International Young Researchers Workshop
River Basin Environment and Management
8-9 February, 2014
Asian Institute of Technology, Thailand

ABSTRACT

Development and application of Flood Vulnerability Indies for commune level – A case study in Lam river basin, Nghe An province, Vietnam

Nguyen Quang Hung, Nguyen Thanh Son, Tran Ngoc Anh, Dang Dinh Kha
Department of Hydrology, Faculty of Hydrology, Meteorology and Oceanography,
Hanoi University of Science, VNU

Vietnam is a country with typical tropical meteor, and the people are vulnerable to natural disasters, especially flooding problem. In recent years the impacts of floods have became seriously since the number of resident who are affected by its adverse effects are increasing rapidly. With the development of the socio-economic, consequences are making people more and more open to flood risk.

To assess the risk and impact of flooding, and to serve the purpose of planning, management and flood control, the Flood Vulnerable Index (FVI) is approached to use as an effective and comprehensive tool. Based on the research of UNESCO-IHE, in this study, FVI is defined by three main indices: Exposure, Sensitivity and Resilience. Those indices are formed by studying the relationship of social - economic, flood damage records, losses due to natural disasters, different flooding modeling scenarios. Each index is the combination of a set of different parameters which can be obtained by results from flood model and from field surveys (questionnaire).

Selected Lam river basin is located in the central part of Vietnam, where more than 3000 thousand people suffered every year from six to ten hurricanes. Upstream area of Lam river basin characterizes with steep slopes, causing floods along the river banks. Downstream of Lam river basin are the receiving area where large amount of water flock in during rainy season, therefore even protected by banks but the area is still be heavy flooded a month or so every year. In this study, 21 communes along Lam river were selected for applying FVI, a questionnaire with 36 questions is developed, and total 468 data sheets were collected during data collection period at sites. Mike Flood model is used to simulate the representative flood event in 1978 with corresponding 1% flood frequency. Preliminary results show that the FVI have high potential to help identify the coping ability of residents to flood.

International Young Researchers Workshop
River Basin Environment and Management
8-9 February, 2014
Asian Institute of Technology, Thailand

Development and application of Flood Vulnerability Indies for commune level – A case study in Lam river basin, Nghe An province, Vietnam

Nguyen Quang Hung, Nguyen Thanh Son, Tran Ngoc Anh, Dang Dinh Kha
Department of Hydrology, Faculty of Hydrology, Meteorology and Oceanography,
Hanoi University of Science, VNU

1. Introduction

Vietnam is a country with typical tropical meteor, and the people are vulnerable to natural disasters, especially flooding problem. Based on the statistical data, the flood situation in Vietnam is increasing every year in both quantity and damage. For the last 50 year, Vietnam has been hit by around 400 typhoon and tropical depressions, suffers average annual GDP (PPP) losses of USD1.9 billion (or 1.3 percent of GDP). This year (2013), the damage by typhoon and flood to Center part of Vietnam reached the number of USD1.400 billion. There is a need to identify the risk in flood-prone areas for risk management, from high-level planning proposals to detailed design. The Flood Vulnerability Index recently becomes a good tool for minimizing flood damage as much as possible and making the better decisions on sustainable region development.

The concept of vulnerability was first introduced by O'Keefe et al. in 1976 by exploring the key role played by socioeconomic factors in creating a weakness in responding to, and recovering from the effects of natural hazards. The use of the term, in the context of disasters, has varied over last several decades (Liverman, 1990; Dow and Dowing, 1995; Watts and Bohle, 1993; Cutter, 1996; Vogel, 1997).

The definition of vulnerability has been divided in three main aspects: Natural sciences mainly focus on the physical system to define vulnerability. In 2005, Downing looked upon the vulnerability as the residual impacts of climate change after adaptation measures have been implemented. This definition includes the exposure, susceptibility, and the capability of a system to recover, and to resist hazards as a result of climate change.

In the other hand, social researchers focus on the human's capacity to respond to hazards and to promptly recover from damages and losses to explain vulnerability. Watts and Bohle (1993) looked to the social context of hazards and relate (social) vulnerability to coping responses of communities, including societal resistance and resilience to hazards. They are trying to find an easier way to understand and reduce the concept through a better understanding of the social background

The third party, recently suggest that a natural disaster is a complex system, involving the above mentioned aspects. Wei et al. (2004) improved definitions on vulnerability, and describes a holistic view of society. Blaikie et al. (1994) described vulnerability as a measure of a person or a group's exposure to the effects of a natural hazard, including the degree to which they can recover from the impact of that event. Cutter (1996) defined vulnerability as a hazard of place that encompasses biophysical risks as well as social response and action. This definition is increasingly gaining significance in the scientific community in recent years. Cardona (2003) also tried to holistically integrate the contributions of physical and social sciences to define a vision of indicators that create vulnerability. It is now commonly understood that "vulnerability is the root cause of disasters" (Lewis, 1999) and "vulnerability is the risk context" (Gabor and Griffith, 1980). Many authors discuss, define and add detail to this general definition. Some of them give a definition of vulnerability to certain hazards like climate change (IPCC, 2001), environmental hazards (Blaikie et al., 1994; Klein et al., 1999;ISDR,2004), or the definition of vulnerability to floods (van der Veen and Logtmeijer, 2005; Connor and Hiroki, 2005; UN, 1982; McCarthy et al., 2001).

The paper is structured as follows: after introducing the background and the aim of the study in Section 1 and Section 2, the study area is presented in Section 3. Section 4 then expands on the Flood Vulnerability Index approach and its indicators. Preliminary results are discussed in Section 5 before coming to some conclusions in Section 6

2. *Objectives*

In this research, the main object is to develop a methodology for Flood Vulnerability Index for commune level. Therefore, the research will

- Select the suitable method to assess flood vulnerability (FVI's equation, weighting method for FVI's factors and identify FVI's indicators)
- Survey, questionnaire to collect data, analyze the data
- Apply to calculate FVI at commune level
- Create different utility map.

3. *Study area and data collection*

Lam river basin locates from $18^0$15'50" to $20^0$10'30" North latitude, $103^0$45'10" to $105^0$15'20" East longitude. North boundary is Chu river basin, west boundary is Mekong river basin, south boundary is Giang river basin and east boundary is East sea. Lam river, one of the two biggest river in the North Central of Vietnam with the total length of 530km which 432 km flows inside the territory of Vietnam, has a 17,730km^2 catchment area. Lam river derives from XiengKhuang highland in Laos, named Nam Khan, flows through Nghe An province, joins with La river and to the sea at Hoi estuary. In details, Lam river passes Kì Sơn, Tương Dương, Con Cuông, Anh Sơn, Đô Lương, Nam Đàn districts, along Thanh Chương, Hưng Nguyên district, Vinh city and Nghi Lộc district before flows to the Tonkin Gulf as seen in Figure 1. Lam river has 44 tributaries level I, the smallest tributary's area is Khe Trò 44 km^2, and the largest is Hiếu river with catchment area of 5,340km^2. Main tributaries: Nam Mo (F=3,930 km^2), Huoi Nguyen (F=800 km^2), Khe Choang (F=431 km^2), Hieu River (F=5,340 km^2), Giang River (F=1,050 km^2), Ngan Sau (F=2,310 km^2), Ngan Pho (1,110 km^2).

The Lam river bed is quite narrow, with steep slope in the upstream area, widens up in the middle basin (from Con Cuong to Anh Son), then joins the Hieu River on its left side. In the downstream area, the Lam river flows through the plain and finally joins the La River on the right side.

Figure 1. Location of Lam river basin

Every year, the basin receives average precipitation of 1100 ÷ 2500 mm. In the large rainfall centers such as upstream of Hieu, La and Giang Rivers, average annual rainfall can reach to 2000 ÷ 2400 mm. The rainy season lasts from May to October in the upstream and from August to November in the downstream. Similar to the annual rainfall distribution, the annual river flow is uneven distribution in spatial scale, ranging from less than 20 $l/s.km^2$ to above 80 $l/s.km^2$ in the eastern side of the North Truong Son mountain range. Heaviest rainfall occurs in September when mean of maximum daily rainfall is up to 250 mm in the coastal area, and in 2010 a maximum value up to 800 mm was recorded in 24 hours.

Floods threaten frequently Lam river. Focusing in the recent past, in 2007 a series of five floods occurred in only one month period causing huge damage on both people and properties in the central districts of Nghe An province in the Lam river basin; also in October 2010 about 50 casualties and widespread inundation occurred in the same area.

The flood season usually occurs in April, July to October and November on the main branch of the river and its tributaries in the middle stream and upstream. On the other tributaries, the flood season occurs from August or September to December. The total flow volume in flood season occupies from 55-75% of the annual flow. The three subsequent months of highest flow discharge are usually occurred in July, August and September, or from August to October and from September to December. The three driest months are usually occurred from February to April or from March to May. The total flow volume in three months only occupies from 4.5-9.5% of the total annual flow. The maximum flood peak can reach to more 10 m^3/s.km2 on the main stream, 0.6-6.6 ($m^3/s.km^2$) on the small branches and about 0.4-0.5 ($m^3/s.km^2$) on medium streams. The maximum flood discharge of 10,200 m^3/s at Dua station was recorded by the flood that occurred in Sep1978.

Figure 2. Hydrological network of Lam river

To calculate the FVI, data was collect by questionair during field survey, from statistical yearbook of districts in Nghe An and Ha Tinh provinces. Total 3280 questionairs was dispatched to 74 communes, 74 statistical yearbooks of commune, 25 statistical yearbooks of 25 districts were collected. To run flood simulation for diferents scenario in the catchment, meteo-hydrological data, Digital Elevation Model, cross-section of Lam river, historical records of flood were also collected and processed to put into models. In this study, Mike 11 and Mike Flood were applied to simulate flood situation in river basin.

4. *FVI*

As mention above, the Flood Vulnerability Index (FVI) is a method to assess flood vulnerability by identifying different components that influence the susceptibility to floods of the people who live in these areas. The FVI is defined by some different ways, lead to an apparently large and diversified set of definitions and approaches.

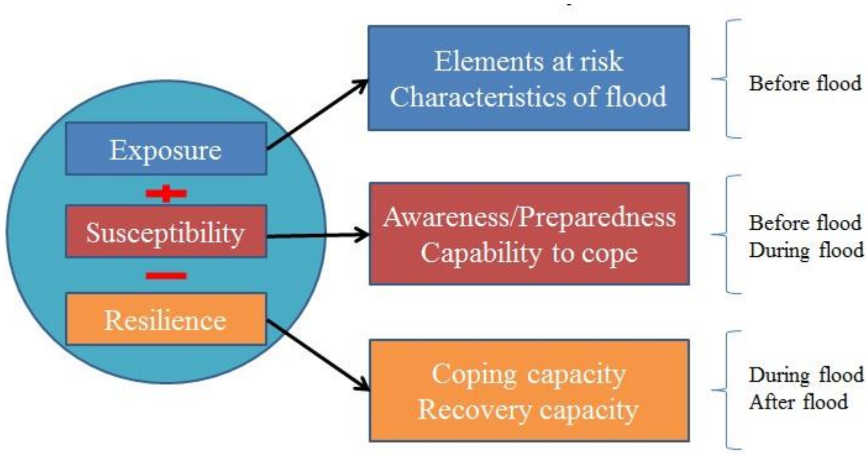
In 1982, UN gave the definition of flood vulnerability as the degree of loss to a given element, or a set of such elements, at risk resulting from a flood of given magnitude and expressed on a scale from 0 (no damage) to 1 (total damage).

Vulnerability is considered as the extent of harm, which can be expected under certain conditions of exposure, susceptibility and resilience (Balica et al. 2009; Hufschmidt 2011; Scheuer et al. 2010; Willroth et al. 2010; Fuchs et al. 2011). More specifically in the case of floods, a system is susceptible to floods due to exposure in conjunction with its capacity/incapacity to be resilient, to cope, recover or adapt to the extent.

During the 1980s and especially the 1990s the relationship between human actions and the effects of disasters, the socio-economic dimension of vulnerability, has increased. Improved definitions on vulnerability describe a holistic view of society, involving the natural andsocio-economic aspects of the system “The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards “(UN-ISDR)

This study uses the following definition of vulnerability specifically related to flooding: “The extent to which a system is susceptible to floods due to exposure, a perturbation, in conjunction with its ability (or inability) to cope, recover, or basically adapt” – by UNESCO-IHE.

FVI = (E)xposure + (S)ensitivity – (R)esilience



Source UNESCO-IHE

Figure 3. Flood Vulnerability Factors

The living environment is vulnerable to floods due to three main factors; exposure, susceptibility and resilience. The vulnerability is reflective of the exposure and susceptibility of that system to hazardous conditions and the resilience of the system to cope, adapt and/or recover from the effects of those conditions (Smit & Wandel, 2006). Better understanding the meaning of each factor and identifying indicators of each factor will help recognize the characteristics the vulnerability of different system, based on that, certain actions can be identified to decrease it.

Exposure

Exposure is defined as the predisposition of a system to be disrupted by a flooding event due to its location in the same area of influence.

Exposure can be divided into two main category, the first one is the exposure of different elements at risk and the second provide information about the natural of the flood, i.e flood duration, flood areas, velocity of flood. The first can be goods, infrastructure, cultural heritage, agricultural fields or mostly people, giving detail of the location, elevation, population density, land-use, their proximity to the river, their closeness to inundation areas.

The Exposure indicators were identified include: Flood velocity, Flood depth, Flood duration, and Land use (as seen in Table 1). The first three indicators were extracted from the results of 2D Hydrological model, and the Land use indicator is generated from Land use map (officially issued by Ministry of Natural Resources and Environment). The other indicators was susposed to collected from survey's i.e population in the flooded area, closeness to inundation, type of vegetation, contact to river, ect.. but not completed yet.

Susceptibility

In this research, susceptibility is defined as the elements exposed within the system, which influence the probabilities of being harmed at times of hazardous floods.

Susceptibility refers to the characteristics of the system before and during the flood includes the condition of environment, the awareness and preparedness for the flood, the coordination mechanisms of mitigating and reducing the effects of the hazards.

The susceptibility indicators evaluate the sensitivity of an element at risk of flood, devided into three categories: Social indicators, Infrastructure indicators and Institutional indicators. There are 12 indicators was selected from the information collected during survey, includes: Attitude of people toward flood, Ability of evacuation, Flood forecast reliability, Living environment, Flood awareness, Flood control structures, Flood prevention preparation, Communication, Flood prevention structures, Reservoir impact, Flood prevention plan, type of houses.

Resilience

Flood resilience can be interpreted as the ability of a system or community to alter itself from experiences so that the damage of floods is mitigated or minimized. Resilience to flood damages can be considered only in places with past events, since the main focus is on the experiences encountered during and after the floods. Resilience indicators are combined by coping capacities and recovery capacities. During floods, coping capacity indicators must include technical systems, because the social impact of floods significantly relates to the susceptibility of basic infrastructure and lifelines which support the population's supply of basic needs, like water, energy or food. After the flooding event, recovery capacity indicators refer to the impact of floods on economic, social, environmental and physical components.

In this research, the resilience indicators are: Flood experience, Help from family, Help from government and Medical quality.

Table 1. Indicators of Flood Vulnerability Index

Exposure	**Sensitivity**	**Resilience**
Flood depth	Attitude of people toward flood	Flood experience
Flood velocity	Ability of evacuation	Help from family
Flood duration	Flood forecast reliability	Help from government
Land use	Living environment	Medical quality
	Flood awareness	
	Flood control structures	
	Flood prevention preparation	
	Communication	
	Flood prevention structures	
	Reservoir impact	
	Flood prevention plan	
	Houses	

As shown in the Figure 4, the methodology to calculate the FVI is described in the following steps:

- From the Hydro-meteorology and other data, the Hydrological and Hydraulic model will be set up. Results of these models are flood situations in the research area, i.e flood duration, flood depth… These will be used as indicators for Exposure factor. The Exposure map is created by combination other indicators such as Land use, distance to evacuate line, closeness to inundation area, ect.. The weights for each indicators are calculated by Lyengar-Shudarhan method.

- Information retrieved from questionnaire is used to form Susceptibility and Resilience indicators, weights
- Combination of all three factors results in FVI map.

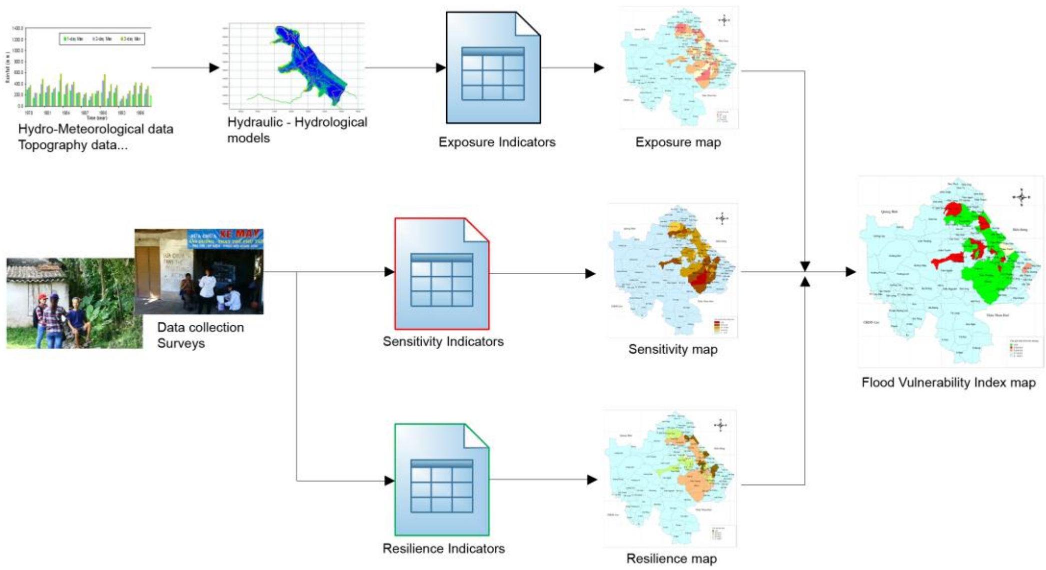


Figure 4. Step by step procedure to calculate FVI

5. Preliminary results

Simulation results of the flood event 1978 from the hydraulic model (Mike Flood) are extracted and built three utility map including: Flood inundation map (Figure 5), Flood duration map (Figure 6) and Flood Velocity field (Figure 7).

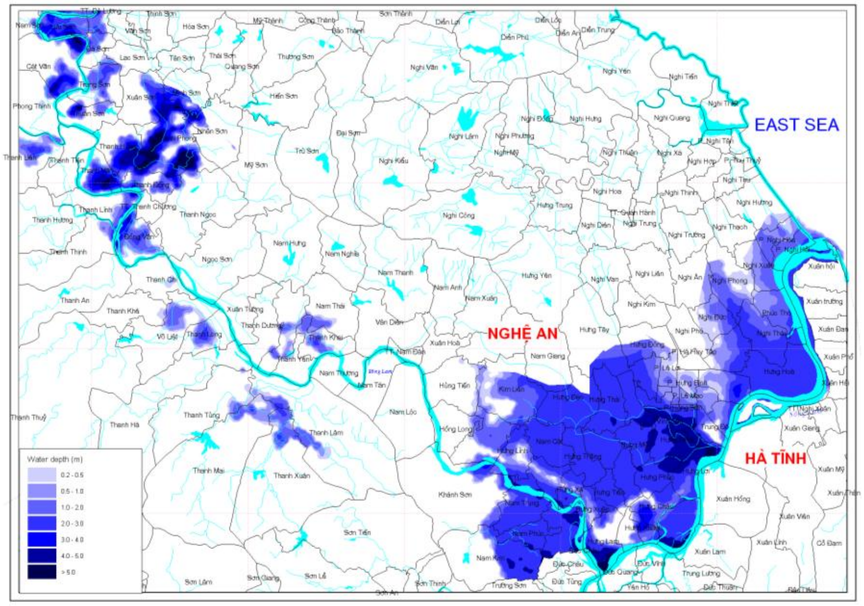


Figure 5. Flood inundation map of Lam river basin (simulation result of flood event 1978)

Results show that during the historical flood of 1978, the maximum flood depth reached to more than 5 meter in a very large area. The upstream area is also flooded, but most of the right bank of the river (Ha Tinh province) are protected, so there is not much flood in that area.

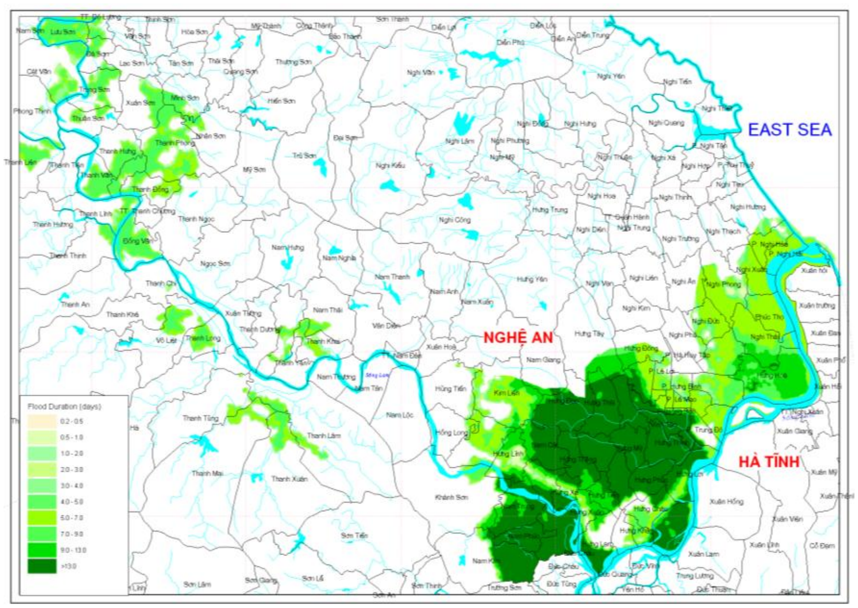


Figure 6. Flood duration of Lam river basin (simulation result of flood event 1978)

Based on the Flood duration result we can see that there are quite large area which the water lasts for about three month.

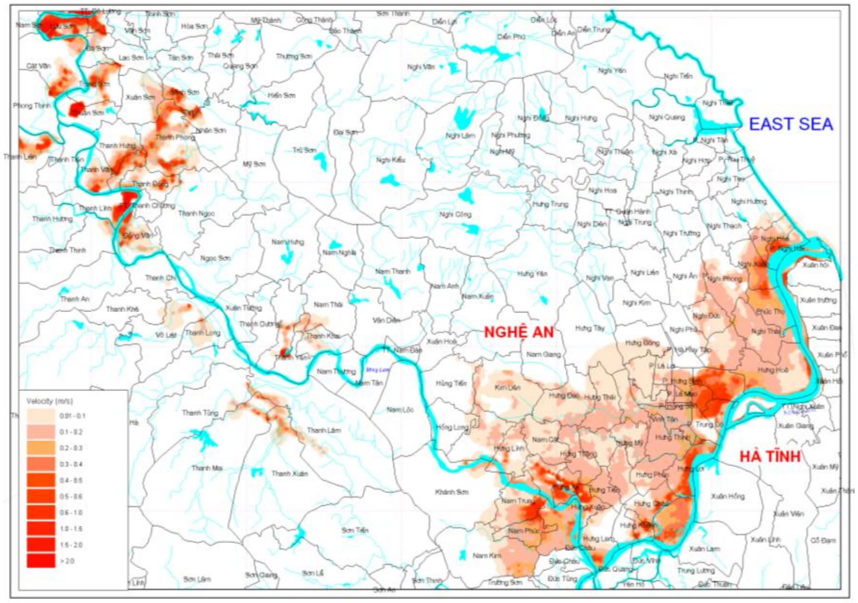


Figure 7. Velocity field (simulation result of flood event 1978)

The next step is to combine these three maps with Land use properties, creates Exposure map, but due to the limitation of time, the Land use map is not ready yet, hence, further study should be done in order to fulfill the ultimate object of calculating FVI.

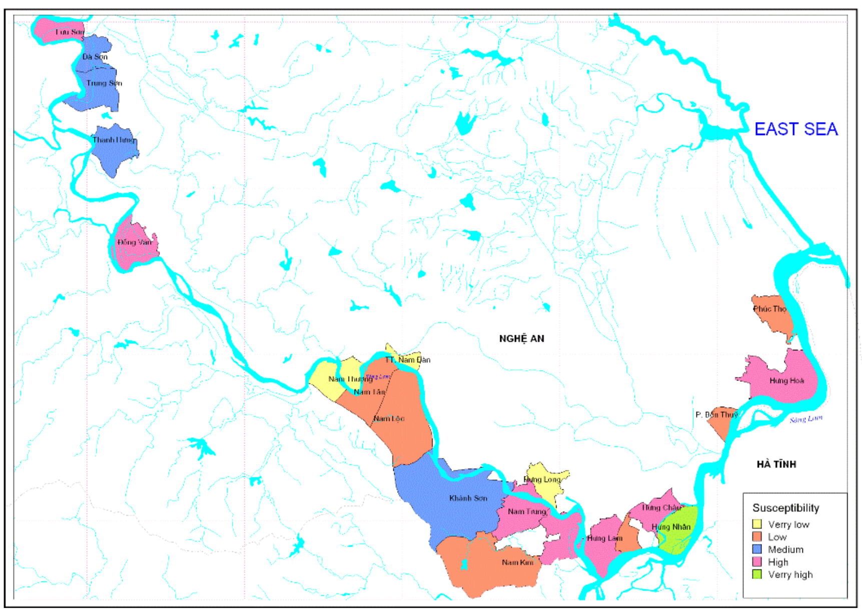


Figure 8. Susceptibility of Lam river basin

From 12 indicators, the Susceptibility was calculated and display on the map in the Figure 8.

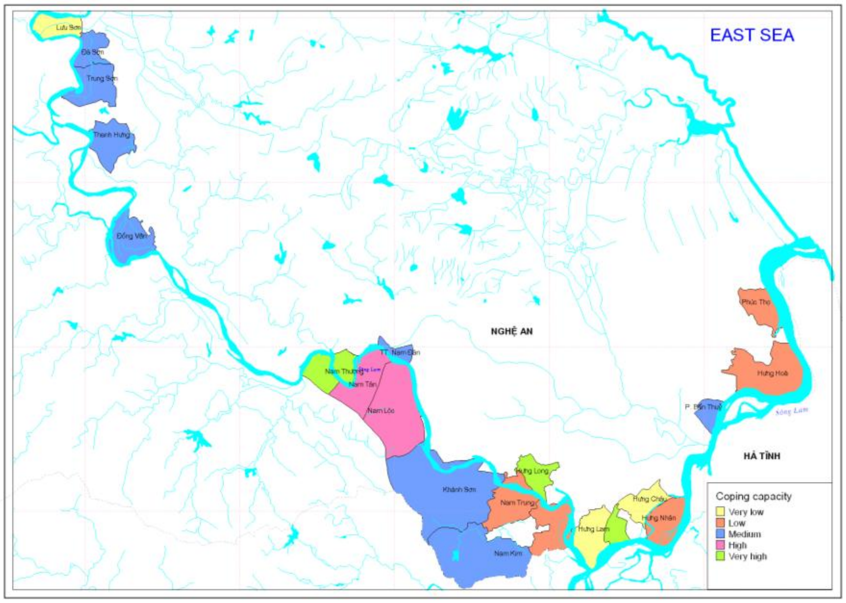


Figure 9. Coping capacity

In the Figure 9, Coping capacity is shown, this is the combination of Susceptibility factor and Resilience factor. Result from the map reflects the real situation when most of the resident in Lam river basin coped with flood every years and they are very experienced with how to deal with flood.

6. Conclusion and Discussion

The study has selected the suitable method, defined the Flood Vulnerability Index (FVI) that works for commune level. Based on the information of the study area, FVI's indicators were identified and applied for Lam river basin.

Preliminary results prove that FVI could be a useful tool for managing river basin against flooding problem. By using FVI, it helps better explanation of the complicated natural vulnerability, and easy to compare different basins/communes.

For further study, there are few questions listed:

- Which indicators should be added?
- Weighting method?
- Cell size of the model?
- How to calibrate/verify FVI

This study was granted the access to the data collected from National Project BDKH-19, and financial provision also from the project. The authors would like to say thank to the Project for its constructive support.

References

Blaikie, P., Cannon, T., Davis, I., and Wisner, B.: At risk-natural hazards, people's vulnerability and disasters, London, 1994.

Cardona, O.: A need for rethinking the concept of vulnerability and risk from a holistic perspective: A necessary review and criticism for effective risk management, as see on http://www.desenredando.org/public/articulos/2003/nrcvrfhp/nrcvrfhp_ago-04-2003.pdf,on 8th of November, 2006

Climate Change - IPCC Third Assessment Report 2001

Connor, R. F.; Hiroki,K.: Development of a method for assessing flood vulnerability, Water Science & Technology;, Vol. 51 Issue 5, p61,2005.

Cutter, S. L.: Vulnerability to environmental hazards, Prog. Hum.Geog., 20, 529–539, 1996

Dow, K. and Downing, E.: Vulnerability research: where things stand, Hum. Dimen. Q., 1, 3–5, 1995

Downing, T., Patwardhan, A., Klein, R., Mukhala, E., Stephen, L., Winograd, M., and Ziervogel, G.: Assessing Vulnerability for Climate Adaptation, in: Adaptation Policy Framework for Climate Adaptation: Developing Strategies, Policies and Measures, edited by: Lim, B. and Spanger-Siegfried, E., UNDP, Camdridge University Press, Cambridge, UK, 61–90, 2005.

Fuchs S, Kuhlicke C, Meyer V.: Editorial for the special issue: vulnerability to natural hazards—the challenge of integration. Natural Hazards, 2011.

Gabor, T. and Griffith, T.K.: The assessment of community vulnerability to acute hazardous materials incidents. Journal of Hazardous Materials 8, 323-33, 1980

Hufschmidt, G.: A comparative analysis of several vulnerability concepts In: Natural Hazards 58:621-643, 2011.

ISDR. International Strategy for Disaster Reduction. 2004 Version

Klein, R. J. T., Nicholls, R. J., and Thomalla, F.: Resilience to natural hazards: How useful is this concept?, Environ. Hazards, 5, 35–45, 2003.

Lewis, J.: Development in Disaster-prone Places. London: IT Publications, 1999.

Liverman, D.: Vulnerability to global environmental change, in: Understanding global environmental change: the contributions of risk analysis and management, edited by: Kasperson, R. E., Dow, K., Golding, D., and Kasperson, J. X., Report on an International Workshop, Clark University, Earth Transformed Program: Worcester MA, 1990.

Scheuer S, Haase D, Meyer V.: Exploring multicriteria flood vulnerability by integrating economic, social and ecological dimensions of flood risk and coping capacity: from a starting point view towards an end point view of vulnerability. Nat Hazards, 2010.

Smit, B., Wandel, J.: Adaptation, adaptive capacity and vulnerability, Global Environmental Change, 16, pp. 282- 292, 2006.

S. F. Balica, N. Douben and N. G.: Wright Flood vulnerability indices at varying spatial scales Water Science & Technology—WST Vol 60 No 10 pp 2571–2580

O’Keefe, P., Westgate, K., and Wisner, B.: Taking the naturalness out of natural disasters, Nature, 260, 566–567, 1976.

Van Der Veen, A. and Logtmeijer, C. J. J.: Economic hotspots: visualizing vulnerability to flooding, Nat. Hazards, 36, 65–80, 2005

Vogel, C. H.: Vulnerability: meaning, measure and motivation, Paper presented at the Regional Workshop on Risk Reduction in Southern Africa, Disaster Mitigation for Sustainable Livelihoods Project, SADEP, University of the Western Cape, Cape Town, 1997.

Watts, M. J. and Bohle, H. G.: The space of vulnerability: the causal structure of hunger and famine, Prog. Hum. Geog., 17, 43–67, 1993

Wei, Y. M., Ying, F., and Cong, L.: The assessment of vulnerability to natural disasters in China by using the DEA method, Envrion. Impact Assess. Rev., 24, 427–439, 2004.