GIS-based Assessment of Coastal Tourism Vulnerability to Climate Change – Case Study in Danang City, Vietnam

Tran Thi An[1], Le Ngoc Hanh[2], Saizen Izuru[3], Truong Phuoc Minh[2], Vo Van Minh[2], Nguyen Thi Kim Thoa[2], Nguyen Vinh Long[4]

[1]*Faculty of Management Science, Thu Dau Mot University*
06 Tran Van On Street, Thu Dau Mot City, Binh Duong Province, Vietnam
tranthian.gis@gmail.com
[2]*University of Science and Education, The University of Danang*
459 Ton Duc Thang Street, Danang City, Vietnam
[3]*Graduate School of Global Environmental Science, Kyoto University*
Yoshidahonmachi, Sakyo Ward, Kyoto, 606-8317, Japan
[4]*Vietnam Disaster Management Policy and Technology Center - Representative office in Central and Highland - Vietnam Disaster Management Authority*

Abstract: Da Nang City is a coastal City in the Central Vietnam which is considered as a sensitive area to climate change and its consequences. This City is also one of the famous tourist destinations in the Coastal Central of Vietnam. This study tends to figure out the impacts of climate change on the sustainable tourism development for Danang City under the vulnerable context. The main objective of the project is to determine the vulnerability of climate change on the tourism development of Da Nang City based on a comprehensive assessment of three factors: exposure to hazards, local sensitivity and adaptive capacity. The method of using satellite image data (remote sensing) and Geographic Information System (GIS) combining field survey data is main approach in this research. Integrating remote sensing and GIS methods to assess the impact of natural disasters (floods, droughts, salinization, etc.) is considered as an effective method with advantages of quick and accurate updating according to temporal and spatial changes of natural disasters. The climate change vulnerability index (CVI) integrated with the AHP hierarchical analysis method (Saaty, 2008) has been implemented in this study to determine the tourism vulnerability for the study area. As the results, Ngu Hanh Son and Son Tra district have been pointed out as the highest vulnerable areas to the city tourism. The study also proposes a number of adaptive solutions for areas under highly vulnerable level to climate change.

Keyword: Climate change, tourism vulnerability, GIS database, Danang City, Analytical Hierarchy Process.

1. Introduction

Climate change (CC) impact and responsibility is one of the top concern in many cities all over the world, especially the coastal cities which are currently under the high risk of climate

change and its consequences. Located in the coastal Southeast Asia region, Vietnam is reported to be one of the most significantly impacted nations in the world from climate change that was measured by the Global Climate Risk Index 2019 (GermanWatch, 2019). Therefore, studies on vulnerability assessment due to climate change become a virtual need. This is an important baseline for planning solutions, strengthening the adaptive capacity and mitigating the impacts of climate change.

Da Nang City is a coastal city in the Central Vietnam which is considered as a sensitive area to climate change and its consequences (storms, floods, droughts, salinization, ...). The statistics from Central Committee for Flood and Storm Control (CCFSC) about disaster history in Danang from 1999 to 2020 (according to Danang People Committee) has proved that flood annually occurs from 1998 to 2020 with at least 2 floods per year and the typhoon is also yearly affect. Meanwhile, this City is considered as one of the famous tourist destinations in the Coastal Central of Vietnam. The city ranked sixth in the list of the world's 10 most improved cities that tourists should visit in 2015 published by the website The Richest (PEMSEA, 2015). Their main tourist season occurs after the rainy season (August through December) and typically runs from January through August, referred to as the dry season. This climate promotes a long hot summers on their rivers, lagoons, and tropical beaches (Holladay et al., 2020). Recently, Danang City has experienced the increasingly occurrence of natural disasters in relation to the impact of climate change that has been reported by the City government. The climate change also affected on Danang City' tourism observed by the damage on tourist facilities, technical facilities, loss or damage to the value of tourism resources, reduction in the supply of natural products as well as an increase in pandemic situation from that affect all tourism activities.

This study made an effort on assessment of the climate change vulnerability on the development of tourism in Danang City. The approach is based on the concept of IPCC (2014) in which the CC vulnerability is a function of three main components: exposure, sensitivity and adaptive capacity. In order to quantitatively assess the impact of climate change, the vulnerability index is calculated based on the parameter set for each component of the vulnerability function. The parameters are standardized from 0 - 1 and integrated with the AHP hierarchical analysis method (Saaty, 2008) to determine the weights for component variables, thereby determining the vulnerability index for each area. The results of the project will identify the tourist areas with different levels of vulnerability to climate change from low, medium to high. The study also proposes a number of adaptive solutions for areas under highly vulnerable level to climate change.

2. Methodology

2.1. Overview of the study area and its tourism activities

The study area locates in Danang City which is one of the key tourism destinations in Central of Vietnam. Da Nang borders with Thua Thien-Hue Province in the north, Quang Nam Province in the south and the west, and the East Sea in the east (Figure 1). The city of Da Nang consists of inland area and an archipelago on the East Sea, namely Paracel islands. The Danang's territory is divided into 8 districts including 6 urban districts (Hai Chau, Thanh Khe, Son Tra, Ngu

Hanh Son, Lien Chieu, and Cam Le), 1 suburban district (Hoa Vang) and 1 island district (Hoang Sa). This study focuses on evaluation of climate change vulnerability on tourism of the mainland area of Danang City including 7 districts since the tourism activities is currently not available on the Hoang Sa island.

Da Nang is located in the zone of typical tropical monsoon. Its climate is characterized by two seasons in a year: a rainy season from August to December and a dry season from January to July, with rainfall mainly concentrated from September to December. On an average, this area is directly or indirectly affected by 1-2 typhoons and 1-2 serious flooding spells each year (Do and Nagasawa, 2014). Average humidity is 83.4%, average temperature is about 26^{0}C, the highest is 28-30^{0}C in June, July and August; the lowest is 18-23^{0}C in December, January and February. Average rainfall is 2,505mm per year that concentrates during October and November (Danang City Government). The topography of this area has great variation from flat to mountainous regions with elevation ranging from 0 to 1664m above mean sea level. The location and topographic overview of Danang City is shown in Figure 1.

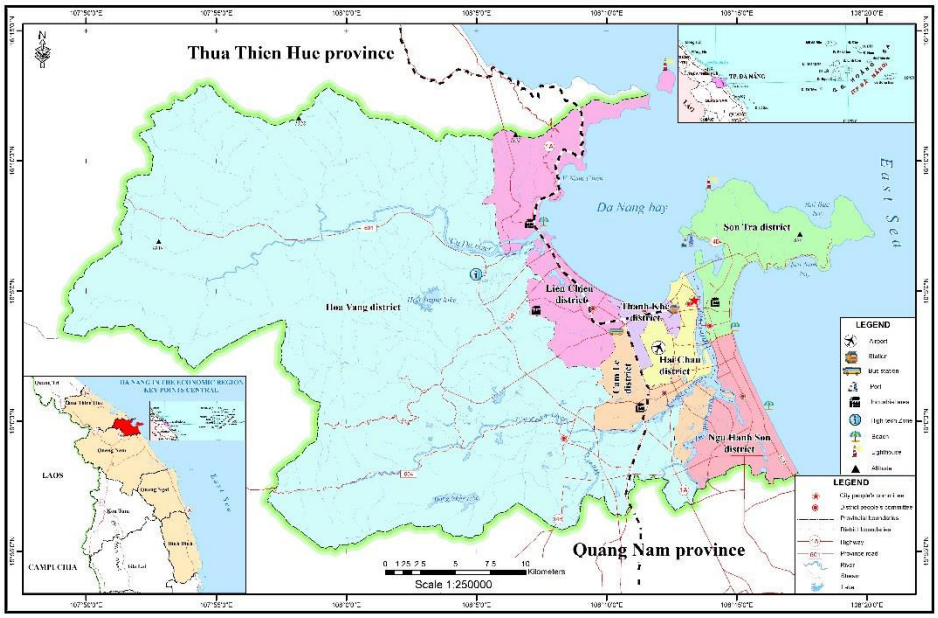


Figure 1. Administrative Map of Danang City

The city's economy has grown continuously with the gross social product (GRDP) in the period 2010-2020 is estimated to increase on average 7.89%/year. In which, the service sector including tourism, accounts for the highest proportion in the economic structure of this coastal city with the rate of 64.56% in the total GDP of Danang City (Danang GSO, 2020).

As a tourism gateway city, Danang attracted the large and increasing number of domestic and international visitors (Table 1). The total passengers visiting Danang reached to 8.7 million persons in 2019 (Danang GSO, 2020) that makes it become a tourism hotspot in Central Vietnam. Statistics from the Department of Tourism in Da Nang (2020) informed that there were 943 hotels and resorts, 40,074 rooms, 376 travel agencies, 4646 tour guides, and 35 international direct flights and 10 domestic flights to the city. The total revenue from tourism of Danang City in 2019

reached to 30.9 billion Vietnamese dongs, occupying about 31.4 percentages of the City's GRDP (Gross Regional Domestic Product) (Danang Department of Tourism, 2020)

Table 1. Total number of visitors to Danang from 2009 to 2019

	2009	**2010**	**2011**	**2012**	**2013**	**2018**	**2019**
Total visitors	1131104	1499210	2227909	2570957	2938563	7671958	8700 000
International	155912	290933	402752	409551	595095	1590000	3700 000
Domestic	975192	1208277	1825157	2161406	2343468	6081958	4000000

Although tourism has play as a leading factor in economic development of Danang City, its activities relatively depend on the natural conditions, especially the climate characteristics and represents the seasonality. The main tourist season in Danang occurs after the rainy season (August through December) and typically runs from January through August, referred to as the dry season. This climate promotes a long hot summers on the rivers, lagoons, and tropical beaches (Holladay, 2020). Recent climate change has reflected on the increase of climate stressors as well as natural disaster occurrences in Danang City that has reported in DONRE, 2020. Therefore, it is very necessary to conduct the assessment on climate change vulnerabity to the tourism of Danang City towards the tourism sustainable development.

2.2. GIS-based multi-criteria for climate change vulnerability assessment

The definition of vulnerability has been mentioned in various studies in the literature (Turner et al., 2003, Barroca et al., 2008, IPCC, 2014). Although there have been many different definitions of vulnerability due to the differences in research fields, people agreed that vulnerability can be determined by three components: exposure, susceptibility, and adaptive capacity (IPCC, 2014). This study applied the method of recommended by IPCC (Intergovernmental Panel on Climate Change) in evaluation of climate change vulnerability on tourism in which the vulnerability (V) can be simulated through the following formula:

$$V = f(E, S, AC) \qquad (1)$$

which: V represents for climate change vulnerability; E is exposure to disasters (hazard), S is sensitivity of the local environment, and the AC represents for adaptive capacity which concentrated on how a system cope with the hazards and climate stressors.

Based on this approach, the research focuses on the following main outcomes in order to qualitatively determine the vulnerability of climate change:

- Firstly, building a set of indicator parameters to determine the level of vulnerability due to climate change based on the natural and socio-economic conditions of Danang City. This set of parameters includes variables that reflect the level of exposure (E), sensitivity level (S), adaptive capacity (AC), thereby quantifying the level of vulnerability due to climate change.

- To determine the exposure index (E), the study focuses on assessing the spatial impact of climate stressors in Da Nang using remote sensing and GIS, in which focus into the following main types of natural disasters: typhoons, inundation, and temperature stressor.

- Evaluating the sensitivity (S) of the local environment in Danang based on the natural, residential, economic, social and infrastructure conditions.

- The study also focuses on determining the adaptive capacity (AC) index of each area to climate change based on the capacity of the authorities as well as localities, the awareness of communities, the policies and activities in relations to climate change adaptation that has been implemented in each local community.

- Finally, the research identifies the climate change vulnerability index (V) of each commune/ward using a multi-criteria analysis (AHP method of Saaty, 2008), taking into account the weights of the driving factors. All steps of the data processing can be expressed in the Figure 2.

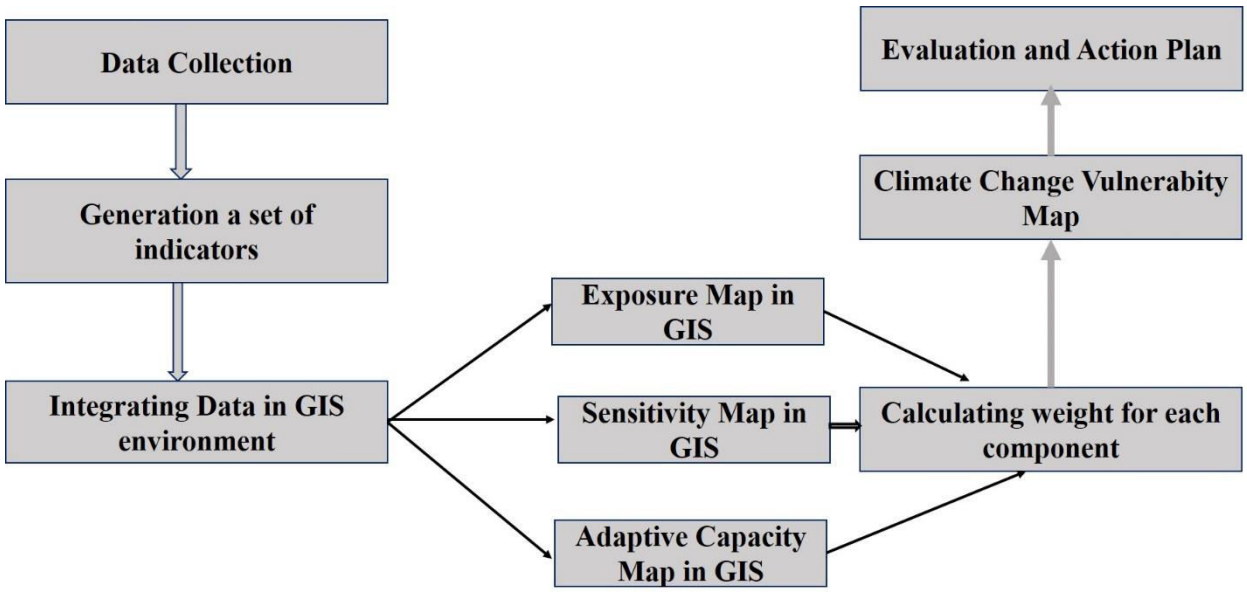


Figure 2. Flowchart of Data processing

2.3. Data normalization and weighting

Based on the field survey integrated with the statistical data on the natural hazard and socio-economic condition of Danang City, a set of indicators for climate change vulnerability assessment including 18 indices has been developed as shown in Table 2.

In the first stage of this study, all the indices were normalized into the same scale from 0 to 1 using the Equation (2) and (3) bellow:

$$x_{ij} = \frac{X_{ij} - Min\{X_{ij}\}}{Max\{X_{ij}\} - Min\{X_{ij}\}} \quad (2)$$

$$x_{ij} = \frac{Max\{X_{ij}\} - X_{ij}}{Max\{X_{ij}\} - Min\{X_{ij}\}} \quad (3)$$

These indices then were integrated with the AHP model for weighted calculation and generating a combined index for climate change vulnerability.

The weight applied for each indicator in each component have been calculated using the Analytical Hierarchy Process (AHP) method developed by Saaty, 2008. AHP is considered as an effective tool for dealing with complex decision making. Weighting by AHP is widely used in many studies (Mishra, 2013, Ouma and Tateishi, 2014, Kazakis *et al.*, 2015 and Danumah *et al.*, 2016). Detailed explanations of applying AHP method in determination of the weights for each parameter were mentioned in Tran *et al,* 2017. The results calculation of the weight scheme is shown in Table 2. All the weight schemes show the consistency ratio (CR) less than 0.1 which is reasonable in AHP method (Saaty, 2008).

Table 1. Indicators used for climate change vulnerability assessment for Danang City.

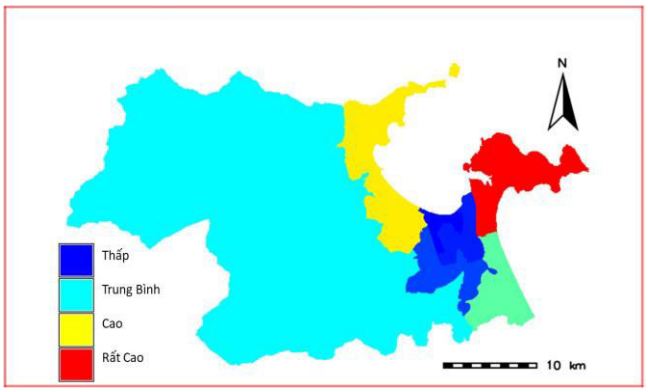
Components	Indicators	Detail	Relationship to vulnerability	Weight
Exposure	Typhoon	Distance to coastline and river channels (DIST)	+	**0.16**
	Flooding	Average flood depth by district	+	**0.28**
	Wind Speed	Average wind speed during typhoon	+	**0.28**
	Elevation Variation	Difference in elevation per unit area	+	**0.09**
	Temperature Change	Surface temperature in hot season by district	+	**0.09**
	NDVI	Normalized Difference Vegetation Index	-	**0.09**
Sensitivity	Population Density	Population density by district	+	**0.27**
	Poverty Index	Percentage of poor household/ total household	+	**0.15**
	Population Structure	Percentage vulnerable groups including disable persons, women, children under 5 years and people over working age in the total population	+	**0.27**
	Enterprise	Total number of tourism enterprises by district	+	**0.15**
	Revenue	Total tourism revenue by district	+	**0.08**

	Hotel	Number of hotels by district	+	**0.08**
Adaptive Capacity	Income Index	Average Income of each household	-	**0.27**
	Education Level	Percentage of people having high-education levels	-	**0.15**
	Health Care	Percentage of medical staffs in total population	-	**0.15**
	Traffic	Road density	-	**0.08**
	Water Drainage	Total length of water pipe in the district	-	**0.08**
	Living condition	Total rate of household having car, Televisions, mobile phone and laptop	-	**0.27**

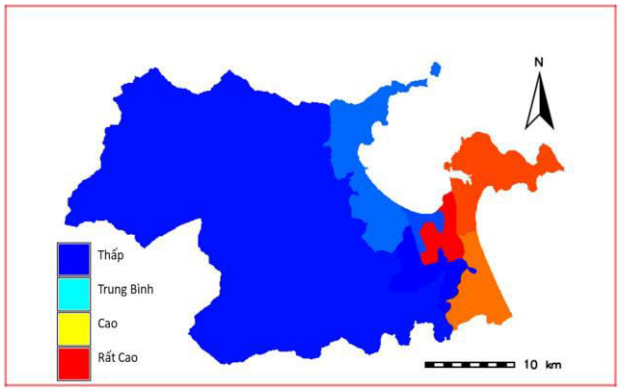
3. Results and discussions

Climate change vulnerability index (CCVI) is calculated by combining of the exposure, sensitivity and adaptive capacity using the equation 1 in which the weighting scheme has been taken into account. Subsequently, CCVI values were then normalized on a scale from 0 to 1 and classified into 4 levels with equal intervals as follows: 0.0 – 0.25 (low); 0.25 – 0.50 (medium); 0.50 – 0.75 (high) and 0.75 – 01 (very high).

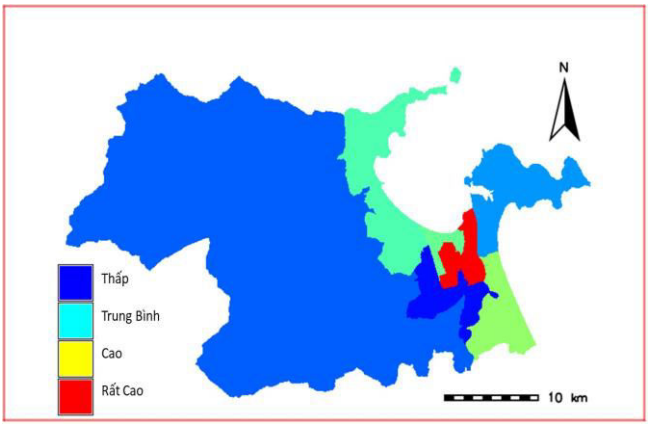
Figure 3 and Figure 4 indicated that, the very high vulnerability areas in Danang City belong to the Son Tra district and the high level located in Ngu Hanh Son district. These districts are currently two tourism hotspots in Danang area. These areas are characterized by the coastal topography, nearest distance to the coastline and river channel and high density of population. These areas are also under high impact of tropical cyclones with the strongest wind speed in Danang City. On the other aspect, the low vulnerability level is corresponded to the centre city located in Hai Chau district which has high rate of economic development and comparable adaptive capacity. Although Hai Chau district has highest value of sensitivity (Figure 3b and 4b), it is also leading in the adaptive capacity map of Danang City (Figure 3c and 4c) and that makes the vulnerability level of the district keeping in lowest level in the study area. It can be concluded that enhancing adaptive capacity is one of key factor in responding to the climate change vulnerability.



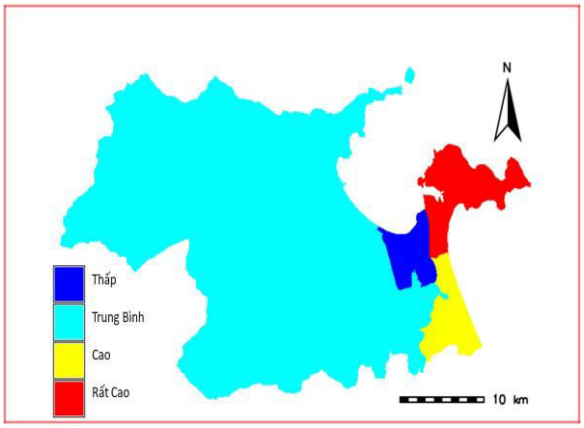
a. Exposure index



b. Sensitivity Index

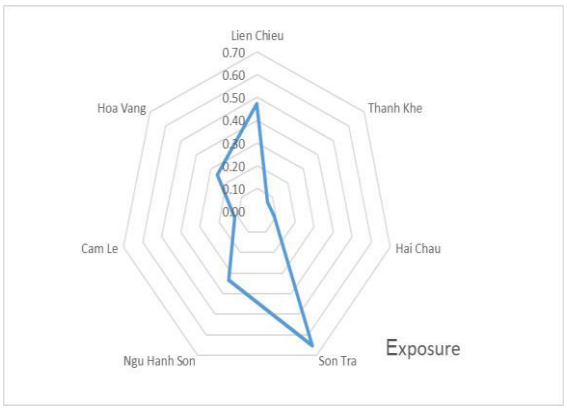


c. Adaptive Capacity index

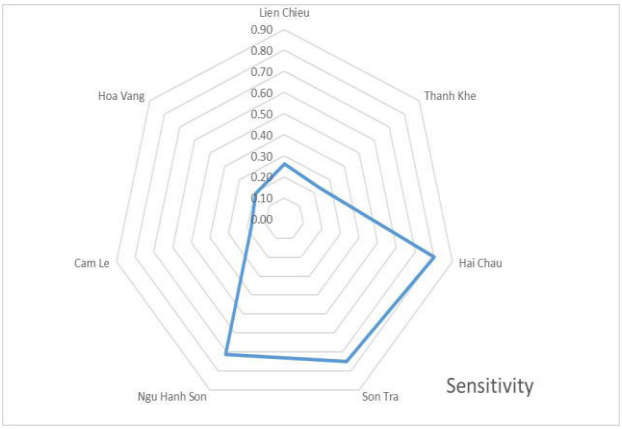


d. Climate Change Vulnerability Map for Danang City

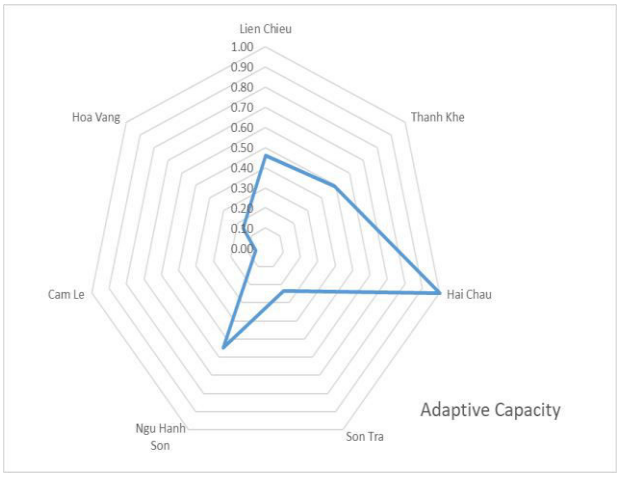
Figure 3. Climate Change Vulnerability Assessment results for Danang City.



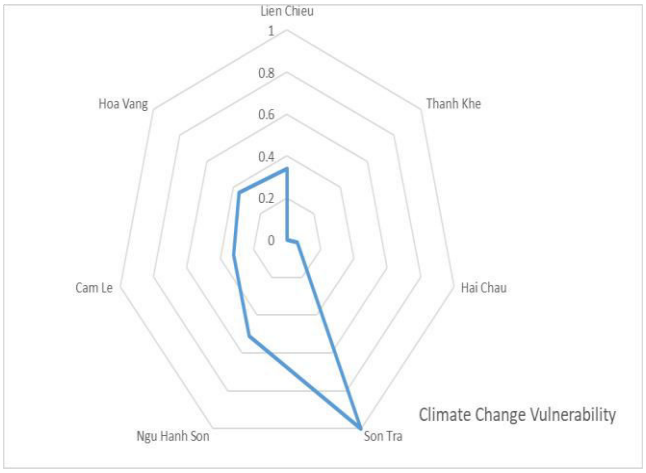
a. Exposure by districts



b. Sensitivity by district



c. Adaptive Capacity



d. Climate Change Vulnerability

Figure 4. Spider chart for each component of the climate change vulnerability

4. Conclusions

By using the GIS approach, this study has generated a set of indicators for climate change vulnerability assessment in tourism for Danang City including 18 indices covering both natural and socio-economic condition of the City.

The present study demonstrates the effectiveness of integrating GIS method and multi-parametric AHP model for climate change vulnerability assessment for Danang City. The proposed method shows the potential use of climate change vulnerability model for other study areas.

In the future work, we will focus on developing the indicator system for climate change vulnerability assessment. The field survey and interview for improving the database on climate change impact and responsibility will be also integrated. In addition, the future scenarios on climate change will be also considered for the comprehensive vulnerability assessment.

The study has pointed out the areas under high level of vulnerability in the aspect of climate change on tourism. Results from this study are useful for proposing the responsibilities to climate change for the sustainable development in Danang City in which enhancing the local adaptive capacity should be concentrated.

References

1. Central Committee for Flood and Storm Control (CCFSC), 2006, National Strategy and Action Plan for Disaster Prevention, Control, and Mitigation in Vietnam: 2001 to 2020. September. CCFSC, Hanoi, Vietnam

2. Do, T. V. H. and Nagasawa, R., 2014, Potential Flood Hazard Assessment by Integration of ALOS PALSAR and ASTER GDEM: a Case Study for the Hoa Chau commune, Hoa Vang District, in Central Vietnam, Journal of Applied Remote Sensing, 8, pp 1-12.

3. Holladay, Patrick J.; Dixon, Anthony W.; Nguyen, Minh C.; Nguyen, Bao L.; Xu, Shuangyu; and Price-Howard, Kate (2020) "Stakeholder perceptions of Da Nang, Vietnam as a tourism

gateway city," Journal of Tourism Insights: Vol. 10: Iss.1, Article 8, doi.org/10.9707/2328-0824.1089

4. IPCC (2014). Climate Change 2014: the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change on Climate, Copenhagen.

5. PEMSEA, UNDP and the World Bank (2015), ICM Solutions - Coastal Tourism in Danang, Vietnam: Promoting a Win-Win Situation for Achieving Conservation, Economic, and Social Goals, ICM Solutions for Sustainable Seas.

6. Saaty, T. L., 2008, Decision Making with the Analytic Hierarchy Process, International Journal of Services Sciences, 1 (1), pp 83-98.

7. Tran, T.A., Raghavan, V., Masumoto, S., and Yonezawa, G. (2017), Application of Multi-parametric AHP for Flood Hazard Zonation in Coastal Lowland Area of Central Vietnam. International Journal of Geoinformatics, 13 (1), pp. 23-34.