Journal of Environmental Management 91 (2010) 1930–1942

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Assessment of flooding impacts in terms of sustainability in mainland China

Jinren Ni[a,*], Liying Sun[a,b], Tianhong Li[a], Zheng Huang[a], Alistair G.L. Borthwick[c]

[a] Department of Environmental Engineering, Peking University, The Key Laboratory of Water and Sediment Sciences, Ministry of Education, Beijing 100871, China
[b] Key Laboratory of Water Cycle and Related Land Surface Processes, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
[c] Department of Engineering Science, University of Oxford, UK

ARTICLE INFO

Article history:
Received 6 October 2008
Received in revised form
21 January 2010
Accepted 9 February 2010
Available online 2 June 2010

Keywords:
Flood hazard
Sustainability
Rapid assessment
Spatial characteristics
Linkage
Vulnerability

ABSTRACT

An understanding of flood impact in terms of sustainability is vital for long-term disaster risk reduction. This paper utilizes two important concepts: conventional insurance related flood risk for short-term damage by specific flood events, and long-term flood impact on sustainability. The Insurance Related Flood Risk index, *IRFR*, is defined as the product of the Flood Hazard Index (*FHI*) and Vulnerability. The Long-term Flood Impact on Sustainability index, *LFIS*, is the ratio of the flood hazard index to the Sustainable Development Index (*SDI*). Using a rapid assessment approach, quantitative assessments of *IRFR* and *LFIS* are carried out for 2339 counties and cities in mainland China. Each index is graded from 'very low' to 'very high' according to the eigenvalue magnitude of cluster centroids. By combining grades of *FHI* and *SDI*, mainland China is then classified into four zones in order to identify regional variations in the potential linkage between flood hazard and sustainability. Zone I regions, where *FHI* is graded 'very low' or 'low' and *SDI* is 'medium' to 'very high', are mainly located in western China. Zone II regions, where *FHI* and *SDI* are 'medium' or 'high', occur in the rapidly developing areas of central and eastern China. Zone III regions, where *FHI* and *SDI* are 'very low' or 'low', correspond to the resource-based areas of western and north-central China. Zone IV regions, where *FHI* is 'medium' to 'very high' and *SDI* is 'very low' to 'low', occur in ecologically fragile areas of south-western China. The paper also examines the distributions of *IRFR* and *LFIS* throughout mainland China. Although 57% of the counties and cities have low *IRFR* values, 64% have high *LFIS* values. The modal values of *LFIS* are ordered as Zone I < Zone II ≈ Zone III < Zone IV; whereas the modal values of *IRFR* are ordered as Zone I < Zone III < Zone IV < Zone II. It is recommended that present flood risk policies be altered towards a more sustainable flood risk management strategy in areas where *LFIS* and *IRFR* vary significantly, with particular attention focused on Zone IV regions, which presently experience poverty and a deteriorating eco-system.

1. Introduction

The concept of sustainability has brought fundamental changes in terms of development and environment since the 1980s (Lélé, 1991). Sustainability involves considering the consequences of present actions from a long-term perspective, the goal being to achieve a satisfactory quality of life both in the present and in the future (Gasparatos et al., 2008). To help achieve this goal, various tools are being developed in order to obtain integrated measures of sustainability, including interactions between environmental, social and economic issues (Ravetz, 2000). Of these tools, indicators and indices are widely used due to their simplicity. Examples include the 58 national indicators used by the United Nations Commission on Sustainable Development (UNCSD), the Environmental Pressure Indicators (EPIs) developed by the Statistical Office of the European Communities (Eurostat), and the Sustainable National Income (SNI) indicator developed in the Netherlands (Ness et al., 2007). In China, a large number of indicators and indices have been proposed for measuring sustainable development. For example, a five-level indicator system was used to evaluate sustainability in 31 provinces in 1990 (Chinese Academy of Sciences Research Group on Sustainable Development, 1999). In the companion paper, a Sustainable Development Index (*SDI*) has been constructed from data relating to 2339 counties and cities in mainland China, based on a four-layer sustainable development index system with 31 basic indices (Sun et al., 2010).

Certain natural hazards can greatly hinder sustainable development. A major threat is posed by extreme natural water-related disasters, such as the European floods in 2002, the Indian Ocean Tsunami in 2004, and Hurricane Katrina in 2005. Such disasters can

* Corresponding author. Tel.: +86 10 62751185; fax: +86 10 62756526.
E-mail address: nijinren@iee.pku.edu.cn (J. Ni).

0301-4797/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jenvman.2010.02.010

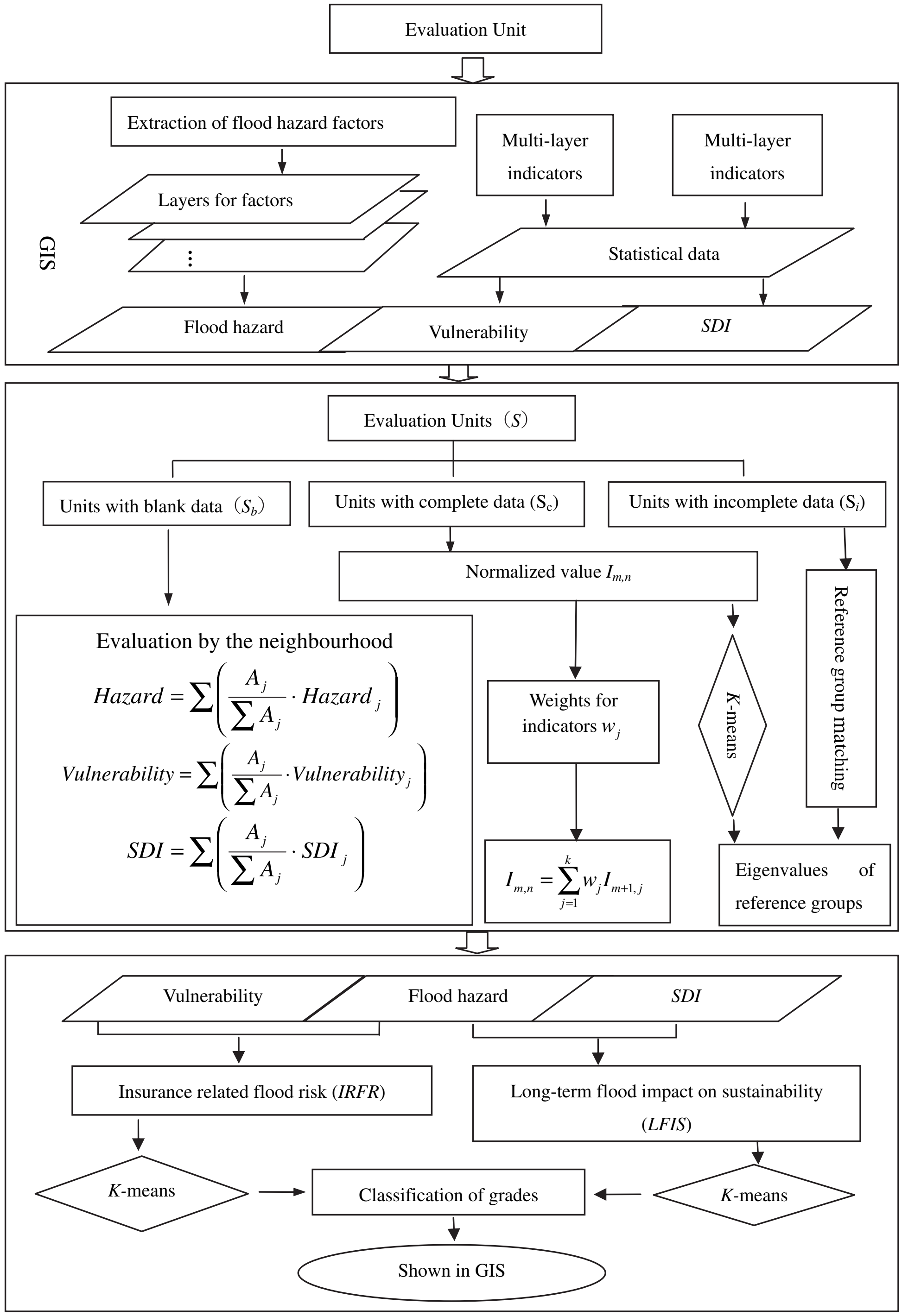

Fig. 1. Technique route of rapid assessment.

be devastating, and threaten to derail sustainable development (Griffis, 2007). Cumulative impacts are caused by frequently occurring natural disasters. For developing and vulnerable countries, extreme disasters may destroy the groundwork towards sustainable development (Khandlhela and May, 2006). Of natural water-related hazards, flood events occur relatively frequently worldwide and can have severe impacts. Berz (2000) reports that about one-third of all natural disasters are flood-related, and provides data on the economic and human costs of major floods in the late 20th Century. There are some notable floods in history. For example, the Great Flood of 1993, which occurred in the American Midwest, caused between US$ 12 and 16 billion worth of damage (Hipple et al., 2005). Another example is the 2000 Mozambique Flood, which caused the worst flood damage in 50 years to local areas and displaced 450,000 people (Hashizume et al., 2006). China is particularly prone to flood disasters (Zong and Chen, 2000). Huge numbers of people have lost their lives in floods along the Yellow River, including more than 300,000 at Kaifeng in 1642, more than 870,000 in 1887 and between 100,000 and 4 million in 1931 (see e.g. White, 2001). In 1998, China experienced losses in excess of US$ 30 billion caused by the large-scale flooding of the Yangtze River (Berz, 2000). However, conventional sustainable development