Impact of sea level rise on coastal zone of Vietnam

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Abstract

The coastline of Vietnam is more than 3,260 km and stretches across from north to south. Here occur a series of interactive processes between the land and the sea, between the dynamic force of rivers and the sea, between the natural and human processes, etc. Recently, sea level rise due to climate change is serious global threat. Some researches being undertaken in Vietnam indicates that significant impacts due to sea level rise may already be occurring. These impacts have resulted increasing unpredictability and severity of coastal problems such as landloss, increasing flooding of low lying coastal areas, accelerated erosion along the coasts, watersalt intrusion, degradation coastal ecosystem and impact directly people living coastal region.

Introduction

Vietnam located on the Indochinese peninsula of South - East Asia. Mainland stretches from 08°10' to 23°24' north latitude and widens from 102°09' to 109°30' east longitude. Its mainland frontier amount to 4,510 km, of which 1,306 km are adjacent to China in the north, 2,067 km to Laos in the west and 1,137 km to Cambodia in the west-south (*Figure 1*).

Vietnam embraces around 3,260 km of coastline from Mong Cai in the north to Ha Tien in the south (excluding the coastline of islands) with two fertile deltas of Red river and Mekong river discharge into the sea. It's bordered by the Gulf of Tonkin and the South China Sea to the east and the Gulf of ThaiLan to the south. Offshore Vietnam's continental shelf, there are thousands of islands and islets lying scattered from the northern to southern end. Among them, the Truong Sa (Spratly) and Hoang Sa (Paracel) are the largest archipelagos (*Figure 2*).

Vietnam covers relatively complicated terrain: countless mountains, criss-crossed rivers, stretching and meandering coastline, percentage relation between mountain and plains in mainland area indifferent among regions. The country is divided into 8

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Figure 1. Map of Vietnam in the region

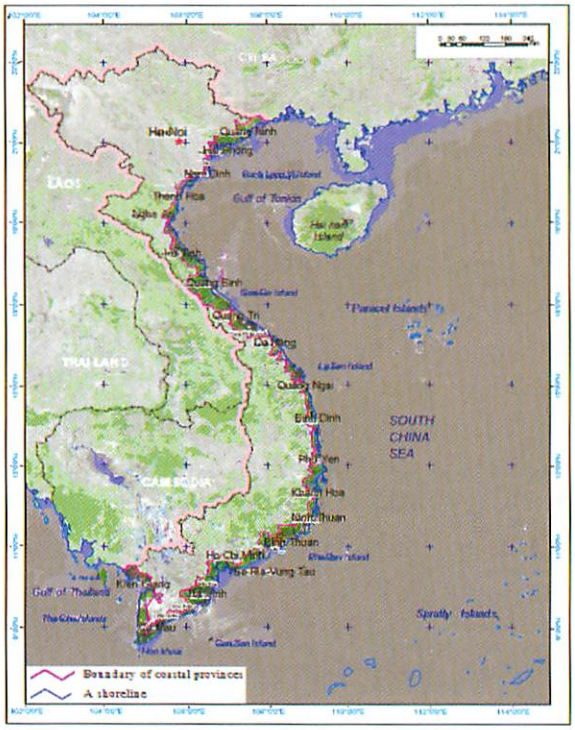

Figure 2. Vietnamese coastal zone from space

regionswith total 64 provinces and centrally-run cities. The coastal zone is divided into 3 regions: north, central and south with 28 coastal provinces. This area was settled by nearly a haft of nation's population.

Lying tropical monsoon climate regime, Vietnam is influenced by natural calamities as typhoon, monsoons, storm surge, sea level rise and El-Nino phenomena. Scientific research currently being undertaken in Vietnam indicates that significant impacts due to sea level rise may already be occurring. Even a limited rise in sea level over coming decades could seriously affect human and nation, especially influence direct on people living near coastal area. According to Tuong (*2001*) recorded increments in sea level varying from 1.75 to 2.56 mm/ year at 4 Vietnamese stations (Hon Dau, Da Nang, Qui Nhon, Vung Tau). The high value is observed in the north and in the south part of the country. It could be said that sea level rise in Vietnam is in comparision with the sea level rise in the region and in the world. In East Asia, Vietnam is a nation that would suffer the heaviest impacts by sea level rise and in Vietnam the Mekong river and Red river delta would be impact at the highest level. A rise in sea level would inundate wetlands and lowlands, erode shorelines, exacerbate coastal flooding, increase the salinity of estuaries and aquifers and otherwise impair water quality and impact coastal ecosystem.

Sea level measurement and sea level rise in Vietnam

1. The character of tide in Vietnamese coastline

According to Le Ba Thao (*1998*), there are a various tidal system and always changes in South China Sea, but almost coastal zones are influences by diurnal tide, some other places are influences by semidiurnal tide and mix (*Table 1*).

The tide range reaches about 4.0 m in the north (Red River Delta) and decreases to 0.5 m in the central area, then increases up to 3.5 m in the south (Mekong River Delta). The difference in the tide range and character are caused by different geographical conditions. The coastal current varies in velocity and direction according to season and

Table 1: Character of tide on Vietnamese coast from north to south

Segment of beach	Type of tide	Rising and falling times per day	Maximum high water
From Mong Cai to Thanh Hoa	Typical diurnal tide	1	3-4m
From Thanh Hoa to Dong Hoi	Irregular diurnal tide	1-2	1.2-2.5m
From Dong Hoi to Quy Nhon	Irregular semiduirnal tide	-	0.5-1.2m
Thuan An mouth	Typical semiduirnal tide	2	0.5m
From Quy Nhon to Vung Tau	Irregular diurnal tide	2	1.2-2.0m
From Vung Tau to Ca Mau	Irregular semidiurnal tide	-	1.2-2.5m
From Ca Mau to Ha Tien	Irregular diurnal tide	-	2.0-3.5m

location. Three areas of upwelling exist in the Vietnamese coastal zone. The largest is along the central coast, and the second largest is offshore of the Mekong deltas. In the Gulf of Tonkin, the site of the upwelling changes according to the season, it lies near the south west gulf coast during the south west monsoon season and in the center of gulf during the north east monsoon (*Ministry of Fishery, 1996*).

2. Sea level measurement

When analyzing sea level change at specific coastal locations two components must be considered. First, there is the global component, arising from thermal expansion of ocean water (the steric contribution) and the transfer of continental water reservoirs to the ocean (the eustatic contribution). The second is the local component reflecting vertical land movement or subsidence due to tectonics, isostatic adjustments and sediment compactions. The sum of the global and local components is referred to as relative sea level rise and reflects the rate of sea level change at a specific location (*Cazenave and Nerem, 2004*).

Sea level change is difficult to measure. Relative sea level change have been derived mainly from tide gauge data. In Vietnam, the marine hydrometeorological observing has been recorded at 21 stations (*Figure 3*). A network of tide gauge has been established along the coast and in islands. The observation parameters are main meteorological (wind,

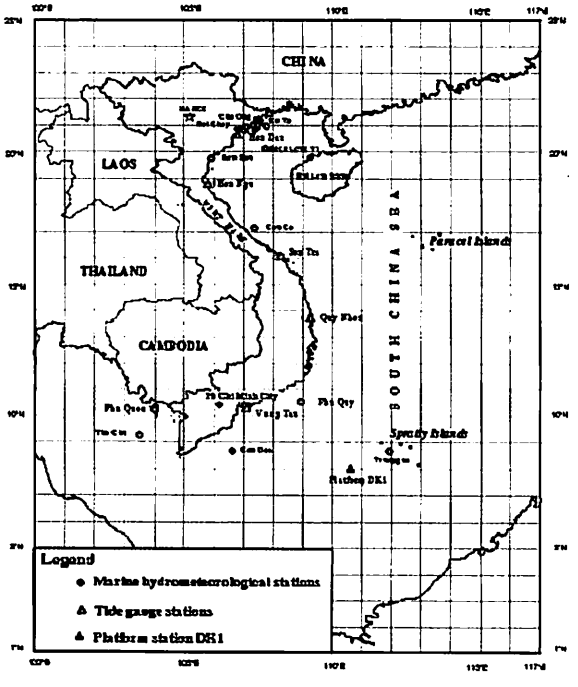

Figure 3. Schema of marine hydrometeorological station network

pressure, air temperature, humidity···) and oceanographic (wave, sea level, salinity, water temperature···). All tide data are transmitted via Inmarsat - C System to the Marine Hydrometeorological Center (MHC) in HaNoi. The data will be analyzed, processed by ORKAN (European) & TIDE (Canada) software and stored there and available using.

Among 21 stations there are 7 tide gauges recording sea level every one hour (*Table 2*). Almost others are observed four times per day at 01; 07; 13; and 19 o'clock local time.

In Vietnam, Global Position System (GPS) technology is not used for network station but used for sea maping monitoring. There are 2 GPS near the tide gauge. One located at near Hon Dau station (in the north) and the other one located near VungTau station (in the south).

Table 2: Location of 7 tide gauges recording sea level every one hour

No	Name of station	Location		Established	Remarks
		Lat. (N)	Long.(E)		
1	Hon Dau	20° 40'	106° 48'	1956	
2	Hon Ngu	18° 48'	105° 46'	1961	
3	Da Nang	16° 06'	108° 13'	1963	
4	Quy Nhon	13° 46'	109° 13'	1963	Gloss station
5	Vung Tau	10° 20'	107° 04'	1918	
6	Phu Quoc	10° 37'	106° 35'	1976	
7	DK1-7	8° 01'	110° 37'	1995	Flatform station

3. Sea level rise results

Relative sea level rise in Vietnam is calculated from tide-gauge data collected by the Marine Hydrometeorological Centre at the 4 chief stations (Hon Dau, Da Nang, Qui Nhon va Vung Tau). The figure 4 illustrated sea level varying for the period 1960 - 2000 at Hon

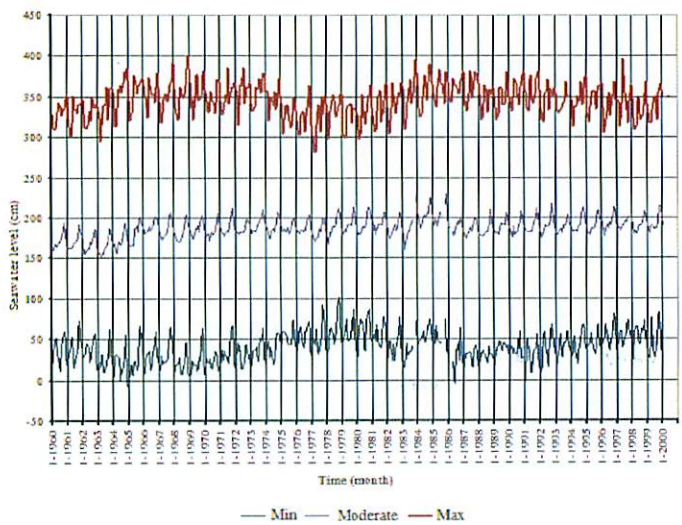

Figure 4. The varying of maximum, moderate and minimum water level following month (at Hon Dau station).

Dau station that is longest station and clear typical data of sea level rise. A sea level rise of 1.9 mm a year has been observed in this period. The station at Vung Tau in south Vietnam shows a different trend. This maybe an unreliable result as the siting of this station has changed, although Da Nang station in Centre Vietnam also shows a different trend from Hon Dau. Up to now scientific researches in Vietnam have been axamined for evidence of sea level rise. According Tuong (*2001*) recorded increments in sea level varying from 1.75 to 2.56 mm/year at 4 chief stations. This is in broad agreement with the observed rise in global mean sea level (*Table 3*).

Table 3: Observed rate of sea level rise and estimate contributions from different sources

Source of sea level rise	Rate of sea level rise (mm per year)	
	1961-2003	1993-2003
Thermal expansion	0.42 ± 0.12	1.6 ± 0.5
Glaciers and ice caps	0.50 ± 0.18	0.77 ± 0.22
Greenland ice sheet	0.05 ± 0.12	0.21 ± 0.07
Antarctic ice sheet	0.14 ± 0.41	0.21 ± 0.35
Sum of individual climate contributions to sea level rise	1.1 ± 0.5	2.8 ± 0.7
Observed total sea level rise	1.8 ± 0.5[a]	3.1 ± 0.7[a]
Difference (Observed minus sum of estimated climate contributions)	0.7 ± 0.7	0.3 ± 1.0

([a] Data prior to 1993 are from tide gauges and after 1993 are from satellite altimetry. Sources: IPCC WGI Fourth Assessment Report, 2007).

Some studies a meteorological events as typhoon, monsoon occurred in very short time - several hours or some days during the last some decades. It could not impact on the change of mean sea level (*Table 4*).

Table 4: Impact of Typhoon on mean sea level (MSL) Δh max cm

Stations	Daily MSL	Monthly MSL	Yearly MSL	20 year MSL
Hon Dau	8	1	0.2	0.01
Da Nang	7	1	0.3	0.015
Qui Nhon	4	1	0.3	0.015
Vung Tau	20	1	0.5	0.025

According Tuong (*2001*), analysing sea level change during the years of El-Nino (1965-1969;1972;1976; 1982; 1983; 1987), it was found out that the yearly mean sea level (MSL) a little decrease in comparison with MSL in previous running year. The value of the decrease is not preceed 10 cm. This confirms that the El-Nino phenomena show the rate of SLR (*Table 5*).

Sea level in Vietnam has increased 5 cm within the past 30 years. Sea level is expected to rise up to 9 cm in 2010; 33 cm in 2050; 45 cm in 2070; and 1 meter in 2100 (*Ninh, 2007*).

Table 5: Impact of El-Nino phenomena on yearly mean sea level change Δh cm

El-Nino year	Hon Dau	Δh (cm) Da Nang	Qui Nhon	Vung Tau
1957	- 2.0			
1968	- 2.0			
1969	- 5.0			
1972	- 2.0			
1976	- 5.0		- 6.0	
1982	- 4.0	-10.0	- 4.0	- 3.0
1987	- 10.0	- 4.0	- 3.0	- 1.0

Sea level rise impacts

Like other developing countries, Vietnam is heavily dependent on natural resources and any change in the prevailing environmental condition is likely to have serious consequences (*Table 6*).

It will exacerbate all these ongoing problems when Global warming and especially sea level rise are growing rapidly. In Vietnam, there are a number of causes for sea level rise such as the north-east monsoon, increased riverflow, local heavy rains, alluvium

Table 6: Assessment of disasters severity in different geographic areas

Natural disasters	Geographic Areas and Economic Zones: North east	Red River Delta	North central coast	South central coast	North east south	Mekong River Delta	Coastal Economic zone
Storm	+ + +	+ + + +	+ + + +	+ + + +	+ + +	+ + +	+ + + +
Flood	-	+ + + +	+ + + +	+ + +	+ + +	+ + + +	+ + + +
Flashflood	+ + +	-	+ + +	+ + +	+ + +	+	+ + +
Whirl-wind	+ +	+ +	+ +	+ +	+ +	+ +	+ +
Saline intrusion	-	+	+ +	+ +	+ +	+ + +	+ +
Inundation	-	+++	+ +	+ +	+ +	+ + +	+ + +
Landslide	+ +	+ +	+ +	+ +	+ +	+ + +	+ +
Storm surge	-	+ +	+ +	+ +	+ +	+ + +	+ +

Notes: The table shows the assessment of disaster severity in each zone.
Very severe (+ + + +) Severe (+ + +) Medium (+ +) Light (+) None (-)

accumulation, human activities and the greenhouse effect. Some are active in the present-day while others threaten the future.

It is estimated that the sea level will rise at a rate between 0.3 and 1.0 m over the next 100 years. For the analysis a 1 m rise was chosen as a base for preliminary assessment of impacts. Coastal areas at or below 1 m of elevation constitute much of Vietnam's coastline. Sea level rise presents a serious threat to these coastal areas in particular to the two low-lying deltaic areas of the north and south. The serious physical impacts of sea level rise on the coastal zone are:

- Loss of wetland and other low land and population displacement;
- Increased vulnerability to flooding, including storm events;
- Accelerated erosion along the coasts and in river mouths;
- Increased salinity of estuaries, saltwater intrusion into freshwater, aquifers and degradation of water quality.

1. Land loss

Coastal marshes and swamps are particularly vulnerable to rising sea level. As the sea rises, the outer boundary of these wetlands will erode, and new wetlands will form inland as previously dry areas are flooded by the higher water levels. The amount of newly created wetlands, however, could be much smaller than the lost area of wetlands. Tidal wetlands are generally found between sea level and the highest tide over the monthly lunar cycle. As a result, areas with small tide ranges are the most vulnerable. In Vietnam, the wetlands affected and threatened by sea level rise could be 1700 km², which is about 60% of Vietnam's coastal wetlands. Most threatened areas will be the Minh Hai and Vung Tau-HCHC mangrove areas, the Xuan Thuy RAMSAR site at the Red River mouth, since these cannot migrate landward (*Huan, 1996*).

According to Tom et al. (*1996*), with 1 m sea level rise the following could lead to loss 40,000 km² of land in Vietnam. Among them are 5,000 km² of rice paddy in the Red River Delta and 15,000 - 20,000 km² of rice paddy in Mekong River Delta. Sea level rise threatens these regions and would drastically affect their peoples. Arable land might be reduced and people may have to be relocated, increasing pressure on some resources in neighbouring areas. The impacts of sea level rise on coastal populations in term of displacement or forced migration as a result of inundation will depend on rate as well as magnitude of change.

2. Increase flooding

The geographical character of Vietnam with its long coastline and narrow hinterland creates an exceptionally high ratio of coastline and land area. There is about 100 km² of land on the mainland for each kilometer of coastline. Recently, flooding in the coastal zone have increased in intensity and frequency of occurrence. It is mainly a result of high

river discharges, elevated sea level during typhoon and weak dikes. Even now flooding due to high tide has been serious in the south of Vietnam especially in the areas near Ho Chi Minh city. Annual flooding in the Mekong River Delta, inundates an area of more than 1.7 x 10^6 ha affecting 9 million people directly. The impact is not limited to a narrow coastal zone but will even be more serious further inland.

According to data collected by Hydrometeorological Service, there has been an increase in the number of tropical cyclones affecting Vietnam since the 1950s. When the typhoon surges falling in spring tide, the sea level rise up 5 - 6 m and very strong wave can break out seadikes and make coastal deformation deeply. The storm - surges, which pose a danger to the coastal inhabitants have amplitudes ranging from 0.5 to a maximum of 3 m along the coast to the west of the Gulf of Tonkin. The avegare amplitude is 1.4 m along the central and south coasts (*Ninh et al., 1992*).

3. Coastal erosion

Vietnam has around 3,260 km curving shoreline with many river estuaries. A long the coastline in average in every 20 km there is a river mouth. It has important geographical position especially it has enrichment and diversity of resources but it is sensitive place at once. According to results research of Vietnamese Geography Institute (2004), erosion and accretion are occurring popularly in the whole coastline and river mouths. Coastal erosion is caused by a variety of factors, which broadly fall in to 2 categories. First, sand often migrates along the shore, causing some areas to erode and others to accrete. Second, rising sea level causes virtually all shores to erode. Measurements of coastal parameters such as wave action and beach erosion rates are still poorly covered although fragmentarily being addressed in some joint- funding programme.

In both the Mekong River Delta and Red River Delta, erosion has occurred along one-fourth of the coastline of each delta. Nowadays coastal erosion is key concern increasing in scale and amount with the resulting damage. Overall 243 coastal sites covering 469 km of coastline have eroded at a rate of 5-10 m/year. Ninety-six of these sites have lost even more than 1 km of coastline to erosion. The longest eroded coastal stretch extends 60 km at Ganh Hao in Mekong River Delta and along the Bo De coast; some 36 km of coastline have been eroding at a rate of 30-50 m/ year for the last century.

The second longest eroding coastal stretch at Van Ly (Nam Dinh province) in Red River Delta which extends over a length of 30 km. The Van Ly coast has been eroding at a rate of 10-15m/year during the last half century, the mean rate of coastal erosion increased from 8.6 m/year during 1965-1990 to 14.5 m/year during 1991-2000 along the Van Ly coast. In Cat Hai island (Hai Phong City), from 1949 to 1965, this segment was eroded with 6.4 km long in the southern and rate of 5-18 m/year. From 1965 to 1988, it was kept continuously eroding with an extent of 2.9 km long rate of 10-25 m/year. From 1988 to 2001, the coast continued to be eroded but the erosional extent and rate were

decreased thanks to presence of newly built jetties and seadykes. In addition the segment of Dinh Vu area, in period 1965 - 1980, erosion occurred with highest rate, reaching 11.8 m/year. In period of 1980-2001, the rate of erosion decreased due to upgrading protection and the average rate of erosion is 4.3 m/year.

At Central Vietnam, the coastline from Thanh Hoa to Binh Thuan have 263 areas with coastal erosion. The total length of the eroded coast of the region is 392 km. The most serious erosion coasts are Tuy An (Phu Yen province), Phan Ri Cua and Phan Thiet city (Binh Thuan province). In general, the erosion rate ranges from 1-5 m/year, but sometimes it is as much as 10-15 m/year.

In Vietnam, there are several of studies about the coastline erosion. Figure 5, 6 and 7 show a change of shoreline in some segment of Red River Delta due to coastal erosion.

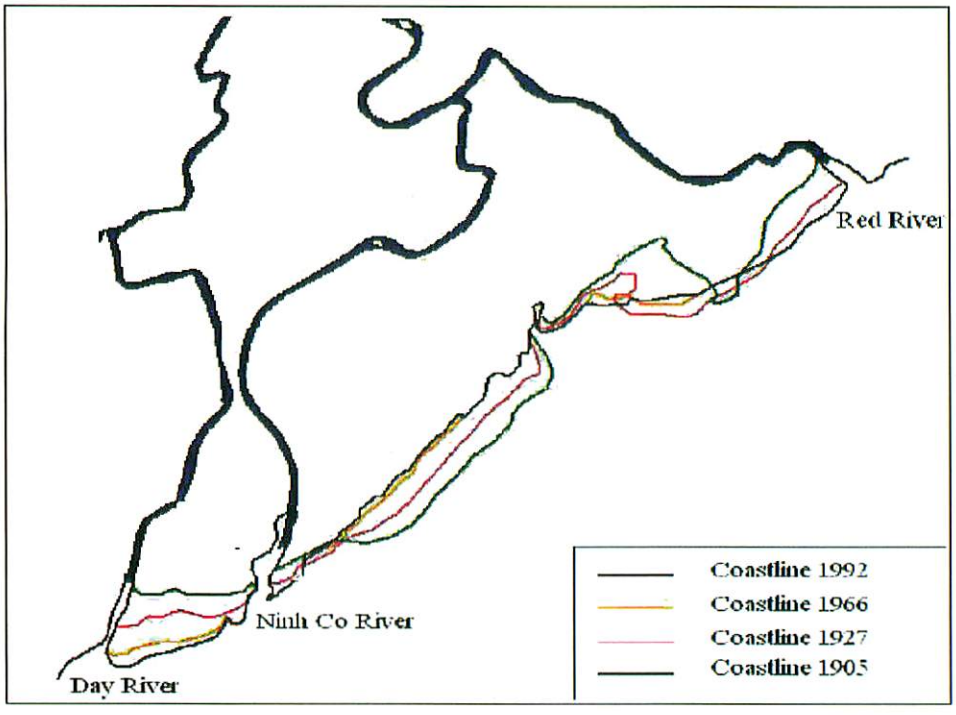

Figure 5. Change of shoreline in Nam Dinh province from 1905 to 1992

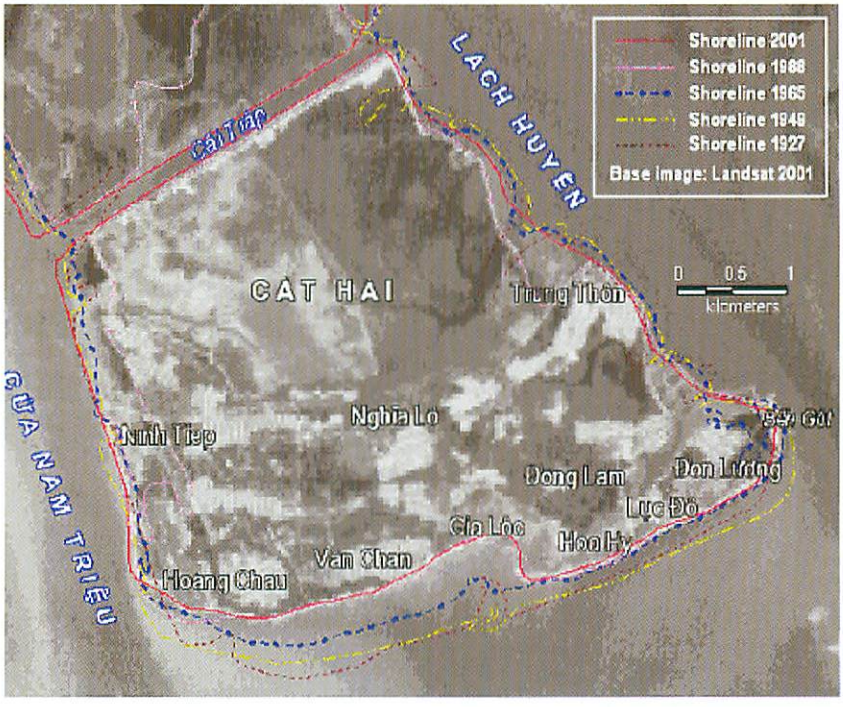

Figure 6. Change of shorelines in Cat Hai from 1927 to 2001

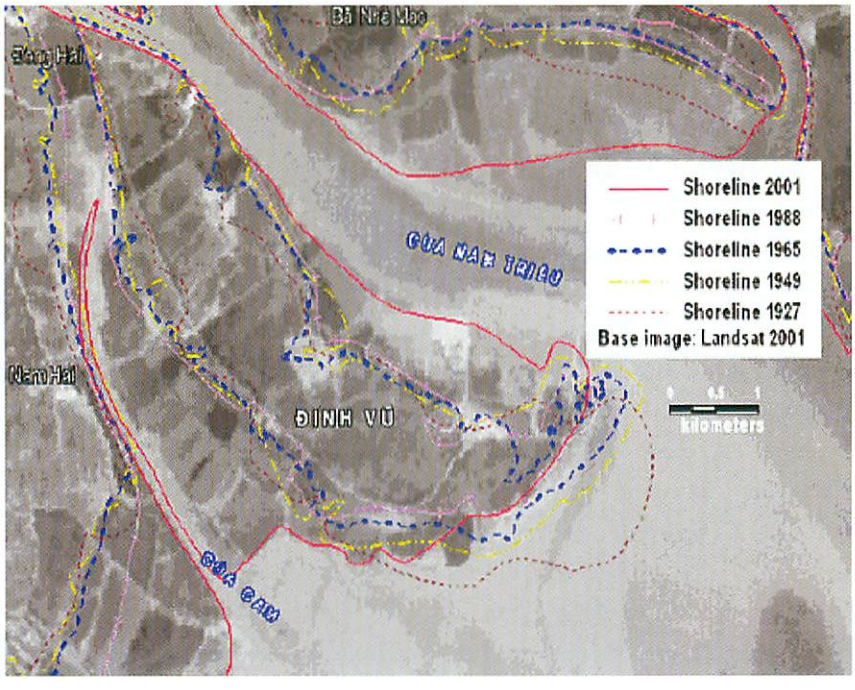

Figure 7. Change of shorelines in Dinh Vu from 1927 to 2001

4. Increase salinization

As sea level continues to rise the associated effects of permanent inundation, erosion and episodic flooding is likely to increase the salinity of surface and groundwater near coastal area. Sea level rise would generally enable saltwater to advance inland in both aquifers and estuaries. In estuaries, the gradual flow of freshwater toward the ocean prevents low - lying continental water systems from having the same salinity as the ocean. A rise in sea level would increase salinity in open bays because the increased the cross-sectional area would slow the average speed at which freshwater flows to the ocean. Furthermore, the impact of sea level rise on ground-water salinity could make some areas uninhabitable even before they were actually inundated, particularly those that rely on unconfined aquifer just above sea level. Generally, these aquifers have a freshwater 'lens' floating on top of the heavier saltwater. As sea level rises, the depth of the freshwater lens in the coastal zone is greatly reduce, leading to salinization of water supplies. In extreme cases exacerbated by over - pumping, the aquifer may rapidly become unsuitable for dinking and even for irrigation. Because of tidal pressures, saltwater now penetrates 30-50 km up the Red River and 60-70 km up the Mekong River. More than 1.7 x 10^6 ha of land has been affected by saltwater intrusion in the Mekong River Delta; this area is predicted to increase to 2.2 x 10^5 ha in the near future if suitable management practices are not implemented. In recent decades, the 1‰ salinity contour (isohaline) has moved landward by 4-10 km in the northeast part of the Red River Delta (*Thanh et al.,2004*).

The saltwater intrusion is a serious problem not only for coastal agriculture, but for other economic sectors as well. The irrigation of paddy rice maybe seriously affected area results of the increased intrusion of saline or brackish water. In Vietnam, for instance, 50% of national rice production comes from the Mekong delta in the south, while 20% is produced in the Red river delta. Although much of this production is for export, a disaster in the deltas would have profound effects on the whole country.

Saline intrusion associated with sea level rise can have considerable impact on coastal ecosystems, especially mangrove forest. Salinity is one of the most important determinants of mangrove forest growth and distribution. Mangrove develop well in place where the salt concentration is between 20 and 35%. Too high a salt concentration (40-80%) diminishes the number of species and their size. In place where salt concentration reach 90%, only a few species can exist and even then they grow slowly. Obviously no mangrove forest can be found where the salinity is too low. However, mangrove do need a certain amount of freshwater during their growth. Freshwater from river, channel and rain dilutes the salinity of sea water, creating brackish water suited to many species during specific stages of their growth. As sea level rise and river flow alter, the distribution of salinity and freshwater in mangrove areas will change. The mangrove ecosystem will respond by changing in productivity, areal extent or species diversity or by migrating. These changes will likely modify fish, shrimp, crab and wildlife populations

living in mangrove forest. The more that the mangrove forest is reduced the greater the impact from salt water intrusion and erosion on the neighbouring land and the greater the vulnerability to storm- induced flooding. The loosing of mangrove forests at muddy coasts of Red River Delta is very serious and since without mangrove forests, coastal protection in this area is almost impossible.

It should be noted that the other types of impacts can be important as well. The social and economic consequences of sea level rise could well be wide-ranging. Port facilities may have to be re-engineered. Coastal industries may be lost. Transportation will be disrupted. About USD 17 billion of capital value will be lost by annual flooding, which is about 80% of the yearly GDP. At a 30 year development scenario, the loss of capital value will be close to USD 270 billion which would be even higher than the projected GDP at that time. The damage increases faster than GDP.

From World Bank data, in Vietnam about 5.3 % of land, 10.8 % of population, 10.2 % of GDP, 10.9 % of urban area, 7.2 % of agricultural area and 28.9 % of low ground could be affected if sea level rise by 1 metre.

Conclusion

In conclusion that Vietnam had a evidence sea level rise occurring. Sea level rise has been traditionally based on tide gauge records which indicated an average rate of sea level rise in the range 1.75 - 2.56 mm/year. This results agreed with observed rise in global mean sea level.

The past and current affect of sea level rise on Vietnamese coast are apperent. Even a small sea level rise increase the risk of storm surges - sudden rises in sea level during the high tides. In addition sea level rise could also result in the permanent flooding of low-lying in two fertile deltas of Mekong river and Red river, damaging coastal cropland and displacing millions of people living near coastline, as well as increase coastal erosion and saline intrusion. Rising sea levels are already contaminating underground fresh water supplies in Vietnam. Sea level rise also threatens coastal wetland including mangroves add to threats to these ecologically valuable areas.

The study of sea level rise and its impacts on coastal zone in Vietnam remain limited. To cope with consequences of increasing sea level on coastal zone, Vietnam need to carry out researches to evaluate more comprehensively influence of sea level rise; to orient ability of coastal zone vulnerability to give a protection strategy against 1m sea level rise scienario in the near future. Furthermore, Vietnam must work with relevant bodies to monitor, update and timely deal with information about climate change and sea level rise and cooperate with international organizations involved in climate changes to research and develop an appropriate action programme to climate change and sea level rise. It's sound good that Vietnam would have an official forecast about sea level rise at the end of this year.

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