

ASSESSING CLIMATE CHANGE IMPACTS BY DPSIR FRAMEWORK FOR QUANG NAM COASTAL ZONE, CENTRAL VIETNAM

P. H. Nga,¹ K. Takara² and P. T. H. Lan³

ABSTRACT: Coastal area of Central Vietnam are always highly vulnerable to natural disasters. Moreover, due to the trend of increased weather extremes caused by global climate change, the vulnerability of coastal communities would be further exacerbated causing high risk of casualties and damages. On the other hand, being aware of the complication of the physical processes as well as socio-economic issues in such dynamic coastal area, this paper presents the application of conceptual analysis by using modified DPSIR framework through statistical analysis of hydro-meteorological as well as socio-environmental data for the Case Study of Quang Nam province. Based on that, a tailor made set of potential impacts is developed that can be useful to enhance the awareness local communities about their vulnerability (social, economic, environmental and morphological) to various types of disasters and therefore, and to strengthen their resilience in the long term.

Key words: Disaster vulnerability, climate change, modified DPSIR framework, coastal zone management.

INTRODUCTION

Quang Nam province is located in Central Vietnam where is known as highly disaster-prone region. Having the basin of Vu Gia -Thu Bon river system, one of the largest river system in Vietnam, every year, the province has to confront with various natural hazards, mainly water related, such as typhoon, storm surge, flooding, drought, landslide and erosion. Although, the coastal zone of the province undergoes rapid economic development but still poor and highly vulnerable. Moreover, according to IPCC report, Vietnam is projected to be seriously affected by global warming which will potentially result in increased disaster risk for coastal community. Moreover, the coastal area in Quang Nam province is characterized by far complicated hydro-morphological processes and thus, this paper presents the combined application of statistical and conceptual cause-effect approaches named DPSIR in order to understand and analyse potential impacts caused by climate change intensified hazards. Then, a discussion presents on how to integrate of this conceptual analysis into overall coastal zone management in local area. Although the paper is not going to propose detailed mitigation measures to these impacts, it will come up with recommendations on further works that can help eliminate their negative consequences in order to enhance the resilience of the local community.

STUDY AREA

This study selected Quang Nam coastal zone, Central Vietnam for pilot application of DPSIR framework in developing disaster vulnerability indicators because this area is critically prone to various types of water related hazards. Quang Nam coastal zone is the downstream of Vu Gia Thu Bon river system, which originates on the eastern side of the Truong Son mountain range at the elevation of 2,000m. Its upper part is short and steep with a narrow riverbed, steep banks and many cascades. The system meanders once or twice. In the middle and downstream reaches, the riverbed is rather wide and shallow. In the downstream reach, the banks become low, allowing overflow into fields and villages during the flood season. The system is formed by two main rivers, namely Vu Gia and Thu Bon. Both rivers have many tributaries creating a dense and complicated hydrological system.

Below is the summary of main issues of the study area which are used as input of DPSIR framework application:

Topography and geology

Quang Nam province is located in the narrow Central region of Vietnam with a total area of 10,408 km². The province's topography is flat land along a long coast line of more than 80 km and increasingly high elevation towards the west. Such large surface slope

¹ M.Sc, Water Resources University (175 Tay Son Street, Dong Da, Hanoi, VIETNAM)

² Professor, Disaster Prevention Research Institute, Kyoto University (Gokasho, Uji, Kyoto 611-0011, JAPAN)

³ Ph. D, Water Resources University (175 Tay Son Street, Dong Da, Hanoi, VIETNAM)



Fig. 1 Topographic map of Vu Gia Thu Bon river basin

strongly influences the overall hydrological regime of local river systems which is to be discussed in the next paragraph.

Annual rainfall and typhoon

The annual rainfall in Vu Gia Thu Bon basin is highest compared to other parts of the whole country. Average annual rainfall is approximately 3000 – 4000mm and 2000mm in the upper area and in the coastal zone, respectively (see Figure 1).

Torrential rain for many days is a typical weather characteristic in this region during wet season. Another issue of concern caused by rainfall is extreme fluctuation in annual precipitation. The wettest years bring approximately 4-6 times more rainfall than the driest years. The maximum monthly rainfall occurs during September – November. The driest months are February and March and have about 15 times less rainfall than wettest months. Moreover, maximum monthly rainfall can be caused by typhoons but can also occur without typhoon. Every year, 2 -4 typhoons make landfall in this region bringing huge rainfall and whirlwind. Consequently, these climate characteristics result in extreme hydrological regime of Vu Gia – Thu Bon rivers which is to be discussed in the next parts.

Hydrological regime. As a result of high geographical slope and torrential rainfall for days Vu Gia Thu Bon river system experiences extreme flash floods in mountainous area and deep inundation in the downstream plain and coastal area. Especially, during wet season, the rivers are flashy, meaning that there are rapid variations in flow, hourly, daily and weekly. For example, long-term average maximum monthly and daily flows for Vu Gia river at Thanh My gauging

station are 350m³/s and 3,400m³/s. The largest daily flow recorded at this station was about 7,000m³/s on November 20th 1998.

Similarly, long-term average maximum monthly and daily flows for Thu Bon river at Nong Son gauging station are 700m³/s and 5,700m³/s. According to local water experts in Quang Nam Hydro-Meteorological Center, the discharge of 400m³/s results in the flooding of emergency level II in the downstream plain and coastal zone. As shown in Figure 2, almost every year, Quang Nam province is stroke by damaging flooding.

Another type of water related hazard faced by local communities living in Quang Nam coastal zone is critical water shortage and salt intrusion in dry season. As a result of the fact that most of annual flow concentrates during a few months, from September through November. For the rest of the year, the river flow is rather low: the flow during 6 dry months, from February through July, accounts for only 7% - 12% of total annual flow [ADB, 2008]. Furthermore, the low flow results in serious salt intrusion: even in the years of historical flooding during 2007 and 2008, the salinity at Duy Thanh barrage located 10km from Dai river mouth is of about 19.2‰ [ADB, 2008]. Therefore, the damaging flood during half year and right after that, critical water shortage and salt intrusion during another half year cause high risk for human safety and livelihood as for natural ecosystem integrity.

Aquatic ecosystems. Having a coastline of 125km with two major river mouths as well as many near shore islands, Quang Nam coastal zone is characterized by far diverse aquatic ecosystems of low-lying delta, river estuary, lagoon and sand dune. Especially, it is estimated that there is about 500ha of sea grass scattering over An

Hoa lagoon bed and Thu Bon river estuary. Around Cu Lao Cham, the largest island in the area, coral reefs cover an area of about 200ha with more than 135 coral species. Besides, large area of mangrove and protected forest planted on sand dune also helps to provide valuable habitat for numerous aquatic fauna species (fishes, lobster, shrimp, bivalves, mollusca, benthos...) **Social issue.** The population living in 16 coastal communes of the province is about 840,000 which account for 57% of the whole province population. Regarding the livelihood of local people, apart from traditional rice cultivation, there is boom of aquaculture, fisheries and tourism. However, overall, the income of local people is still rather low; 20% of households in the study area has income lower than national threshold of poor households.

CLIMATE CHANGE ISSUE.

In August 2012, Vietnam Government has issued the official report on climate change projection for different regions of the country based on the IPCC scenarios. This report again emphasizes that Vietnam is one of most countries affected by global climate change. According to the main findings of that report based on medium emission scenario (B2) by the end of 21st century, the study area is located in the region with an increase, approximately, in temperature by 2–3°C, in sea level by 57-73cm and in annual rainfall by +2.2%. Moreover, the such projected increase in annual rainfall is not even for the entire year: Jan-Feb: -1.9%; March-May: -5.0%; Jun-Aug: +2.9%; Sep-Dec: +4.7% [MONRE Vietnam, 2012]. The latter is considered as most critical issue of concern as it would exacerbate vulnerability of whole downstream and coastal areas due to more and more extreme events occurred.

The statistical analysis of past record also shows the result which is in line with the downscaling model one. Fig. 2 shows the increasing tendency of annual maximum water level during 1976-1992 and 1993-2009. For example, flood events with 20% frequency for these two periods were 420cm and 500cm, respectively.

Being different from flood data, there is rather limited official estimation on droughts and consequential loss. Almost every year, Quang Nam province has to confront with water shortage at different level. It is reported that the province experience more frequent severe water shortage in recent years. The record at near shore Hon Dau station over last 50 years shows an increase of maximum tidal level (see Fig 3) but the subsequent change of salt intrusion is not clear as it is influenced by many factors from the sea but also from the upstream. Nevertheless, the storm surge induced by

typhoon has become more serious in recent years, e.g. it causes more flooding and more erosion.

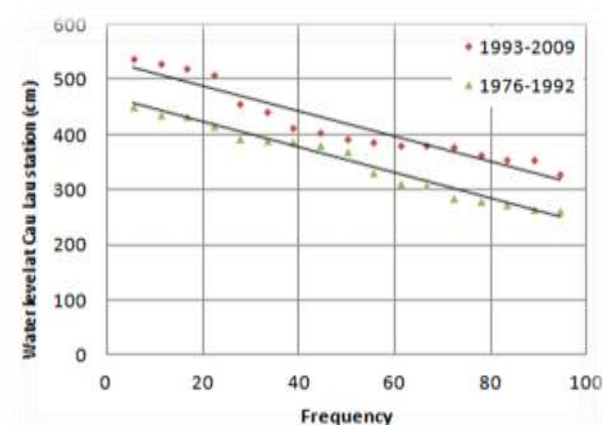


Fig. 2 Comparison of annual maximum water level frequencies during 1976-1992 and 1993-2009.

DPSIR FRAMEWORK FOR ASSESSING IMPACTS CAUSED BY CLIMATE CHANGE

DPSIR, Driver – Pressure – State – Impact – Response, framework is a conceptual model to understand the connections among the different indicators of both, environmental and social systems. The DPSIR framework, firstly developed by the European Environmental Agency, has being suggested as an advantageous method to define cause – effect relationship, highlighting the connection among the causes of environmental problems, their impacts and the society's response to them, in an integrated way. As shown in Fig. 4, the framework structures the indicators of environmental and human systems in five groups connected by two types of links: a direct causal chain

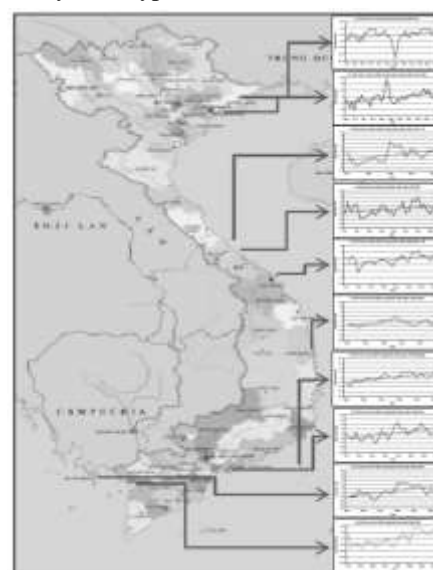


Fig. 3 Change in tidal level over last 50 years [MONRE, 2011]

(Driver, Pressure, State, Impact and Response); and feedback links between the Responses and their targets (Drivers, Pressure, State and Impacts) [EEA, 1999].

The advantage of this DPSIR is being able to clarify and analyse complex multi-sectorial inter-relationship. Therefore, it can also be applied in coastal vulnerability assessment. The coastal zone, a transitional zone between the land and the sea, is usually characterized by complex and diversified features, such as estuaries, coastal lagoons, sand dune... that are recognized as far important component in terms of their ecological values and utilization by humans (Clark, 1996). Such threat seems to be exacerbated due to climate change, which is reality and its impacts have been experienced in many parts of the worlds, such as increased disaster magnitude and uncertainty, fresh water shortage due to increased salt intrusion, tidal inundation in coastal cities... As original DPSIR framework used mainly for environmental management, this study has carried out the modification to apply this framework for assessing impacts caused by climate change intensified disaster. A range of data on physical as well as socio-economic issues was collected and used in the analysis. However, the scope of this paper is to cover mainly the analysis of direct causal chain, but not the feedback chain.

RESULT AND DISCUSSION

This part is to discuss the result of application of modified DPSIR framework for Quang Nam coastal zone, Central Vietnam. To select the main drivers for this assessment, an overview of existing socio-economic stressors is needed. As described earlier, Quang Nam has a coast of 125km, stretching along 5 districts named Dien Ban, Duy Xuyen, Que Son, Thang Binh and Nui Thanh and a city of Hoi An, UNESCO World Heritage with a density as high as 1,000 people/km² [ADB 2008]. The living standard and average income of local people is rather low and unstable compared to other regions of Vietnam. The major economic activities in Quang Nam coastal zone include agriculture, aquaculture, fishery and tourism, which all strongly depends on natural resources and be influenced by natural conditions and thus, highly vulnerable to natural hazards.

Based on these factors, there are 5 DRIVERS to be included in this modified DPSIR assessment, namely rapid POPULATION GROWTH, AQUACULTURE, FISHERIES, AGRICULTURE and TOURISM.

Although agriculture does not bring much income for local farmers, it is a traditional livelihood to engage large rural population, especially woman. Therefore, it is quite important activity to maintain food security. However, during a field survey, the local farmers reveal that in the recent years, they have been experiencing decrease in

crop production because of insufficient irrigated water and increased salinity as well as increased damaging floods. Being different from agriculture, fisheries and aquaculture activities have been extended rapidly during past years. In 2011, total area of agricultural lots is about 7,500ha occupying most surface of estuary, coastal lagoon and even sand dune which result in undesirable changes of morphological features and consequently, high vulnerability to flooding and erosion [VAST, 2011]. Similarly, offshore fishery has been expanded in terms of number as well as capacity of vessels and become one of the most dynamic activities in Quang Nam coastal zone because of its significant contribution to poverty alleviation and employment promotion [ADB 2008, VAST 2011].



Fig. 4 Original DPSIR framework [EEA, 1999]

The PRESSUREs exerted by these booming economic activities are subsequently transformed in a variety of natural processes that may result in changes in the STATE of both physical and biological environment. This causal-effect relationship is analysed in modified DPSIR framework (see Fig. 5). Moreover, as described earlier, Quang Nam coastal zone is projected to have an increase of sea level by 57-73cm and of rainfall by 20%, according to IPCC scenario B2 and consequently, this area is vulnerable to increase of all types of coastal hazards, i.e. typhoon induced whirl wind and storm surge (sea flooding), river flooding, drought and salt intrusion. Except degradation of water quality, all other changes of state would accelerate the vulnerability of local communities to natural hazards. Fig. 5 also presents four groups of IMPACT indicators, namely social, economic, environmental and morphological.

The usefulness of this tailor made set of IMPACT indicators is that the local managers can have answers to several questions for developing long term coastal zone management plan, like: which types of negative impacts that local people have to cope with? what are the main societal driving forces that cause pressures to lead to the generation or increase of such impacts? What are the consequent changes of environmental status at present and its trends in the future, especially in the context of climate change? What are the necessary responses or

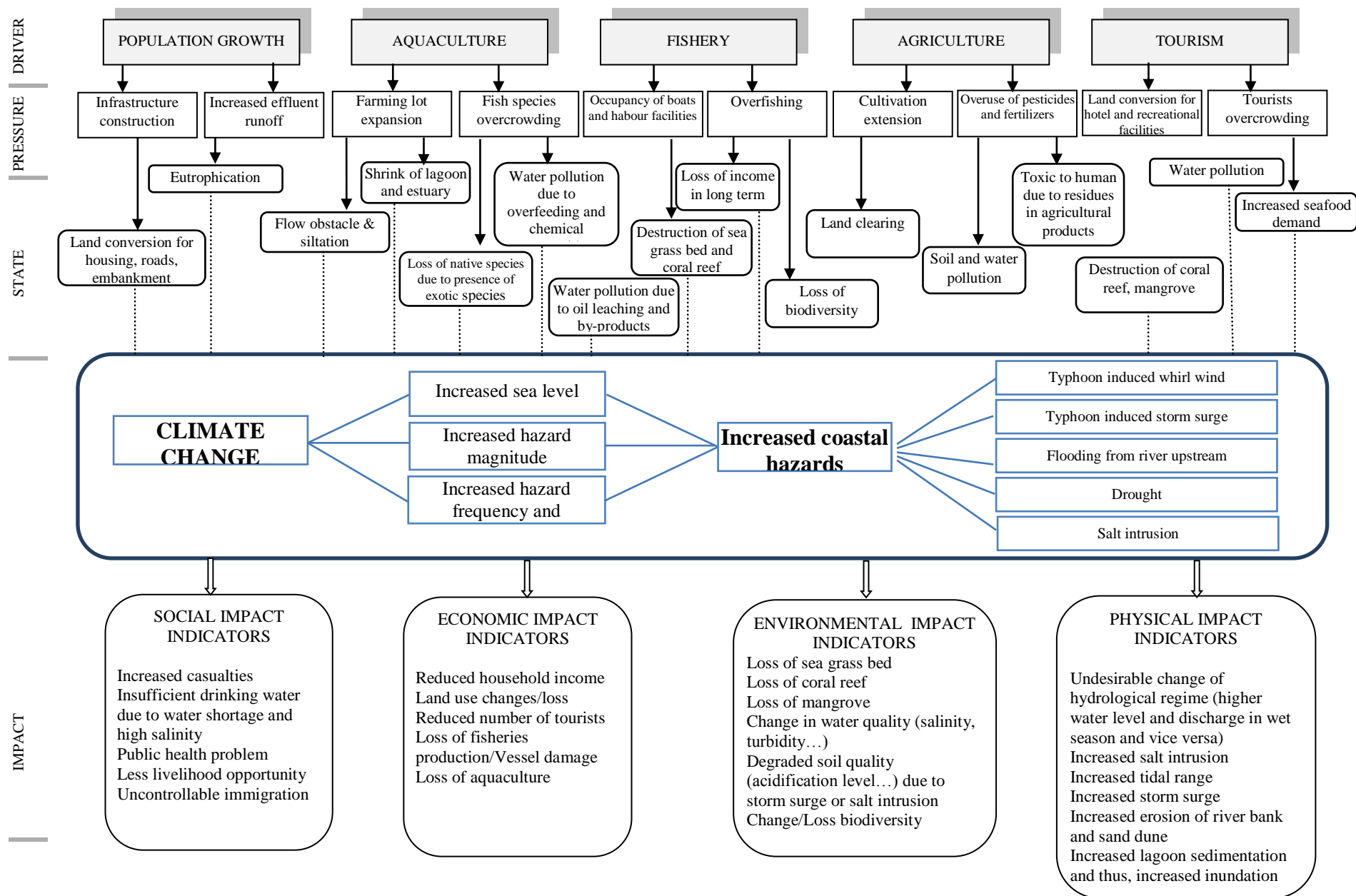


Fig 5. Application of modified DPSIR framework for climate change impact assessment in Quang Nam coastal zone, Central Vietnam

counter measures to reduce vulnerability and thereby, to reduce disaster risk and to enhance resilience capacity of local community.

CONCLUSION AND RECOMMENDATION

Quang Nam coastal zone has been subject to numerous studies that touch upon the complexity of its physical, environmental, social and economic issues. The diversity of these studies serves as a knowledge base for the area. However, the potential impacts of climate change and especially their influences on the disaster vulnerability have not yet been addressed explicitly. This paper has attempted to apply an integrated assessment approach by using modified DPSIR framework to assess the natural disaster impacts in the study area which are projected to be exacerbated due to global warming and sea level rise. This approach produces the tailor made set of vulnerability indicators defining the social, economic, environmental and physical (hydro-morphological) impacts, which can be an useful tool for community based disaster management in a developing country like Vietnam. Although elimination of the change of climate would be done only at global, regional and then national scales by long term policies, as noted from the analysis, actions taken to alleviate causes of climate change impacts and to strengthen resilience are mostly on the local level and thus, the assessment used in this paper can be helpful for provincial authority in planning and undertaking mitigation measures, especially .

Nevertheless, the approach is not without its weaknesses. In particular, it relies on range of data sources that might not be adequate quality and of not complete coverage. The analysis might suffer from gaps attributable to a lack of comparable data on a number of high priority issues, such as the lack of time series data on salinity and tidal regime and lack of long term biodiversity record. Furthermore, the process of reviewing and screening the various indicators used in assessing vulnerability to select those best suited for the study area is of subjective nature. The use of a panel of experts or relevant stakeholders to select the most suitable indicators can be a less subjective approach in future studies.

ACKNOWLEDGEMENT

This paper was carried out in the framework of the study supported by Japan Society for the Promotion of Science (JSPS) and Disaster Prevention and Institute, Kyoto University. We would like to thank colleagues in Institute of Geography, VAST and staff of Department of Natural Resources and Environment and Department of Agriculture and Rural Development, Quang Nam province for their comments and sharing data.

REFERENCES

- ADB and MONRE Vietnam: SEA of Quang Nam province Hydropower Plan for the Vu Gia – Thu Bon River Basin: Final report, 2008.
- Clark J. R.: Coastal Zone Management Handbook, Lewis Publisher, 1996.
- EEA: Environmental Indicators: Typology and Overview. Copenhagen, European Environmental Agency. Technical Report, 1999.
- EEA: Methods for assessing coastal vulnerability to climate change: ETC CCA Background Paper, 2011
- Ho L.T.K et al.: Flood hazard mapping by satellite images and SRTM DEM in the Vu Gia-Thu Bon alluvial plain, Central Vietnam: J. Remote Sensing and Spatial Information Science XXXVIII, Part 8, 275-280, 2010.
- Kaiser Gunilla: Risk and vulnerability analysis to coastal hazards – an approach to integrated assessment: Kiel University, Germany, 2006.
- MONRE Vietnam: Scenarios of climate change and sea level rise for Vietnam: 2012.
- Omann Ines et al.: Climate change as a threat to biodiversity: An application of the DPSIR approach: J. of Ecological Economics 69, 24 – 31, 2009.
- Pham Hong Nga: Improving Environmental Monitoring Plan for Thua Thien Hue Coastal Zone, Vietnam: MSc Thesis. IHE UNESCO Institute, The Netherlands, 2003.
- Quang Nam People's Committee. Annual Statistical Report 2010.
- Vasconcelos R. P at al.: Assessing anthropogenic pressures on estuarine fish nurseries along the Portuguese coast: A multi-metric index and conceptual approach: J. of Elsevier, Science of the Total Environment 374, 199 – 215, 2007.
- VAST (Vietnam Academy of Science and Technology): Assessing the impact trends of climate change on physical and environmental conditions and socio-economic development in Central Vietnam: Project VIE08-P1, 2011.
- Westen C. J et al.: Guide book on “Geo-Information Technology for Hazard Risk Assessment”: ITC The Netherlands, 2010.