Ocean & Coastal Management 116 (2015) 1–8

Contents lists available at ScienceDirect

Ocean & Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

# Categorizing social vulnerability patterns in Chinese coastal cities

Shiliang Su [a, b, *], Jianhua Pi [a], Chen Wan [a], Huilei Li [a], Rui Xiao [c], Binbin Li [d]

[a] *School of Resource and Environmental Sciences, Wuhan University, Wuhan, China*
[b] *Collaborative Innovation Center of Geospatial Technology, Wuhan University, Wuhan, China*
[c] *School of Remote Sensing and Information Engineering, Wuhan University, Wuhan, China*
[d] *He'nan Academy of Engineering of Surveying and Mapping, Zhengzhou, China*

A R T I C L E I N F O

*Article history:*
Received 16 November 2014
Received in revised form
20 June 2015
Accepted 28 June 2015
Available online xxx

*Keywords:*
Social vulnerability
Vulnerability assessment
Adaption
Coastal management
China

A B S T R A C T

Coastal cities play a leading role in world development; however, they are highly vulnerable to natural disasters given their specific locations and rapid urbanization pace. Characterizing the social vulnerability of coastal cities to hazards should provide critical references for coastal management. This paper developed a composite social vulnerability index (SVI) for Chinese coastal cities by integrating 17 indices from three aspects (exposure, sensitivity and adaptive capacity) that shaped the vulnerability of urban society to hazards; and then verified SVI effectiveness by quantifying its correlation with the total economic loss of hazards. Social vulnerability patterns along the Chinese coast in 2000, 2005 and 2010 were then obtained. Results showed that cities around the Bohai Bay generally presented lower SVI values in the three years. Cities in the eastern and southeastern coast generally had higher SVI values in space but became lower with time. Conversely, SVI values became higher for cities in Hainan and Guangxi Province. The clustering approach categorized the 53 cities into different groups according to their profiles of vulnerability. These categorized groups could facilitate more targeted coastal management options. This paper highlighted that adaption should be incorporated in analyzing the reaction of urban society to hazards. The SVI was believed to be an applicable and reliable tool to inform coastal management.



## 1. Introduction

Coastal cities are subjected to hazards both from the sea (e.g., tsunami, sea level rise, storm surge) and from the land (e.g., land subsidence, flooding) (Newton et al., 2012). They cover less than 10% of the global terrestrial surface, but sustain over 60% of the world's total population (UNEP, 2009). A number of megacities have emerged as a consequence of the accelerating urbanization in coastal zones (Pelling and Blackburn, 2013). Statistics showed that one third of the coastal cities accommodate more than one million residents (UNFPA, 2009). However, population increasingly concentrates on potential hazardous places, often in slum conditions or informal settlements, in the coastal cities of developing countries (Newton et al., 2012). The potential of casualty loss and volume of disaster affected victims increase as a consequence (Newton et al., 2012; Sekovski et al., 2012; Taramelli et al., 2015). Besides, the rapid urbanization heavily consumes the coastal vegetation and further accelerates the coastal erosion process, which increases the vulnerability to hazards (Nicholls and Tol, 2006; Sekovski et al., 2012). Increasing cities have gradually become vulnerability hotspots that are disproportionately distributed across coastal zones (Newton and Weichselgartner, 2014; Pelling and Blackburn, 2013). Under such circumstances, increasing emphasis has been recently placed on vulnerability assessment for hazard attribution in coastal management (Huang et al., 2012; Jacob et al., 2013; Newton and Weichselgartner, 2014).

In the natural science based paradigm, most studies emphasized disaster exposure risk and assessed the physical vulnerability (Turner et al., 2003; Wang et al., 2014). However, increasing scholars have been reluctant to take this perspective in recent years. They rather embrace the theory that the incorporation of social factors should contrite to more scientific interpretation (Cutter and Finch, 2008; Adger et al., 2011; King and Blackmore, 2013; Lee, 2014). It was evidenced that the effects of disasters could be magnified by certain social factors, including poverty, low living standards, low socioeconomic status, and poor public infrastructure (Brooks et al., 2005; Adger, 2006). These proxies of social inequality specify the social vulnerability collectively (Cutter et al., 2003; Brooks et al., 2005). Social vulnerability describes the extent to which the urban social system is susceptible to external

* Corresponding author. No.129 Luoyu Rd, Wuhan, Hubei Province, China.
*E-mail address:* shiliangsu@163.com (S. Su).

http://dx.doi.org/10.1016/j.ocecoaman.2015.06.026
0964-5691/

disturbances (Adger, 2006; Depietri et al., 2013). Social vulnerability plays a critical role in mediating the external impacts on specific places. It not only determines the local sensitivity to disasters, climatic events, and environmental changes, but also influences the capacity to cope with the external threats (Brooks et al., 2005; Roger et al., 2007; Adger et al., 2011). Social vulnerability accordingly provides a more comprehensive framework for hazard research than physical vulnerability, which solely focuses on the probability of risk exposure (Lee, 2014). However, social vulnerability of coastal cities has not been adequately quantified in recent literature. Besides, rather few efforts have been spared to compare and categorize the social vulnerability among coastal cities at regional and global scales.

Scholars have proposed different frameworks to examine the response of vulnerable societies to external threats (Adger and Vincent, 2005; Cinner et al., 2012; Huang et al., 2012; Depietri et al., 2013). Under these frameworks, vulnerability is typically measured from three dimensions: exposure, sensitivity, and adaptive capacity (Adger, 2006). Exposure refers to the magnitude of external or internal perturbations sustained by a system, and sensitivity is defined as the degree to which it would be affected by those perturbations (McCarthy et al., 2001). Adaptive capacity denotes the self-regulated ability of a system in order to adapt changing conditions and cope with external perturbations (Brooks et al., 2005). Coastal cities are exposed to multiple perturbations, and their sensitivity and adaptive capacity are determined by various social factors. A common approach to vulnerability assessment is to integrate a set of indicators into one composite index (Luers et al., 2003; Andrade et al., 2010; Huang et al., 2012). Such composite index can combine together various sources of different dimensions, and therefore provides a simple way to inform managers and policy makers (Depietri et al., 2013; Lee, 2014). However, a composite social vulnerability index for coastal cities is unavailable in the literature. A pilot study at regional level should be carried out for a potential future larger assessment at cross-national and global level.

With the geographical extent from 108°20′59″E to 124°20′56″E and from 18°15′16″N to 39°59′56″N, China has a coastline of over 18,000 km, stretching three climate zones (tropical, sub-tropical and temperate). Fig. 1 show the fifty three cities located in the Chinese coastal zones. These cities suffer from high frequency of hazards. Statistics showed that the coastal cities were attacked by 345 tropical cyclones during the period from 1961 to 2008 (Zhang et al., 2012). Though they cover only about 4.0% of land area, coastal cities play a leading role in China's socioeconomic development. For example, they contribute to 35% of the national total gross domestic product and account for 18% of the total population (China Statistical Yearbook, 2011). The fast socioeconomic development, in general terms, has dual influences on social vulnerability. For one thing, anthropogenic activities, in synergy with the physical pressures, lead to the situation that coastal cities are more prone to hazards (Newton and Weichselgartner, 2014). For another, higher economic production would promote better protection and warning systems, enhancing the resilience of coastal cities to hazards (Cross, 2001). All these factors should lead to the dynamic vulnerability of the coastal cities. Considering the great heterogeneity in natural and socioeconomic conditions, China provides a useful pilot case to investigate the social vulnerability of coastal cities in time and space.

The primary goal of this study was to quantify the social vulnerability of the coastal cities in China. We specifically attempted to: (1) develop a composite index to measure social vulnerability of coastal cities; (2) compare and categorize the social vulnerability among the Chinese coastal cities in time and space; and (3) provide some references for coastal management.

## 2. Materials and method

### *2.1. Development of a composite index*

No agreement has been reached on the definition of vulnerability, since the vulnerability terminology is a context-specific concept (Thywissen, 2006). In this paper, social vulnerability is the extent to which the urban social system is susceptible to the impacts from hazards. It can be expressed as a function of exposure, sensitivity, and adaptive capacity. Following this, it takes four steps to develop the composite social vulnerability index (SVI): (1) establishment of index systems; (2) pretreatment of data; (3) integration of the indices; and (4) verification of index effectiveness.

#### *2.1.1. Selection of indices*

Procedure of indices selection followed the approach demonstrated in Maes et al. (2011) for environmental assessment. We first selected 48 relevant indices after literature review and at the same time considering data accessibility. Reasons for indices selection were briefly summarized as follows.

(1) Exposure index (EI): exposure is defined as the degree to which an urban society is exposed to hazards. Indices were therefore chosen to indicate the frequency and intensity of hazard occurrence.
(2) Sensitivity index (SI): sensitivity in this study is inferred through the predisposition of the social context to suffer harms associated with the levels of disadvantageous conditions, fragilities of settlements, and relative weaknesses. Low socioeconomic status groups, the elder and children always lack the ability to cope with external harms during emergency situations (Depietri et al., 2013). Besides, for people living in the coastal lowlands, the degree to be affected should be higher, since the coastal lowlands are at the forefront of hazard attacks. Indices were there selected from these aspects.
(3) Capacity index (CI): Adaptive capacity, which reflects the potential of implementing adaption measures, is tightly correlated with deliberate anthropogenic attempts to cope or adapt. Capacity always involves a variety of factors such as technology, knowledge and skills, education, institutions, infrastructure, and social capital (Metzger et al., 2006). Indices were therefore selected to indicate the ability of human society to deal with the harms from hazards.

We then performed Pearson's correlation analysis with 95% confidence and principal component analysis (PCA) with varimax rotation to reduce the redundancy of the original data set. On condition that one pair of indices presented high correlation ($|r| > 0.9$), one of them was discarded (Su et al., 2014). Besides, indices with low factor loadings ($|r| < 0.75$) in each component were also discarded (Su et al., 2014). Expert panel evaluation was further performed on the remaining indices. Sixteen experts participated in the meeting for indices selection. These experts were from urban planning bureau, meteorological bureau and coastal management bureau. Each expert was given a manual that explained the whole procedure, all the indices and measurement method. In particular, expert judgment was guided by five criteria: measurability, discriminating ability, scientific validation, suitability, and scale appropriateness (Maes et al., 2011). Experts assigned a score to each indicator between 1 (very unfit) and 5 (very fit) by judging its relevance to the five criteria. The average score for each indicator was then calculated by assigning equal weight to all criteria and experts. Equal weight was assigned