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VULNERABILITY ASSESSMENT IN THE COASTAL PLAIN OF THE VIETNAMESE MEKONG DELTA

Pham Le My Duyen[1], Truong Thanh Tan[1], Van Pham Dang Tri[1], Tran Thi Le Hang[1] and Hiroshi Takagi[2]

[1]*College of Environment and Natural Resources, Can Tho University, Vietnam*
[2]*Department of International Development Engineering, Tokyo Institute of Technology, Japan*

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ABSTRACT

The coastal plain is considered to be one of the most vulnerable areas in the Vietnamese Mekong Delta due to negative impacts of surface water resources changes driven by regional and local climate change and sea level rise. In addition, the vulnerability is also exaggerated due to low adaptive capacity of local residents. In this study, components of vulnerability index (including exposure, sensitivity and adaptive capacity of local residents under negative impacts of both flood and saline intrusion) were calculated in details according to actual conditions of the study area. High vulnerability index would be shifted from coastal areas (at the time being) to zones further inland and along the main rivers (in the future) as local residents would not be well-prepared for physical changes. Furthermore, sensitivity analysis was done to understand the reliability of assigned weight for each parameter.

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1 INTRODUCTION

The Vietnamese Mekong Delta (VMD) (Figure 1) is one of deltas having great benefits from natural resources for agriculture development. However, about 50% area of the delta is usually affected by annual floods from upstream of Mekong river (Sneddon and Binh, 2001) and more than 1 million ha of the area is strongly affected by tidal flood and saline intrusion (Wassmann *et al*., 2004). In addition, the VMD is also projected to be heavily vulnerable as the surface water resources are significantly changing in the context of the rising sea level and regional and local climate changes (IPCC, 2007; ADB, 2009; Smajgl *et al*., 2015). Therefore, saline intrusion leading to negative impacts on livelihood of local people are projected to be exaggerated (Nhan *et al*., 2007; Trung and Tri, 2014).

This research was done in order to assess vulnerability of local residents in a coastal plain of the VMD due to negative impacts of climate change and sea level rise. The Ben Tre province (Figure 1) was selected as a case study as: (i) hard-measures (such as the dyke and flood gates) have been built and maintained to minimize negatives impacts of annual flood and saline intrusion since early 2000s; (ii) a large range of agriculture and aquaculture activities could be found; and, (iii) the area is projected to be strongly affected by surface water resources changes.

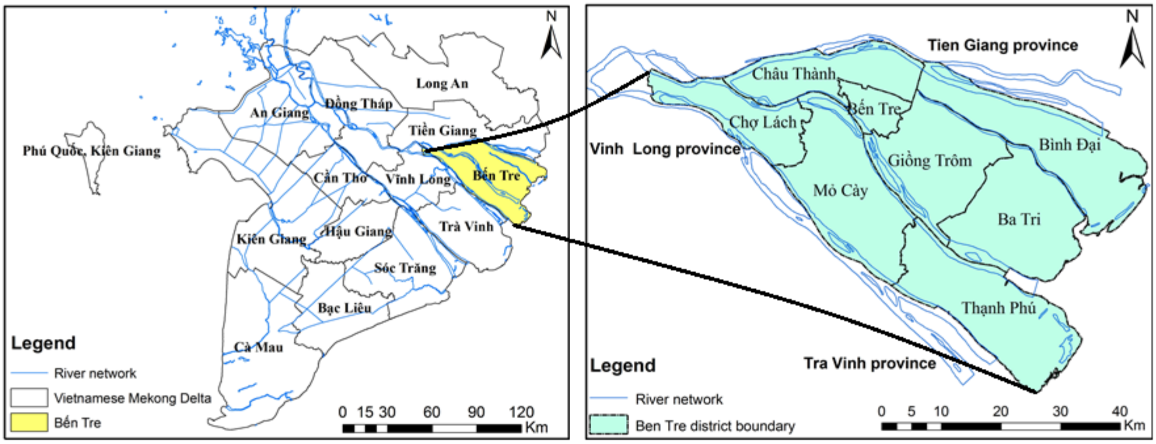

Fig. 1: The Vietnamese Mekong Delta (left) and Ben Tre province (right)

2 METHODOLOGY

2.1 Vulnerability index quantification

The vulnerability index (VI) was calculated according to the exposure (E), sensitivity (S) and adaptive capacity (AC) of local residents to unexpected natural events (Eq. 1). The *Exposure* (E) component is direct threats (rainfall and temperature) which are rather similar over the whole Ben Tre province so that it was not considered in the study. For the *Sensitivity* (S) and *Adaptive capacity* (AC) components, parameters were divided into 3 groups (economic, social and environment) after the UNDP approach (2010) (with specific modification to meet local actual conditions) (Table 1).

Table 1: Components and relevant parameters of vulnerability index due to changes of surface water resources

Components	Symbol	Parameters			
			Ec	So	En
Sensitivity (S)	S1	Population density		x	
	S2	Percent of households at flooding			x
	S3	Agriculture area			x
	S4	**Irrigation system**		x	
	S5	**Transport system**		x	
	S6	**Major labor ratio**		x	
	S7	The income generating sectors		x	
	S8	**Year income**	x		
	S9	Type of house		x	
	S10	Type of family		x	
	S11	Education level		x	
	S12	The ability to receive information on forecast		x	
	S13	Anxity level		x	
	S14	The ability of cope preparation		x	
	S15	**Production experience**		x	
	S16	The level of loss house level	x		
	S17	The level of loss economic	x		
	S18	Shelter when disaster happend		x	
Adaptive capacity (AC)	A1	Awareness the risk of living			
	A2	The adaptation ability of water resources changes' impact		x	
	A3	Enhance prevention capacity		x	
	A4	The effective of irrigation system			x
	A5	Support expense from local government	x		
	A6	The level of recovery after damage		x	

Note: Ec: economic, So: society and, En: environment; bold parameters are the opposite effect with injury

VI = E + S - AC (Metzger, 2005) and Balica and Wright, 2010)

Or $$VI = \frac{\sum_{i=1}^{n} X_{Ei}.W_{Ei}}{\sum_{i=1}^{n} W_{Ei}} W_{cE} + \frac{\sum_{i=1}^{n} X_{Si}.W_{Si}}{\sum_{i=1}^{n} W_{Si}} W_{cS} - \frac{\sum_{i=1}^{n} X_{ACi}.W_{ACi}}{\sum_{i=1}^{n} W_{ACi}} W_{cAC} \quad \text{(Eq. 1)}$$

where: E: Exposure, S: Sensitivity, and AC: Adaptive capacity.

– X_{Ei}, W_{Ei}, X_{Si}, W_{Si}, X_{ACi}, W_{ACi}: standardized value and weight of component E, S, AC.

– W_{cE}, W_{cS}, W_{cAC}: balance weight of component E, S, AC; $WcE = \frac{\sum E}{\sum E,S,AC}$, $WcS = \frac{\sum S}{\sum E,S,AC}$, $WcAC = \frac{\sum AC}{\sum E,S,AC}$

The spatial distribution of the vulnerability index in the study area was calculated for each village according to the parameters with references of census data of the study area and direct interviews to government staffs (ranging from provincial, district and village level) and local residents who experienced changes of surface water resources and consequent impacts (*details are presented at section 2.2*). Raw data collected for each indicator including qualitative and quantitative parameters were standardized in order to reach the common scale (Eq. 2 and Eq. 3 were applied if parameters were proportional and inversely proportional to the vulnerability, respectively). In addition, each parameter weight was determined by the Analytic Hierarchy Process (AHP) approach (Saaty, 1984) with reference to actual conditions of the study area (by interviewing local residents and authorities).

$$x_{standardised} = \frac{x_i}{x_{maximum}} \quad \text{(Eq. 2)}$$

$$x_{standardised} = 1 - \frac{x_i}{x_{maximum}} \quad \text{(Eq. 3)}$$

After standardizing step, each parameter was multiplied by corresponding weights (Table 2) and vulnerability index was classified according to Tingsanchali and Karim (2005) (Table 3). The awareness and adaptation preparedness of local residents on possible changes of the natural condition were compared with trends of climate change projected for the next three decades (Tuan, 2012) to re-standardized parameter from which the vulnerability index in the future was calculated to predict in the future. Consequently, the map of vulnerability was created based on vulnerability index value (from components and weight of parameters).

Table 2: Weight of each parameter

Weight	2	3	4	5	6	7	8	9	10	11
Parameters	S5	S1	S2	S4	S6	S8	S14	S16	S18	S17
	S9	S3		S11	S7	S10	S12			
	A3	A1	A6				S13			
	A5		A2				S15			
	A4									

Table 3: Classification of vulnerability index

Vulnerability Index (VI)	≤ 0.2	0.2 < VI ≤ 0.4	0.4 < VI ≤ 0.6	0.6 < VI ≤ 0.8	0.8 < VI ≤ 1
Categories	Very low	Low	Average	High	Very high

2.2 Household and local government interviews

In this study, 17 communes were selected randomly ranging from the seawater, brackish water and freshwater-dominated areas. In total, there were 212 household interviews and 17 interviews with local government staffs. Communes were divided into 4 zones based on the current natural condition, land use and available hydraulic infrastructures, including: (i) Zone 1: upstream zone (Phu Phung, Long Phu and Tan Phu); (ii) Zone 2: middle zone (Giao Hoa, Long Dinh, Phu Nhuan, My Thanh, Tan Thanh Binh, An Hiep, Thanh Thoi B and Hoa Loi); (iii) Zone 3: coastal zone (Thua Duc, Bao Thuan and Thanh Phong); and, (iv) Zone 4: Ba Lai sluice affected zone (Thanh Tri, Tan Xuan and Tan My). The fourth zone was selected to assess impacts of the Ba Lai sluice on natural conditions and livelihood of local residents. The combination of household and local government interviews provided belief and behaviours of different stakeholders, minimizing the distortion of information provided by a certain group of the studied society.

2.3 Sensitivity analysis

Sensitivity analysis was done to clarify the reliability of the vulnerability index when weight of each parameter changed from the original value (Eq. 4). Each weight value of parameter corresponded to three values of each component and vulnerability index was calculated again in Eq. 1 to make the range of vulnerability index values. The zone had a large fluctuation range that was sensitive of weight changes.

W' = W ± 1 (Eq. 4)

where: W: initial weight, and W': weight for sensitivity analysis

3 RESULTS AND DISCUSSION

3.1 Vulnerability index at the time being (in 2014)

The coastal zone (Thanh Phong, Bao Thuan and Thua Duc commune) was of the greatest vulnerability due to environmental problems and economic loss (Figure 3) (including: (i) directly affected by ocean tide and saline intrusion; (ii) dependent on available freshwater resources (groundwater and surface freshwater from the upstream); and, (iii) waterborne disease outbreaks). On the contrary, communes located further upstream (along the Mekong river) (Phu Phung, Long Thoi, and Tan Phu commue) and region directly upstream of the Ba Lai sluice were not strongly influenced by saline intrusion and floods induced by tidal impacts and upstream discharge. Local residents were experienced to cope with annual floods from upstream area (i.e. changing crop calendar and farming systems). In addition, the effective operation of irrigation system (full-dyke, sluice and drainage system) also led to low vulnerability.

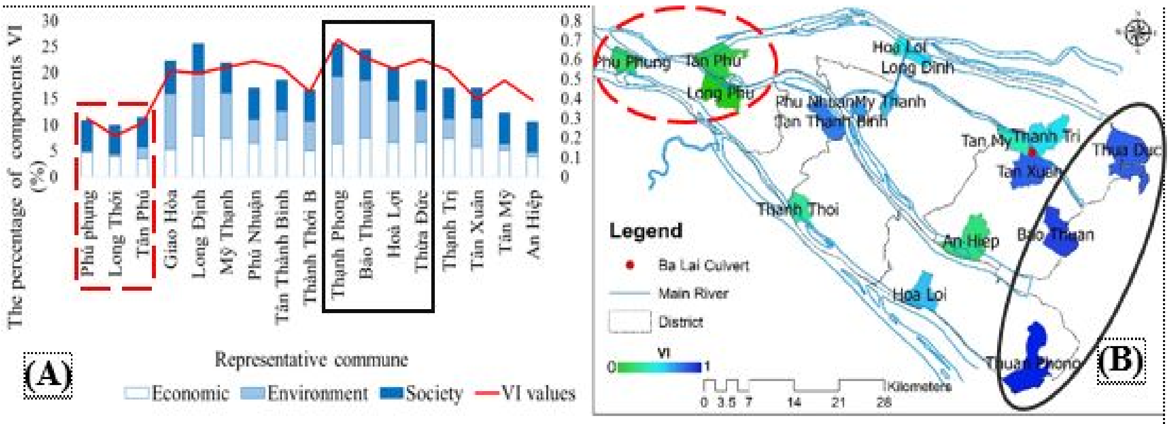

Fig. 2: Vulnerability index (A) and vulnerability map (B) due to surface water resources changes in 2014

3.2 Vulnerability index due to surface water resources changes in the future

Future vulnerability index in the coastal areas was projected to be less serious than what was found at the time being. Local government were aware such the trends and supports from government at different levels were recognized via the introduction of adaptive land use planning and different climate change adaptation programs to support the improvement of capacity of local residents to cope with natural condition changes. The most vulnerable factor of local residents living in the coastal zone would be associated with tidal-induced floods, especially for those who lived outside of sea-dyke system. For the areas further inland where local residents were not experienced problems caused by tidal-induced flood and saline intrusion, future changes of water resources would cause high vulnerability mainly associated with social and environmental factors (Figure 4). Vulnerability shifted from coastal area to middle area, which agrees with what was found in the recent publication of Smajgl *et al*. (2015). In fact, local residents located in this area did not fully recognize the negative impacts of changes and the hydraulic infrastructure system was not properly investigated and managed.

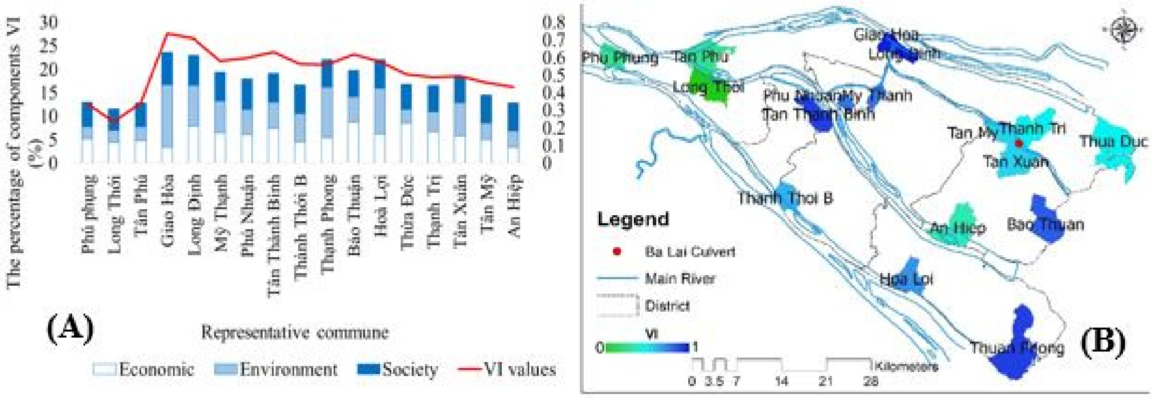

Fig. 3: Vulnerability index (A) and vulnerability map (B) due to future change patterns (in the future)

3.3 Sensitivity analysis

3.3.1 Sensitivity of vulnerability index in 2014

Coastal area had the greatest vulnerability index while the lowest value could be found in upstream zones of study area (Figure 5A). The range of vulnerability index values (according to the sensitivity analysis) was not significantly large for each commune so vulnerability index based on the pre-assigned weight was reliable (Figure 5B). Zone 1 (upstream zone) and 4 (Ba Lai sluice zone) were of greater sensitivity than of zone 2 (middle zone) and 3 (coastal zone). Based on the calculated vulnerability index and ranges of sensitivity, zone 3 was of the most vulnerable in comparison to the others.

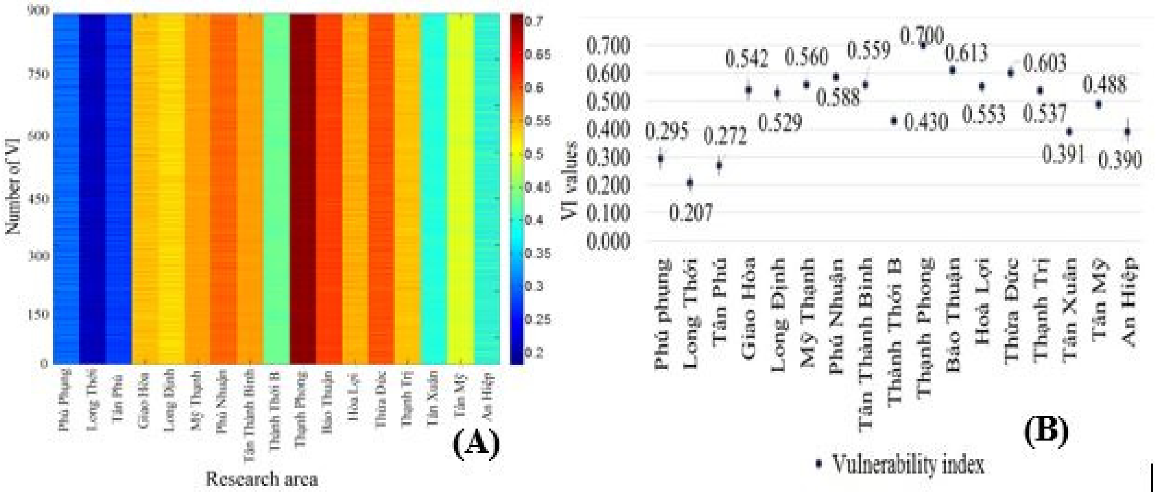

Fig. 4: Vulnerability index change (A) and fluctuation range (B) in 2014

3.3.2 Sensitivity of vulnerability index in the future

Figure 4B and 5A showed that the greatest vulnerability index changed from coastal area (zone 3) to middle zone (zone 2) where the awareness of local people was low and already-built infrastructure were sufficient enough to mitigate negative impacts from the changes. The fluctuation range of each commune in 2030 would be greater than that in the present (Figure 5B), which means that changes of parameters weight led to great impacts to vulnerability index. Therefore, the reliability of weight in future was lower than that of the time being, especially `in zone 2 and 3.

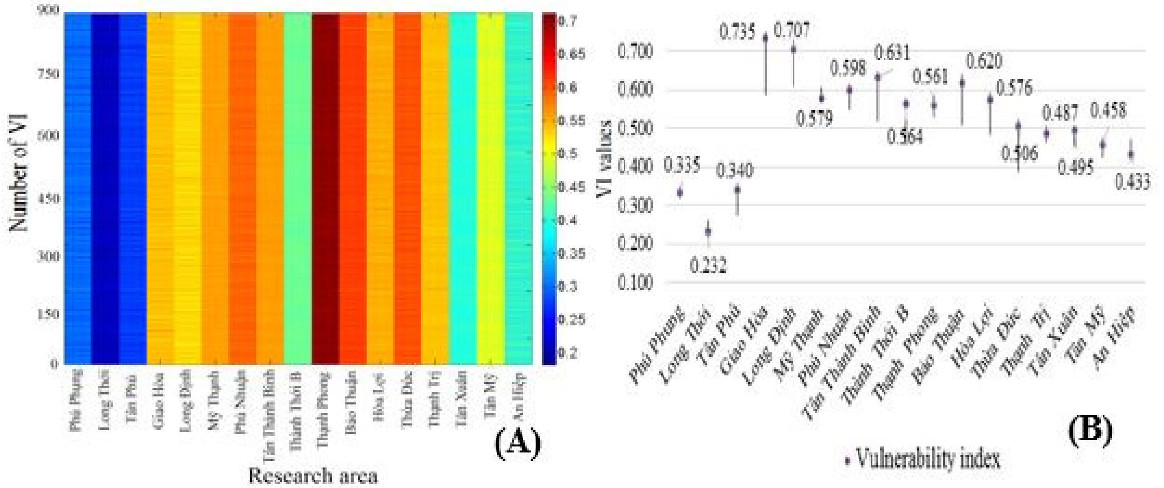

Fig. 5: Vulnerability index change (A) and fluctuation range (B) in next three decade

4 CONCLUSIONS

The vulnerability assessment approach according to Metzger (2005) was successfully adjusted and applied for the actual conditions in the coastal plain of Vietnamese Mekong Delta. The coastal zone (zone 3) was highly subject to vulnerability at the present in comparison to other regions as they were directly affected by the on-going surface water resources changes, which was driven by the up-stream flows. In the future, high vulnerability would be shifted further inland as the local residents would not have sufficient experiences and relevant knowledge and the infrastructure was weak to resist the natural condition changes. The assigned weights for each component parameter were verified on reliability by the sensitivity analysis, especially in the time being.

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