way. That is by itself something worthy of discussion. In this work we used a cluster based aggregation method.

Figure 1: PCA flood risk vulnerability map.



This form of classification does not impose any kind of constraint on the distribution of the areas to be classified. When performing PCA, only one vulnerability scenario is available.

3 Results and Discussion

The implication of using different methodological approaches (Figure 1 and Figure 2), is patent on those vulnerability maps. This information will be used to take actions, so it is very important to define which method should be used for each situation.

When considering PCA the information offered is unique, the decisions have to be made according to that scenario. If the decision maker wants to take action promptly in order to be prepared for the next flood, he will not have the time to look to different scenarios and the investments in prevention must be cautiously taken. Therefore, our conviction is that a vulnerability assessment must be done according to the PCA approach with the cluster aggregation method, which provides the decision maker with a unique solution that highlights clearly the hot spots.

On the other hand if the decision maker is enrolled in a planning process he must carefully analyse different scenarios. The timetable allows them to include other stakeholders in the criteria weighting process, which will greatly improve the results. So if the goal is to define the measures to be implemented on a long term agenda, the GIS-MCDA will certainly be the most adequate method.

It should be added that the results of the two approaches are not comparable.

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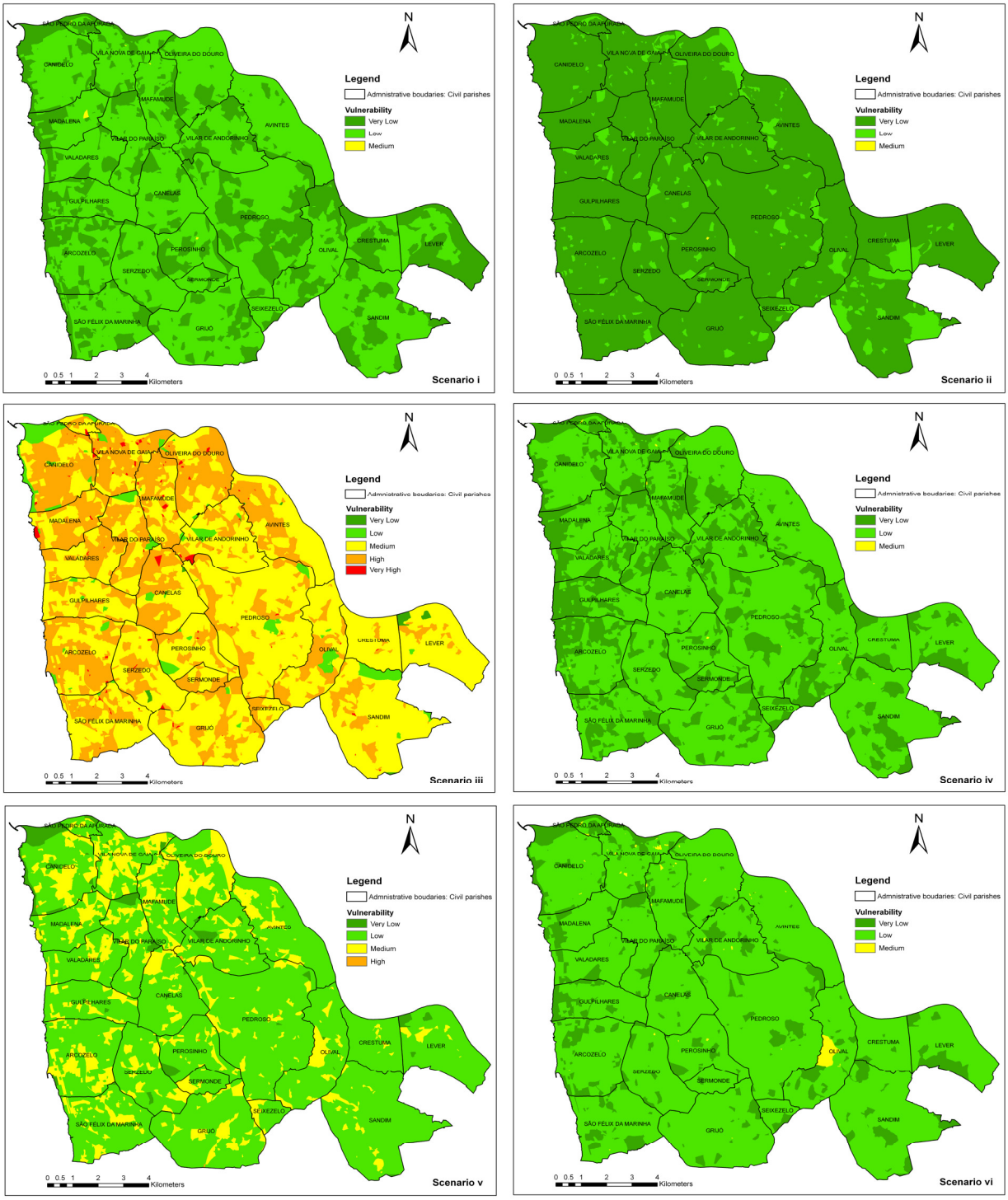
Figure 2: GIS-MCDA flood risk vulnerability for 6 scenarios on the decision strategic space.



Source: [8]