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Climate Change Impacts On Coast: Coastal Disasters Damage Costs In Vietnam

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Abstract - The South Economic Focal Region in Vietnam (SEFR) is responsible for 50% of national production, and has a population density more than three times that of the country as a whole. The most developed coastal region in Vietnam has also experienced great annual property loss due to intensive storms and floods which has threatened the economic growth of the country. Based on the assumption that more developed regions have higher risks and higher damage costs from coastal disasters and climate change, this study focuses on the economic damage costs of coastal flooding by intensive storms and sea level rise. The Pearson statistical model is employed by utilizing total costs of losses, land area, and population in the SEFR from 1996 to 2006. Moreover, this study includes research on literature of coastal erosion and the interviews with local residents. Using this analysis, we found that the average damage costs in this region were equivalent to around half of total damage costs for the entire country even though the number of annual coastal disasters was four or five times less than total in-country coastal disasters. Additionally, this study confirms the relationship of the damage costs with land area and population. The coastal erosion in this region has been increasing mainly resulted from tidal and wave action and local people still have their property near the shoreline, at high risk of damage from storms and floods.

Keywords: Pearson Regression model; Coastal damage cost; Economic development; Climate Change; Vietnam

1. Introduction

According to Fourth Assessment Report of the Intergovernmental Panel on Climate Change [1], Vietnam will be one of the five countries worst affected by sea level rise and extreme weather. A vulnerability study of Vietnam found that the coastline of Vietnam will suffer severe impacts from sea level rise and intense storms [2]. Many coastal areas in Vietnam have suffered from loss of property, infrastructure, sandy beaches and coastal roadways [3] resulting from 4-6 or more storms which have struck the Vietnam coast annually [4] and the costs of coastal damage have been dramatically increasing. According to Huy [4, the economic loss from storms and by 1996 has reached US$700million and 2006 Cyclone Xangsang caused losses equivalent to VND 10,375 billion (US 650million), which is comparable to total annual losses during the 1990s [4].

The South Economic Focal region, which has been designated as an economic development center is responsible for 50% of national production, and has a population density more than three times that of the country as a whole. This region, most developed coastal region in Vietnam is the most vulnerable coastal area for coastal disasters. In 1997, a typhoon struck this region and affected approximately one million people, causing USD 470million in damages, half of total damage costs in the whole country. Since the damage from extreme storms is immense in highly developed costal regions, it is necessary to study their impacts on coastal region to explore the relationship between damage costs of coastal disasters and intense storms. Moreover, climate change which induces more extreme and intensive storms and sea level rise would be a risk to maintain sustainability of economic development and to protect people toward coastal disasters. This is why it's important to look into economic impacts of coastal storm and sea level rise.

Based on the assumption that more developed regions have higher risks and higher damage costs from coastal disasters and climate change-induced phenomena has influenced the increase of damage costs, this study focuses on the economic cost of coastal flooding by intense storms. However, since it is difficult to measure damage costs from the impacts of sea level rise itself, this study assumes that sea level rise will have a correlation with damage costs of impacts of intensive storms and accounts it as an explanatory variable. This study explores total costs of losses in the SEFR from 1996 to 2006 from data provided by the World Bank. In addition, the study accounts sea water level to influence coastal risks as one of explanatory variable to increase damage costs. Because southern coastal regions are highly vulnerable to coastal erosion by tide and waves during monsoon season [5] and sea water level should be considered as critical variables to influence coastal vulnerability and damage risks. Given these assumptions, this study uses the Pearson statistical model to analyze the relationship of the damage costs of coastal disasters with socio-economic characteristics and sea level rise. With the statistical model, this study tests the hypothesis that coastal disasters such as intensive storms and floods tends to increase damage costs in developed coastal regions, exacerbated by sea level rise.

Moreover, this research 1) compiles the data of losses of property and infrastructure in South Economic Focal Region of Vietnam from 1996 and 2006 and the data of climate change such as intensive storms and sea level rise, 2) compiles data on socio-economic characteristics in this region such as population, density, GDP, average income, 3) examines the results of statistical analysis, and 4) explores additional or potential factors to influence damage costs through interviews and field trips. This study's outcome supports a correlation between climate change and the economic extent of coastal damages, especially in urban areas, and to investigate decadal change of sea water level rise, and shoreline erosion.

Southern Economic Focal Region in Vietnam (SEFR)

The south coastal region has a river mouth every 20km along the coast of Vietnam which has evolved by a series of interactive processes between the land and sea, the river mouth and the sea, and due to the natural and economic development. The landforms of the coastal zone of Vietnam are multiform and diverse, and the coastal zone of Vietnam also receives many natural calamities, causing multidirectional impacts on natural and socio-economic conditions. [6].

As the Vietnam coastline is long and narrow geologically, it is very vulnerable to coastal damage from severe disasters and erosion (Table 1).The SEFR (Fig. 1) consists of Ho Chi Minh (HCM), Ba Ria-Vung Tau, Dong Nai, and Long An and has 900 people per km2, while the whole country 200 people per km^2.

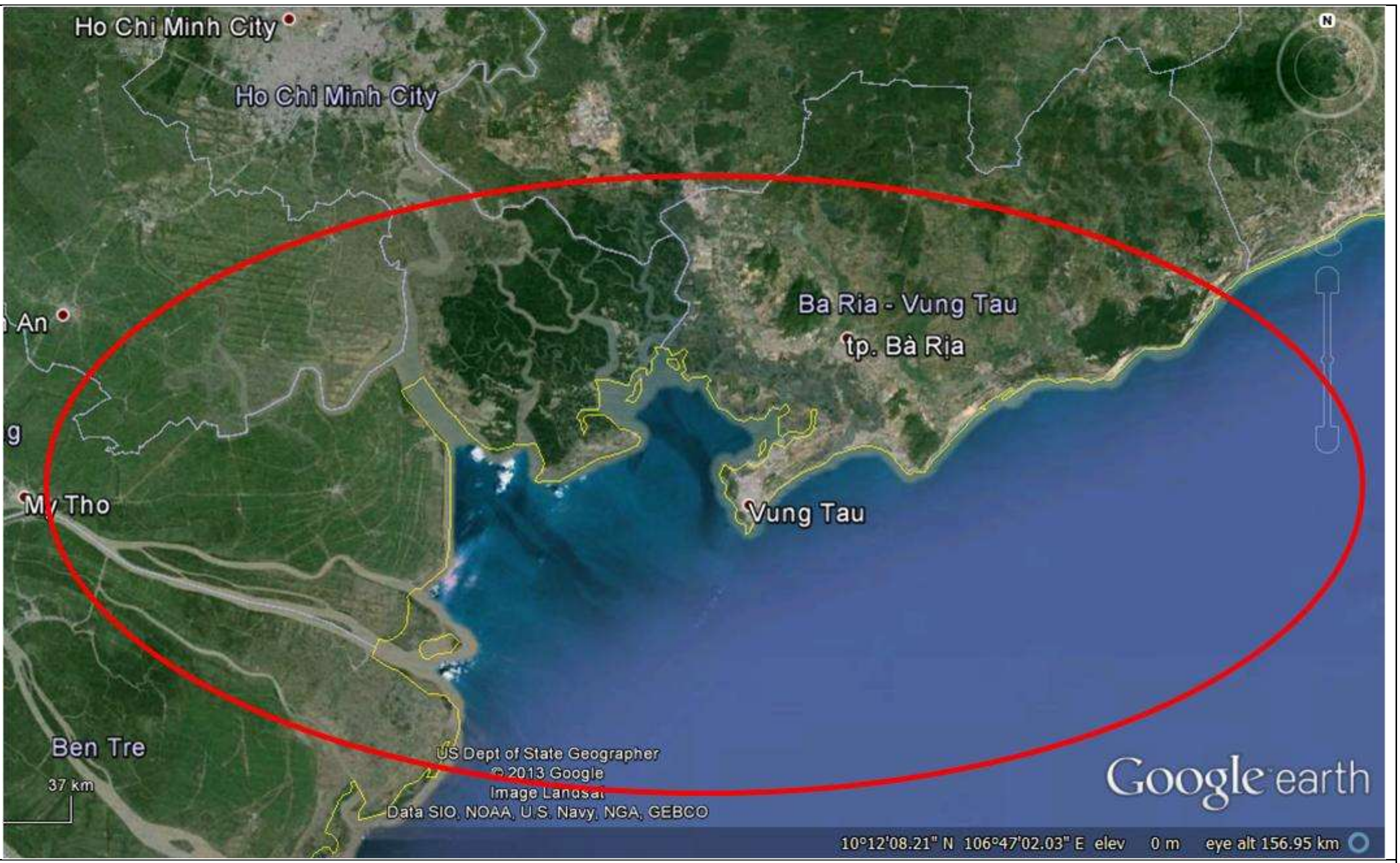

Fig.1. Research area of South Economic Focal Region of Vietnam (Source: Google earth, 2012)

The region has suffered from 1-2 intense storms which are caused by extra-tropical cyclones, thunder storms and typhoon with mostly wind gusts of 21 m/s to 36 m/s [7]. Most extreme storms and typhoon are resulted from a flow of high pressure polar air masses south or southwestward off the Asia [7]. While 58 % of storms hit the northern coast, only 5% the southern coast (Fig. 2).

Table1. Hazard zone of the coastline of Vietnam

Region	Hazard Zone	Hazards
North	Northern Upland	flash floods, landslides
	Red River Delta	monsoon river floods, typhoon storms, storm surge
Center	Central Provinces	typhoon storm, flash floods, drought
	Central Highlands	flash floods, landslides
South	South Coastal Economic zone	floods, typhoon storms
	Mekong River Delta	river flooding from upstream, typhoon storms

Source: (TUDelft, 2011)

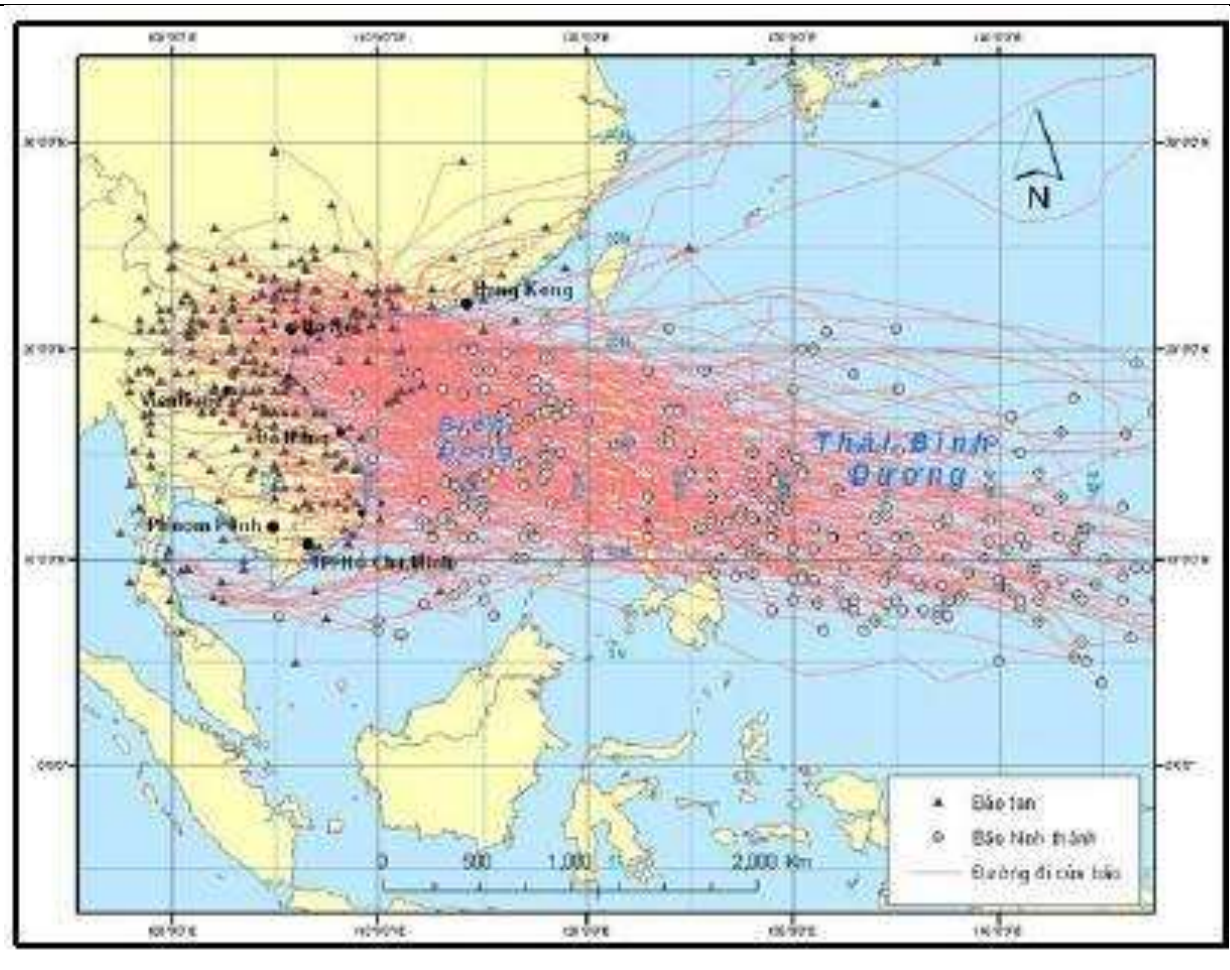

Fig.2. Typhoon entering Vietnam 1951-2008 (Source: TUDelft, 2011)

2. Methods and Data

Coastal disasters can result in immense loss of life, property damage, and other forms of social and economic destruction. The measurement of hazard-risk and damage from coastal disasters involves both geographic and sociological matters. The hazard-risk analysis in terms of economic perspective considers interdisciplinary variables including both geomorphologic and socio-economic characteristics, because a single perspective is limiting in seeking to understand risk reduction from natural hazards [8]. UNDP/BCPR [9] analyzed the number of deaths from tropical storms, cyclones, hurricanes and typhoons by considering physical exposure, percentage of arable land, and human development index (Table 2). And Costanza et al [10] utilized economic analysis to explore economic damage by wind speed and area of wetlands. Das and Vincent [11] also utilized economic analysis of impacts of 1999 super cyclone by testing the relationship with human deaths and mangroves to reduce risks of coastal disaster impacts. Das and Vincent [11] studied the role of mangrove to reduce coastal disaster vulnerability with the assumption of coastal retreat of mangroves through regression models by compiling 1999 village socioeconomic data, village spatial characteristics, and coastal physical characteristics such as distance to coast and height of the storm surge.

Table 2. Study of relationship of coastal disasters damage and different variables

Type of Event	Region	Dependent variables	Explanatory variables	Reference
Tropical storms, cyclones, hurricanes, typhoons	Global	Ln Number of death	Ln physical exposure Ln percentage of arable land Ln human development index	UNDP/BCPR, 2004
Cyclones, hurricanes, tropical storms	US	Ln Economic damage/GDP	Ln wind speed Ln area of wetlands	Costanza et al, 1997
Cyclones, hurricanes, tropical storms	Global	Ln number of deaths/pop	Ln frequency Ln land use type Ln GDP	Maqueo et al, 2006
Cyclones	India	Number of death	Mangrove width Height of storm surge Topography, Distance at coast Socioeconomic characteristics Government administration	Das & Vincent, 2009
Intensive storms, floods	Vietnam	Economic damage/GDP (TD)	water level (W) Population (P) Land Area (L)	This study

Source: (modified based on [22]

Using approaches similar to UNDP/BCPR [9], Costanza et al [10], Maqueo et al [12], and Das and Vincent [11], this study explored the economic impacts of coastal hazard and disasters by analyzing the relationship with coastal physical and socio-economical characteristics. According to Vietnamese scientists [5, 13, 14], the intensity of coastal damages depends on the physical dynamics of coastal environments and socio-economic factors. And the sea water level is analyzed as an explanatory variable to examine the relationship with damage costs.

The following equation was used in the Pearson regression analysis for this study,

$STD = b_0 + b_1L + b_2P + b_3W$ (*Costanza et al in* [10] (1)
(STD = Total damage costs in South Economic region/GDP)

Where L is land area, P is population, W is sea water level, and b1, b2, and b3 are coefficients of explanatory variables.

Even though the regression model is limited in its ability to explain coastal risks and disasters due to limited metadata, this study examined decadal trends of coastal disaster damage, sea water level, and socioeconomic characteristics in detail as well. Data utilized in this analysis includes coastal damage cost from 1996 to 2006 of SEFR given from World Bank is analyzed; data from interviews with local people; the socio-economic data given from General Statistics Office of Vietnam and sea water level and shoreline (Table 3).

Table 3. Data table for analysis

Category	Data	Period of Data	Data source
Geomorphological factor	Shoreline erosion	2005	(Cat, 2006)
	Sea water level	1996-2007	(Pham Huy Tien et al, 2005)
Socio-economic factor	Population	1993, 1999, 2006	General Statistics Office of Vietnam
	GDP, average income	1996-2007	
	land use	1996-2006	
Climate change factor	Costal disaster (intensive storms)	1996-2006	World Bank
	Costal disaster damage costs	1996-2006	

3. Results and Discussion

3.1 Coastal disaster damage costs

According to coastal disaster data from 1996 to 2006 supplied by World Bank (Table 4), the SEFR of Vietnam has 1-2 coastal disasters every year while 4-6 disasters hit along all coastal regions of Vietnam including northern and central coastline. Most coastal disasters in the southern region are intensive storms and floods while northern and central coastal region experience cyclones and intensive storms Even though the average damage costs for a decade in the SEFR (US$134 million) is slightly less than average damage cost from 2001 to 2006 (US$ 101 million), the damage cost in SEFR is US$ 450 million in 2006 which consists of 40% of total damage costs. While the number of intense storms and floods in this region is much less than other coastlines, damage costs in these regions were 80% of total damage cost and 0.8% of GDP in 2000. The following Table 5 shows the comparison between total damage costs and those of the in the SEFR.

Table 4. Coastal disaster damage in south economic region from 1996 to 2006

Year	Disaster type	Dis_ value	Dis_ Unit	Death (persons)	Injury (persons)	No_ affected	No_ homeless	Total_ affected
1996	Flood	22610	km^2	162	0	375000	0	375000
1997	Storm	102	Kph	3682	857	697225	383045	1081127
1998	Storm	150	Kph	43	0	81635	3010	84645
2000	Flood	1400	km^2	460	4	5000000	0	5000004
2000	Storm	0	Kph	0	100	0	5630	5730
2001	Flood	745	km^2	310	0	1570270	0	1570270
2002	Storm	0	Kph	0	0	1800	0	1800
2002	Flood	0	km^2	82	0	1138200	0	1138200
2004	Flood	47760	km^2	34	0	30000	0	30000
2006	Storm		Kph	95	1360	975000	250000	1226360

Source: (World Bank [22]

The Table 5 shows total coastal disaster damage costs and south economic region's damage costs from 1996 to 2006:

- Mean total damage cost: 400million (US$)
- Mean damage cost of South Economic Region: 134 million (US$)

Table 5. Total coastal disaster damage costs and south economic region's damage costs from 1996 to 2006

year	GDP ('000 US$)	Total_dam_cost ('000 US$)	SE_total_dam ('000 US$)	% total dam cost / GDP	% SE total dam / GDP	% SE / total dam costs
1996	24,657,470	751,420	138,000	3.05	0.56	18.4
1997	26,843,701	887,000	470,000	3.30	1.75	53
1998	27,209,601	121,900	15,000	0.45	0.06	12.3
1999	28,683,658	309,500	0	1.08	0.00	0
2000	31,172,517	291,035	250,000	0.93	0.80	80.8
2001	32,685,199	171,900	84,000	0.53	0.26	48.9
2002	35,058,216	284,200	100	0.81	0.00	0.035
2003	39,552,513	105,000	23,900	0.27	0.06	22.8
2004	45,427,854	38,000	-	0.08	0.00	-
2005	52,917,296	346,370	42,120	0.65	0.08	12.2
2006	60,913,515	1,099,000	456,000	1.80	0.75	41.5

Source: (modified based on World Bank [22]

3.2 Regression Analysis

Given the comparison of total damage costs in the country as a whole and in the SEFR from 1996 to 2006, we learn that average damage costs in this region is US$134 million which is around half of total damage costs even though the number of coastal disasters annually is four or five times fewer. Since the SEFR has higher damage costs, this region as a vulnerable area should identify critical factors that increase damages and prepare measures to mitigate risks and hazards. To analyze key factors to induce risks and hazards, several studies have been conducted by exploring the relationship of coastal disaster damage and physical and social and economic characteristics. Based on Maqueo et al [28], this study utilized the Pearson regression model by exploring a decade of data on land area, population, and water level. In the regression model, shown in the Table 6, the coefficient of coastal damage costs in the SEFR is significantly associated with land area and population (p>0.05).

Table 6. Relationship of disaster damage costs of south economic region with explanatory variables

STD	Value	Std. error	t value	Pr
Land area*	-.0062	.0022	-2.78	.032
Sea Water level (Hmax)	-.0043	.00043	-.99	.359
Population*	.0004	.00016	2.77	.032
Cons	112.96	40.68	2.78	.032

(* p>0.05)

The relationship between damage costs and land use is negative but population is positive. The regression model in this study supports the outcome of previous research (Table 7).

Table 7. Outcome of Person regression model

Ref.	Regression model	Reference
UNDP/BCPR(2004)	ln (no of deaths) = -15.86+0.63ln(physical exposure)+0.66ln(%of arable land)-0.03ln(human development index)	Positive physical exposure Positive arable land Negative human development
Costanza et al (in revision)	ln(economic damage/GDP)=-10.551+3.878ln(wind speed) -0.77ln(area of wetlands)	Positive wind speed Negative area of wetland
Maqueo et al (2006)	Ln(no. of deaths/pop)= -8.95+1.43ln(frequency)-0.92ln(semi-altered land use type)-1.90ln(GDP)+1.29ln(Liberty index)	Positive frequency Negative semi-altered land use type Positive liberty index
This study	Economic damage/GDP= 112.96-0.0062(land are)+0.0004(pop)	Negative land area Positive population

Many studies show coastal damage has impacts on physical exposure and arable land that more development exacerbates coastal damage [9, 15, 16, 17]. Maqueo et al [12] presents negative impact of wetlands. Given similar patterns of the relationship of land area with coastal damage, our study verifies the negative impact of land area and positive impact of population. Therefore we can say that more developed area and population have more vulnerable and higher risk of coastal disaster.

Even though this regression model has similar outcome of previous studies and confirmed the relationship of the damage costs with land area and population, it failed to explain the relationship with sea level rise. Since p-value of coefficient of sea water level is greater than 5% (0.359), we cannot say that sea water level has a significant impact on coastal damage cost. In addition, the scatter plot (Fig. 3) shows no pattern between the damage costs and water level. Even though we assume that coastal damage cost will be associated with a change of sea water level as well, the analysis cannot verify that sea water level has a relationship with coastal disaster damage. Since the regression model approach is limited to support the relationship of coastal risks of sea level rise, this study will further examine coastal risks and hazards from shoreline change and water level by analyzing data in detail.

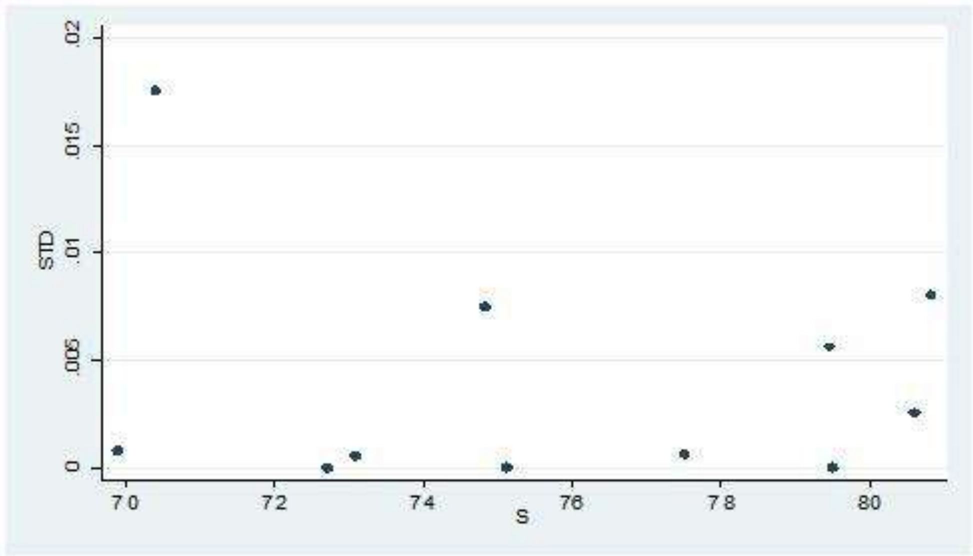

Fig.3. Scatterplot of damage costs of southern economic region and sea water level

3.3 Relationship of Coastal Damage and Economic Development

Before analyzing the relationship of sea water level and coastal disaster damage, this study explores the economic development of the SEFR to support regression results. As our regression model verified, populations and urbanization have a significant relationship with coastal disaster damage. Many research also emphasized that population and urbanization are key factors related to higher risk of fatalities in developing countries due to lack of infrastructure and standardized building codes as well as inadequate development of the land [18, 19, 20, 21].

Vietnam experienced sharp increase of GDP for a decade from 1999 to 2008 by a factor of four times and the average income of South Economic Region has increased by a factor of three over a decade and twice as much as the average income increase in the county as a whole (Table 8). Particularly, the municipal coastal areas of HCM, Ba Ria Vung Tau, and Tien Giang have the greatest average income in Vietnam.

Table 8. GDP (World Bank) and monthly average income per capita in Vietnamese dongs

Year		1999	2002	2004	2006	2008
GDP (Thous. US$)		28,683,658	35,058,216	45,427,854	60,913,515	91,094,051
Average Income (Thous. Dongs)	Whole Country	295	356	484	636	995
	Southern Economic region	457	519	682	887	1357
	HCM, Ba Ria-Vung Tau, Tien Giang	571	667	893	1146	1773
	Mekong River Delta (Ben Tre, Long An)	342	371	471	628	940

Source: (http://www.gso.gov.vn)

Since the Southern Economic Region has been designated as a center of economic development, coastal provinces have been responsible for approximately half of Vietnamese national production. The population density has increased by around 200 people per km2 for a decade while population density in the country as a whole has it increased by 50 persons per km2. In 2008, population density in HCMC was 3,155 people per km2, twelve times that of the county as a whole, 260 people per km2.

Given high population density, the area in SEFR of Vietnam is more vulnerable from higher risks and damages from intense storms and floods. These serious impacts result not only from the geographical characteristic of being located near the Mekong River basin but also from continued economic development [22, 23, 24].

3.4 Relationship of Coastal Damage and Coastal Erosion

Even though our regression model cannot support the impacts of sea water level on coastal damage, several studies asserts that tide and waves in the south coastal region caused coastal erosion which is in Can Gio area near HCMC. Can Gio has 400m beach width (the least width in Ben Tre province was 200m in 2005). According to Pham Huy Tien et al [5], south coastal region has increased coastal erosion by tide and wave especially during the Northeast monsoon season. The highly developed area near HCMC such as Can Gio, Dong Hai of Tra Vinh province has the lowest beach width. The Can Thanh, Thanh An, Can Gio district of HCMC has been seriously eroded [5]. Based on these studies, the sea water level is certainly one of the key factors in coastal vulnerability and it is necessary to look into sea water level data itself to explore the relationship of coastal erosion with coastal damage and risks.

In the south coastal region, water level from 1996 to 2007 has changed from 0.69m to 0.80m in maximum height and from -1.89m to -1.65m in the minimum height (Table 9). The average water level shows that sea water level has been increased to -1.82m in 2001-2000. For a decade, we can learn that sea water changes 0.1m.

Table 9. Average Sea Water level in the South Coastal Region

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Htb (m)	-0.18	-0.29	-0.26	0.-20	-0.19	-0.18	-0.21	-0.23	-0.25	-0.29	-0.25	-0.24
Hmax (m)	0.79	0.70	0.73	0.79	0.80	0.81	0.78	0.75	0.73	0.70	0.75	0.76

Hmin (m)	-1.65	-1.77	-1.76	-1.71	-1.72	-1.72	-1.78	-1.82	-1.83	-1.89	-1.86	-1.85

Source: (Pham Huy Tien et al [4]) ; Note: 1996-2000 average Hmin: -1.72m;

Huy Tien et al [5] studied the status of coastal erosion of Vietnam, finding that all coastal provinces of the central region have coastal erosion, with a total 263 erosion sites in 284 coastal sections and 10 areas that have been completely eroded (Table 10). In addition, the southern coastline, in particular Tien Giang province and Tra Vinh province have the highest coastal erosion rate (>30m/year). The coastal erosion in this region has been increasing. In Tien Giang province, coastal erosion has mainly resulted from tidal and wave action, which causes sediment deficit and frequent inundation.

Table 10. Coastal Erosion Rate of Southern Province in 2005

Communes	Districts	Provinces	Width (m)	Area (km^2)
Long Hoa	Can Gio	HCM	400	748
Ly Nhon	Can Gio	HCM	400	1,072
Ly Nhon	Can Gio	HCM	400	1,151
Thach An	Can Gio	HCM	1,000	6,786
Tan Thanh	Go Cong Dong	Tien Giang	750	750
Tan Dien	Go Cong Dong	Tien Giang	1,700	3,400
Vom Lang	Go Cong Dong	Ben Tre	175	175
Thanh Phuoc	Binh Dai	Ben Tre	200	743
Thanh Phuoc	Binh Dai	Ben Tre	200	363
Thua Duc	Binh Dai	Ben Tre	800	3,865
Bao Thach	Ba Tri	Ben Tre	500	1,718
Thanh Hai	Thanh Phu	Ben Tre	1,000	11,780

Source: (Huy Tien et al [4])

According to the World Bank [22], the southern coast of Vietnam is highly vulnerable to sea level rise. Particularly, the area of the southern coast near HCMC would be the most inundated by sea level rise. These serious impacts are likely the result of proximity to the Mekong River mouth and to general economic growth and land development [25].

Moreover, interviews with local people who have expressed great concerns about serious beach erosion underscore the potential damage and risks faced by their property. A local woman who has lived on the beach for more than 10 years explained that the beach has been seriously eroding. Its width was over 1,000 m when she gave birth to her son ten years earlier, but now has diminished to 200m (Fig. 4). The vulnerability to coastal erosion and the increased risk to life and property near the beach become visible. Given our Pearson regression analysis, population and land use are associated with the damage costs. Data and interviews with local people support the notion that sea level rise increases beach erosion and could increase the risk of damage from coastal disasters.

Fig. 4. Beach erosion of southern coastline, Can Gio, Vietnam

4. Conclusion

This study found that coastal disasters in the SEFR for a decade have occurred infrequently over the past decade but their economic impacts have been comparable to the total damage costs of all disasters occurring in Vietnam for a decade. In 2000, the damage costs in the SEFR alone were 80% of total damage costs of coastal disaster in Vietnam, even though only one coastal disaster hit this region. There is a pattern that the damage costs in this region comprise more than half of the total damage costs in the whole coastal region over a decade. With the Pearson regression, the economic damage costs of coastal disasters are associated with the population and land. The densely inhibited land are more vulnerable. Studying the socio-economic characteristics clearly identify that SEFR has experienced intensive economic development over 10 years. The average income of the south economic region is more than twice the average income of the whole country and has increased by a factor of three over ten years. Moreover the population density of the south economic region is four times great than that of whole country almost 940 people per km2.

Without considering risks of beach erosion and coastal disasters, the SEFR has developed to attract more people to migrate to this region and has become more vulnerable for coastal disasters. It was observed that local people still have their property near the shoreline, at high risk of damage from storms and floods.

The risks of damage or loss are currently the responsibility of local people. If there is no serious plan to mitigate damage and risks from intense storms, flooding, and beach erosion in Vietnam, the damage from coastal disaster will not be reduced, but will continue to produce negative impacts on the economy of the whole country. it is necessary to explore mitigation strategies to minimize risks and erosion, such as standardized building codes and shoreline setbacks. These measures would contribute to minimizing the risk to the coastal areas of SEFR in Vietnam.

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