A Shoreline Analysis using DSAS in Nam Dinh Coastal Area

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Abstract
The shoreline change in Nam Dinh province in Vietnam is a chronic problem. Based on the 87-year historical data from 1905-1992, the shoreline change in Nam Dinh was re-analyzed using the ArcView extension entitled DSAS (Digital Shoreline Analysis System). The rates of changes was calculated by four statistical methods, namely, End Point Rate (EPR), Average of Rates (AOR), Linear Regression (LRR), and Jack-Knife Rate (JKR). The computational results show that there is beach erosion in Hai Hau and a beach accretion in Nghia Hung and Xuan Thuy, respectively. Annually, the shoreline retreats 25-29m in Hai Hau and advances 12-23m in Nghia Hung and 37-39m in Xuan Thuy correspondingly. DSAS shows its advantages comparing to traditionally manual shoreline analyses and its promising applications for coastal management purposes in other regions of the country.

1. Introduction

The nearshore processes induced by winds, waves, currents, tides result in the beach profile changes and shoreline evolutions. The long-term shoreline changes are of most interest and concern of the coastal managers. Along with many models developed to simulate the long-term shoreline changes such as GENESIS (Hanson and Kraus, 1989), UNIBEST (Delft, 1993) and LITPACK (DHI, 2000), the shoreline analyses from measured data using statistical methods are meaningful and may not be obsolete. Many developed countries have deployed advanced technology for the beach and shoreline monitors such as satellite images, GPS, video or digital camera (Tanaka, 2006); most of developing countries are still far from the international standards for applying the new technology. In the coastal provinces of Vietnam, the field survey and shoreline analyses are mostly based on the traditional and manual estimations. The applications of Web-GIS or GIS toolbox are not widely used in the field of coastal engineering and oceanography for beach and shoreline analyses. Since the beginning of the previous century, the coastal evolution has occurred remarkably in Nam Dinh, a coastal province in the northern part of Vietnam (Figure 1). Although Hai Hau, a central coast of Nam Dinh, has been protected by a system of double dikes, the first sea dike of the system was destroyed at least once every decade. Consequently, the agricultural land has lost and the houses vanished. This affected the socio-economical development in Nam Dinh remarkably. There have been many studies in the area by field measurements and numerical models to find the causes and counter-measurements for erosion controls (Vinh et al., 1997, Haglund and Svensson, 2002, Sjodahl and Kalantari, 2005 and Ca et al., 2006). However, the causes of the erosion are not yet fully understood. The reasons for erosion may be due to the dam construction, deforestation and hydrodynamic conditions (Quy, 2002). In this paper, a shoreline analysis using DSAS based on the 87-year historical data from 1905 to 1992 in Nam Dinh Coastal area will be presented (Figure 1). Subsequent to the brief introduction of the natural conditions in Nam Dinh, four methods adopted for shoreline change analyses and the procedure generating transects in DSAS are described. Finally, discussions of the computational results and conclusions will be made.

2. The Natural Conditions in Nam Dinh

Nam Dinh coast stretches from Nghia Hung to Xuan Thuy. It is separated by three rivers, namely, Day River in the south west, Ninh Co River, and Red River in the north east. These rivers divide Nam Dinh coast into three regions that are known as follows (Figure 1):

- Region-1 is Nghia Hung. It is limited from Day River to Ninh Co River. The length of the coast is approximately 8km,
- Region-2 is Hai Hau. It is the central part of Nam Dinh coast and from Ninh Co River to Ngo Dong River in which a dam was constructed in 1955. The length of Hai Hau coast is about 19 km,
- Region-3 is Xuan Thuy. It is from Ngo Dong River to Red River.

The length of the coast is about 5 km. gically, two wind seasons are experienced in Nam Dinh coast. The winter season north-east and east monsoon begins from October and lasts until March next year, and the summer season south, south-east and west-east monsoon during the remaining months. Hydrologically, the tide plays an important role in the coastal and estuarine areas. The amplitude of the tide which can be as high as 4m together with mild beach slope produces a wide breaking zone. This influences the coastal sediment transport processes and the stability of coastal structures. During flood tide, non-breaking waves can propagate to the surface of the revetment. The tides also induce strong currents near the coast and at the river mouth. The high tides in winter along with high waves cause serious coastal erosion and collapses of the river dikes (Ca et al., 2006). The wind setup at the coast mainly appears during winter under the north-east monsoon for a long duration. The 40-year statistical results (1962-2002) shows that wind setup during north-east monsoon in combination with high waves is in the range of 50–80cm and the storm surge can be as large as 2m. The mean offshore wave height normally is 1.2 m. For offshore wave heights, the maximum height may reach 6 m. The highest waves of 7-8m during storms have been observed. During the transition period of April and May, the offshore waves change their directions from north-east to south. During October and November, the wave directions are reversed which are from south-east to north. During these transition periods, waves are calmer than those in the winter and summer.

3. Methodology

3.1 Shoreline Data Analysis

Many methods to analyze the rate of shoreline changes are available. They are End Point Rate (EPR), Average of Rates (AOR), Minimum Description Length (MDL), Jack-Knife Rate (JKR), Ordinary Least Squares (OLS) or Linear Regression (LRR), Reweighed Least Squares (RLS), Weighted Least Squares (WLS), Least Absolute Deviation (LAD), and Weighted Least Absolute Deviation (WLAD). Each method has their own advantages and disadvantages (Thieler et al., 2003, To and Thao, 2006 and Genz et al., 2007). Among many standard methods for shoreline analyses, four methods were selected in this paper, i.e., the End Point Rate, the Average of Rates, the Linear Regression and the Jack-Knife Rate, to calculate the rate of shoreline changes. The computed results then were compared together. Following the instructions of DSAS, four methods can be described as follows (Thieler et al., 2003).

The End Point Rate (EPR) is calculated by dividing the distance of shoreline movement by the time elapsed between the earliest and latest measurements (i.e., the oldest and the most recent shoreline). The major advantage of the EPR is its ease of computation and minimal requirement for shoreline data (two shorelines). The major disadvantage is that in cases where more than two shorelines are available, the information about shoreline behavior provided by additional shorelines is neglected. Thus, changes in sign or magnitude of the shoreline movement trend, or cyclicity of behavior may be missed. The Average of Rates (AOR) method calculates separate end point rates for all combinations of shorelines when more than two are available. A minimum time criterion is introduced to filter the available shorelines and it is a function of measurement errors and the magnitude of the rates of changes. Advantages of this method include a means to filter "bad" data (by the measurement errors), and the ability of AOR to reflect changes in trend and data variability. The major disadvantages are the lack of a computational norm for the minimum time span equation. A Linear Regression (LRR) rate-of-change statistic can be determined by fitting a least squares regression line to all shoreline points for a particular transect. The rate is the slope of the line. The advantages of linear regression include: a) all the data are used, regardless of changes in trend or accuracy; b) The method is purely computational; c) It is based on accepted statistical concepts; and d) It is easy to employ. The Jack-Knife Rate (JKR) method is implemented as an iterative linear regression that calculates a linear regression fit to shoreline data points with all possible combinations of shoreline points, leaving out one point in each iteration. The slopes of the linear regression lines are averaged to yield the Jack-Knife Rate. It is evident that since JKR is using all possible combinations of data is less influenced by extreme data. The principal disadvantages include the amount of computational burden and the questionable statistical value when using a small number of shorelines.

3.2 DSAS

DSAS stands for Digital Shoreline Analysis System written by Thieler and co-workers in 2003 using Avenue for ArcView extension. The purpose of this extension is to extend the normal functionality of the ArcView GIS to include historic shoreline change analysis. The application extension is designed to efficiently lead a user through all the major steps of change analysis in a clearly organized and attractive user interface.

Figure 1: Nam Dinh province and its separated coastal regions

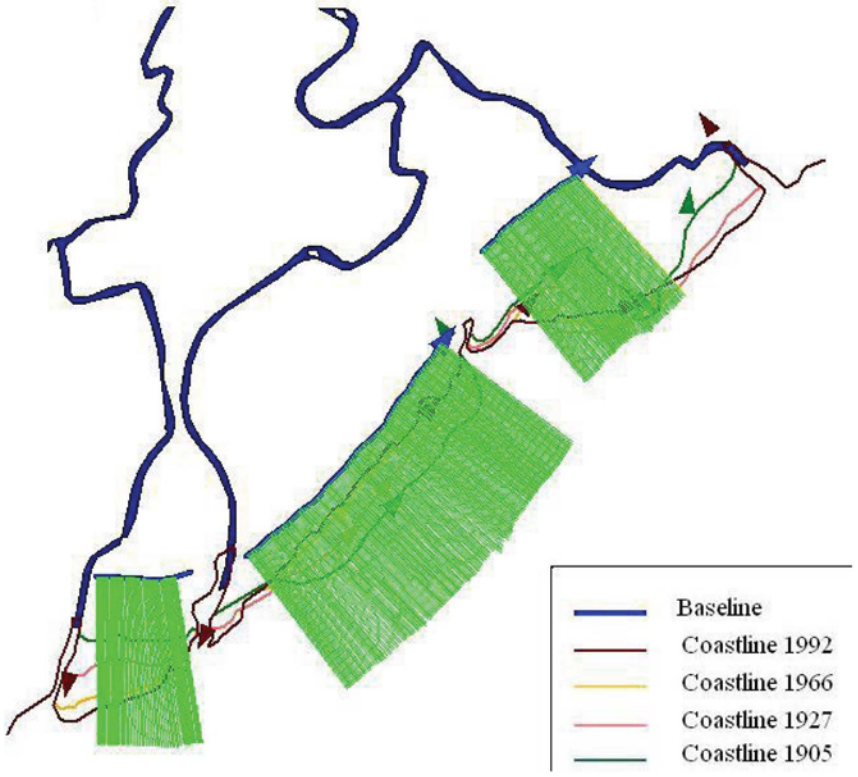

Figure 2: Transects generated along the baseline (without base map)

This extension to ArcView contains three main components: a) to assist a user to define a landward baseline, b) to generate orthogonal transects at a user defined separation, and c) to calculate rates of change. For shoreline analyses, the transects (i.e. the normal of shoreline) referenced to the baseline should be established. As Nam Dinh coast is separated by three small rivers, the baseline that is parallel to the oldest coastline in 1905 was divided correspondingly for three regions as shown in Figure 1. As a result, 329 transects with 100m-transect-interval were automatically established as seen in Figure 2. There are 82 transects in region-1, 193 in region-2 and 54 in region-3. Since the transects near the river mouths frequently intersect each other and the baseline is not totally straight, it is impossible to adopt DSAS directly and some transects near the river mouth would require manual corrections to avoid the transect intersections.

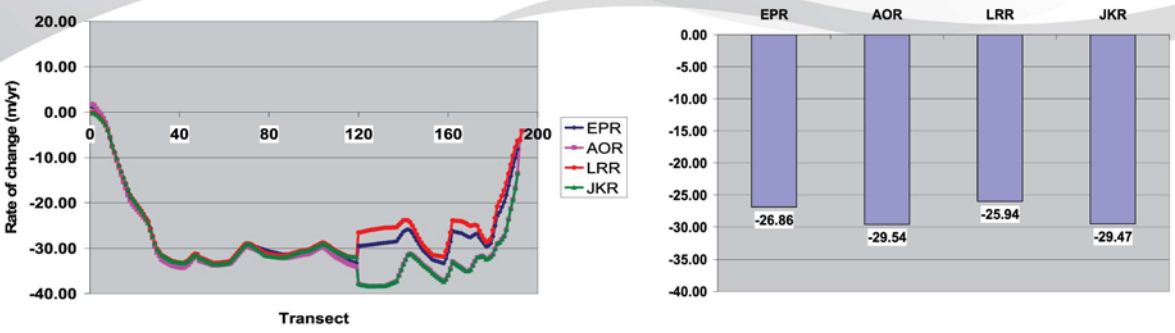

Figure 3: The computed rates of changes vs. the transects and the methods in region1

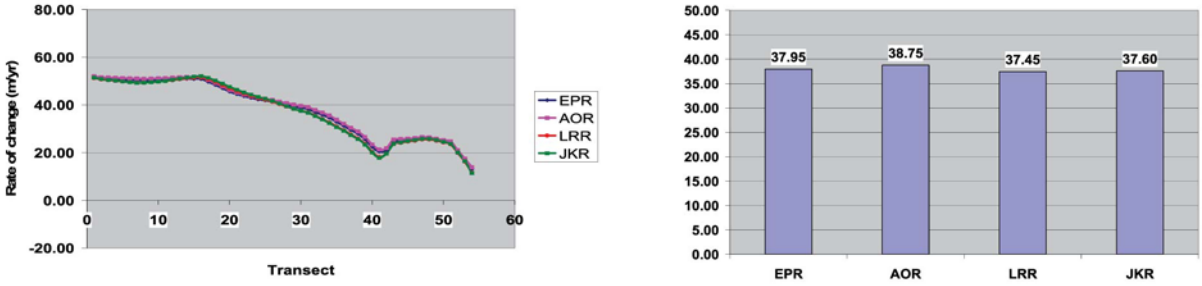

Figure 4: The computed rates of changes vs. the transects and the methods in region2

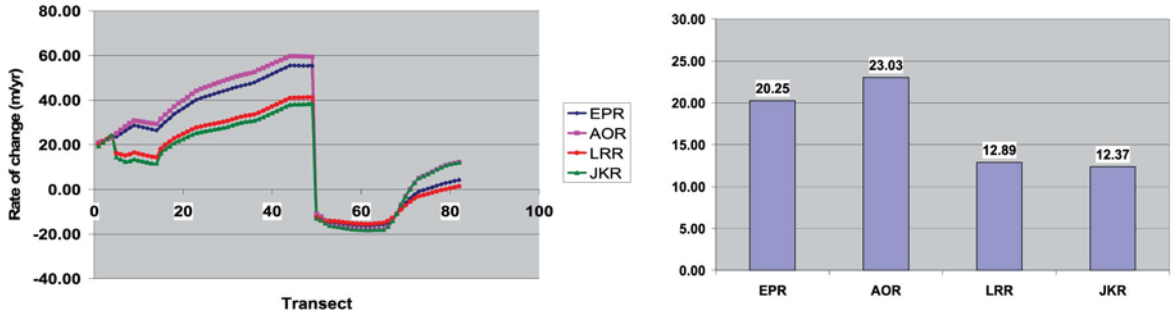

Figure 5: The computed rates of changes vs. the transects and the methods in region3

Table 1: Computed rates of shoreline changes using EPR, AOR, LRR and JKR in one year for the total number of transects in Nam Dinh coastal area

Methods	**Region 1** (*m/yr/total transects*)	**Region 2** (*m/yr/total transects*)	**Region 3** (*m/yr/total transects*)
EPR	1660	-5183	2049
AOR	1888	-5701	2092
LRR	1056	-5007	2022
JKR	1014	-5627	2030

Table 2: Computed rates of shoreline changes using EPR, AOR, LRR and JKR in one year for a single transect in Nam Dinh coastal area

Methods	**Region 1** (*m/yr/ transect*)	**Region 2** (*m/yr/transect*)	**Region 3** (*m/yr/transect*)
EPR	20.25	-26.86	37.95
AOR	23.03	-29.54	38.75
LRR	12.89	-25.94	37.45
JKR	12.36	-29.48	37.59

5. Results and Discussions

Based on the established transects in Figure 2, the computed rates of shoreline changes in three regions can be illustrated in Figure 3, Figure 4 and Figure 5, Table 1 and Table 2 respectively. It can be seen that the positive and negative rates of changes in the figures show the beach accretion and beach erosion correspondingly. In Figure 3, the computed rates of shoreline change using EPR, AOR, LRR and JKR are demonstrated. The left hand size of Figure 3 indicates the rate of changes versus the transect number; the right hand size of Figure 3 shows the rates of changes versus different methods (EPR, AOR, LRR, JKR). On average, there is a beach advancement in region 1 (Nghia Hung) about 1014-1888m/year/82-transects (Table 1) and 12-23m/year/transects (Table 2). The shoreline advances from the 0th- to the 50th and the 70th to the 80th transects; but it retreats from the 50th to the 70th transects. Both erosion and accretion occurs in region 1, the deposition process dominates. Different methods applied for regions 1 have shown different computed rates of changes. For EPR and AOR, the rates of changes are quite similar (i.e. 20.25 vs. 20m/yr). Analogically, the computed rates of changes are quite similar using LRR and JKR (i.e. 12.9 vs. 12.3m/yr). However, the computed results are not the same between EPR and AOR with LRR and JKR (i.e. 20.25 vs. 12.9m/yr). But the differences between these two groups (i.e. EPR and AOR vs. LRR and JKR) are small (i.e. approximately 10m/yr) and they can be explained as follows. For EPR and AOR, the rates of changes are calculated by averaging from separate end point rates for all combinations of shorelines. In contrast, for LRR and JKR, the computed results are given by fitting a least squares regression line to all shoreline points. For EPR and AOR, they average all established transects which represents erosion or deposition. Therefore, it would produce larger errors comparing to LRR and JKR. Because of similar techniques, the computed results using averaged methods (EPR and AOR) are quite the same. It is also the case for fitting methods (LRR and JKR). Figure 4 shows the computed rates of shoreline change in region 2 by four methods (EPR, AOR, LRR and JKR). Similar to Figure 3, the left of Figure 4 is the rate of changes versus the transect number; the right is the rates of changes versus different methods. On average, there is a beach withdrawal in region 2 (Hai Hau) about 5007-5701m/year/193-transects (Table 1) and 25 - 29m/year/transects (Table 2). Comparatively, other studies for Nam Dinh coast shown that the rates of changes were about 29m/yr (Vinh et al., 1997) and about 15-20m/yr (Imamura and To, 1997) which are approximately same as the present study. The computed rates of shoreline changes using four methods from the 0th transect to the 120 th transect are similar. But they are scattered from the 120 th transect to the 193 rd transect. The beach erosion is dominant in region 2. Figure 5 illustrates the computed rates of shoreline change in region 3 (Xuan Thuy) which shows the shoreline advancement of the whole region. Four methods yields similar rates of changes. On average, there is a beach accretion in region 3 about 2022-2092m/year/54-transects (Table 1) and 37-39m/year/transects (Table 2). In short, from the beach evolution in Nam Dinh coast, the shoreline in region 1 and region 3 advance. In contrast, the shoreline in region 2 retreats. It seems that Nam Dinh coast tends to change and reach its equilibrium planform by balancing the accretion in regions 1 and 3 with the erosion in region 2. For other quantitative comparisons, the statistical measures such as variances, standard deviations, intervals of confident have not been performed here rather than leaving for the future study.

6. Conclusion

Based on the extension of ArcView entitled DSAS, the 87-year shoreline changes was quantitatively re-analyzed. Following results can be obtained: A series of 329 transects which is quite time consuming in standard manual methods was automatically generated using DSAS although having some difficulties to establish the baseline and transect corrections. The shoreline evolution was described quantitatively by the rates of changes through four methods (EPR, AOR, LRR, and JKR). The computed rates of changes in the present study are quite the same as other studies. There are small differences for computed results from four methods, but they still represent the overall tendency in all three studied regions. Specifically, there are 25-29m shoreline withdrawal annually in Hai Hau and 12-23m and 37-39m beach advancement in Nghia Hung and Xuan Thuy respectively. With adequate data available, DSAS that is useful for the coastal management may be adopted to perform shoreline analyses in other provinces in Vietnam.

References

Ca, V. T., Thuc, T., and Trinh, N. Q., 2006, Study on the regime of dynamic and sediment transport processes for the solutions of the coastal erosion problem in Nam Dinh, Vietnam, Proceedings of the Vietnam – Japan Estuary

Workshop 2006, 78-86, Water Resources University, Hanoi.

Delft, 1993, UNIBEST User's Manual. Version 4.00. Delft Hydraulics Laboratory, The Netherlands.

DHI, 2000, LITPACK User's Manual. Danish Hydraulics Laboratory, Denmark.

Genz, A. S., Fletcher C. H., Dunn R., Frazer L. N., and Rooney J. J., 2007, The Predictive Accuracy of Shoreline Change Rate Methods and Alongshore Beach Variation on Maui, Hawaii. *Journal of Coastal Research*, 23, 1.

Hanson, H., and Kraus, N. C., 1991, GENESIS: Generalized Model for Simulating Shoreline Change. Tech. Rep. CERC-89-19. Reprinted, 1: 185p.

Imamura, F., and To, D. V., 1997, Flood and Typhoon Disasters in Viet Nam in the Half Century Since 1950, Natural Hazards, 15, .71–87.

Haglund, M., and Svensson, P., 2002, Coastal Erosion at Hai Hau Beach in The Red River Delta, Vietnam, Master Thesis, Lund University, Denmark.

Sjodahl, M., and Kalantari, Z., 2005, Nearshore hydrodynamics at Hai Hau Beach, Vietnam - Field measurements and wave modeling. Master Thesis, Lund University, Denmark.

Quy, (ed), 2002, Nam Dinh Coastal Zone and Beach Erosion Problem. VNICZM –Vietnam Netherlands Integrated Coastal Zone Management.<http://www.nea.gov.vn/projects/Halan/English/VNICZM_Issue_NamDinh.html>, 15 April, 2002

Tanaka, H., 2006, Monitoring of Short-Term Morphology Change at a River Mouth. Proceedings of the Vietnam-Japan Estuary Workshop 2006, 1-6, Water Resources University, Hanoi.

Thieler, E. R., Daniel Martine and Ayhan Ergui, 2003, Tutorial for the Digital Shoreline Analysis System (DSAS)–Extension for ArcView,USGS. <http://woodshole.er.usgs.gov/project-pages/dsas/>. 10 April 2005.

To, D. V., and Thao, P. T. P., 2006, Analyses of shoreline change by digital shoreline analysis system (DSAS). The 5th Scientific Conference, Summary of papers, 96, *University of Natural Sciences*, Hochiminh, Vietnam.

Vinh T. T., Kant, G., Huan, N. N., and Pruszak, Z., 1997, Sea dike erosion and coastal retreat at Nam Ha Province, Vietnam, Coastal Dynamics 1997.