EVALUATION OF THE VULNERABILITY OF THE COASTAL SOCIO-NATURAL SYSTEMS (EXAMPLE FROM KHANH HOA COASTAL ZONE)

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Abstract

The methods for evaluation of vulnerability of coastal socio-natural systems proposed by National Oceanic and Atmospheric Administration (NOAA, 1999) and Cutter (1996, 2000) is improved on the basis of research results from the Khanh Hoa coastal zone. The applied methodology includes (1) defining danger levels resulting from hazards by a number of criteria such as type, intensity, frequency of hazards; (2) identifying all socio- natural components that are vulnerable to hazards and ranking them by different vulnerable levels; (3) vulnerability zoning and (4) assessing the capability of the community to respond to hazards in each area represented by a vulnerable level. The database for this study was constructed on the basis of interviews, field surveys and archive documents on the characteristics and mitigation of hazards and vulnerable socio - natural components. Thirteen types of environmental hazards threatening 18 socio- natural components have been identified and presented on different maps. On the basis of the analysis of spatial distribution of environmental hazard and socio-natural components, four areas of different vulnerability levels (very high, high, medium and low vulnerability) have been differentiated.

The results obtained by the above mentioned methods indicate relatively linear correlation between hazard density and the vulnerability levels of Khanh Hoa coastal natural systems. This method is effective not only in mitigating hazards but also provides an important database for policy-making agencies to ensure sustainable development of the coastal zone.

Introduction

For the last decades, the increase of damages resulting from hazards in general and geo-environmental hazards in particular have led to the change of viewpoints about methods of assessing potential hazards, degree of damages, damage mitigation alternatives, etc. One of the new approaches in studying and mitigating the adverse impacts of hazards is evaluating the vulnerability of socio-natural systems (Blaike P et al., 1994, Cutter 1996, D. Etkin 1999, Comfort L 1999, Sander et al., 2002, Karspeson 2001 (Fig. 1). By the end of the 20th century, the methodology of vulnerability assessment of a socio-natural system based on a series of systematically quantified parameters had been applied worldwide (Cutter et al., 2000; National Oceanic and Atmospheric Administration – NOAA, 1999; D.Etkin 1999, Comfort L 1999, Sander et al., 2002, Karspeson 2001). These methods are focused on the research and compilation of zoning maps for danger levels resulting from hazards and density of vulnerable socio-natural components based on which vulnerability assessment maps can be compiled.

In the past, environmental hazard maps only gave individual and qualitative information on the possible impacts of one or some hazards on a certain area. This information is not sufficient to sere as the basis for proposing measures for hazard mitigation and sustainable socio-economic development.

This paper introduces the method of vulnerability assessment by combining the vulnerability assessment model proposed by Cutter (1996, 2000) and the vulnerability assessment procedure proposed by NOAA (1999) adjusted to be suitable and compatible with the available data on socio-natural systems of the Khanh Hoa coastal zone (from Mui Giom cape to –Cu Lao island).

Method of study

In order to assess the vulnerability degree of the coastal zone socio-natural systems, a systems of survey points was designed in a rectangular grid with 1 km^2 and 4 km^2 cells corresponding with the 1:50,000 and 1:100,000 scales covering areas different in geology, topography, hydrography, antropogenic activities and formations, etc. The field data obtained in combination with the pre-existing data is assembled as per the following main subjects:

- Type, occurrence history, intensity, extent, imprints and consequences of hazards together with the affected socio-natural features.
- Prevention and control of hazards applied and proposed to be applied.
- Present status and predicted damages resulting from human activities in the area (hydraulic, transport infrastructure, aquaculture, mining, tourism, etc.)

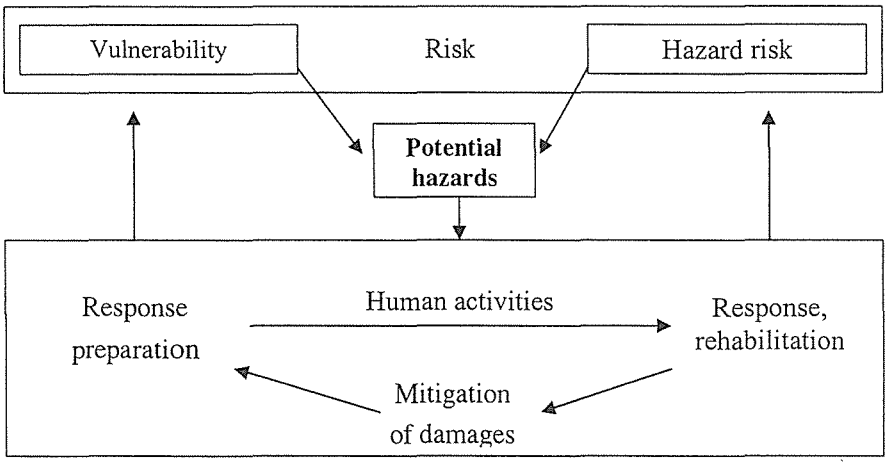

Figure 1. Hazard adaptability model (after Etkin. D, 1999 with modification)

The definition of danger level resulting from hazards for the coastal zone and offshore area is carried out in the following steps:

- Defining types of hazards and giving points to the danger levels of the hazards by various criteria such as type, intensity, occurrence frequency, etc.
- Identifying types of hazards and calculating the total number of points representing the danger level for each cell and putting the result in that cell. (DIi = SHi/SHtb; DIi – is the danger index of each cell, SHi – is the total number of points of the ith cell, SHtb – is the average danger level of the whole area)
- On the basis of the total points of each cell and other additional indexes of the coastal zone, a danger level zoning map was compiled.
- For zoning the density of vulnerable socio-natural components it is necessary to:
- Identify vulnerable socio-natural components and rank them by different vulnerability levels. The vulnerable components in this study are limited to those impacted by human activities such as tourist sites, port terminals, aquacultural ponds, factories, etc.
- The point rating of vulnerable socio-natural components in each cell which are of linear or areal form was derived based on the diagonal and area of each cell combined with the expert knowledge.
- The average density of vulnerable socio-natural components for the whole area was calculated by the formula SODtb = Σ SODi / N (i = 1, 2...N) (where SODtb – is the density of the vulnerable component, SODi is the number of points of vulnerable component in the ith cell, N – is the number of cells of the study area).
- Based on the density of the vulnerable components, SODi max in the study area was determined and the vulnerable socio-natural components were classified into 4 levels: vulnerable socio-natural components, relatively high vulnerability socio-natural components, high vulnerability socio-natural components and very high vulnerability socio-natural components.

The zoning and assessment of vulnerability of the socio-natural systems was carried out by overlaying and analyzing the above maps.

Results and Discussion

Zoning of danger levels resulting from hazards

The results of field survey and document study show that the study area is likely to be under strong impacts of 13 types of geo-environmental hazards, comprising: 1) earthquake; 2) sand drift; 3) erosion; 4) collapse; 5) salinization; 6) sea level rise; 7) sedimentation changing the shipping channels; 8) flood; 9) oil pollution; 10) Organic matter pollution; 11) Pollution by some metallic elements; 12) radioactive pollution; 13) solid waste pollution. These hazards were identified and described on the geohazards and hazard prediction maps.

On the basis of the number of points of individual potential hazards and the total number of points of all hazards at the location where they occurred, a schematic zoning map of danger levels due to hazards in the Khanh Hoa coastal zone (Tuy Hoa – Nha Trang) was compiled, showing 4 danger levels (Figure 2):

a) $D_i < 1$ ----> little dangerous; b) $1 < D_i < 1,7$ ---> Fairly dangerous;
c) $1,7 < D_i < 3,4$ ---> dangerous; d) $D_i > 3,4$ ---> very dangerous;

The area of very dangerous potential hazards covers the sand bars extending from Hon Giom cape to Hon Ngang cape in the Hon Gom peninsula, the coastal strip extending from Van Tho to behind Cua Gia, Hon Khoi cape and Ninh Hoa. In these locations are highly concentrated various potential hazards such as erosion, sand invasion, pollution, etc. with very high estimated frequency and intensity.

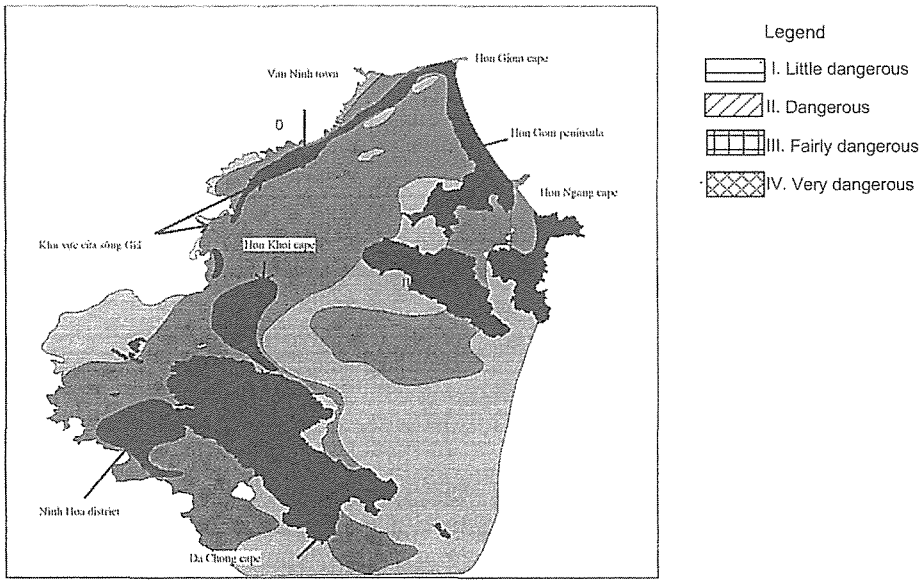

Fig. 2 Schematic zoning map of danger levels due to potential hazards in Khanh Hoa coastal zone

The areas of dangerous and fairly dangerous potential hazards are alternated with each other in the hilly area adjacent to the sea, the coastal strip and in various lagoons surrounding the area of very dangerous potential hazards. The number and frequency of hazards are not high.

The area with little dangerous potential hazards covers mainly bedrock island in the bays. In these locations the number and frequency of hazards are very low, and the hazards are of low intensity, such as pollution, sand invasion, etc.

Zoning of vulnerable socio-natural components

Based on the criteria proposed by Cutter (1996, 2000) and NOAA (1999) together with the results of surveys of socio-natural components in the study area, 13 socio-natural components which are vulnerable when hazards occurs have been identified, comprising: 1) tourist sites; 2) ports; 3) piers; 4) petroleum station; 5) Salt fields; 6) aquacultural ponds; 7) aquacultural cages; 8) ships and boats (in ports, near shore and offshore); 9) main population areas (cities, small towns, villages, scattered population points); 10) airports; 11) railways; 12) main roads (National road No 1, provincial roads, district roads); 13) large bridges; 14) sea dikes; 15) dams across rivers; 16) mining sites; 17) factories, industrial zones; and 18) farming/forest land. These socio-natural components were given points and divided into 4 areas with different densities (Fig. 3).

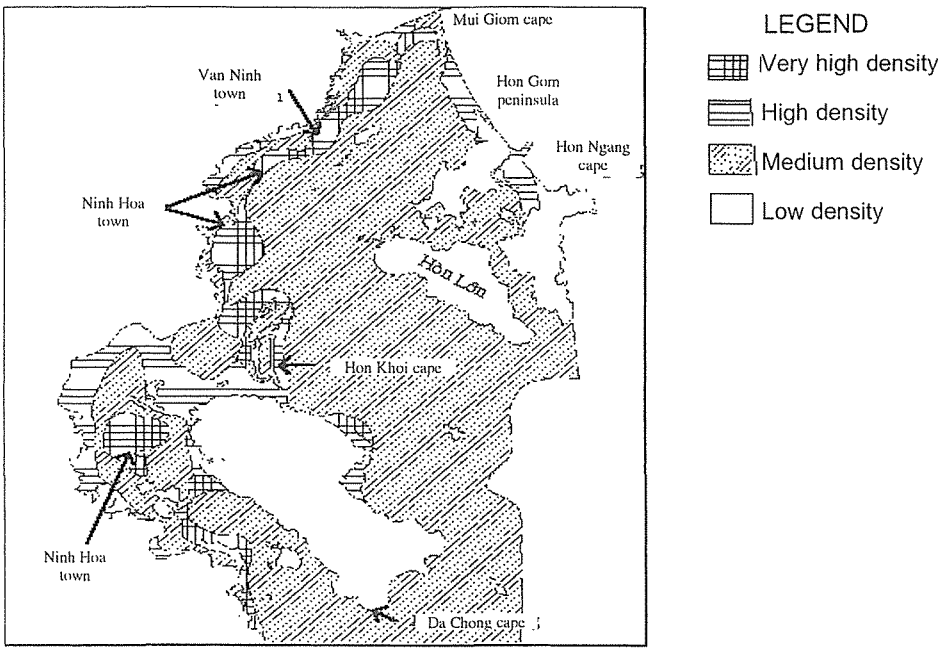

Fig 3. Schematic density zoning map of vulnerable socio-natural components in Khanh Hoa coastal zone

The area with very high density of vulnerable socio-natural components is distributed mainly in the coastal zone from Mui Giom to Mui Hon Khoi, the coastal zone of Nha Phu lagoon and Ninh Hoa, Van Gia townships. These locations are of high population density, with many important socio-natural components such as petroleum stations, major population points, shrimp ponds, airports, factories, industrial zone. The area with high density of vulnerable socio-natural components is located in the lagoons and sand bars surrounding the small towns. The vulnerable socio-natural components with medium and low density are concentrated mainly in the coastal mountains and hills, the islands and Hon Gom peninsula.

Vulnerability zoning of the socio-natural systems.

Based on the analysis of the potential hazards and vulnerable socio-natural components mentioned above, 4 areas of different vulnerability levels have been differentiated (Fig. 4):

1. Low vulnerability area: (area I) is the area with low (little dangerous) hazard potential, located far inland, or in the islands and peninsulas with low economic development, far from concentrated population points and infrastructures.

2. Medium vulnerability area (area II) is mainly onshore, north of Ninh Hoa town. This area has fairly high density of hazards with population density and degree of economic activities higher than area I.

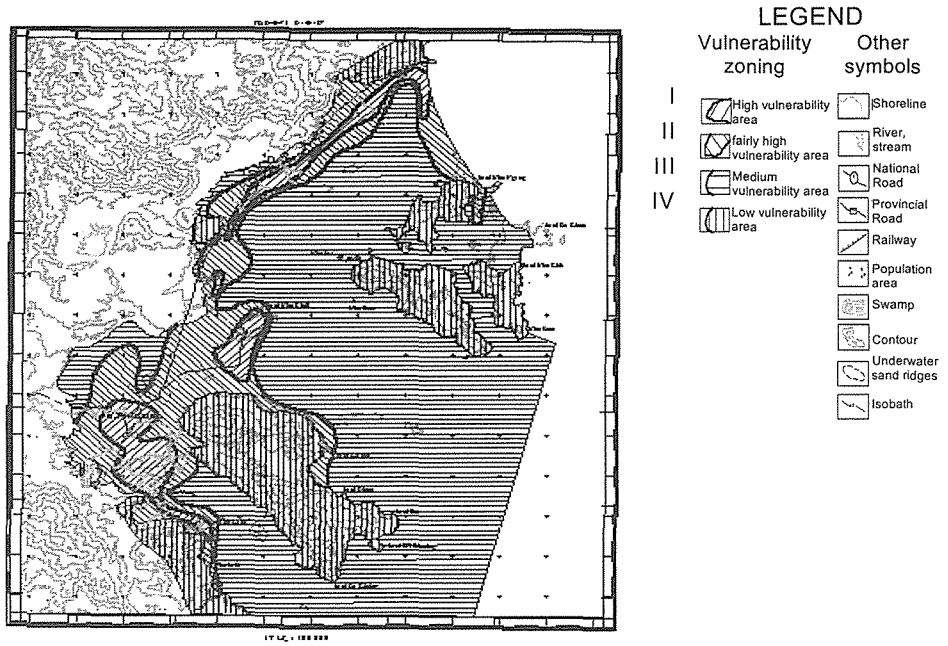

Fig. 4 Schematic vulnerability zoning map of Khanh Hoa coastal zone

3. Fairly high vulnerability area (area III) consists of the coastal strip and nearshore zone extending from Hon Gom peninsula to My Giang island, covering most of the Hon Khoi bay, Ninh Hoa town and Southwest of Nha Phu swamp. These are areas with fairly dangerous hazards, medium to high density of vulnerable components, characterized by high concentration of population and socio-economic activities.

4. High vulnerability area (area IV) consists of the coastal strip extending from the south of Van Gia town, south of Hon Khoi peninsula and from Ninh Hoa town to Southwest of Nha Phu swamp and Hon Nua. This area has a very high hazard density combined with high density of vulnerable components and many important socio-economic activities.

Remarks

The vulnerability of the socio-natural systems in the study area has a nearly linear relationship with the density (danger level) of the environmental hazards and the density of the vulnerable socio-natural components. This proves that the capability of the community in prevention and mitigation of damages caused by environmental hazard is still very low. This is also a factor making the socio-natural systems more vulnerable.

In the present situation of our country, in order to efficiently mitigate the damages caused by hazards, one should not only focus on the measures for direct actions against hazards, but also pay attention and give priority to the capability of the community to respond to hazards.

The result of vulnerability assessment and zoning serves as an indispensable basis for proposing strategy and measures for prevention and mitigation of damages caused by hazards.

The clear description of the "lifelines" in the case of hazard such as: roads, bridges, dams, airport, ports rescue stations and rescue facilities on the compiled vulnerability zoning map provides valuable information for planning the mitigation of damages caused by hazards.

Conclusion

To assess the vulnerability by the methods proposed by Cutter and NOAA with adjustments, data from interviews, field surveys and archive documents on hazard characteristics, vulnerable socio-natural components, hazard prevention and control, etc. must be collected. Thirteen types of environment hazards threatening up to 18 different socio-natural components have been identified and presented on various maps. By analysis and spatial comparison of hazards and vulnerable socio-natural components, 4 areas have been differentiated: high vulnerability, fairly high vulnerability, medium vulnerability and low vulnerability areas; of which the high vulnerability area is the area of highest risk level. This method not only makes active contribution to the prevention and mitigation of damages caused by hazards, but also provides a database for making strategy and policy for sustainable development of the coastal zone. The precision and efficiency of these assessment methods depend much on the detail and reliability of the data on hazards and vulnerable socio-natural components.

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