



AN APPLICATION OF DIGITAL SHORELINE ANALYSIS SYSTEM (DSAS) TO STUDY SHORELINE CHANGE ALONG KY ANH COASTS (HA TINH PROVINCE) DURING 1989 - 2013

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Abstract

In the context of global climate change and sea level rise, studying shoreline change is aimed at not only formulating important engineering techniques but also dealing with challenges in multi-disciplinary data integration. This is valuable to many researchers, local government and local stakeholders. In order to identify the trend of changes, there are various effective models and systems that have been designed and developed. One of them is the Digital Shoreline Analysis System (DSAS) integrated in a geographical information system (GIS) developed by the USGS. The DSAS is applied for monitoring the shoreline changes in the district of Ky Anh, Ha Tinh province from 1989 to 2013. The research results consist of determining the shoreline positions during the study period based on using Landsat images; quantification of the erosion and accretion relationship between 1989 and 2013 in different topographical segments; and a map of affected areas where the shoreline is equal to the high-tide water line. The results updated by the internet would provide the decision makers, researchers and local communities with the benefits of monitoring shoreline change and help them to have quick responses to the abrupt change in the area.

Keywords: DSAS; Shoreline changes; Erosion; Accretion; Ky Anh coasts.

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1. Introduction

Vietnam is highly vulnerable to hazards and risks from climate change impacts (IPCC, 2007, 2014), especially the 3,000 kilometer long coast. The coastal area of Vietnam is mainly influenced by three types of hazards, of which integrated effect could be associated with climate changes including drought, sea level rise, and extreme weather conditions. The turns of these primary effects cause floods and erosion. Both sea level rise and storms result in the erosion of beaches and dune ridges. As well as throughout the world, from 1990 up to now, the coastal erosion in

Vietnam has witnessed an increase in both length and intensity, especially in the low lying coastal land made by unconsolidated sediments (sand, silt-clay).

Digital Shoreline Analysis System (DSAS henceforth) has its own advantages for examining historical shorelines compared with traditional ground survey techniques [7]. It is considered as a practical application for decision-making in coastal management. Most recently, the combination of remote sensing, GIS and DSAS was applied in coastal studies which can be found in notable research on determining the rate

of shoreline change along the Kenitra coast, Morocco during 1969 - 2009 [3], along the Mangalore coast, West Coast of India (2005 - 2013) [1], in the North of the Coramandal Coast (1972 - 2013) [6], along the Tamil Nadu coast (1978 to 2014) [4], along the Karnataka coast (1991 - 2014) [2]. In Vietnam, several shoreline studies that applied DSAS are listed below: calculating shoreline change in Nam Dinh coastal area [8]; examining the rates of coastal shoreline change in Kien Giang coast during 1995 - 2009 [5]; detecting long-term mangrove shoreline changes in Mui Ca Mau [9].

This paper aims at identifying historical shoreline changes during the period 1989 - 2014 in the Ky Anh coastal area of Ha Tinh province (in central Vietnam). The rate of erosion and accretion was calculated based on the data derived from satellite images and the result of DSAS analysis.

The rest of the paper is organized as follows: Section 2 presents the DSAS methodology; case study results are indicated in Section 3; and finally, conclusion and recommendations are detailed in Section 4.

2. DSAS methodology

DSAS, or USGS DSAS (United States Geological Survey Digital Shoreline

Analysis System) is a GIS tool (a free available ArcGIS extension) designed by the United States Geological Survey (USGS). Its web-based version (DSAS web) was published in 2013 (USGS, 2013). DSAS has been used to analyze coastal change based on detecting shoreline movements and calculate the rate of change as follows: (i) Mapping historical shoreline position by using available spatial data; (ii) Evaluating historical changes and trends of selected transects; (iii) Analyzing shoreline geometry; and (iv) Predicting shoreline patterns.

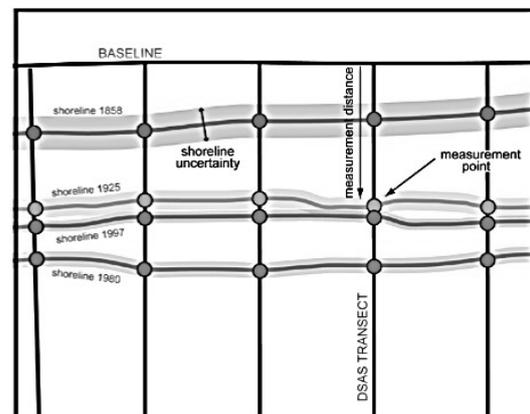


Figure 1: Historical shorelines and DSAS-generated transects [7]

The DSAS approach calculates rates of shoreline change through measuring gaps between the shoreline positions in specific periods of time. According to [7], it is possible for DSAS to measure statistical data. Table 1 shows the spatial patterns of shoreline change statistics as follows:

Table 1. Statistical measures in DSAS [7]

Statistical measures	Definition
Shoreline Change Envelope (SCE)	A measure of the total change in shoreline movement which considers all available shoreline positions and reports their distances without reference to their specific dates.
Net Shoreline Movement (NSM)	A measure reports the distance between the initial position and the latest position of shoreline.
End Point Rate (EPR)	A measure derived from dividing the distance of shoreline movement during the period of time between the initial positions and the latest position of shoreline.
Linear Regression Rate (LRR)	A measure that determines a rate-of-change statistic by fitting a least square regression to all shorelines at a specific transect.

3. The case analysis

As shown in the Fig. 2, Ky Anh is the furthest South-Western district of Ha Tinh province. The total district area is 105,428 hectare entailing 7 coastal communes from Ky Xuan in the North to Ky Nam in the South. The coastline of 7 communes is 63 kilometers long, mainly covered by beaches, sand and to a lesser extent, rocks. Behind the dune ridge, delta zones are covered with irrigated rice fields. A small area which is dryer is used for growing peanuts and vegetables. There are low hills covered by conifers, mixed leafy trees and scrub vegetation. Mangroves are planted surrounding rivers. Moreover, there are some lakes, one of which is artificial, providing water for rice irrigation.

The most significant driving forces (from both nature and human) of coastal erosion in Ky Anh are storms, floods, and sandy collection (in Vung Ang Economic Zone). The Ky Anh coastal area is frequently affected by tropical storms and

induced flooding. Storms occur from the Southeast to the Northwest or from the Southeast East to the Northwest West over the area more frequently from January to August and less frequently in December. During the last 50 years, the Ha Tinh province has been affected by 47 storms, 18 of which impacted directly on the Ky Anh coastal area (ISPONRE, 2009). Ky Anh witnessed 0.9 storm per year on average, and there has been an increase in the frequency during recent years. In Vietnam, there were 285 tropical storms between 1951 and 2010 (4.75 tropical storms per year on average), 38 tropical storms from 2011 to 2013 (Matsumoto and Shoji, 2003). However, during recent two and a half decades (1996 - 2005), there were only 4 storms (0.4 storms per year on average). This figure was lower than that in the long term trend analysis shown (ISPONRE, 2009). In the study area, a progression from 20 to 200 m depending on the inclination of the beach is reported for the periods 2003 - 2010.

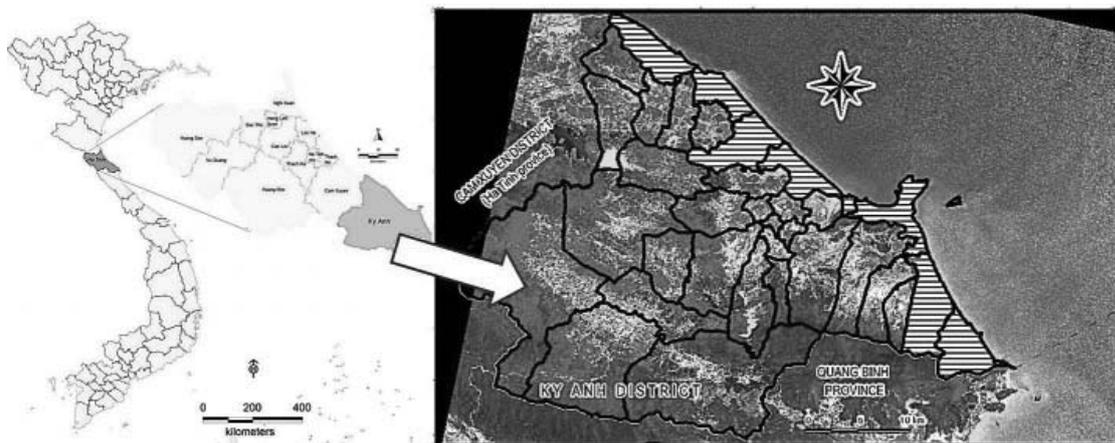


Figure 2: Selected study area in Ky Anh district (Ha Tinh, Vietnam)

Shoreline changes happening in the study area were investigated based on five satellite images, which is available in the period 1989 - 2013. Movements of both the Mean Low Water (MLW) and Mean High Water (MHW) are observed

through GIS based on DSAS extension developed by the USGS [7]. Shorelines were digitized from an individual map. Net Shoreline Movement (NSM) and End Point Rate (EPR) were calculated. NSM showed the distance between the initial

position (1989) and the latest position of shoreline (2013), which indicated the overall change in shorelines position over the 24 years. EPR converted net shoreline movement into an annual rate of shoreline change by dividing the distance of shoreline movement from the

initial position to the latest position of the shorelines passed during a particular period of time. 200 meters of the shorelines in 2013 was chosen as a baseline, and 961 transects created (about 50 meters of a distance range) were numbered in order (Fig. 3).

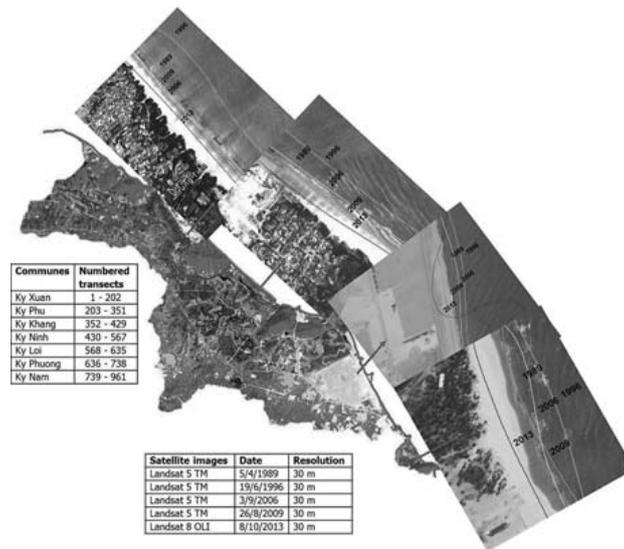
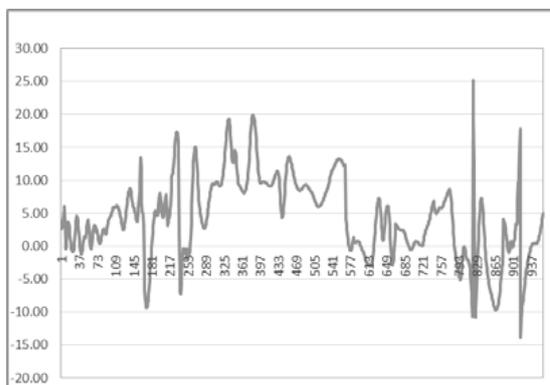


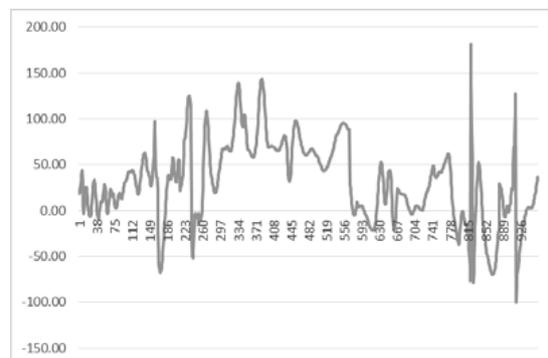
Figure 3: The numbered transects were classified by administrative boundaries

As shown in Fig. 4, net erosion and accretion rates were calculated for five coast sections using the same boundaries during the periods 1989 - 2013. During the period 1989 - 1996, the rapid accretion of more than 25.25 meters per year (average values is approximately 6.6 meters per year) was observed in the Southern Ky Anh district with a low erosion of 13.86 meters per year (-3.4 meters per year on average). The results

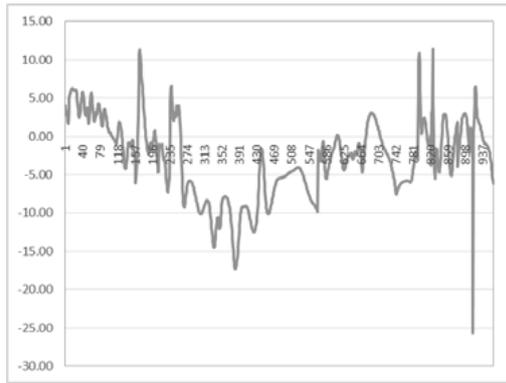
show that the accretion trend in this period was dominant and it changed quickly. During 1996 - 2006, the main trend of shoreline changes was the erosion with more than 5.3 meters per year, which was higher than the accretion rate (3 meters per year) in the study area. Beginning with the erosion, this process happened continuously in whole shorelines with the range featuring from 24 meters per year to 92.5 meters per year during 2006 - 2013.



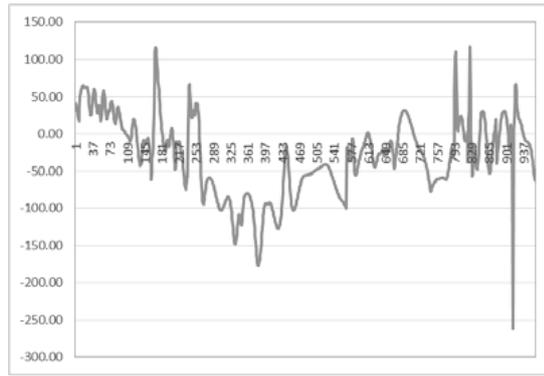
(a) NSM (1989 - 1996)



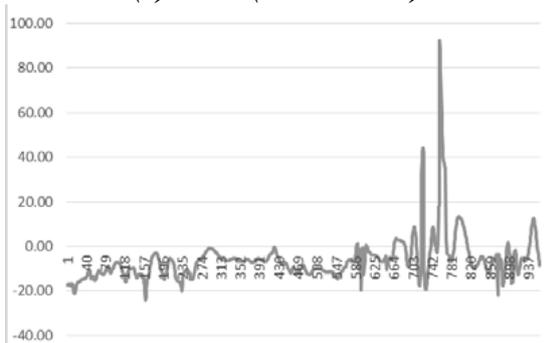
EPR (1989 - 1996)



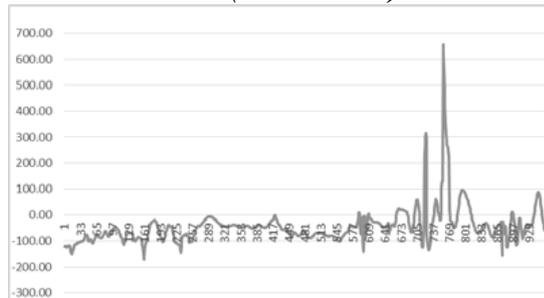
(b) NSM (1996 - 2006)



EPR (1996 - 2006)



(c) NSM (2006 - 2013)



EPR (2006 - 2013)

Figure 4: Change of NSM and EPR values during 1989 - 2013

Net erosion and accretion rates were calculated for each commune as follows:

(-) *Ky Xuan commune*: The coastal zone was observed at 202 transects, which showed that accretion is more than erosion in the period of 1989 - 2006. The Net Shoreline Movement (NSM) changed from -60 meters at the nearest point to 110 meters at the furthest point. The changing trend in this period was accretion rate with the average highest rates reducing from approximately 14 meters per year during the period of 1989 - 1996 to 5 meters per year during the period of 1996 - 2006. However, in the years of 2006 - 2013, the dominant trend was erosion. The highest rate was 10 meters per year with the highest movement change of erosion increasing to 160 meters.

(-) *Ky Phuong, Ky Khang and Ky Ninh commune*: The shorelines status experienced a change from accretion during the period 1989 - 1996 to erosion

during the period 1996 - 2013. The shoreline movement changed from 5 - 20 meters during 1989 - 1996 to -17.27 - 0.0 meters during 1996-2006; to -14 - 0 meters during 2006 - 2013. The highest accretion rate was 140 meters per year during 1989 - 1996. The dominant processes were erosion with the highest rate reducing from 170 meters per year in 1996 - 2006 to 140 meters per year during 2006 - 2013.

(-) *Ky Loi commune*: In Ky Loi commune, the shoreline movement in 1989 - 1996 changed from -2.5 to 12.3 meters with the highest accretion rate reaching approximately 88 meters per year and the highest erosion rate being -20 meters per year. Therefore, the process of accretion was faster than that erosion during this period. During 1996 - 2013, the highest erosion rate increased from the -100 meters per year in 1996 - 2006 to -140 meters per year in 2006 - 2013. The

shoreline movement in 1996 - 2013 was at the range from -10 to -20 meters.

(-) *Ky Nam commune*: The coastal zone in Ky Nam saw greater erosion than accretion from 1996 - 2013. The highest shoreline movement changed from -13 to 17 meters in 1989 - 1996; reducing the range from -25 to 6.3 meters in 1996 - 2006; and maintaining the ranged between -21 and 10 meters in 2006 - 2013. Thus, during the period of 1989-1996, the erosion rate was 100 meters per year whereas the accretion rate was 128 meters per year. The accretion was the dominant process in this period. During the remaining years, the highest erosion rate was 260 meters per year while the highest accretion was 66 meters per year.

During a period of 24 years (1989 - 2013), Ky Anh district witnessed many changes in the shorelines. A total of 961 transects were established whereas there were 881 transect records of erosion and 80 transect records of accretion. There were no unchanged transects records (no

accretion or no erosion). The movement of erosion ranged from -1.39 to -223.89 meters, and the rate ranged from -0.06 to -9.13 meters per year; the average rate of the whole period was -2.27 meters per year. The erosion point was located in Ky Khang, Ky Ninh communes. The accretion movement fluctuated from 1.99 to 669.43 meters, and the rate fluctuated from 0.08 to 37.31 meters per year. The average accretion rate was 4.81 meters per year distributing in port construction area in Ky Loi commune.

In comparison with the changes between three periods, it can be concluded that the erosion trend saw an increase in both movement and rate during the whole period. The rate of erosion increased from 0.02 to 13.86 meters per year during 1989 - 1996; to 0.01 - 25.66 meters per year during 1996 - 2006; and to 0.02 - 24 meters per year during 2006 - 2013. The average erosion rates fluctuate from 3.34 to 5.33 meters per year. The accretion process experienced a downward trend in the rate and the movement.

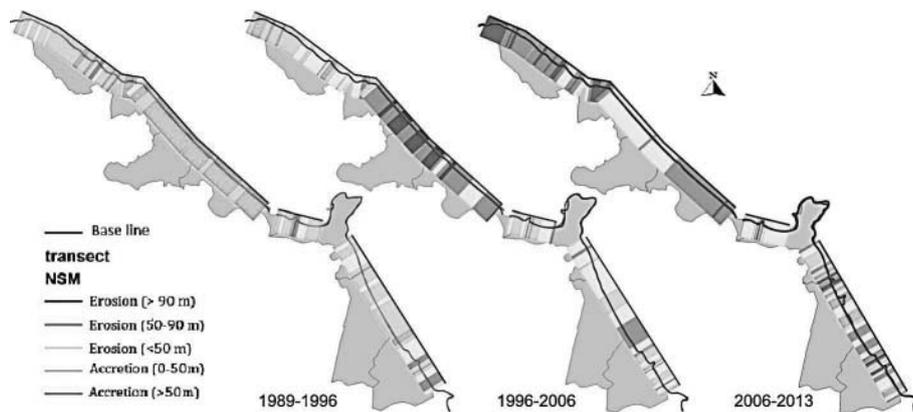


Figure 5: DSAS shoreline change results in the Ky Anh district

4. Conclusion and recommendations

(-) Due to significant factors such as storm, flooding, and sandy collection, Ky Anh is regarded as one of the coastal areas experiencing the strongest shoreline changes among the Central Coast in

Vietnam. The results of DSAS show that during 1989 - 1996, the low erosion was 3.4 meters per year on average. However, from 2006 to 2013, the erosion witnessed an rapid increase going up from 24 to 92.5 meters per year. These are similar results

to recent research on coastal erosion in this area. Nguyen and Pham (2003) indicated that before 2000, there were 32.2 kilometers of Ky Anh shoreline eroded with the rates featuring from 0.2 meters per year (in Ky Loi commune) to 15.0 meters per year (in Ky Phuong commune).

(-) Ky Anh is an example of Vietnam which has a wide and international importance of coastal protection and regional planning. Although Vietnam has many experiences of coastal protection and flood management, the impacts of intensified storm and monsoon conditions frequently offer new challenges. Currently, the district and the province are building fortify dykes, plant protecting tree ridges, restore and extent mangroves. The shoreline change extraction and change detection analysis using DSAS could be applied in several fields such as setback planning, hazard zoning, the erosion and accretion studies, regional sediment budgets and conceptual or predictive modeling of coastal morphodynamics [1]. Especially, a setback planning has been designated as an effective spatial planning for coastal erosion mitigating in Ky Anh district.

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