

# APPLICATION OF REMOTE SENSING FOR COASTAL HAZARD MONITORING IN TAM GIANG - CAU HAI LAGOON, VIETNAM

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**ABSTRACT:** Stretching on the coastline of 70 km, the Tam Giang - Cau Hai Lagoon plays a very important role for the coastal ecology and socio-economic development of Hue region where was Vietnam's Ancient Kingdom Capital and recognized as a World's Cultural Heritage. Recently, coastal hazard in the lagoon have occurred seriously such as inlet movement and fill up, coastal erosion, flood and inundation, etc. These hazards have impacted on lagoon environment, resources, ecosystems, socio-economic and sustainable development of this coastal area. This paper present a case study using remote sensing data in combination with ground survey for monitoring the coastal hazards in Tam Giang - Cau Hai lagoon in recent decades. Analysis results find that during its natural evolution, the lagoon has been being in three situations of only one, two and three inlets. When inlets opened or displaced, coastal erosion have occurred seriously toward new balance condition. Flood and inundation occurs every rainy season in lowland plain around lagoon. The historical flood happened in early of November 1999 with six days long, created very terrible damages for Thua Thien Hue province. Remote sensing data with capability of regular update, large area coverage is effective provide real-time and continuous information for coastal hazards monitoring.

## 1. INTRODUCTION

Stretching on the coastline of 70 km, the Tam Giang - Cau Hai Lagoon plays a very important role for the coastal ecology and socio-economic development of Hue region where was Vietnam's Ancient Kingdom Capital and recognized as a World's Cultural Heritage. Recently, due to natural and human influences, coastal hazards have occurred rapidly such as inlet movement and fill up, coastal erosion, flood and inundation, etc. These hazards have impacted on lagoon environment, resources, ecosystems, socio-economic and sustainable development of this coastal area.

Ground survey on coastal hazards have just implemented in given manpower and weather condition. Ground survey is usually coast and time consuming. Remote sensing data with capability of regular update, large area coverage is effective provide real-time and continuous information on coastal hazards. This paper present a case study using remote sensing data in combination with ground survey to assess coastal hazards in Tam Giang - Cau Hai lagoon in recent decades.

## 2. DATA AND METHODOLOGY

This paper was completed base on the survey data collected from the projects implemented by Institute of Marine Environment and Resources in Tam Giang - Cau Hai lagoon since 1993, existing relevant publications, the topography maps, and satellite data. The used map data consisted of UTM maps of 1:50,000 made from airphoto by American Army in 1965 and Gauss maps of 1:25,000 published in 1978. The used satellite data consist of

spacecraft Soiuz image in 1983; Mos-1/Messr image acquired on 10 July 1992; Adeos/Avnir image acquired on 03 April 1997; Radarsat images acquired on 6, 10 and 15 November 1999; Landsat TM images acquired on 08 January 1989, 11 March 1991; Landsat ETM images acquired on 01 September 1999, 06 November 2000, 25 November 2001, 04 March 2003, 07 April 2004; Aster image acquired on 18 August 2000, 17 October 2001; Spot-5 image acquired on 17 February 2005.

The satellite images were enhanced, geometric rectified to geographical coordinate, and interpreted for lagoon coastal line, land-water boundary. Color composite of near infrared band of satellite image acquired at different time method was used to show the changes due to coastal erosion and inlet movement. Threshold method was used to determine land-water boundary on images. GIS analysis method was also used to overlay situations of inlets to assess the opening, closure, and displacement of lagoon inlets. The topographic maps of 1:50,000 and 1:25,000 provided information on the situation of lagoon inlets before 1979 was combined with map derived from satellite data to detect the changes of lagoon inlets in last decades.

## 3. RESULTS AND DISCUSSIONS

### 3.1. Change in lagoon inlets

According to ancient documents, ago, Tam Giang - Cau Hai lagoon had only Tu Hien inlet. After that Thuan An inlet was broken in 1404 (Don, L. Q., 1776). Since the open of Thuan An inlet, Tu Hien inlet has become secondary and both have been unstable. The instability of

inlets was manifested by situations of its displacement, reopen, enclose and change in water cross-section and deformation of tidal channel many times in the pass (Thanh, T. D., 1985). In this study, the displacement, reopen, enclose of lagoon inlets are analysed from remote sensing images and collected other data since 1979.

During its natural evolution, the lagoon has been being in three inlet situations. The situation of two lagoon inlets was noticed from 1959-1979 and 1990-1994 and the situation of one lagoon inlet from 1979-1989 and 1994-1999. The terrible coastal flood from 1-6 November 1999 began by the situation of one lagoon inlet and ended by the situation of five inlets. The situations of only one or many inlets are regarded as the coastal risk cause bad consequences on environment, ecosystem and socio-economy.

The lagoon has only one inlet when Tu Hien inlet closed. This inlet has been closing and opening many times with a period of many years (Thanh T.D., 1999). Recently, it was closed from 1979-1990, opened from 1990-1994, closed from 1994-1999 and has opened from 1999-now (Figure 1). The intrinsic cause of close of Tu Hien inlet concerns the geological evaluation of lagoon with the combination of endogenous and exogenous dynamic factors. The direct cause of close of Tu Hien Inlet is the interaction between the longshore sand drift transported by wave and the tidal and flood eroded current through this inlet. The close of inlet happens, generally, in the late stage of northeast wind season from December to April and falls in the time of ending the flood flow. After a closed duration from 4-11 years, the inlet can be opened at the coincident of a heavy flood and strongly coastal erosion, generally, in the early stage of northeast wind season. The opened duration of inlet is from 4-20 years (Thanh T.D., 1999).

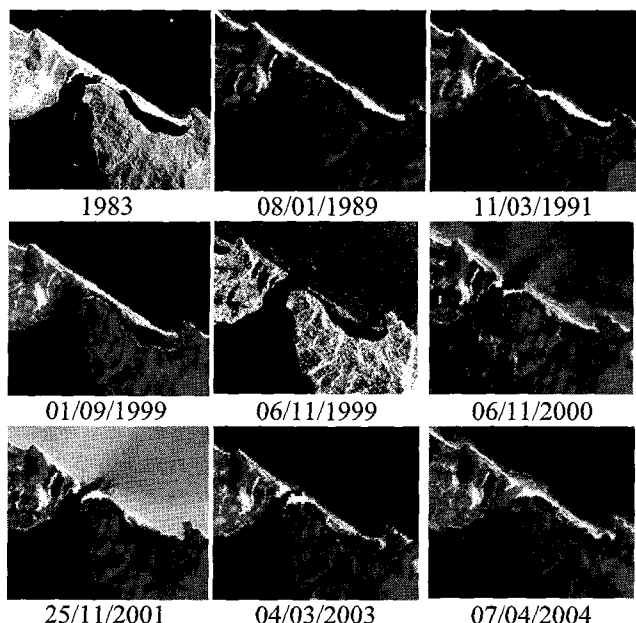


Figure 1. Satellite images of Tu Hien inlet

Table 1. Historical situation of Tu Hien inlet

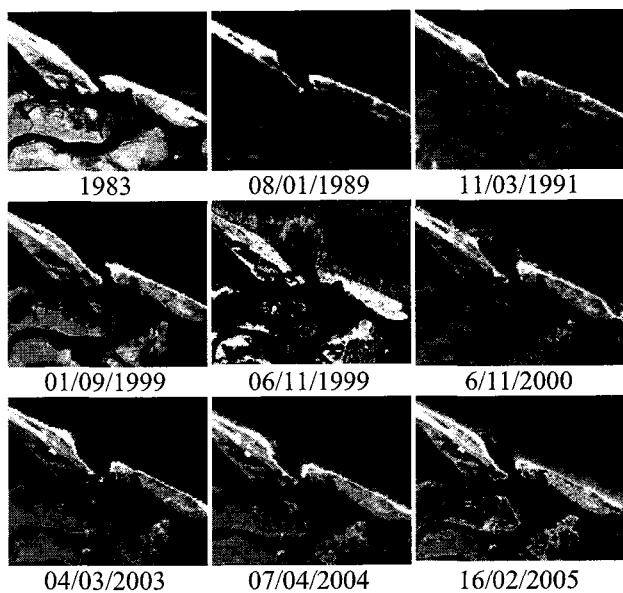
Year	Inlet situation	
	Vinh Hien	Loc Thuy
1979	Enclosed	Opened
1984		Enclosed
1990	Opened	
1994	Enclosed	Opened
1999	Opened	Opened
2000		Enclosed

According to historical record, Thuan An inlet was broken in 1404 and become the main one the lagoon. Thuan An inlet has been at two positions, about 200 years, since 1504, at Thai Duong Ha in the north, and after that, about 200 years, until 1897 at Hoa Duan in the south (Phan H.T., Trang H., 1991). Since 1897, Thuan An inlet has been at about present position at Thai Duong Ha and tended to move northward. In terrible flood in November 1999, Thuan An inlet was enlarged with one more inlet channel created and named Hai Duong. The old inlet at Hoa Duan closed about 100 years ago was reopened in this flood (Hai, N.V., 1999).

The Thuan An inlet have not been closed completely, but suddenly displaced on the distance of 8km with long period. In the last century, it has moved northward at the rate of 15-40m/yr. The mechanism and historical occurrence of Thuan An inlet change is more complex than Tu Hien inlet. Although locating at Thai Duong Ha or Hoa Duan site, this inlet is always to move northward under the influence of sand longshore drift dominated Northwest ward. On the way of moving northwards, the inlet is longer, narrower and shallower that leads to worsen the drainage of flooding water. In a certain strong flood, this situation is ended by opening a new inlet, and the former inlet is enclosed. This situation was happened in the historic flood from 1-6 November 1999 (Figure 2). However, in this time, the reopened inlet at Hoa Duan site has been embanked for the maintaining the ship channel to Tan My harbour passing the existing inlet. Not only influenced greatly from marine dynamic factors, the displacement of Thuan An inlet is also related to mechanism of winding of lower section of Huong river. The mechanism of displacement of this inlet is influenced by the situation of Tu Hien inlet, too. When Tu Hien inlet opened, Thuan An inlet seems to be smaller and flow slower. When Tu Hien inlet closed, flow of Thuan An inlet is faster, and deformed into deeper (Thanh T.D., 1997).

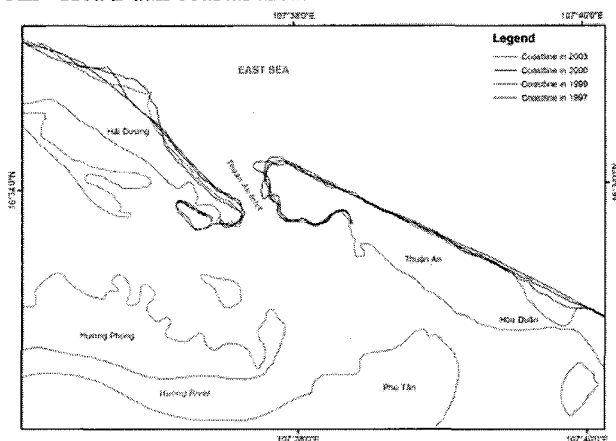
### 3.2. Coastline changes and coastal erosion

After historical flood in November 1999, Hoa Duan inlet opened, coastal erosion in Thuan An beach happened seriously. Since 2003, at Thuan An beach coastal erosion have stopped, and started accretion. At coastal section between Thuan An beach and Thuan An inlet, erosion are still happening.



**Figure 2.** Satellite images of Thuan An inlet

Coastal section left side of Thuan An inlet at Hai Duong commune, coastal erosion have happened seriously due to movement of inlet to northward. Since 2003, erosion have stopped and started accretion. Results of images analysis show that coastal area at Northwest of village 3 of Hai Duong commune, erosion and accretion are alternated with an appearance of sand bar. The movement of this sand bar is seasonally due to longshore drift. Table 2 shows the erosion and accretion in Thuan An - Hoa Duan coastal area.



**Figure 3.** Coastline change in Thuan An area

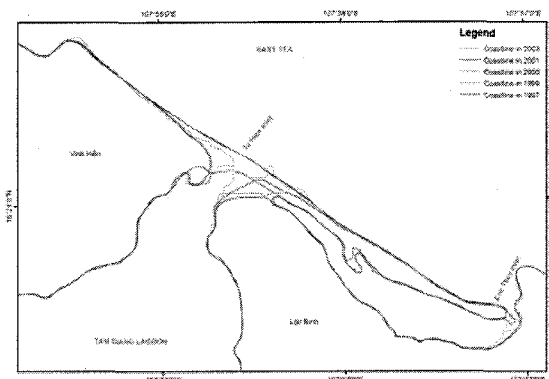
Though, average rate of erosion is not so high, but Thuan An coastal area was eroded continuously during 1997-2001. Erosion rate increased southeast ward to Hoa Duan inlet. Coastline in 1999 move landward 29m/year when compare with coastline in 1997. Strong coastal erosion and over flow during flood in November 1999 opened Hoa Duan inlet. After Hoa Duan inlet was dammed up, erosion in Thuan An beach had been happening strongly, coastline in November 2001 show the maximum erosion distance. Since 2002, erosion at Thuan An beach has stopped and started accretion. Since dammed in 2000, Hoa Duan area have accreted rapidly, coastline have

approach to coastline in September 1999. To 2005, this coastline has got back balance situation.

**Table 2.** Average rate of coastal erosion - accretion in Thuan An - Hoa Duan coastal area

Coastal area	1997-1999	1999-2000	2000-2001	2001-2002	2002-2003
Northwest Village 3	+ 18	- 65	+ 47		
Village 3	- 27	+ 260	+ 57	+1.78	+101
Village 2	- 8	- 48	- 16	- 8.26	+105
Northwest Thuan An	- 12	- 11	- 24	- 11.72	+66
Thuan An beach	- 25	- 24	- 22	+16.32	+26
Hoa Duan inlet	- 29	- 157	+ 90	+11.50	+85

Coastline of Tu Hien area changed due to open, close and movement of inlets. Erosion and accretion was alternated. Coastline was at dynamic balance situation, alternate erosion and accretion at small scale. During 1997-1999, Tu Hien inlet closed, Loc Thuy inlet opened, coastline of this area was stable. Tu Hien inlet opened in November 1999 caused erosion and accretion happened strongly. Tu Hien inlet was opened and enlarged during flood, and narrowed due to accretion at both sides. Erosion and accretion in Tu Hien area was happening at small scale and locally.

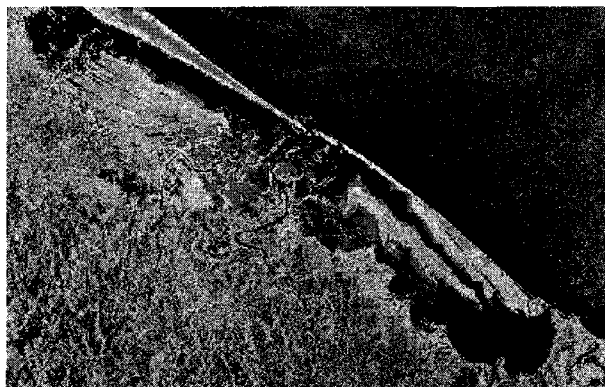


**Figure 4.** Coastline change in Tu Hien inlet area

### 3.3. Flood and inundation

Lowland plain behind lagoon was flood every rainy season. However, during heavy rain period, flood and inundation occurred due to raising of water level in lagoon because water flow out inlet to the sea less than rainy water flow from river to lagoon. Flood level in this study is considered as land-water boundary in satellite image. On dry season image, water level is boundary of lagoon. On rainy season images, land-water boundary is flood boundary at image acquired date. Image acquired on 01 September 1999 is considered as dry season image because rainfall is lowest in Thua Thien - Hue from June to September. Water level in this image was considered as lagoon based water level for comparing with water

level in rainy season images. Results of overlay water levels derived from satellite image show clearly flood level change during historical flood in November 1999. Flood area derived from analysing satellite images acquired in rainy season 1999, 2000, and 2001 was shown in table 3.



**Figure 5.** Map of flood area around lagoon in November 1999

Flood occurred mainly in low plain behind lagoon, mainly at 3 area: O Lau river plain include Phong Binh, Phong Truong, Dien Mon, Huong Dien, Dien Loc communes of Phong Dien district and some communes of Hai Lang district; plain between Huong and Bo rivers include Quang Tho, Quang Thanh, Quang Vinh, Huong Vinh communes of Quang Dien and Huong Tra districts; Dai Giang river plain include Phu Luong, Phu Ho, Thuy Thanh, Thuy Luong, Thuy Tan, Vinh Thai communes of Huong Thuy, Phu Loc an Phu Vang districts.

**Table 3.** Area (ha) of water area and flood area in rainy season of 1999, 2000 and 2001

No	Image acquisition date	Water area	Flood area
1	06 November 1999	63144.66	40530.41
2	10 November 1999	56048.41	33434.16
3	15 November 1999	41709.76	19095.51
4	06 November 2000	38699.42	16085.17
5	25 November 2001	38273.62	15659.37

#### 4. Conclusions and Recommendations

Remote sensing data have effectively contributed for monitoring lagoon inlet change, detected and predicted its change for purpose of prevention and response with risks in coastal lagoon area. Remote sensing images acquired by Spot, Aster, Landsat, Mos-1, Adeos and Radarsat associated with field survey data have recognized lagoon inlet situation and its change since 1979. Situation two inlets were from 1959 to 1979 and from 1989 to 1994. Situation of one inlet was from 1979 to 1989 and from 1994 to 1999. Terrible flood from 1-6 November 1999 killed 300 people occurred when there is only one inlet and opened four inlets for flood water flow to the sea. Radarsat image acquired on 6 November 1999 show that actually four inlets opened by flood due to over flow at ruin inlets in the past. Now two of them were natural closed and Hoa Duan was dammed. Continuous

examining of lagoon inlet situation and its change are significant importance for prediction of flood risk, salt intrusion and other consequences.

Coastline of Thua - Thien Hue province was at dynamic balance situation, alternated accretion and erosion phases on coastal sections from 1989 to 2003. Particularly, drastic coastline change at lagoon inlets were related closely to opening, closure and movement phases of inlet. At Hai Duong and Thuan An sections, coastal erosion from 1997 to 2001 with average rate of 8-48m per year. Since 2002, these coastal sections have accreted and approached dynamic balance.

Flood happening in rainy season occurs mainly in lowland plain of O Lau, Bo and Dai Giang rivers. Due to relatively step terrain, when longtime heavy rain occurred, almost plain area was flooded by over flowing and raising of lagoon water level.

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