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Vulnerability assessment including tangible and intangible components in the index composition: An Amazon case study of flooding and flash flooding

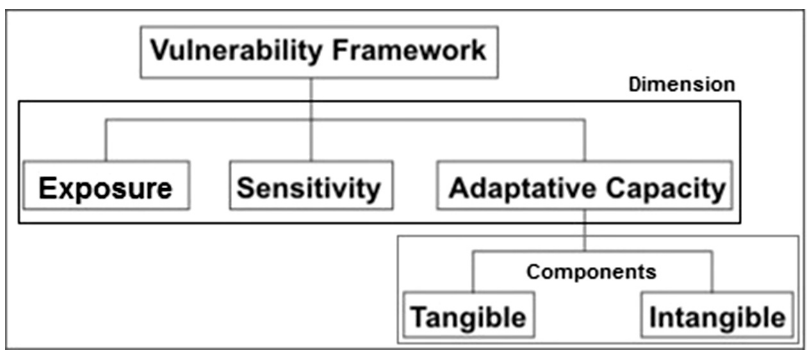
Milena Marília Nogueira de Andrade [a,*], Claudio Fabian Szlafsztein [b]

[a] Universidade Federal Rural da Amazônia, ICIBE/Engenharia ambiental, Avenida Presidente Tancredo Neves, N° 2501, Bairro: Terra Firme, Cep: 66.077-830, Cidade, Belém, Pará, Brazil
[b] Universidade Federal do Pará, Núcleo de Meio Ambiente, Rua Augusto Corrêa, 1, CEP: 66075-900, Belém, Pará, Brazil

HIGHLIGHTS

- The used of mixed-methods for use quantitative and qualitative data.
- The adaptive capacity dimensions separated into tangible and intangible components.
- The role adaptive capacity in vulnerability reduction beyond physical infrastructure
- The vulnerability incensement due exposure

GRAPHICAL ABSTRACT



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ABSTRACT

The vulnerability of cities and communities in the Amazon to flooding and flash flooding is increasing. The effects of extreme events on populations vary across landscapes, causing vulnerability to differ spatially. Traditional vulnerability studies in Brazil and across the world have used the vulnerability index for the country and, more recently, municipality scales. The vulnerability dimensions are exposure, sensitivity, and adaptive capacity. For each of these dimensions, there is a group of indicators that constitutes a vulnerability index using quantitative data. Several vulnerability assessments have used sensitivity and exposure analyses and, recently, adaptive capacity has been considered. The Geographical Information Systems (GIS) analysis allows spatial regional modeling using quantitative vulnerability indicators. This paper presents a local-scale vulnerability assessment in an urban Amazonian area, Santarém City, using interdisciplinary methods. Data for exposure and sensitivity were gathered by remote sensing and census data, respectively. However, adaptive capacity refers to local capacities, whether infrastructural or not, and the latter were gathered by qualitative participatory methods. For the mixed data used to study adaptive capacity, we consider tangible components for countable infrastructure that can cope with hazards, and intangible components that reflect social activities based on risk perceptions and collective action. The results indicate that over 80% of the area is highly or moderately vulnerable to flooding and flash flooding. Exposure and adaptive capacity were determinants of the results. Lower values of adaptive capacity play a significant role in vulnerability enhancement.

* Corresponding author.
E-mail address: milenamarilia.andrade@gmail.com (M.M.N. Andrade).

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1. Introduction

Natural hazards afflict countries differently, but many countries are subject to multiple hazards such as floods and flash floods (UN-WB, 2010). Floods are defined as the overflow of a large amount of water beyond its normal confines, and flash floods are a sudden rush of water over dry land, usually caused by a large amounts of rain over a relatively small area (UN-SPIDER, 2017; Ministério das Cidades, 2007). Together these two hazards events were responsible for 74% of the deaths caused by natural disasters in Brazil during 1991–2010 (CEPED, 2013; Debortoli et al., 2017).

Approximately 4756 km of Brazil's rivers are highly susceptible to high-impact floods, and 180,000 people face either high or very high risks of flooding (ANA, 2014; Andrade et al., 2017a, 2017b). Around 47 deaths and 261,791 instances of dislodgement were attributed to flash flooding during 1991–2012 in 42 affected municipalities (CEPED, 2013). In 2009, extreme flooding and flash flooding events occurred in the Amazon region of Brazil and were associated with the "La Niña" phenomenon (Marengo et al., 2012; Sena et al., 2012). Deforestation, unsustainable land use management, and high-vulnerability social conditions also contributed to the increased risk of flood disasters in the region (Sternberg, 1987; Nagy et al., 2016; Hummel et al., 2016).

Risk is a product of hazard and vulnerability, and this latter refers to the conditions that increase the susceptibility of a community to the impact of hazards determined by physical, social, economic, and environmental factors or processes (UNISDR, 2004, 2009). In the natural hazard and climate change research, the vulnerability concept is a function of the exposure, sensitivity, and adaptive capacity dimensions (Brooks, 2003; Adger, 2006; Füssel, 2007).

Communities within the same hazard exposure zone can have varying sensitivity or adaptive capacity (Frazier et al., 2013a, 2013b; Wood et al., 2010), making the assessment of these capacities important to understanding the variations in vulnerability from the exposed elements at risk. The vulnerability assessment, at a diversity of scales, has been addressed by using indicators and indexes, operated, and displayed using GIS platform's for spatial results (Birkmann and Welle, 2016; Papathoma-Köhle, 2016; Mansur et al., 2016; Frazier et al., 2014; Hummel et al., 2016; Szlafsztein and Sterr, 2007; Andrade et al., 2010; Wood et al., 2010; Cutter et al., 2003).

Exposure and sensitivity indicators are mainly related to countable or the density of exposed assets (Röthlisberger et al., 2017) and quantitative socioeconomic factors (Hummel et al., 2016; Eakin and Luers, 2006; Morrow, 1999; Cutter et al., 2003), respectively. However, adaptive capacity focus on adjustments, adaptation (Turner et al., 2003), and institutional capacity (Adger et al., 2004; UNISDR, 2007) that requires qualitative research methods of investigation. This requirement leads to our research question: how to integrate quantitative and qualitative methods to assess vulnerability from a holistic perspective?

To approach this issue, interdisciplinary scope and mixed methods should be used. As the exposure and sensitivity data are well known from the quantitative data in the literature mentioned above, we focus on vulnerability reduction by physical or non-physical factors separating the tangible and intangible aspects of adaptive capacity (Fig. 1).

The tangible components include the existing structural assets and physical infrastructure that manages hazards that can be expressed in monetary values (Messner and Meyer, 2006). Engineering strategies and shelter were primarily considered, but health and psychological support institutions for the affected population during and after disasters are also included (Cutter et al., 2010; Birkmann and Welle, 2016).

The intangible components include the adaptive capacity of people, their attitudes and beliefs that influence their action shaping the vulnerability (De Marchi and Scolobig, 2012), such as risk perception and collective action. Collective action dynamics involve a social network and its characteristics in a common action to pursue a shared interest (Matta and Alavalapati, 2006). Social networks that develop adaptive strategies in natural hazard context can decrease vulnerability (Ireland and Thomalla, 2011; Adger, 2003; Massmann and Wehrhahn, 2014).

Risk perception has a background of cultural and appropriate judgments based on knowledge, practice, and previous experience (Brondizio and Moran, 2008, Renn, 2008; McElwee et al., 2017). The Cultural Theory of Risk can be used to identify community preferences in adaptation understanding cultural phenomena of how a group perceive and act upon environmental phenomena (McNeeley and Lazrus, 2014; Oltedal et al., 2004; Douglas and Wildavsky, 1982). Depending on the population's view of the natural environment, hazards shape these cultural worldviews in any of four ways: through fatalism, individualism, egalitarianism, or hierarchy (Lima and Castro, 2005). Egalitarian people view nature as fragile and believe that human interference can cause unexpected disasters (Hulme, 2009). The individualistic group views nature as benign and believes that humans are meant to rule over the environment. The hierarchical group believes that the government and laws can control nature's problems, while fatalists understand nature as capricious and unpredictable (Thompson et al., 1990).

2. Material and methods

2.1. Study area

The municipality of Santarém is located in western Pará State, Brazil. The city has a population of approximately 215,790, constituting 73% of the municipality's total population (IBGE, 2010). Socioeconomic characteristics of the Municipality Index for Human Development, which analyses life expectation, education, and income are at a medium level for Santarém (PNUD, 2013). The social vulnerability index concerning natural hazards is high owing to poverty and poor infrastructure (Hummel et al., 2016).

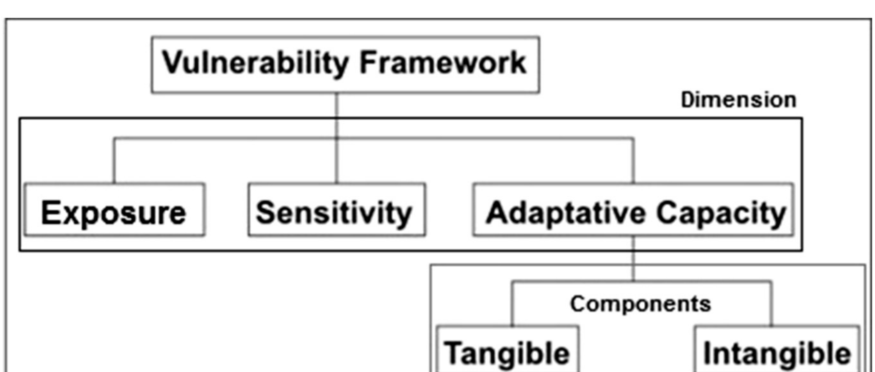

Fig. 1. Adapted vulnerability framework based on Adger (2006) and Füssel (2007) including tangible and intangible components.