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# Social vulnerability of rural households to flood hazards in western mountainous regions of Henan province, China

D. L. Liu<sup>1,2</sup> and Y. Li<sup>2</sup>

<sup>1</sup>Safety and Emergency Management Research Center, Henan Polytechnic University, Jiaozuo, 454000, China

<sup>2</sup>Department of Civil and Environmental Engineering, Michigan Technological University, Houghton, MI 49931, USA

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Correspondence to: D. L. Liu (liudelina@163.com)

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Liang, 2014). In order to effectively reduce the adverse effects of a flood disaster, it is necessary to enhance the understanding of the social vulnerability of flood hazard-prone areas (Cutter et al., 2003, 2013; Zhang and You, 2014). Since Cutter developed a social vulnerability index to measure the social vulnerability to environmental hazards (Cutter et al., 2003), there have been growing concerns and interest in this area (Bjarnadottir et al., 2011; Noriega and Ludwig, 2012; Zebardast, 2013; Siagian et al., 2014; Garbutt et al., 2015). For example, Noriega and Ludwig (2012) assessed the social vulnerability of local earthquake risk in Los Angeles County. Zebardast (2013) constructed a social vulnerability index to earthquake hazards using a hybrid factor analysis and analytical network process model. Using the social vulnerability index approach, Siagian et al. (2014) determined the driving factors of social vulnerability to natural hazards in Indonesia. Garbutt et al. (2015) presented an open source vulnerability index and mapped the social vulnerability to flood hazards in Norfolk, England. All these studies provide a good understanding of the social vulnerability to natural hazards. However, these studies focused on contributing to theoretical research or empirical study at national or regional scales (Garbutt et al., 2015; Zhou et al., 2014; Cutter and Finch, 2008; Cutter et al., 2013). The studies at the household level are very little. The household is the basic unit of social organization, and which is also one of the most important flood hazard-prone areas (Eakin and Bojorquez-Tapia, 2008; Ghimire et al., 2010), and more than six hundred million people live in a rural area in China. Therefore, understanding the social vulnerability at rural household level is crucial for both rural households and local governments to prepare, mitigate and response to natural hazards (Ghimire et al., 2010; Linnekamp et al., 2011).

The objectives of this paper were (1) to identify and prioritise key influencing factors of social vulnerability to flood hazards at household level, (2) to develop and use a household social vulnerability index to assess the household social vulnerability to flood hazards in western mountainous regions of Henan province, China, and (3) to propose some targeted mitigation strategies to reduce the household social vulnerability to flood hazards.

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## 2 Household social vulnerability index (HSVI)

Several methods can be used to evaluate the social vulnerability to natural hazards, such as assessment method based on historical disaster data and scenario-based, GIS-based and index-based assessment methods (Li et al., 2008). The index-based assessment method was used here mainly because (1) which can effectively reveal the spatial and temporal patterns, evolution of vulnerability to a natural hazard at different scales, and (2) the assessment results among different regions are comparable due to the use of the same assessment index system (Cutter et al., 2003; Garbutt et al., 2015). There are five steps for using index-based method to assess the household social vulnerability to flood hazards as the follows:

1. Determination of assessment scales. Firstly of all, it is necessary to determine the research scales because index-based assessment method can be used at different scales with different indicators. In this study, the rural household-level was chosen.
2. Selection of indicators. There are a number of factors affecting the social vulnerability of rural households to flood hazards. In order to make the selected factors as comprehensive as possible, two methods were used in this study. One is interactive discussions with multidisciplinary specialists and local farmers (Ghimire et al., 2010), and another is obtaining indicators from the existing literature (Cutter et al., 2003; Werg et al., 2013; Linnekamp et al., 2011).
3. Collection and processing of data. Two methods, participatory rural appraisal (PRA) and household survey, were used to gather the data. The PRA method was used to gather some supporting information, such as their socioeconomic status, attitudes to flood hazards. Household survey (individual interviews) was used to collect the quantitative data of social vulnerability indicators (Ghimire et al., 2010). When the data were gathered together, it is necessary to normalize them to have a uniform dimension. Meanwhile, some indicators have favorable impacts, while

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the 11 villages is  $88.2 \text{ km}^2$ , and most of which is hilly land. The area of arable land ( $7.2 \text{ km}^2$ ) only accounts for 8.2 % of the total area. The per capita income is less than USD  $250 \text{ yr}^{-1}$ , and the poverty rate was higher than that in China (Xi, 2012). The annual mean precipitation is about 750 mm, and about 60 % of which occurs during the period of June to September. Rainstorm can easily result in a flood because of the steep and narrow riverbeds, poor flood discharge capacity and intense human activities (Shao et al., 2013). These villages were chosen as the study area mainly because (1) the conditions of nature, society and economy are very similar to most other villages' in the western mountainous regions of Henan province, and (2) it is easy to obtain sufficient and reliable data because these villages had undergone some severe flood disasters in recent years.

### 3.2 Selected indicators and weights

Based on the existing literature (Cutter et al., 2003; Werg et al., 2013; Linnekamp et al., 2011) and interactive discussions with multidisciplinary specialists and local farmers, eight indicators were identified to assess the social vulnerability at household level to flood hazards. The selected indicators and their weights, definitions, measurement methods and underlying assumptions are shown in Table 1.

The eight selected indicators can be divided into two categories. One is the basic information of family characteristics, including family size, dependency ratio, illiteracy ratio (15+) and the ratio of perennial working in other places. Another is the ability to prepare, mitigate and response to flood disasters, including per capita income, access to hazard-related information, vehicles per capita and hazard-related training. The weight of each indicator was determined by using PCA method and SPSS 17.0 software (Qu, 2012). Table 1 showed that the indicator with the biggest weight value (0.17) was the ratio of perennial working in other places, the indicator with the smallest weight value (0.09) was dependency ratio, and the weight values of other indicators ranged from 0.10 to 0.14.







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phi and experts grading method. The second category is objective weighting method, such as entropy method and PCA. The third category is an integrated subjective and objective weighting method, such as analytic hierarchy process (AHP). Each of these methods has its advantages and disadvantages (Wang et al., 2012), and different index weight could affect the scores of assessment results. Therefore, how to determine the reasonable index weights is an important problem to be solved in assessment research. (3) A comparison between the assessment results and a post-event situations is a feasible method to test the validity of selected indicators and their weights. For example, Cutter tested the validity of the SoVI during Hurricane Katrina (Cutter et al., 2003; Cutter and Finch, 2008). In this study, we calculated the correlation coefficient between scores of household social vulnerability and the casualties of each household in a storm flood in July 2010. The results showed that the correlation coefficient was significant at 0.05 significance level ( $r = 0.248$ ), which indicated that the selected social vulnerability indicators and their weights were valid.

### 4.2 How to reduce social vulnerability

There were much exciting researches on how to reduce social vulnerability, but they mainly focused on the scales of country, region and river basin. For example, based on the analysis of driving factors of social vulnerability to natural hazards in Indonesia, Siagian et al. thought that it was a good way to reduce the social vulnerability by integrating social vulnerability maps in early warning systems (Siagian et al., 2014). Chen et al. put forward to some suggestions to reduce social vulnerability in the Yangtze River Delta region, such as reducing the unequal distributions of social resources, improving the employment rate (Chen et al., 2013). The studies at household level were little, especially to flood hazards (Chen et al., 2013; Siagian et al., 2014). In this study, the target strategies to reduce the household social vulnerability to flood disasters were discussed based on the assessment results (Table 3). At first, the ratio of perennial working in other places should be reduced as soon as possible, because it was the most dominant factor to result in high vulnerability. According to the investigation, in

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the 95 households, the number of people who perennial working in other places due to limited local job opportunities was 141, which accounted for 27.2% of the total people (519), 52.4% of the population aged between 18 and 64, and 82.5% of the people aged between 18 and 49, respectively. In order to solve this problem, the reasons why the local residents preferred working in other places to staying at home needs to be understood. The most important reason was that the high cost of farming and low price of agricultural products resulted in the low income of a family. Besides, the agricultural income in these regions is not guaranteed due to the variation of climate conditions. Another important reason was that there were few companies or factories to provide work opportunities for local residents. Therefore, the ratio of perennial working in other places should be reduced by establishing agricultural insurance and increasing the work opportunities to guarantee the local residents' income. And then, the disaster related knowledge and evacuation skills of the local residents should be enhanced through disaster related trainings. Some unexpected observations were found during this survey. For example, there were 64.2% of the interviewed people thought that a flood did not occur in this region, and only 23.2% of the interviewed people often received trainings of hazard-related knowledge or evacuation skills. As a result, certain level of trainings about flood hazards should be often held in order to improve the hazard-related knowledge and evacuation skills of local residents. Finally, the literacy ratio should be improved. From the perspectives of communities or governments, the following measures could be effective to reduce the social vulnerability to flood disasters. (1) Preparing flood hazards mitigation plan based on risk assessment results of flood hazards. (2) Improving the accuracy of disaster monitoring and warning systems. (3) Establishing specialized emergency management department and comprehensive rescue systems. (4) Developing an emergency plan and carrying out emergency drills and trainings.

## 5 Conclusions

In order to understand the rural household social vulnerability to flood hazards, a household social vulnerability index was developed, and the household social vulnerability at the selected 11 villages were assessed. Some mitigation strategies to reduce the household social vulnerability were proposed based on the assessment results. There are some interesting findings. (1) Through relevant references and interactive discussions with multidisciplinary specialists and local farmers, eight key indicators were identified and used to develop a household social vulnerability index. Their weights were determined using PCA method. The eight indicators and their weights were dependency ratio (0.09), illiteracy ratio (0.12), the ratio of perennial working in other places (0.17), per capita income (0.14), access to hazard-related information (0.12), vehicles per capita (0.10) and hazard-related training (0.14), respectively. (2) The results showed that the numbers of high, moderate and low vulnerable households were 14, 64 and 16, respectively, which accounted for 14.9, 68.1 and 17.0% of the total evaluated households, respectively. The correlation coefficient of HSV scores and casualties was significant at 0.05 significance level ( $r = 0.248$ ), which indicated that the selected social vulnerability indicators and their weights were valid. (3) The ratio of perennial working in other places, hazard-related training and illiteracy ratio (15+) were the most dominant factors to result in higher vulnerability. Access to hazard-related information and per capita income had the smallest impact on higher vulnerability, and the impacts of family size and vehicles per capita were moderate. (4) To reduce the household social vulnerability to flood hazards. Reducing the ratio of perennial working in other places, enhancing the hazard-related knowledge and evacuation skills were effective measures and must be carried out as soon as possible.

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**Table 1.** Selected indicators and their weights, definitions, measurement and underlying assumptions to social vulnerability (SV).

Indicator	Weight	Definition	Measurement	Assumptions
Family size	0.13	Total number of family members	Number of family members	The more the family members, the higher the SV. Because there are more people are exposed to flood hazards for a big family
Dependency ratio	0.09	Number of dependents (aged 0–18 and over the age of 65) to number of working-age people (aged 19–64)	(Number of dependents/number of people aged from 19 to 64) × 100%	The larger the ratio, the greater the burden on the average working-age people, and the higher the SV
Illiteracy ratio (15+)	0.12	Number of illiteracy (people are over the age of 15 and with inability to read and write) to the family size	(Number of illiteracy/family size) × 100%	The higher the ratio, the lower the ability to access to hazard-related information and resources, the higher the SV
The ratio of perennial working in other places	0.17	Number of people (who work in other place and can not return home for a long time) to family size	Number of people who work in other place/family size	The more people work in other place, the higher dependents ratio, and the higher the SV
Per capita income	0.14	The average income earned per person in a family	The total family income/family size	The higher the per capita income, the more the accumulation of wealth and ability to access to hazard-related information and resources, the lower the SV
Access to hazard-related information	0.12	It mainly refers to the ability to receive disaster risk information	Number of information receiving tools, including telephone, cell-phone, TV and Internet	The more information receiving tools, the more ability to access to risk information, the lower the SV
Vehicles per capita	0.10	Total number of vehicles in a family to family size	Number of vehicles/family size	The more vehicles per capita, the more ability to evacuate from a disaster, the lower the SV
Hazard-related training	0.14	Times to take part in hazard-related training for last 5 years	No = 0; One time = 0.5; Two or more times = 1	The knowledge, attitudes and behaviours to disasters can be improved by attending training. So, the more times to attend, the lower the SV

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**Table 2.** Spatial distributions of household social vulnerability (%).

Village	High	Moderate	Low
Manying	33	67	0
Shimen	29	57	14
Zhaozhuang	25	67	8
Gucheng	18	73	9
Hujia	13	87	0
Xipo	11	56	33
Tantou	11	61	28
Zhifang	10	60	30
Gouyu	0	100	0
Hecun	0	83	17
Zhangjia	0	83	17



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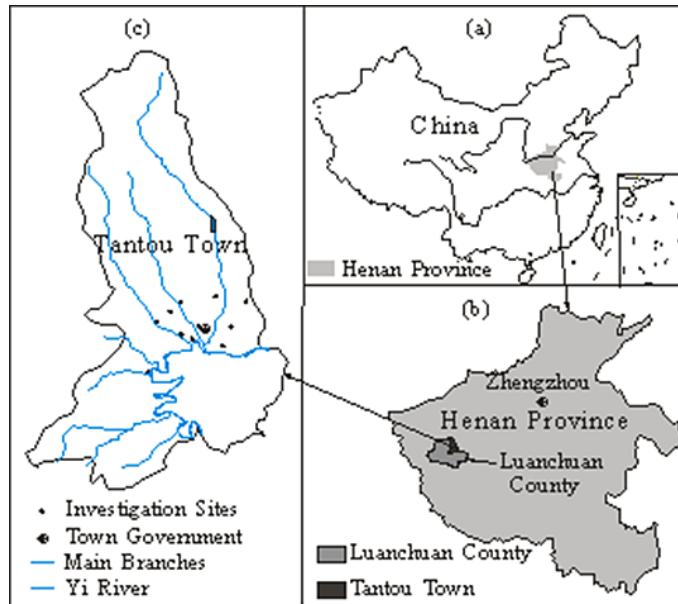
**Table 3.** The mean scores of low, moderate and high vulnerable households for each index ( $\times 100$ ).

Indicator	Low	Moderate	High	Ms/Ls	Hs/Ls
Ratio of perennial working in other places	2.03	7.19	11.4	3.54	5.62
Hazard-related training	2.19	6.45	9.5	2.95	4.34
Illiteracy ratio (15+)	2.00	5.14	6.66	2.58	3.34
Family size	6.26	8.31	11.03	1.33	1.76
Vehicles per capita	5.68	7.62	8.61	1.34	1.52
Dependency ratio	1.97	2.14	2.78	1.08	1.41
Access to hazard-related information	9.83	11.02	11.64	1.12	1.18
Per capita income	11.23	12.48	12.99	1.11	1.16

Note: Ms/Ls is the ratio of moderate vulnerability score to low vulnerability score;  
Hs/Ls is the ratio of high vulnerability score to low vulnerability score.

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**Figure 1.** Maps of study area **(a)** Location of Henan Province in China. **(b)** Location of the study area in Henan Province. **(c)** Investigation sites and distributions of rivers in study area.

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