

Vulnerability assessment of environment and natural resources in Vietnam coastal zone for sustainable use of natural resources, environment protection and adaptation to climate change (case study the Red River Delta coastal zone)

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, Pham Thi Tuyet

Vietnam National University, Hanoi, 144 Xuan Thuy, Hanoi, Vietnam

Received 27 April 2011; received in revised form 31 May 2011

Abstract. The Red River Delta Biosphere Reserve has the highest biodiversity in the Northern Vietnam, has an important role in protecting environment and natural resources and socio - economic development. In recent years, study area has been increased vulnerability by negative human activities (e.g., agriculture, aquaculture, transportation and industry) and climate change. Using ArcGIS 9.3 and Expert Choice 11 software, this article presents the results of vulnerability assessment map of environment and natural resources. Based on vulnerability assessment of environment and natural resources, several solutions aimed at sustainable use of natural resources, environmental protection, disaster prevention and mitigation, and adaptation to climate change have been proposed such as planning for sustainable use of environment and natural resources (eco-agriculture, eco-aquaculture and eco-tourism), environmental protection, raising awareness of community. Research results have significant roles particularly in establishing policies and strategies to protect natural resources and environment, mitigating hazards, adapting to climate change.

Keywords: vulnerability assessment, sustainable use, climate change.

1. Introduction

Sustainable use (SU) of resources is an important solution on environmental protection and adaptation to climate change (CC) [1-4], especially to Vietnam, one of the five countries which is most seriously damaged by CC [5], is

speeding up industrialization and modernization based on natural resources use, labor, other resources.

With over 3,200 km coastline, Vietnam coastal zone is characterized by abundant and diverse natural resources which great potential to promote socio-economic development especially is wetland resources (e.g., mangroves, coral reefs, sea grass, lagoons and tidal flats); geosite (e.g., gulf, cape and river

^{*} Corresponding author. Tel.: 84-4-35587060.
E-mail: quytrandang@yahoo.com

mouth); mineral resources (e.g., oil, coal, placer mineral deposits and construction materials). However, the coastal zone is highly vulnerable from hazards which typically are natural disasters due to CC such as typhoons, floods, sea level rise, salinity. Moreover, this is the region which is under pressure from human activities such as population growth, rapid urbanization and industrialization rate, massive development of fisheries cause negative impacts to natural resources and environment, reduce the quality of natural resources and environment, biodegradation. Therefore, SU of natural resources is vital for biodiversity conservation, environmental protection, CC adaptation. Following the SU of natural resources and environment and CC adaptation based on vulnerability assessment (VA) of Vietnam coastal zone, this article presents the initial research results for the Red River Delta (RRD) coastal zone.

Located in the Northern Coastal Plain, RRD coastal zone belongs to the World Biosphere Reserve and Xuan Thuy Ramsar site - the first Ramsar of the Southeast Asia, which is rich and diverse in natural resources, it plays an important role in conservation and reservation of natural resources, regional environmental protection and socio-economic development (Fig 1). Xuan Thuy wetland area is known as the highest biodiversity and biological productivity in the coastal zone of Northern Vietnam and also the most sensitive ecosystems. It also is home to various wildlife and rare bird species (total amount of individual birds can reach 30.000 – 40.000 ones). Some rare bird species are recorded in the World Red Book and Vietnam Red Book such as *Tringa guttifer*, *Eurynorhynchus pygmeus*, *Larus saundersi* [3, 6, 7].

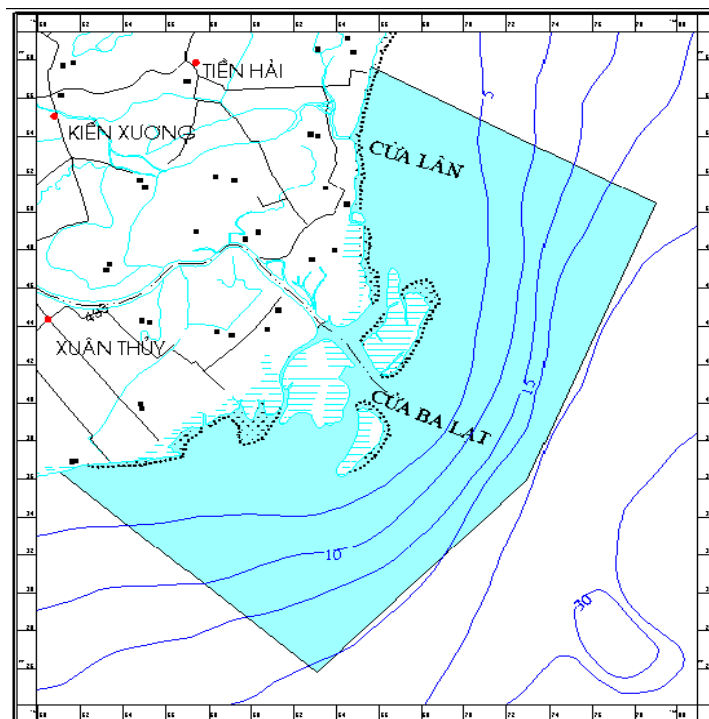


Fig. 1. Location of the study area.

Environment and natural resources of the RRD coastal zone have been exploiting and using for different purposes, especially in aquaculture farming, agriculture, tourism. However, the exploitation and utilization of natural resources and environment are not reasonable as destructive fishing operations tools (small mesh nets, electricity shock and exploiting small breeds) waste from agricultural activities, handicraft, and aquaculture [3]. Moreover, exploitation and utilization of water resources of the dams in the upstream of tributaries of the Red River system has caused many negative impacts to natural resources – regional environment such as changing water flow and the balance of sediments, loss of habitat, breeding grounds, spawning grounds, fisheries resources decline of some rare fish species in the Red River [8, 9]. In addition, this area has been affected by disasters related to CC such as coastal erosion river bank erosion (Giao Hung, Giao An, Hong Tien), channel siltation (Con Lu, Con Ngan, Con Mo), storms and sea level rise (the low coastal areas, wetland areas), pollution by heavy metals, oil and PCBs in water and sediment [3, 6, 10]. These above factors are agents that cause the vulnerability of environment and natural resources, threaten the sustainable development of the region.

2. Study methods

2.1. Approach to sustainable use of natural resources

There are many ways to approach to SU of coastal resources [1, 2, 11], of which SU of resources based on the VA solving three problems at once is the exploitation of

resources combined with environmental protection that meet the needs of present generations but still conserve natural resources and environment for future generations and accommodate for CC impacts (Fig 2). Forecasting and assessment vulnerability are scientific basis for not only implementing and establishing of natural resource SU plan, environmental protection, disaster mitigation and CC adaptation but also proposing management and enhancing community capacity to SU of natural resources (Fig 3). This approach was developed and expanded from geological resources SU approach based on VA [2].

2.2. Vulnerability assessment method

The VA method applied in this study were derived from the methods and criteria for coastal zone VA (CVIs) of the U.S. [12], environmental vulnerability (EVI) of SOPAC [13], the process of VA of NOAA [14] and the Cutter [15], and the assessment of Mai Trong Nhuan et. al., [1, 2, 10, 16-20].

VA of environment and natural resources in coastal zone has been built according to function: $V_{x_i y_j} = f(aR_{x_i y_j}, bP_{x_i y_j}, cC_{x_i y_j})$, in which: $V_{x_i y_j}$ is vulnerability level of environment and natural resources, $(R_{x_i y_j})$ is due to the risk level of vulnerability factors; $(P_{x_i y_j})$ is the density of the vulnerable object, and $(C_{x_i y_j})$ is the resilience capacity of social and natural systems; $(x_i y_j)$ are geographical coordinates and a, b, c is the weighted value of the level of importance. The evaluation criteria are determined by paired comparison matrix method of Saaty Thomat [21]. Calculation process consists of three steps: 1) set paired comparison matrix; 2) calculate for these

criteria, 3) stability rate assessment (CR) of the weights, ($CR \leq 0$, accepted) [22]. Finally, Expert Choice software was used to calculate weights of each component. The process of VA

is analyzed database by ArcGIS 9.3 software which use the spatial analysis to establish maps of each component.

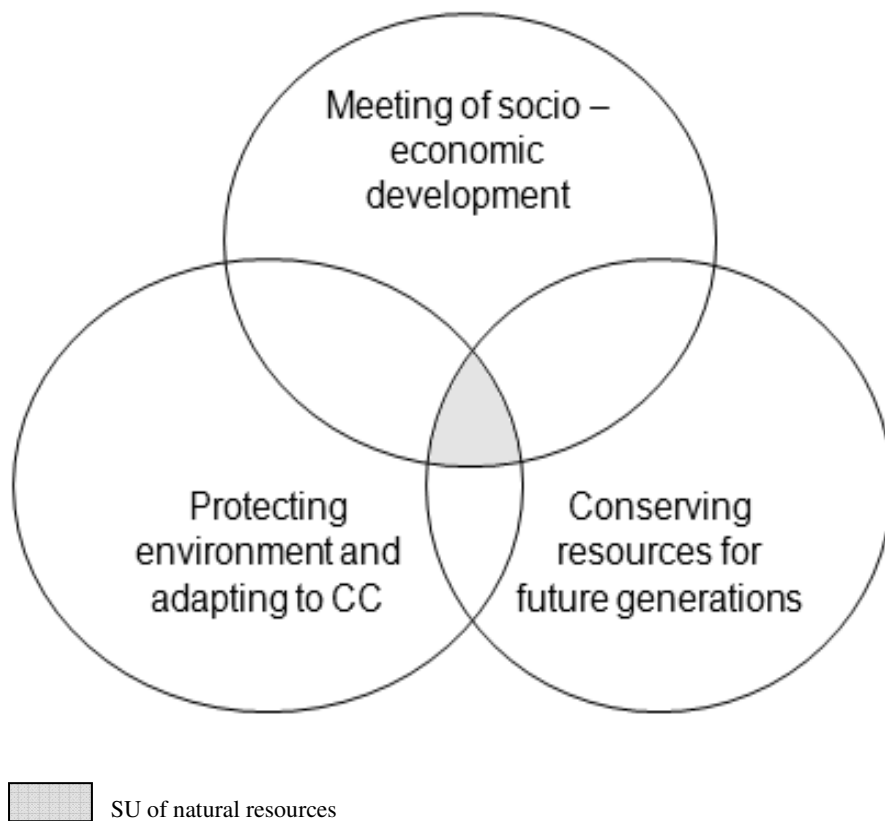


Fig 2. Model of SU of natural coastal resources in the context of CC.

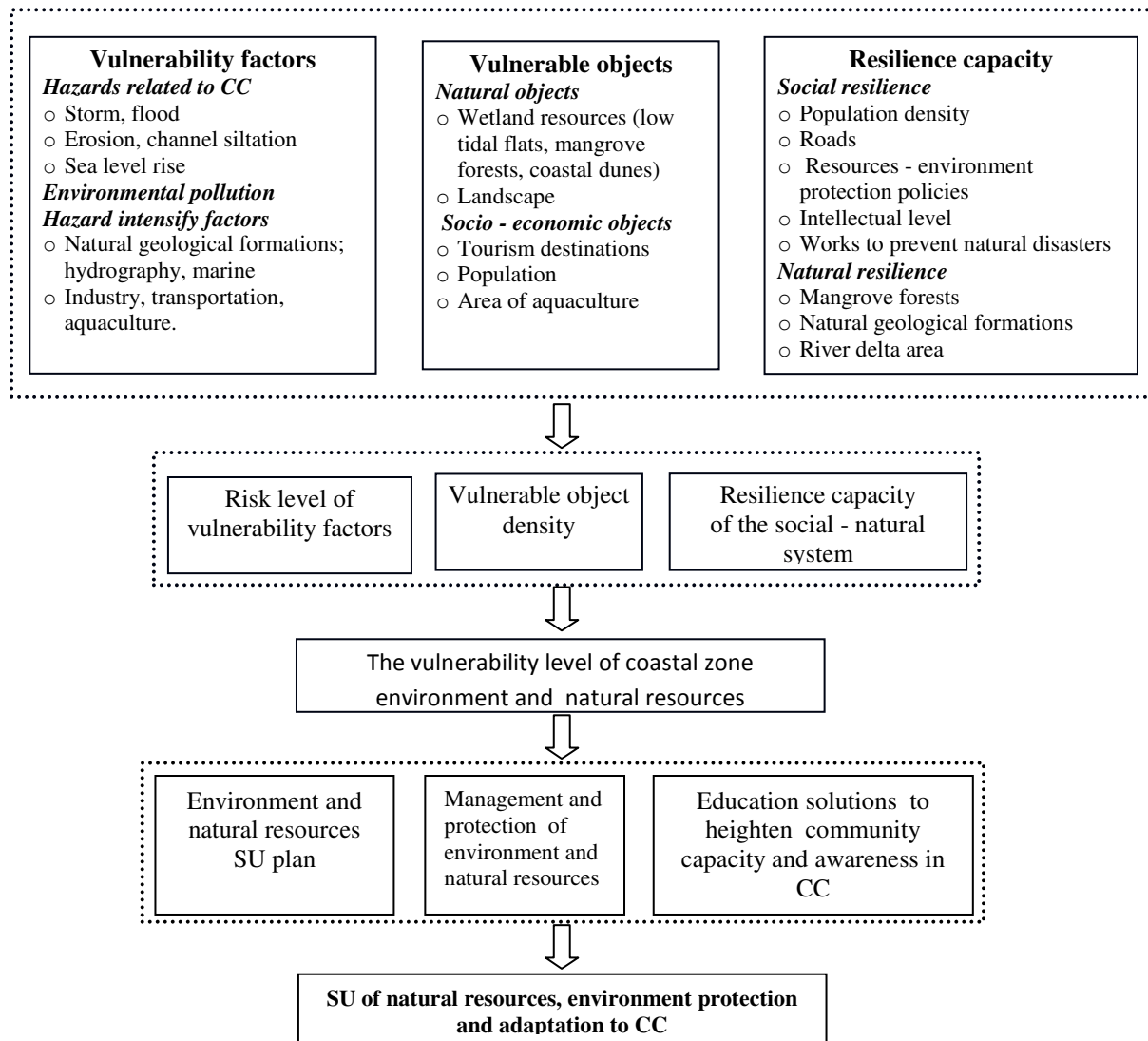


Fig 3. Natural resources SU approach, environmental protection, CC adaptation of coastal zone in Vietnam on the basis of natural resources-environment VA.

3. Vulnerability assessment of environment and natural resources in the RRD coastal zone

3.1. Vulnerability factors

Identified vulnerability factors of the RRD consists of two main groups: i) hazards related to CC including erosion, channel siltation, typhoons and floods, sea level rise,

environmental pollution (Table 1) and ii) hazard intensifying factors which include group of natural factors (the coastal geological formations: mud, silt, sand, bedrock) and human activities (aquaculture, agriculture, transportation, industry, handicraft).

Risk assessment from the vulnerability factors is proceeded as shown in Fig 3. Consequently, the study area has been classified

by the level of risk from low to high (Fig 4). In particular, areas with low risk level accounted for approximately 14% of the study area, including areas on the mainland far from coastal line to the east from Hong Tien to Dong Phong (Tien Hai district) back to the mainland. Areas with average to relatively high level

accounted for the largest area, about 70% of the study area, distributed in the Tien Hai town, Ngo Dong town and coastal communes Hong Thuan, Giao Nhan, Giao Than. Areas with the highest risk level in the Red River accounted for approximately 16% of the study area.

Table 1. Hazard characteristics of the RRD coastal zone

Hazard	Distribution	Intensity	Frequency	Incidence
Erosion	Along the banks of Red River, such as Hoanh Son, Giao Hung, Giao An (Nam Dinh), Hong Tien	High rate, 8mm/year (Giao An); 10mm/year (Nam Thinh)	Annual	Loss of lowland and wetland
Channels siltation	Northern of Ba Lat Delta, Con Lu, Con Ngan, Con Mo	High deposition rate	Frequently	Inhibit waterway transport
Typhoons and flood	Coastal lowland area that has weak drainage system terrain	Quite hard	1 – 2 typhoons/year	Inundation of coastal area
Sea level rise	Coastal lowland, wetland	Quite hard	Frequently	Loss of coastal lowland, natural resources and wetland ecology system
Environmental Pollution (Oil pollution, pollution by heavy metals in water and sediments)	Coastal zone in Nam Thinh, Nam Phu, Nam Thang, Giao An, Giao Xuan and 14 – 20m water depth area	Average – Low	Increase by years	Water & sediments environment, ecology and human

Source: [3, 6, 10]

3.2. Vulnerable objects

Vulnerable objects in the RRD coastal zone were considered socio-economic objects and natural resources. In particular, the socio-economic objects include the main residential areas, towns, villages, coastal communes (e.g., Nam Phu, Nam Thinh, Giao An and Giao Thien, Ngo Dong town); socio-economic objects include coastal transportation systems, ports huge bridges, sea dikes; aquaculture and fisheries farms, sand mining, schools, hospitals, cultural facilities, tourism sites (Dong Chau beach, Con Thu and Con Vanh, Xuan Thuy National Park).

The natural resources include minerals, wetland and land resources. Typical wetland resource in the RRD coastal zone including 9 wetland types: shallow sea at less than 6m water depth, river mouth, sea grass, dunes and beach at the flooding outfall, the sandbank in intertidal zone, sandbank/mud-bank in intertidal areas, the aquaculture ponds and salt-producing area [3, 6]. Which has the highest biodiversity of Northern Vietnam, especially Xuan Thuy wetland area has 192 plants (mostly submerged plants) and 55 species of zooplankton, 113 species of insects, 177 benthic species, 108

fishes, 24 reptiles, 13 amphibians, 136 birds and 9 mammals [3].

The vulnerable objects assessment result of RRD coastal zone was shown in Fig 3. As a result, the density of vulnerable objects in the study area is divided into levels from low to high (Fig 5). Areas with low density of vulnerable objects: 45% of the study area distributed in Nam Binh, Dong Hoang, Nam Cao, Binh Minh and others communes. Areas with relatively high to average of vulnerable objects: about 45% of the area, including a part of muddy sandbank in intertidal areas and some communes such as Hong Thuan, Giao Nhan, Giao Thanh, Tien Hai town and Ngo Dong town. Areas with high density of vulnerable objects: about 10% of the territories of Giao Thien, Giao An, Giao Lac, Giao Xuan, Giao Hai (which has Xuan Thuy National Park), Nam Phu, Nam Hung and Nam Thinh (Tien Hai Nature Reserve Center).

3.3. Resilience capacity of natural - social systems

The resilience capacity of the Red River natural - social system includes resilience of natural systems (e.g., ecosystems, geological formations, terrain factors - coastal geomorphology) and resilience of socio-economic systems (e.g., education level, environment and resources conservation and management, education and propaganda aimed at raising awareness on hazards mitigation, environmental protection, natural resources, infrastructure).

Resilience capacity of socio-economic systems

Key criteria to assess are education, management, policies, organization and protection to prevent hazards (schools, teachers,

garbage collection, the legal system related to the protection of natural resources, environment) and infrastructure (transportation systems, communication stations).

Resilience capacity of natural systems

Key criteria to assess the resilience of environment and natural resources include self-recovery aptitude of renewable resources (biological resources, ground water), retention ability of non-renewable natural resources (minerals, oil, gas), resistance, maintenance and natural values, self-restoration of the environment (natural formations, ecosystems). In these objects, mangrove ecosystems are the highest natural resilience ability, due to its resistance, reduction the impacts of the hazards (erosion, typhoon, flood, environmental pollution) together with high recovery after the impacts. The second one is the type of wetland tidal marsh, the solid geological formations, ... Meanwhile, the loose geological formations of the RRD with poor binding capacity, easily destroyed by waves, water flows and other natural factors, erosion hazard sensitivity is less likely considered to be natural response potential.

Evaluated resilience of natural - social systems in the study area are proceeded following the process in Fig 3 and separated into sections from low to high (Fig 6): Area with low resilience with low response ability consists of the whole river delta and coast accounted for 33% of the study area. Area with average resilience accounted for approximately 25% of the study area, comprising the entire coastal strip – which includes mangrove forests, belongs to the territory of Giao Lac, Giao Xuan, Giao Hai (Giao Thuy district) and Nam Phu, Nam Hung, Nam Thinh (Tien Hai district). In

addition, there is distribution of land in many places such as Hong Tien, Binh Dinh, Bac Hai and scattered in other communes. Areas with relatively high resilience accounted 25% of the study area, distributed in Nam Hai, Binh Dinh, Giao Long, Giao Lac, Giao Thanh and Giao Huong (Giao Thuy District) and Tay Son, Dong Phong, Dong Lam (Tien Hai District). Area with high resilience approximately 27% of the area and including coastal communes such as Dong Minh, Nam Thinh, Nam Thanh, Giao Thien, Giao An.

3.4. Vulnerability assessment of environment and natural resources in the RRD coastal zone

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. Vulnerability map of RRD coastal zone in scale 1:100.000 was established with four different areas from low to high (Fig 7).

Area with low vulnerability about 3.3% of the study area scattered in communes located in Tien Hai districts: Vu Bang, Binh Minh, Nam Binh and Dong Phong. These areas are far from the coast, less influenced by hazards (only affected by typhoons, floods in small intensity and almost under no pressure of human activities), not rich in natural resources and medium resilience (without mangrove system and disaster resistance on average).

Area with average vulnerability covered about 13.8% of the study area. One part is the sea – where the fault systems runs through, garbage causes pollution, but no one lives here. Most of the inland continent is at average vulnerability level, including the following communes: Hong Thuan, Giao Hai, and a part of Giao An (Giao Thuy District).

Area with relatively high vulnerability covered great part of study area that affected by some disasters (typhoons, floods, pollutions, erosion and channel siltation), but the density of vulnerable objects is moderate. In addition the centers of Tien Hai district, Giao Thuy district are counted with the high population density and lots of human buildings.

Area with high vulnerability about 8% of the study area include coastal areas of Giao Thien, Giao An and Giao Lac, Giao Xuan, Giao Hai (Giao Thuy district) and Nam Thinh, Nam Hung, Nam Phu (Tien Hai District). These areas have important wetland ecosystems which is sensitive to the socio-economic impacts.

4. Solutions proposal for natural resources SU, environmental protection, adaptation to CC in the RRD coastal zone

VA result of environmental and natural resources in the RRD showed that area with high vulnerability level usually link with relatively high risk from hazards and density of vulnerable objects from medium to high. Low vulnerability areas were far from the center of socio-economic, sparsely populated and little risk from hazards.

For SU of natural resources, environmental protection and CC adaptation should be highly concerned with the RRD VA results to tackle appropriate solutions to minimize the impacts of the hazards related to CC and human activities degrading natural resources, environment, plan SU of vulnerable objects, enhancing resilience capacity. On that result, solutions for SU of environment and natural resources and adaptation to CC are proposed: management (to enhance the effectiveness of laws, policies and community-based

management, integrated coastal zone management); environment and natural resource SU planning (with the sustainable economic model like eco-agriculture, eco-aquaculture, ecotourism and wetland resources protection models); hazards mitigation due to

CC (planting mangroves forest, constructions for coastal protection, anti-erosion), (Table 2). This approach is a new and modern method in order to protect environment and natural resources and strengthen resilience capacity, especially CC.

Table 2. Proposing solutions for natural resources SU, environmental protection, CC adaptation in the RRD coastal zone

Vulnerability Zoning	Location	Solutions proposed
Area with low vulnerability level	Located in some communes far from sea belonging districts: Tien Hai Vu Bang, Binh Minh, Nam Binh, Dong Phong	<ul style="list-style-type: none"> - Encourage the development of sustainable economic model: eco-agriculture, eco-aquaculture. - Apply environment and natural resources management solutions, community education about functions and values of resources - environment (especially wetland resources).
Area with average vulnerability level	Include the following communes: from Hong Thuan to Giao Hai and a part of Giao An (Giao Thuy district).	<ul style="list-style-type: none"> - Develop sustainable economic models: eco-agriculture and eco-aquaculture. - Apply environment and natural resources management solution under the statutes of the national park. - Planting mangrove forest.
Area with relatively high vulnerability level	Include the intertidal area, centers of Tien Hai and Giao Thuy districts	<ul style="list-style-type: none"> - Apply development of sustainable economic model: eco-aquaculture, sustainable fishing exploitation, green industries - Apply resources – environment management solutions, community education about functions and values of resources - environment (especially wetland resources).
Area with high vulnerability level	Located in some coastal communes: Giao Thien, Giao An and Giao Lac, Giao Xuan and Giao Hai (Giao Thuy district); Nam Thinh, Nam Hung, Nam Phu (Tien Hai district)	<ul style="list-style-type: none"> - Apply resources - environment management and protection solutions, under the strict statutes of the national park. - Propagandize and educate community on the functions and values of resources - environment. - Implement measures to minimize damage from hazards related to CC and environmental pollution (planting mangrove forest).

Conclusions

1) Vulnerability levels of the RRD coastal zone were evaluated by three components: vulnerability factors (e.g., erosion, typhoons, channel siltation, sea level rise, environmental pollution and hazards intensifying factors - natural and human activities); vulnerable objects (e.g., wetland resources and human

works) and resilience of natural - social system (e.g., education, health facilities, communication and transportation). VA result of environment and natural resources in the RRD is divided into four areas from low to high level: The area with high vulnerability level is often strongly affected by the hazards, densely populated, important types of wetland resources (concentrated in coastal communes Giao An,

Giao Lac, Giao Xuan and Giao Hai (Giao Thuy district) and Nam Thinh, Nam Hung, Nam Phu (Tien Hai district). Area with low vulnerability level is mostly less affected by hazards, less abundant wetland resources, far from economic centers and sparsely populated (Vu Bang, Binh Minh, Nam Binh communes).

2) Based on the vulnerability assessment of environment and natural resources in RRD coastal zone, solutions for SU of environment and natural resources and adaptation to CC are proposed including management (to enhance the effectiveness of the law, policies, community-based management, integrated coastal zone management), environment and

natural resources SU planning (priority to the development of the sustainable economic development models of agriculture, aquaculture and tourism), measures to minimize hazards and CC adaptation (planting mangroves, coastal protection construction, anti-erosion construction, wetland resources monitoring and conservation).

3) Research in the RRD coastal zone can be applied to the entire Vietnam coastal zone. Study result is an important basis for the managers to make decision about policies, CC adaptation strategies to environment and natural resources in coastal zone and the scientific basis for Strategic Environmental Assessment.

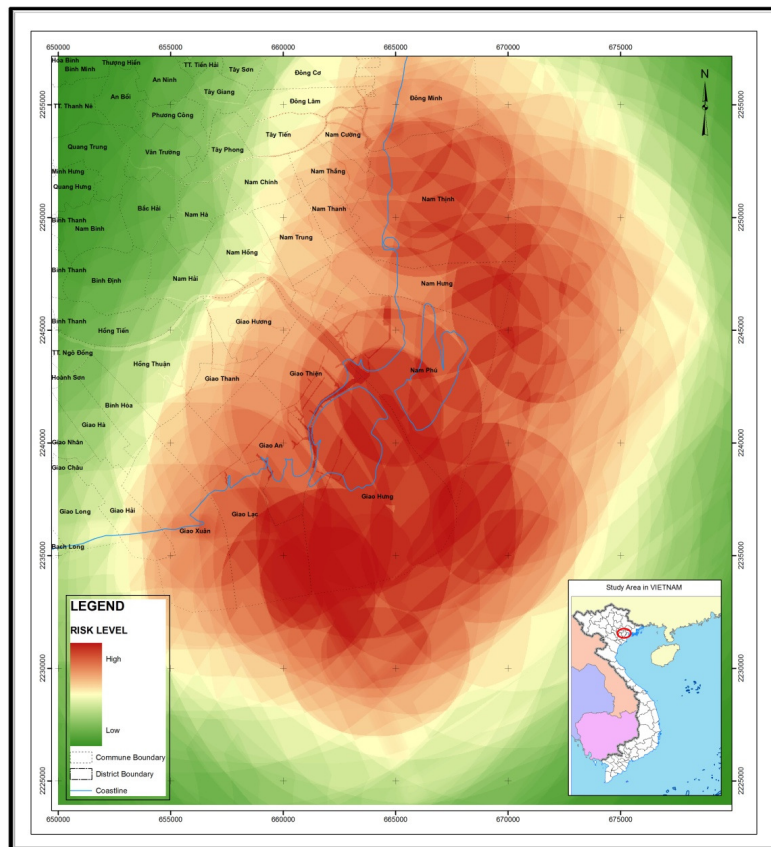


Fig 4. Risk level map by vulnerability factors in RRD coastal zone, at scale 1:100.000.

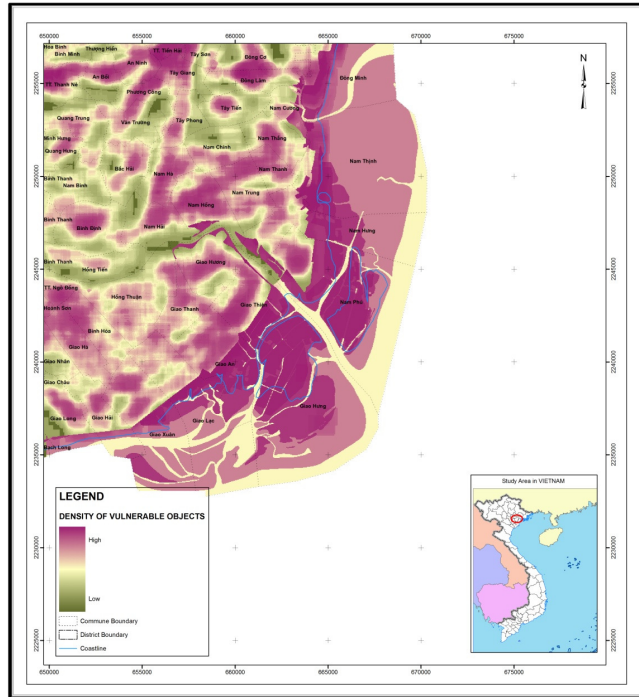


Fig 5. Map of density of vulnerability objects in RRD coastal zone, at scale 1:100.000

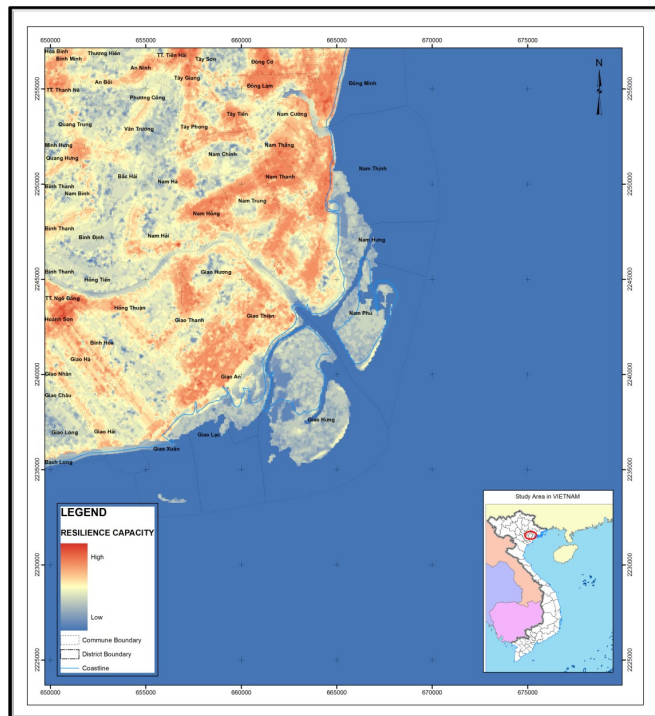


Fig 6. Resilience capacity map in RRD coastal zone, at scale 1:100.000.

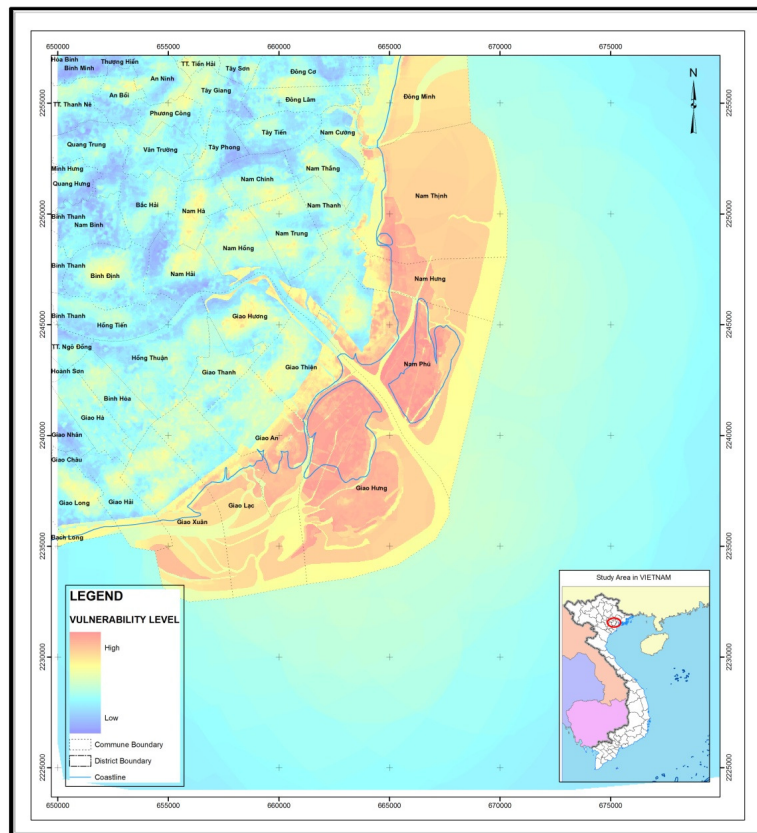


Fig 7. Vulnerability level map of environment and natural resources in RRD coastal zone, at scale 1:100.000.

Acknowledgments

This article is completed with the support from the fundamental research project code 105.09.82.09 and the project "Survey and assessment of environment and natural resources, meteorological and hydrological vulnerability level in Vietnam, forecast natural disasters, environmental pollution in coastal zone".

References

- [1] Nguyen Thi Hong Hue, Mai Trong Nhuan, Nguyen Tai Tue, Nguyen Thi Minh Ngoc, Do Thuy Linh, Pham Bao Ngoc, Luu Viet Dung, Assessment of vulnerability level of geological resources, orientation of sustainable use of the Ganh Rai bay, Ba Ria - Vung Tau province. *Journal of Geology*, 312 (2009) 5. (In Vietnamese)
- [2] Mai Trong Nhuan, et. al., *Study to propose model and solutions for sustainable use of geological resources in the coastal zone of Vietnam (on example of Vung Tau - Phan Thiet region)*. Vietnam National University, Hanoi, 2007. (In Vietnamese)
- [3] Mai Trong Nhuan, et. al., *Investigation, assessment, statistics, and planning for conservation of wetland areas with international and national significance*, Vietnam National University, Hanoi, 2007. (In Vietnamese)
- [4] IPCC, *IPCC Scoping Meeting on Renewable Energy Sources*. Lübeck, Germany, 2008.
- [5] Susmita Dasgupta, Benoit Laplante, Craig Meisner, David Wheeler, Yan Jianping, *The Impact of Sea Level Rise on Developing countries: A Comparative Analysis*, World Bank, 2007.

- [6] Mai Trong Nhuan, et. al., *Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand*. Vietnam National University, Hanoi, 2007. (In Vietnamese)
- [7] Mai Trong Nhuan, et. al., *Investigation and assessment the status and proposal for planning and action plan in use and protection of coastal wetland, environmental protection and disaster prevention*, Vietnam Environment administration, 2008. (In Vietnamese)
- [8] Pham Quang Son, Evolution of the Red River bed downstream of the 15-years operation of the Hoa Binh hydropower plant, *Journal of Earth Sciences*, 26 (2004) 520. (In Vietnamese)
- [9] Research Institute for Aquaculture No1, *Investigation of the current situation and protecting and restoring solutions some rare wildlife species are endangered in the Red river system: Semilabeo notabilis Peters, 1880; Spinibarbus denticulatus Oshima, 1926; Hemibagrus elongatus Gunther, 1884; Bagarius yarrelli Sykes, 1841*, 2000. (In Vietnamese)
- [10] Mai Trong Nhuan, Nguyen Thi Minh Ngoc, Nguyen Tai Tue, Nguyen Thi Hong Hue, Tran Dang Quy, Nguyen Thi Thu Ha, Pham Bao Ngoc, *Characterization and mitigation of Vietnam coastal hazards for sustainable development*. Proceedings Japan - Vietnam Symposium on Environmental science and technology for sustainable development of coastal and urban area. Danang, Vietnam, September 27-29th, 2007.
- [11] Stichting Natuur en Milieu, H.Muilerman, H.Blonk, *Towards a sustainable use of natural resources*, 2001.
- [12] USGS, *Coastal Vulnerability Assessment of National Park Units to Sea-Level Rise*, 2005 <http://woodshole.er.usgs.gov/project-pages/nps-cvi/>.
- [13] SOPAC, *Environmental vulnerability index (EVI) to summarize national environmental vulnerability profile*, 1999. <http://www.sopac.org.fj/Projects/Evi/archive.html#documents>
- [14] NOAA, *Community Vulnerability Assessment Tool CD - ROOM*. NOAA Coastal Services Center, 1999
- [15] Cutter, SL, Vulnerability to Environmental Hazards. *Progress in Human Geography* 20 (1996), 529.
- [16] Le Thi Thu Hien, Mai Trong Nhuan, Tran Van Y, Vulnerability assessment for environmental planning and management (on example of Hai Phong city). *Journal of Earth Sciences*, 28 (2006) 1. (In Vietnamese)
- [17] Mai Trong Nhuan, Nguyen Thi Hong Hue, Tran Dang Quy, Nguyen Tai Tue, Vulnerability assessment of coastal zone from Phan Thiet – Ho Tram, Vietnam for sustainable development. *Journal of Vietnam National University*, 21 (2005) 6. (In Vietnamese)
- [18] Mai Trong Nhuan, et. al., *Environmental resources investigation and assessment of some coastal bays for the socio-economical development and environmental protection*, 2009. (In Vietnamese)
- [19] Mai Trong Nhuan, Nguyen Thi Thu Ha, Tran Dang Quy, Nguyen Thi Ngoc, Do Thi Thuy Linh, Nguyen Thi Minh Ngoc, Nguyen Thi Hong Hue, Pham Bao Ngoc, 2008. The Vietnamese Wetlands Classification System. *Journal of Science, Earth Sciences* 24 (2008) 96. (In Vietnamese)
- [20] Mai Trong Nhuan, Nguyen Thi Minh Ngoc, Nghiem Quynh Huong, Nguyen Thi Hong Hue, Nguyen Tai Tue, Pham Bao Ngoc, Assessment of Vietnam Coastal Wetland Vulnerability for Sustainable Use (Case Study in Xuanthuy Ramsar Site, Vietnam). *Journal of Wetlands Ecology*, 2 (2009) 1. (In Vietnamese)
- [21] Thomas L. Saaty, *The Analytic Hierarchy Process: planning, Priority setting, resource allocation*, McGraw-Hill, New York, 1980. <http://abo.fi/~rfuller/sda8.pdf>.
- [22] Thomas L. Saaty, “Decision aiding: decision - making with the AHP: why is the principal eigenvector necessary”. *European Journal of Operational Research* 145 (2003) 85.