

Constructing the Spatial Units of Vulnerability by the Analysis of Social-spatial Differences : A Case Study of Rainfall Disaster in Central Taiwan

Yu-Ling SONG¹, Pei-Shan LIN², Jien-Yi TU³

¹*Associate Professor,*

Dept. of Geography, National Changhua University of Education, Taiwan, yuling@cc.ncue.edu.tw

²*Assistant Professor,*

Graduate School of Disaster Management, Central Police University, Taiwan, sonialin@mail.cpu.edu.tw

³*Associate Professor,*

Dept. of Geography, National Changhua University of Education, Taiwan

ABSTRACT: The research focuses on investigating part of rainfall disaster area in Central Taiwan to comprehend the relationship between social and physical vulnerability and the possibility of deconstructing the given disaster spatial unit that would provide to GIS a relative proper spatial unit in the analysis. Therefore, we undertook the in-depth interviews in some villages and communities and induced the significances of the role of social vulnerability. Accordingly, we try to discuss that how we consider both of social and physical vulnerability to reconstruct the spatial unit? Regarding the research methods, we sorted the disaster area according to 3 disaster degrees via Soil and Water Conservation Bureau, Council of Agriculture, Executive Yuan, selected 3 villages belonged to 1st degree and 7 villages belonged to 3rd degree in Nantou of Central Taiwan. In-depth interview was adapted and 42 key persons were selected in the first round fieldwork. The contents of interviewed were transferred to texts and took the thematical analysis to discover the population profile, life experience related to the place, the cognition, decision of disaster, social structure and how they affect the resources of disaster prevention and social networks. Moreover, we analysis the spatial relationship between local residential and disaster experiences in Shenmu Village to investigate the possible of the smallest spatial units in disaster prevention and relief. To the present finding, first of all, there are some differences of the design of disaster prevention in 1st degree or 3rd-degree disaster area since the degree of disaster have changed the process of disaster prevention and gave the most power to the head of a village in the 1st degree. Secondly, the social vulnerability of 1st-degree disaster area is from the relationship with government administration that would be the special factor to affect the spatial aggregation in the disaster area. Thirdly, in different degree of the disaster area, the social vulnerability was not emphasized when administrative distribute the resources. However, both of them presented the opposite relationship between social and physical vulnerability. Finally, the spatial units were ignored so far, but we suggest using the various spatial units in different degree disaster area. This research is going to keep extending the area of interviews to collect the material of the characteristics of social and physical vulnerability at the individual level and try to re-build the proper spatial units of rainfall disaster and present the social differentiation of vulnerability.

Key Words: social-spatial differences, vulnerability, spatial units, disaster, central Taiwan

Since 1970, the rising of global temperatures has increased the water vapor content in the atmosphere. Present studies show that the intensity of rainfall has become stronger in most areas under the condition, and the extreme rainfall is more and more distinct. The weather characterized as a drier in dry seasons and more wet in wet season that will be normality in the future (Held and Soden 2006; Vecchi and Soden 2007; Chou et al. 2007; Sun et al. 2007; Chou et al.2013;Huang et al.2013). That does not only enhance the frequency of natural disasters, and more likely to be a serious threat to people's life and property safety. Thus, we cannot dismiss the fact that the environment has changed often.

Taiwan is situated in the sphere where the most notable of the affected monsoon system in the world, also is belong to the Northwest Pacific Ocean with most active typhoons. Both systems bring a lot of rain for Taiwan each year because the complex land conditions of Taiwan island which results in the various rainfall in different regions As the characteristics of climate is variability in Taiwan as well as the different locations and frequencies of disasters result of various disaster risks. According to the information platform for the adaptation to climate change in Environmental Protection Department shows the highly vulnerable area where flood, slope and the coastal disaster happened covers the central area of Taiwan. From the annual rainfall distribution (Figure 1a), the main areas are located rather on the North coast and the Yilan area than in central area. The interesting thing is that central Taiwan is not exclusively the main rainfall area, but it's coastal area shares the minimum annual total rainfall in Taiwan. The extreme rainfall in the same area that highlights the special nature of its climate, of course, is worthy of our concern and discussion the changes of rainfall and the potential for disaster risk in central Taiwan

to be the basis for disaster prevention and early warning in the future.

RESEARCH QUESTIONS AND OBJECTIVES

Although the understanding of current frequent disasters in Taiwan has been done, but how to establish an effective vulnerability unit in order to enhance the ability of disaster prevention that is waiting for more investment in research. Few present researchers who concern about the vulnerability are used to focusing on the vulnerability in geographical scope as defined by administrative district such as towns, counties and countries and build up the index of vulnerability, according to the official governmental statistics to predict the condition of disasters (Wu Jieying, Jiang Yijin, 2008; Ye Gaohua, 2013). However, recent studies appeared that the small-scale vulnerability unit was getting paid attention, especially the small-scale or individual levels analysis of social vulnerability (Lin Zonghong, 2012; Lin Zonghong, Zhang Yijun, 2013; Cutter and Finch, 2008; Rubin and Rossing, 2012; Lee, 2014; Bergstrand et al., 2014; Massmann and Wehrhahn, 2014) which include individuals, neighborhoods and communities, because the analysis of small-scale vulnerability and databases is the foundation for the large-scale estimation. Thus, the relief resource for individual vulnerability unit can be managed during the process of the prevention of disasters (Lin and Chang, 2013). Therefore, basing on the background, this paper select Nantou county which is the severely affected area because of the heavy rainfall in central Taiwan. We focus the discussion on the relationship between social and natural vulnerability in the disaster area and investigate if the current spatial unit for disaster prevention can be broken. Consequently, we interviewed in several settlements and induced the concepts about the social vulnerability's role and significances. Moreover, we also try to explore how to re-draw the spatial units through the negotiation between social and natural vulnerability.

RESEARCH AREAS AND METHOD

Taiwan took place a Richter scale 7.3 earthquake on September 21 early morning, 1999 in Jiji town of Nantou County. It did not only cause casualties but landscape changes dramatically and geological conditions have become more vulnerable. Consistent with the Bureau of Agriculture statistics ending in 2015, there are 249 potential debris-flow torrent and more than 5 households of protection targets in affected area in Nantou County that shares the high proportion in Taiwan (data source: Bureau of Agriculture Web site). It displays Nantou is a high risk of soil and stone disaster zone that seriously threatens the lives and properties of local residents. Regarding with the variation of a number of typhoons, it increased and (Tu et al., 2009) brought a more significant quantity of rainfall after 2000 (Tu and Chou, 2013). It also resulted in many collapses of rock and soil debris flow disaster all over Taiwan, especially in the central region. To analysis the frequency of heavy rains in recent years (≥ 200 mm of daily rainfall) (Figure 1b) and the intensity of rainfall (average rainfall sorting in the first 1%) and spatial distribution (Figure 1c), they obviously showed the intensity and frequency of heavy rains was rising after 2000 in the central Taiwan including Chiayi, Taichung mountain area, and Nantou County. To sum up, above statement approves Nantou County, comparing to other areas, has been facing more threat from the soil and rock collapse which resulted from heavy rainfall for a long time.

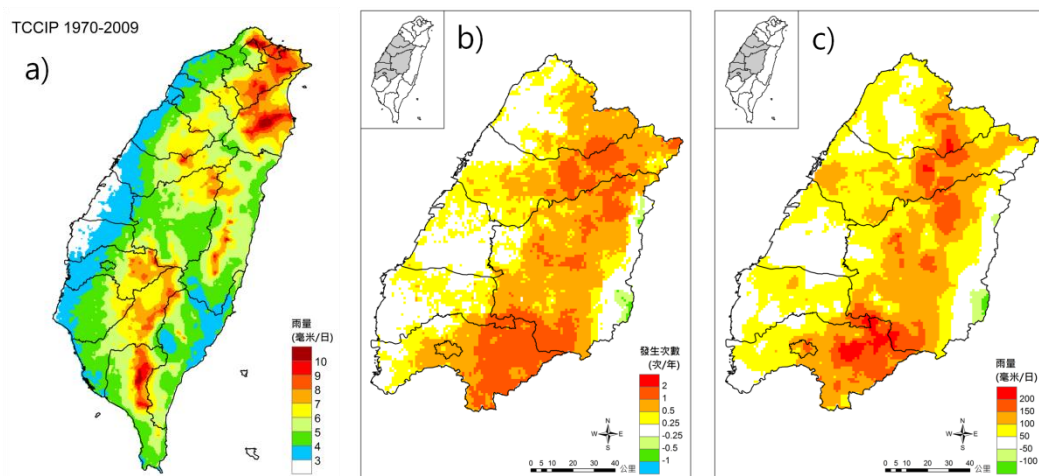


Figure 1:a) The average distribution of total rainfall/ per year in Taiwan from 1970-2015, unit (mm/day); b) after 2000, the distribution graph of the frequency of 200 mm rain in central Taiwan, unit (times/years); c) The distribution of rainfall map sorting in the first 1%, unit (mm/day). b) and c) the average value of difference of

The research based on the classification of debris flow disasters from Soil and Water Conservation Bureau and leveled the disaster to three levels according to past historical records for disaster events. We selected the first-level disaster areas, including Shenmu Village, Tongfu Village in Hsinyi town and Jingying Village in Renai Town, as well as third-level disasters such as Dili Village, Shanlung Village, Zichiang Village, Aiguo Village, Renho Village in Hsinyi Town, and Shangan Village and Hsinlung Village in Shali Town. First of all, we interviewed key persons like the village and heads, heads of basic community units, the presidents of association of community development, police officers, relief commissioners of the fire department (see Appendix a). The semi-structured in-depth interviews were adapted. The thematical analysis was taken to summarize common themes and topics to explore population status, victims' life experiences related to space and place, as well as how the cognitive, decision-making, and social structure affects the resources for disaster prevention and social networks.

The Importance of Spatial Scale in Research of Vulnerabilities

The impact of global climate change lets people pay more attention to the studies of environmental impact. Since 1990, numerous studies of environmental impact stressed the significance of the prediction of the physical hazards affecting to human, then gradually shift to research adopting vulnerability-led approach which believes that the vulnerability is from the people themselves and this kind of researches cover the structural effects of social, political and economic dimension (Lin Guanhuai, 2004). In recent years, vulnerability research has become the core of scientific research on environmental change and sustainability (IHDP, 2001; IPCC, 2001). "Vulnerability" refers to the probability of individuals or groups who affected by disasters and the characteristics of disaster recovery capabilities, including the degree of exposure to disaster of persons, property, environment, social, and economic activities, the capacities of disaster impact resistance, and the ability to recover from the impact of disasters (Blaikie and Cannon, 1994). This trait may come from the natural environment, or the social context which individuals or groups situated in.

Vulnerability consists of three elements: exposure, sensitivity and adaptive capacity (Turner et al., 2003). Early studies of vulnerability focused on the dimension of exposure, which assesses the frequency of the occurrence of extreme natural events, intensity and spatial distribution (Ye Gaohua, 2013). At present, definitions of vulnerability are various, but can be roughly sorted to "natural vulnerability" caused by natural disasters and "social vulnerability" affected by socio-economic factors.

Cutter et al. (2000) is the initiator who combined natural and social vulnerable research in geography through the long-term survey built in United States to construct 12 items of natural vulnerability as the indices (including drought, flood, earthquake, storm, tornado and forest fire et cetera.), and selected 8 items of social vulnerability (including population structure, resources accessibility, economic level et cetera.) to analysis the spatial differentiation of vulnerability under the influence of natural and social factors. Recent research doing from the view of social vulnerability have already pointed out that the class, ethnic group, gender, age is the important factors to result in the various degree of exposure to disaster risk, and also expand the difference of disaster resilience and social inequality (Fordham, 2003; Elliott and Pais, 2006; Cutter and Finch, 2008; Zhang Yijun, Lin Zonghong, 2012; Lin Zonghong, and Zhang Yijun, 2013; Bergstrand et al., 2014).

Referring to social vulnerability, it tends to indicate that some specific minority of area and groups tend to be vulnerable when disaster strikes. In addition to the different probability to be hit by disaster, vulnerability also presents the degree of impact on life after the disaster (Cutter, 1996). The socially vulnerable groups often become disaster victims, even the reconstruction after the disaster, social vulnerability is the important factor to reduce their resilience. But the disaster plans from government departments often ignores the dimension which includes race, class, gender, age, disability, the degree of dependence on land as well as social accessibility of social network (Bolin, 2007; Hemingway and Priestley, 2015; Taibang Sashale, 2012). More even, in the process of disaster prevention of government which pursued the efficiency then led to neglect the communication with victims that become a factor leading to social vulnerability (Ke Yuzhang, 2009; Hong Qidong, and Fu Wencheng, 2013; Lin Zhenzhen, Lin Wan-yi, 2014).

Lin and Zhang (2013) synthesized recent studies related to vulnerability and divided them into micro and macro levels of social vulnerability. The former includes social class such as class or generalized gap between rich and poor, the key factors affecting social vulnerability on the micro level. Micro-level vulnerabilities often become the basis for macro-level of vulnerability. The latter usually presents the geospatial features. With similar social vulnerability on degree and population characteristics often tend to form spatial aggregation that forms the local context of social vulnerability or proximity effect. Therefore, the more vulnerable area people live in, the higher degree of exposure to disaster risk and suffer greater impact which will lead to disparity of distribution in vulnerability and social differences (Cutter and Finch, 2008; Lin Wenyuan, 2011; Lee, 2014; Jabareen, 2013, Ye Gaohua, 2013). Cutter and Finch (2008) connected the changes in population, development, economic and social

characteristics of the disaster landscape over 1960-2000 in counties of United States County. They found more and more population with conditions of social vulnerability lived in the area with disaster landscape. This kind of spatial patterns of social vulnerability began to gather in certain areas, but it spread over time. Above studies emphasized on the features of socio-spatial differences of social vulnerability from macro-level or administrative spatial units. There is little research on the micro-level of social vulnerability in Taiwan so far and they could not reveal the impacts of spatial and environmental factors on disaster risk, so it was unable to define the certain location when an assessment of disaster prevention and disaster relief was undertaking. Our government now has already set up a construction of spatial unit- "The Classification System of Statistic" area by Statistics Department of the Ministry (Table 1). Now it is mainly used to describe the amount of exposure in disaster risk management. It helps to understand the affected population, building, engineering, infrastructure and public facilities, as well as the economic activity such as property damage. The current domestic research has applied the spatial unit to estimate the population in the potential disaster area that is more accurate than using the administrative unit. But the spatial unit has not yet integrated with other socio-economic data. Therefore, for the purposes of disaster relief, creating the micro-level spatial unit of social vulnerability as the basis of macro-level that is a task of utmost urgency in present research of disaster prevention in Taiwan.

Table 1. Estimation of Population Exposure in Various Spatial Units

| Spatial Unit | Number of Affected Spatial Unit | Estimation of Population's Exposure | Percentage of Error |
|--------------------------------------|---------------------------------|-------------------------------------|---------------------|
| | 1 | 37,196 | 73.9% |
| Village and Community | 33 | 117,505 | 17.5% |
| Secondary Area Disaster Announcement | 69 | 137,986 | 3.1% |
| First Area Disaster Announcement | 604 | 141,095 | 0.9% |
| Statistical Area | 775 | 141,251 | 0.8% |
| Population Area (reference) | | 142,432 | |

Note: Si-chi Area in New Taipei City. Population: 187,217, Area : 71.75km²

Sources: Lin Meijun, Suai Ming Road, Cai Bowen, Chen King Hong, Liu Hui Ling (2012). The Classification System of Statistic Area Applied to The Estimation of Population Exposure in Flood Disaster, Journal of Chinese Agricultural Engineering, Vol. 58 No. 3.

Although there is still no a systematic analysis methods and tool which are widely applied to every sphere to estimate the degree of vulnerability, exposure, resistance and resilience (or degree of exposure, sensitivity, and adaptability), we understand that the indices of the spatial level will decide the content of indices. For responding to the requirement of vulnerability and impact assessments, we need to adopt qualitative methods to develop the respective assessment methods in accordance with the characteristics of organization, domain, and system (Lee, 2014). If the indices are applied to disaster prevention and relief and subsequent recovery of equitable distribution of resources, the smaller spatial units which were constructed by the micro-level material integrated resource material of natural environment. In order to get the target, this paper attempts to explore the relationship between social and natural vulnerability in part of areas in central Taiwan, as well as investigate the possibility which the spatial units of disaster prevention and relief can be broken.

RESULTS AND DISCUSSION

According to interview of respondents, this study preliminary extract 5 themes such as "reasons caused disaster", "disaster relief program", "the role of the village leaders," " conservation of soil and water " and "perspective of disaster " through the thematical analysis.

| | The 1st level Disaster Area | The 3rd level Disaster Area |
|---------------------------------|---|--|
| | Shenmu Village, Tongfu Village in Hsinyi town and Jingying Village in Renai Town | Dili Village, Shanlung Village, Zichiang Village, Aiguo Village, Renho Village in Hsinyi Town, and Shangan Village and Hsinlung Village in Shali Town. |
| reasons caused disaster | <ul style="list-style-type: none"> A. The over development of past government B. The misguided policies which developed by Experimental Forest at National Taiwan University (failure reforestation) C. The discard soil from opened up provincial highway no. 21. D. Frequent landslide after the 921 earthquake E. Heavy rainfall F. Illegal planting of betel nut and cabbage which was stigmatized | <ul style="list-style-type: none"> A. People out of towns who planted betel nuts. B. The deforestation in Japanese colonial period C. The deforestation in Nationalist government. D. The housing which was built along the river by villagers. |
| disaster relief program | <ul style="list-style-type: none"> A. Village leaders owned great authorities on disaster relief and obtained the cooperation from the military. B. Nature vulnerability was taken into account in resource distribution of disaster relief. C. C. The social vulnerability was not considered to disaster relief. D. Sufficient resource of disaster relief that enhanced the resilience. E. The “neighbor” was as the spatial unit of disaster relief. F. there were still differences within the “neighbor” G. The assistance from neighbor was an important resource H. The housing of aboriginal tribe was not to be issued that resulted in the necessary self-helps I. The disaster evacuation went smoothly. | <ul style="list-style-type: none"> A. Township office stayed in dominant position in disaster relief and to cooperate with police station B. The residents evacuated based on their own experiences C. Village leaders set up the self-help system with the villagers. |
| the role of the village leaders | <ul style="list-style-type: none"> A. The village leaders could not obtain the sufficient authorities in disaster relief. B. The village leaders obtained the sufficient power to distribute the resources. C. The village leaders gained adequate information via Soil and Water Bureau. D. Facing the difficult of negotiation with the government. | <ul style="list-style-type: none"> A. The village leaders could cooperate with police office and township office. B. The equal distribution of goods resources. C. The village leaders activated the mechanism of disaster prevention and relief. D. The village leaders were used to being familiar the disaster relief exercise in peace time. |

| | | |
|--------------------------------|---|--|
| conservation of soil and water | <p>A. After experiencing several disasters in the past, the government has invested a large amount of budget to do soil and water conversation.</p> <p>B. The resilience was enhancing.</p> <p>C. Being as the excluded inhabitants since stayed on the land owned by the nation.</p> | <p>A. The investment of budget was a relative shortage.</p> <p>B. The conflicts with experimental forest office at NTU led the obstacles in soil and water conversation.</p> |
| the perspective of disaster | <p>A. Having sufficient training and prevention before the disaster.</p> <p>B. The local residents who possessed the good knowledge to judge the disaster.</p> <p>C. Cultivation of vegetable and crop were still the main economic resource for their family.</p> <p>D. The residents owning permanent housing were used to coming back disaster area for planting.</p> <p>E. The disaster areas they had stayed were still an ideal habitation.</p> <p>F. The communities in disaster area would fade away in the future.</p> | |

According to the themes induced, the paper presented the current results of the following discussion:

- Regarding the reasons caused hazards, the process of disaster relief, the role of the village leader and soil and water conservation, the 1st level, and the 3rd level disaster area presented the differences of the narrative. Comparing to the 1st level, the 3rd level disaster area ran the disaster relief process that was more close to the present design of disaster prevention. That could change the process of disaster relief in a vulnerable area, and also gave the village leaders a lot of power.
- The contradictory relationship between local residents and Experiment Forest at National Taiwan University is the common factor of social vulnerability in the 1st level disaster area. Therefore, it becomes observable phenomena of spatial aggregation because of social vulnerability.
- The social vulnerability in the current disaster relief system of villages was not emphasized when considered about the resource allocation. (1) In present prevention system which the village is the basic spatial unit, village leaders were the key persons in mastering the spatial distribution and population of social vulnerability. (2) Both the fire station and police, office played an auxiliary role in disaster prevention and relief.
- In addition to the differences in natural vulnerability between 1st and 3rd disaster area were presented, then there was an inverse relationship between social and natural vulnerability. The area where experienced severe disaster where we're easy to possess the plenty resource investment and become the star of the disaster area. Therefore, higher natural vulnerability had a lower social vulnerability.
- With regard to spatial units, at the research shows that social-spatial unit was indeed ignored. Based on the village as the spatial unit of disaster prevention system, the smaller community such as "neighbor" (lin) was the appropriate disaster unit (for example, some "neighbors" were particularly vulnerable to certain hazards). It means that suitable social-spatial unit would fit villages and communities with different capacities, and social vulnerability was highly correlated with social vulnerability. The initial finding shows that 1st level disaster area had more disaster experiences because of high natural and social vulnerability, then the public sectors invested resources and social concern that changed the program of disaster prevention, the role of village leaders and soil and water conservation. The communities become more flexible and residents had more disaster conscious since the past experiences, thus adopting the "village" as the spatial units were proper. However, with higher vulnerability and lower community public awareness of the village community. It would be better to adopt smaller spatial units such as "neighbors", "settlements", "church pastoral" and so on.
- The ethnic issue in this study is also related to resource allocation. Nantou mountain area is the settlement of aboriginal population and where experienced disasters in the past, thus public sector paid more attention to the aboriginal population but weaken the vulnerability of Han groups living in the same area.
- Regarding the disaster perception, the study found that residents of the 1st disaster had strong emotional and functional attachment with their habitation. Although they had accepted permanent housing as compensation, they usually came back to their original place. Thus, keeping to investigate the social vulnerability of spatial units that are still necessary for the future.

Accordingly, following research is going to extend the interviewees in different level of disaster area that we can collect the characteristics of micro-level social and natural vulnerability, and try to draw the possible spatial units to present the social differentiation of vulnerability and to apply on the practical cases to achieve the effective disaster prevention and relief and equal distribution of resources.

REFERENCES

- Belkhir, J. A., and Charlemaine, C. (2007) Race, gender and class lessons from Hurricane Katrina, *Race, Gender & Class*, 14 (1/2,): p120-152
- Bergstrand, K., Mayer, B. Brumback, B. and Zhang Y. (2014) Assessing the relationship between social vulnerability and community resilience to hazards, *Social Indicators Research*, published online: 16 July 2014.
- Blaikie, P., T. Cannon, et al. (1994) *At Risk: Natural Hazards, People's Vulnerability, and Disasters*. London, Routledge.
- Chou, C., J.-Y. Tu and P.-H. Tan (2007), Asymmetry of tropical precipitation change under global warming. *Geophys. Res. Lett.* 34, L17708, doi:10.1029/2007GL030327
- Chou, Chia, John C. H. Chiang, C.-W. Lan, C.-H. Chung , Y.-C. Liao and C.-J. Lee, 2013: Increase in the range between wet and dry season precipitation. *Nature Geoscience*, 6, 263-267, doi:10.1038/NGEO1744.
- Cutter, S. L., Mitchell, J. T., Scott, M.S. (2000) Revealing the vulnerability of people and places: a case study of Georgetown County, South Carolina, *Annals of the Association of American Geographers*, 90(4): 713-37.
- Cutter, S.L., and Finch, C. (2008) Temporal and spatial changes in social vulnerability to natural hazards, *Proceedings of the National Academy of Sciences of the United States of America*, 105(7): 2301-2306.
- Elliott, J. R and Pais, J. (2006) Race, class, and Hurricane Katrina: Social differences in human responses to disaster, *Social Science Research*, 35: 295-321.
- Fordham M. (1999) The intersection of gender and social class in disaster: balancing resilience and vulnerability, *International Journal of Mass Emergencies and Disasters*, 17 (1), pp. 15-37.
- Fordham, M. (2003) Gender, disaster and development: the necessity for integration. In: Pelling, M. (ed.), *Natural Disasters and Development in a Globalizing World*. London: Routledge, 57-74.
- Gall M., Emrich, C.T., and Cutter, S.L. (2008) Toward a comprehensive loss inventory of weather and climate hazard. In H.F. Diaz and Murnane, R. J. (ed.) *Climate Extremes and Society*. Cambridge: Cambridge University Press: 279-295.
- Godwin, E. E., Foster, V.A. and Keefe, E.P. (2013) Hurricane Katrina families: Social class and the family in trauma recovery. *Family Journal*, 21(1): 15-27.
- Held, I. M. and B. J. Soden (2006), Robust responses of the hydrological cycle to global warming. *J. Climate*, 19: 5686-5699.
- Huang, P.*, S.-P. Xie, K.-M. Hu, G. Huang, and R.-H. Huang, 2013: Patterns of the seasonal response of tropical rainfall to global warming. *Nature Geoscience*, 6, 357-361.
- IHDP (2001) *Special issue on Vulnerability*, 2:1-16, Available online at /http://www.ihdp.orgS.
- IPCC (2007) Climate change 2007: The physical science basis, *Summary for Policymakers*. Available online at http:// www.ipcc.ch/SPM2feb07.pdf.
- Jabareen, Y. (2013). Planning the resilient city: concepts and strategies for coping with climate change and environmental risk, *Cities*, 31: 220-9.
- Lee, YJ. (2014) Social vulnerability indicators as a sustainable planning tool, *Environmental Impact Assessment Review*, 44: 31-42.
- Levy, B. L. (2012) Bayou blues: The social structure of Hurricane Katrina's damage, *Sociological Spectrum*, 32(5): 424-435.
- Lin, K.-H. and Chang, C.-Y (2013) Everyday crises: marginal society livelihood vulnerability and adaptability to hazards, *Progress in Development Studies*, 13(1): 1-18.
- Massmann, F. and Wehrhahn, R. (2014) Qualitative social vulnerability assessments to natural hazards: examples from coastal Thailand, *Revista de Gestao Costeira Integrada*, 14(1): 3-13.
- McGann, K. J. (2012) Women confronting natural disaster: From vulnerability to resilience, In Emmanuel D. and Enarson, E. (ed.) (2012) *The Women of Katrina: How Gender, Race, and Class Matter in an American Disaster*, TN: Vanderbilt University Press.
- Morris, J. E. (2008) Hurricane Katrina Families: Social Class and the Family in Trauma Recovery, *Urban Education*, 43(4): 463-487.
- Sun, Y., S. Solomon, A. Dai and R.W. Portmann (2007), How often will it rain?. *J. Clim.* 20: 4801-4818. doi: 10.1175/JCLI4263.1
- Turner, II., B.L., et al. (2003) A Framework for vulnerability analysis in sustainability science, *Proceedings of the National Academy of Sciences US*, 100: 8074-8079.

- Tu, Jien-Yi**, Chia Chou and Pao-Shin Chu, **2009** : The abrupt shift of typhoon activity in the vicinity of Taiwan and its association with western North Pacific-East Asian climate change. *Journal of Climate*, **22(13)**, 3617-3628.
- Tu, Jien-Yi** and Chia Chou, **2013** : Changes in precipitation frequency and intensity in the vicinity of Taiwan: typhoon vs. non-typhoon events. *Environmental Research Letters*, **8** (1), 014023 doi:10.1088/1748-9326/8/1/014023
- Vecchi, G.A. and B.J. Soden (2007), Global warming and the weakening of the tropical circulation. *J. Climate* 20: 4316-4340.
- 吳杰穎·江宜錦 (2008) 台灣天然災害統計指標體系建構與分析·*地理學報*·51:65-84。
- 林宗弘 (2012) 災後重建的政治：中國 512 地震與台灣 921 地震的比較·*台灣社會學刊*·50:57-110。
- 林宗弘·張宜君 (2013) 「天災也是人禍--社會科學領域的災難研究」·潘美玲、范玫芳、楊谷洋、林宗德、駱冠宏、李河清編·*風和日麗的背後--水、科技、災難*·頁 82-113·新竹市：國立交通大學出版社。
- 林冠慧 (2004) 全球變遷下脆弱性與調適性研究方法與方法論的探討·*全球變遷通訊雜誌*·43:33-38。
- 林文苑 (2011) 「天然災害老人弱勢族群社經脆弱度評估指標」之建立與空間聚集性分析應用·*都市與規劃*·38(3): 219-243。
- 張宜君·林宗弘 (2012) 不平等的災難：921 地震下的受災風險與社會階層化·*人文及社會科學集刊*·24 (2): 193-231。
- 葉高華 (2013) 社會脆弱性可解釋九二一地震死亡率分布嗎?·*思與言*·51(1): 135-153。
- 劉翠溶 (2013) 略論近年來台灣氣候災害對原住民的衝擊與災後調適·台灣及太平洋友邦南島民族氣候變遷調適及因應政策研討會·見
<http://ap2cc.recc.sinica.edu.tw/files/Dr.%20Liu's%20speech%20-%2020130905.pdf>·2014/02/03 查詢。