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Modelling the changing cumulative vulnerability to climate-related hazards for river basin management using a GIS-based multicriteria decision approach

Hung-Chih Hung (1), Ju-Yu Wu (2), and Chih-Hsuan Hung (3)

(1) Department of Real Estate and Built Environment, National Taipei University, New Taipei City, Taiwan (hung@mail.ntpu.edu.tw), (2) Department of Real Estate and Built Environment, National Taipei University, New Taipei City, Taiwan (lovelovejapan603@gmail.com), (3) Department of Real Estate and Built Environment, National Taipei University, New Taipei City, Taiwan (katy791117@gmail.com)

1. Background
Asia-Pacific region is one of the most vulnerable areas of the world to climate-related hazards and extremes due to rapid urbanization and over-development in hazard-prone areas. It is thus increasingly recognized that the management of land use and reduction of hazard risk are inextricably linked. This is especially critical from the perspective of integrated river basin management. A range of studies has targeted existing vulnerability assessments. However, limited attention has been paid to the cumulative effects of multiple vulnerable factors and their dynamics faced by local communities. This study proposes a novel methodology to access the changing cumulative vulnerability to climate-related hazards, and to examine the relationship between the attraction factors relevant to the general process of urbanization and vulnerability variability with a focus on a river basin management unit.

2. Methods and data
The methods applied in this study include three steps. First, using Intergovernmental Panel on Climate Change's (IPCC) approach, a Cumulative Vulnerability Assessment Framework (CVAF) is built with a goal to characterize and compare the vulnerability to climate-related hazards within river basin regions based on a composition of multiple indicators. We organize these indicator metrics into three categories: (1) hazard exposure; (2) socioeconomic sensitivity, and (3) adaptive capacity. Second, the CVAF is applied by combining a geographical information system (GIS)-based spatial statistics technique with a multicriteria decision analysis (MCDA) to assess and map the changing cumulative vulnerability, comparing conditions in 1996 and 2006 in Danshui River Basin, Taiwan. Third, to examine the affecting factors of vulnerability changing, we develop a Vulnerability Changing Model (VCM) using four attraction factors to reflect how the process of urban developments leads to vulnerability changing. The factors are transport networks, land uses, production values of industries, and infrastructures. We then conduct a regression analysis to test the VCM. To illustrate the proposed methodology, the data are collected from the National Science and Technology Center for Disaster Reduction, Taiwan as well as the National Land Use Investigation and official census statistics.

3. Results and policy implications
Results of CVAF analysis demonstrate heterogeneous patterns of vulnerability in the region, and highlight trends of long-term changes. The vulnerable areas unfold as clustered patterns and spatial analogues across regions, rather than randomly distributed. Highest cumulative vulnerability is concentrated in densely populated and downstream reaches (such as Taipei City) of the Danshui River in both time periods. When examining the VCM, it indicates that upper stream and more remote areas generally show low vulnerability, increases are observed in some areas between 1996 and 2006 due to land use intensification, industrial and infrastructure expansion. These findings suggest that land use planning should consider the socioeconomic progression and infrastructure investment factors that contribute to urban sprawl and address current as well as future urban developments vulnerable to hazard risk transmission. The cumulative vulnerability assessment, mapping methods and modelling presented here can be applied to other climate change and hazard risks to highlight priority areas for further investigation and contribute towards improving river basin management.