VULNERABILITY ASSESSMENT OF BA LAT DELTA COASTAL ZONE TO SEA LEVEL RISE AND CLIMATE CHANGE

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ABSTRACT

Ba Lat, the main entrance door of the Red river system spilling to gulf of Tonkin, is the boundary between Nam Dinh and Thai Binh provinces. This is an area characterized by diverse and abundant natural conditions and resources. In recent years, climate change has made a strong impact on this studied area, which illustrates by the increase in strength and frequency of storm, sea level rise, and saltwater intrusion, etc. The hazards related to climate change as well as other intensity factors like natural and social elements lead to the rise of environmental vulnerability, degrade natural resources and threaten human life and sustainable development of this area. Using ArcGIS 9.3 and Expert Choice 11 software in classifying, weighting, combining a number of criteria and building vulnerability map, this paper aims to assess the current vulnerability of Ba Lat delta coastal zone to climate change and sea level rise. In addition, this article presents the forecast of vulnerability of environment and natural resources based on sea level rise scenario (0,5m). Last but not least, research results are expected to propose the solutions for the rational use of resources, adapting to climate change.
Keywords: *vulnerability assessment, Ba Lat delta coastal zone, sea level rise, climate change*

1. INTRODUCTION

The research area covers 11 coastal communes of Nam Dinh and Thai Binh provinces and is located along Ba Lat Estuary. These communes are a part of a buffer zone of Xuan Thuy National Park- the first Ramsar site of Vietnam, Tien Hai Natural Conservation Zone and the Red River Delta Biosphere Reserve which is considered as the highest biodiversity and biological productivity in the coastal zone of Northern Vietnam and as home of the most sensitive ecosystem. For the last few years, hazards typically related to climate change (CC) along with other social and natural factors has intensified vulnerability level of natural resources, put pressure on the lives of human, degraded natural resource as well as environmental quality and threatened regional sustainable development.

Therefore, this paper presents the initial research on vulnerability assessment of the study area under the impacts of CC and it is expressed by maps of two scenarios of the sea level rise (SLR) for the time being and after the sea level increases as much as 0.5m more. AcrGis 9.3 is used in conducting the research. It is believed that the research is vital for biodiversity conservation, environmental protection, CC adaptation and especially appropriate solution for sustainable use of resources.

2. STUDY METHODS

2.1 Vulnerability assessment method

The Vulnerability assessment (VA) method applied in this study were derived from the methods and criteria for coastal zone VA (CVIs) of the US, environmental vulnerability

(EVI) of SOPAC, the process of VA of NOAA and the Cutter, and the assessment of Mai Trong Nhuan *et. al*.

VA of environment and natural resources of Ba Lat estuary under the impacts of climate change has been built according to the following function with three components:

$$Vx_iy_j = f\,(aRx_iy_j,\, bPx_iy_j,\, cCx_iy_j) \quad (1)$$

In which: Vx_iy_j is vulnerability level of environment and natural resources, (Rx_iy_j) is due to the risk level of vulnerability factors, which is determined by the integration of the intensity, scale, frequency and area affected by hazards relating to CC as well as natural and man-made hazards intensifying factors; (Px_iy_j) is the density of the vulnerable object, which is determined by the distribution and role of vulnerable objects; (Cx_iy_j) is the resilience, response and adaptation capacity of social and natural systems; (x_iy_j) are geographical coordinates and a, b, c is the weighted value of the level of importance.

2.2 The method of mapping vulnerability of environment under the impacts of climate change and sea level rise in Ba Lat Delta coastal zone

VA maps are established based on component maps, namely risk level of vulnerability factors, vulnerable object density, and resilience capacity of the social-natural system. The evaluation criteria are determined by paired comparison matrix method of Saaty Thomat. Calculation process consists of three steps: 1) set paired comparison matrix; 2) calculate for these criteria; 3) stability rate assessment (CR) of the weights (CR≤0,1, accepted). Finally Expert Choice 11 software is used to calculate weights of each component. In VA maps, each area is represented by different color according to their VA figure. Thus, the higher the level of vulnerability an area is, the darker it is colored in the map. The process of VA is analyzed database by ArcGIS 9.3 software which uses the spatial analysis to establish maps of each component.

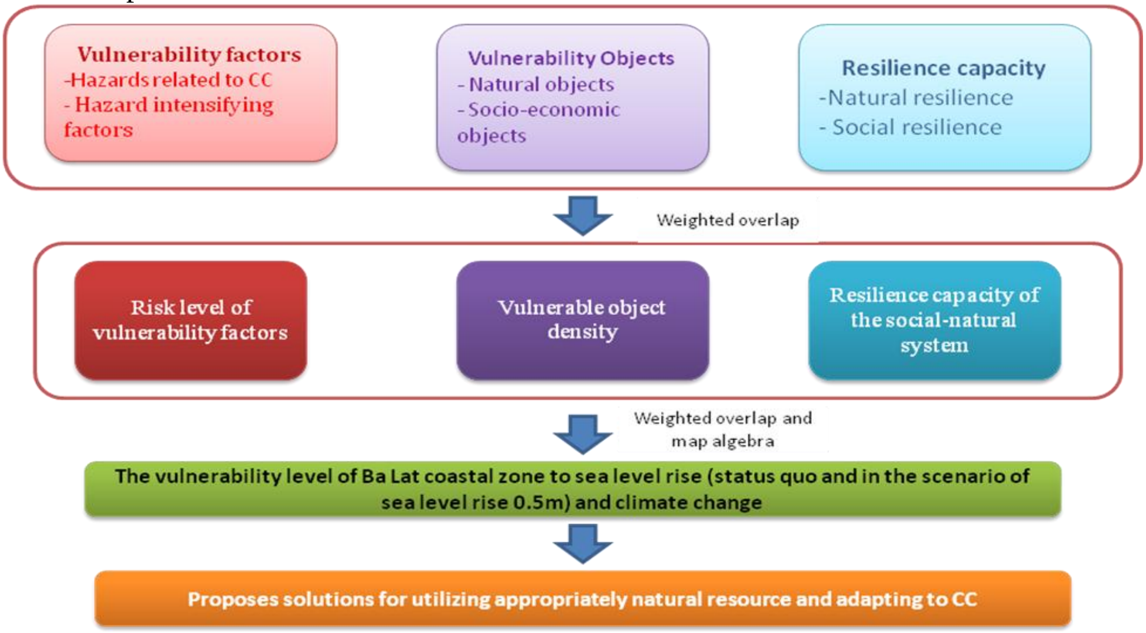

Figure 2. The process of vulnerability assessment of Ba Lat Delta coastal zone to sea level rise (status quo and in the 0.5m sea level rise scenario) and climate change; proposes solutions for utilizing appropriately natural resource and adapting to CC.

3. VULNERABILITY ASSESSMENT OF BA LAT DELTA COASTAL ZONE TO SEA LEVEL RISE AND CLIMATE CHANGE

3.1 Vulnerability factors

Identified vulnerability factors of the study area include hazards related to CC and hazard intensifying factors, which are identified according to criteria of vulnerability assessment of CC. Of which, hazards related to CC consist of sea level for the time being and when SLR as much as 0.5m; increasing salinity; erosion; flooding. Hazard intensifying factors include groups of: i) natural factors (the coastal geological formations); ii) human activities: forestry (deforestation); aquaculture and agriculture (land occupation); salt-producing area (increasing salinity), etc. Agents and situation of hazards are selected to work as indicators for assessing the level of risk. These indicators are commonly categorized into five groups ranging from very low; low; average, relatively high and high and corresponding to 1-5.This is also the method to unify units of indicators.

Risk level by the vulnerability factors relating to CC in Ba Lat Estuary is proceeded as shown in Fig. 2. On the basis of assessment and weighted overlap of all components, risk level map by vulnerability factors relating to CC in Ba Lat Estuary was established with different areas of risk according to the status and scenario of SLR of 0.5m as follows.

Table 1. Zoning risk level from low to high according to the status quo and 0.5m sea level rise scenario

Risk zoning		Proportion to overall study area	
Zone	Level	Status quo	0.5m SLR scenario
I	Low	8,7	7,3
II	Average	47,1	32,4
III	Relatively high	42,1	34,4
IV	High	2,1	25,9

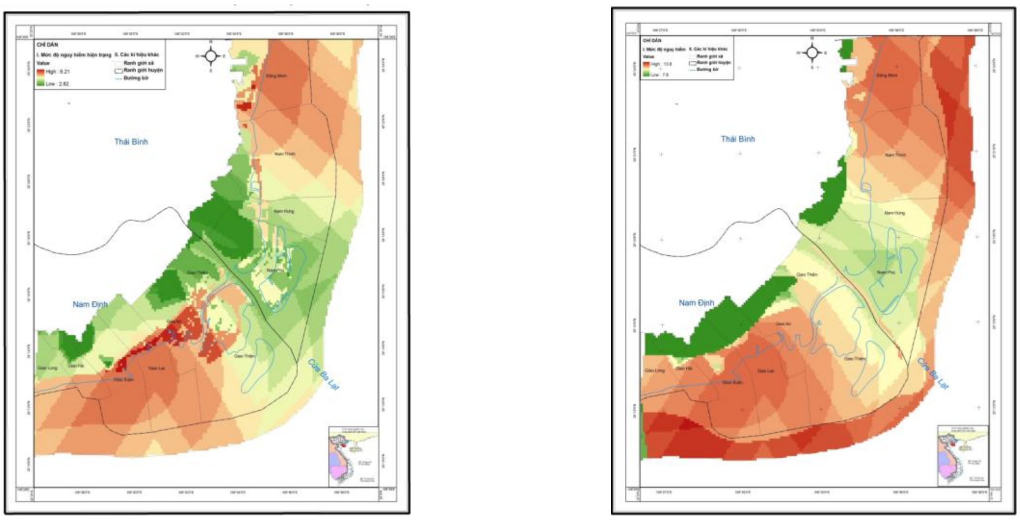

Figure 3-4. Risk level map by vulnerability factors in Ba Lat estuary according to the status quo and the 0.5m sea level rise scenario, at scale of 1:100.000

3.2 Vulnerability objects

Vulnerability objects in Ba Lat Estuary were considered natural objects and human activities. To be more exact, natural objects consist of biological and wetland resources (11 types) [1-2, 4-5]. Meanwhile, human acitivites include the main residential areas, public works, and transportation system [7-8]. Similar to risk assessment, criteria for evaluating the density of vulnerable objects were established as follows:

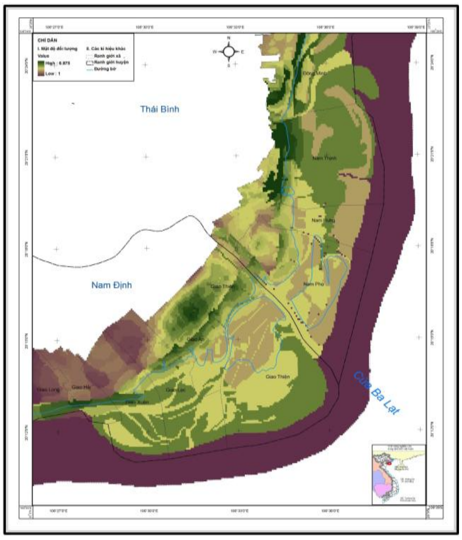

Figure 5. Map of density of vulnerability objects in Ba Lat estuary, at scale of 1:100.000

3.3 Resilience capacity

Resilience capacity of the region includes resilience of natural and social system. Natural factors which are identified to be able to cope with CC consist of geological formations, terrain factors – coastal geomorphology and mangrove ecosystem. Meanwhile, social factors are population density, income, housing status, education, awareness and dike system. Evaluated resilience capacity of natural – social systems in the study area proceeded following the process in Fig. 2. Assessment method based on distance, density, region and weighted overlap, was used to establish the resilience capacity map of natural and social systems. The map divided study area into groups according to resilience capacity ranging from low to high level.

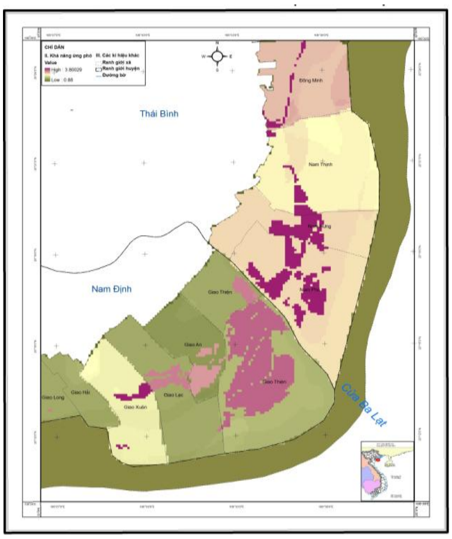

Figure 6. Resilience capacity map in Ba Lat delta coastal zone, at scale of 1:100.000

3.4 Vulnerability assessment of Ba Lat delta coastal zone to sea level rise and climate change

VA result is the weighted overlap of three components: (i) the risk level of vulnerability factors, (ii) the density of vulnerable objects, (iii) the resilience of natural-social system by spatial analysis and map algebra. It divides study area into zones from low to high vulnerability according to the current situation (status quo) and the 0.5m SLR scenario.

When it goes to the 0.5m SLR scenario, the vulnerability density result shows that the total area of high vulnerability zone increase from 15.4% to 28.8% and the area of the relatively high vulnerability zone follows the same pattern with the rise from 29.7% to 32%. Furthermore, those two zones are likely to extend to inland, in particular to area where human activities intensify hazards relating to CC. These figures illustrate that study area is highly vulnerable to the negative impacts of CC in general. Especially, as far as the 0.5m SLR scenario is concerned the vulnerability density level of the area is on the increase both in term of scale and distribution, which directly influence on regional resources including wetland resources and human activities.

Table 2. Zoning vulnerability level from low to high according to the status quo and 0.5m sea level rise scenario

Vulnerability zoning		**Proportion to overall study area**	
Zone	Level	Status quo	0.5m SLR scenario
I	Low	19,9	12,2
II	Average	35	27
III	Relatively high	29,7	32
IV	High	15,4	28,8

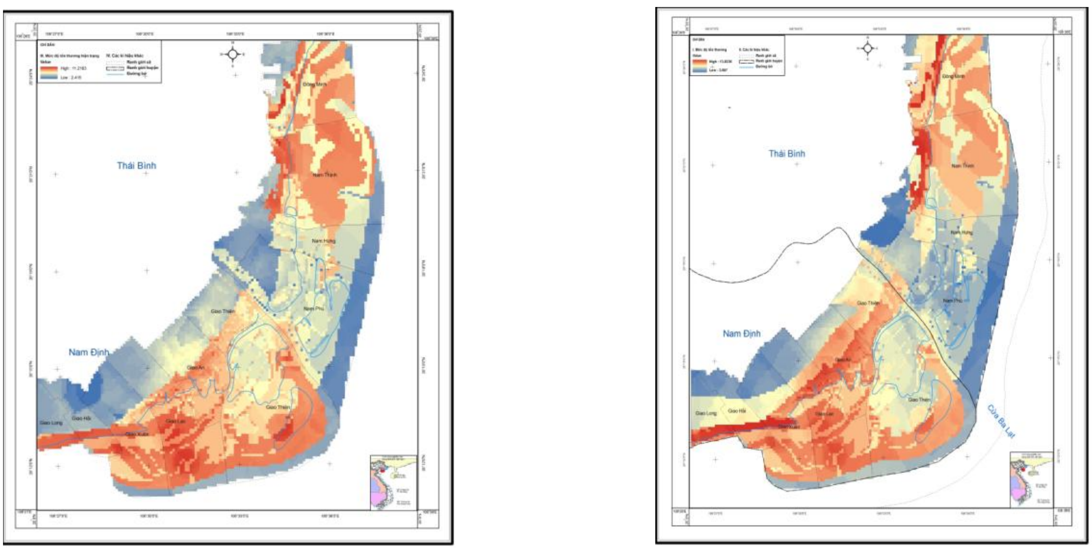

Figure 7-8. Vulnerability level map of Ba Lat estuary to sea level rise and climate change according to status quo and 0.5m sea level rise scenario, at scale of 1:100.000

4. CONCLUSIONS

Vulnerability levels of the Ba Lat Estuary under the impacts of CC were evaluated by three components: vulnerability factors (hazards and hazard inensifying factors relating to CC such as SLR, inundated, erosion, saltwater intrusion); vulnerability objects includes human works (e.g., residents, infrastructure...); resilience of natural system (geological formations, terrain factors – coastal geomorphology and mangrove ecosystem) and resilience of social system (population, infrastructure, education and awareness).

By using Arcgis 9.3 in assessing and conducting the weighted overlap of three mentioned components, vulnerability and forecast map (according to 0.5m SLR scenario) of Ba Lat Estuary under the impacts of CC was established. The vulnerability assessment result is divided into different areas ranging from low, average, relatively high and high level. The research illustrated that the study area is inclined to be in a high vulnerable level group. To be more exact, according to the 0.5m SLR scenario, the vulnerability density of the study area increases 28.8% (in comparison with 15.4% of the current situation)

Based on the vulnerability assessment of environment and natural resources in Ba Lat Estuary, solutions for appropriate use of environment and natural resources and adaption to CC are proposed as follows: enhancing the effectiveness of law, policies and normative documents; ensuring financial supply; taking into account vulnerability density of natural resources and environment when planning and managing; proposing science and techonology solutions; paying adequate attention to education and propaganda aimed at raising awareness of citizen on hazard mitigation. Of those solutions, comprehensive management based on vulnerability density and adaptation to CC lay the foundation for the coordination of local authorities and people living in priority area to implement regional socio-economy development strategy and adaptation to CC.

5. REFERENCES

Institute of Meteorology, Hydrology and Environment, 2010. *Final report on SLR scenarios and the ability to reduce risk in Vietnam*, Hanoi.

Ministry of Natural Resources and Environment, 2010. *Second National Report of Vietnam to the United Nations Framework Convention on Climate Change*, Hanoi

Ministry of Natural Resources and Environment, 2011. *Scenarios of climate change and SLR in Vietnam*, Hanoi.

Mai Trong Nhuan, Tran Dang Quy, Nguyen Thi Hong Hue, Luu Viet Dung, Hoang Van Tuan, Bui Thuy Trang, Pham Minh Quyen, Tran Thi Lua, Nguyen Ho Que, Le Thi Nga, Nguyen Thuy Linh, Vu Thi Thu Thuy and Pham Thi Tuyet, 2009. *Report explaining the vulnerability maps of Red River Estuaries, at scale 1:100,000*, Hanoi.

NOAA, 1999, *Community Vulnerability Assessment Tool.* NOAA Coastal Services Center, United States of American.

Statistical Yearbook of Giao Thuy district, 2011, Thong ke Publisher.

Statistical Yearbook of Tien Hai district, 2011, Thong ke Publisher.

USGS, 2005, *Coastal Vulnerability Assessment of National Park Units to Sea-Level Rise*, http://woodshole.er.usgs.gov/project-pages/nps-cvi/.

SOPAC, Environment Vulnerability index (EVI) to summarize national environmental vulnerability profile, 1999. http://www.sopac.org.fi/Projects/Evi/archive..html#documents

Thomas L.Saaty, 1980, *The Analytic Hierarchy Process: planning, Priority setting, resource allocation, McGraw-Hill*, New York, http://abo.fi/~rfuller/sda8.pdf.

Thomas L.Saaty, 2003, "Decision aiding: decision-making with the AHP: why is the principal eigenvector necessary*". European Journal of* Operational *Research* 145, 85.