ASSOCIAÇÃO PORTUGUESA DE GEOMORFÓLOGOS VOLUME XII

X Congresso Nacional de Geomorfologia

Dinâmicas geomorfológicas no espaço e no tempo

ATAS / PROCEEDINGS

APGeom
Associação Portuguesa de Geomorfólogos

Lisboa
2024

X CONGRESSO NACIONAL DE GEOMORFOLOGIA

ASSOCIAÇÃO PORTUGUESA DE GEOMORFÓLOGOS
LISBOA, 2024

Título: X Congresso Nacional de Geomorfologia.

Editor: Associação Portuguesa de Geomorfólogos

Capa (Conceção): Jorge Trindade

ISBN: 978-972-636-312-5
Lisboa, setembro 2024

Associação Portuguesa de Geomorfólogos
Departamento de Geografia
Faculdade de Letras da Universidade de Coimbra
Colégio de S. Jerónimo
3004-530 Coimbra
Email: apgeom.dir@apgeom.pt

Application of Digital Shoreline Analysis System (DSAS) for analyzing sandy coast dynamics in Essaouira, Morocco

Aplicação do Digital Shoreline Analysis System (DSAS) para a análise da dinâmica de litorais arenosos em Essaouira, Marrocos

A. Khouz[1, 2, 3*], J. Trindade[1,2], S.C. Oliveira[2,4], F. El Bchari[1,5], B. Bougadir[3]

[1]Universidade Aberta, Centro de Estudos Globais, Lisbon, Portugal; jorge.trindade@uab.pt (J.T.); abdellah.khouz@gmail.com (A.K.); elbchari@uca.ac.ma (F.E.),

[2]University of Lisbon, Institute of Geography and Spatial Planning, Centre of Geographical Studies, Lisbon, Portugal; cruzdeoliveira@edu.ulisboa.pt (S.O),

[3]Cadi Ayyad University, Higher School of Technology Essaouira, Laboratory of Applied Sciences for the Environment and Sustainable Development (SAEDD), Marrakech, Morocco; b.bougadir@uca.ac.ma (B.B.),

[4]University of Lisbon, Associate Laboratory Terra, Lisbon, Portugal,

[5]Cadi Ayyad University, Polydisciplinary Faculty of Safi, Department of Earth Sciences, Marrakech, Morocco; elbchari@uca.ac.ma (F.E.).

* Correspondence: abdellah.khouz@gmail.com

ABSTRACT

Coastlines change research plays a crucial role in understanding the evolution and ensuring effective risk management. This is essential for minimizing impacts on the environment and society. Our study aims to assess the coastal dynamics of sandy systems in Essaouira. By employing advanced techniques such as DSAS and GIS, we aim to analyze shoreline changes, erosion rates, and susceptibility to sand movement. The insights gained from our investigation into the sandy coastal system will provide valuable input for making informed decisions regarding territorial management.

Key-words: *Coastline changes, risk management, sandy systems, shoreline analysis, erosion rates.*

1. INTRODUCTION

The study of coastline change is essential for understanding how they evolve over time and for the management of risks and minimization of losses to both the environment and society (Baig et al. 2020). Many researchers have developed monitoring and prediction techniques that utilize different remote sensing imagery/data and Geographic Information Systems (GIS). The Digital Shoreline Analysis System (DSAS) tool, created by the Coastal Change Hazards project at the US Geological Survey, allows for the analysis of shoreline positions, over time enabling the computation of statistics related to shoreline change rates. It provides three functions; establishing a baseline, generating transacts and calculating change rates (Baig et al., 2020). Recent studies have extensively focused on assessing shoreline changes qualitatively using approaches derived from DSAS.

Different methods, such, as shoreline movement (NSM) shoreline change envelope (SCE) endpoint rate (EPR) linear regression rate (LRR) and weighted regression rate (WLR) have been explored in various studies (Sytnik et al., 2018; Nassar et al., 2019; Yasir et al., 2020; Baig et al., 2020; Quang et al., 2021). These studies have shown the advantages of these approaches when analyzing the historical and temporal variations in cliff geometry and shoreline positions (Nassar et al., 2019; Baig et al., 2020).

Our study aims to analyze spatial and temporal shoreline changes along the coast of the Essaouira province over the last four decades using DSAS and GIS techniques. Specifically, we seek to estimate changes in the local erosion/accretion budget and delineate susceptible areas prone to coastal erosion. Through this analysis, we aim to contribute to a better understanding of coastal dynamics in the Essaouira province, thereby informing decision-making processes related to coastal management and risk mitigation strategies.

2. STUDY AREA AND METHODOLOGY

The coastal region of Essaouira province in Morocco is positioned along the African Atlantic coast and spans a length of 134 km. This area boasts a rich and diverse coastal system, featuring estuaries, bays, sandy beaches, spits, cliffs, and rocky shore platforms (Weisrock, 1980; Simone, 2000; Lharti et al., 2006; Khouz et al., 2022;). The region is bordered to the north by the Tensift Estuary and to the south by the village of Timzguida Ouftas. It is also flanked by municipalities within the Essaouira Province on the eastern side. The western boundary is marked by the Atlantic Ocean and the presence of the Mogador Island facing Essaouira City. Although most of the coastal region remains in a semi-natural state, there are densely populated areas, particularly in Essaouira City (Fig. 1).

Our research will follow a specific framework to classify the different components and characteristics of the coastal system dynamic nature within Essaouira province. Additionally, we will use DSAS and GIS tools to analyze the spatial and temporal long-term changes that have occurred along the shoreline of the Essaouira province coast over the past four decades. This analysis will enable us to identify trends and patterns of erosion and accretion, as well as determine areas that are susceptible to sand movement.

To analyze the coastal erosion and accretion patterns, we employed a series of steps. First, we conducted Geo-referencing, Mosaic & Merging, and Shoreline extraction and delineation using multi-temporal aerial photos from 1975, 1985, 1991, 2009, 2016, and 2020. The DSAS was then utilized to calculate the temporal rates of coastal erosion and accretion in meters per year. In this calculation, we employed the vegetation limits as the main proxy for the coastline position, while the wet-dry boundary indicator, was chosen as a secondary proxy to calculate the emerged beach area, enhancing the interpretation of shoreline dynamics.

Linear regression rate (LRR), End Point Rate (EPR), and Weighted Linear Regression (WLR) techniques were applied to determine shoreline change rates. Additionally, GIS analysis was used to classify the shoreline into eroding and accreting regions. This comprehensive analysis allows for the identification of erosion and accretion trends and patterns, as well as the identification of areas prone to sand movement.

3. RESULTS AND DISCUSSION

The EPR statistical method therefore ignores the information resulting from intermediate periods, i.e. the rates of coastline change only consider the data resulting from the delineation of the coastline indicator on aerial photographs from 1975 to 2016 and the 2020 ortho-image.

There was a decrease in the emerged beach area between the years 1975, 1984, 1991, 2009, 2016 and 2020. This decrease is more evident: i) near the northern sector of Essaouira, in the "Soleil" beach (Fig. 1): ii) in the old town of Essaouira coastal sector; iii) in the northern part of Tagharte beach, near the mouth of Oued Ksob; iv) and to the south between Oued Ksob and Cap Sim.

The hypothesis of a substantial reduction in beach area between 1975 and the 2020s could be linked to rising sea levels and longshore drift sediment supply reduction, which would lead to a retreat of the coastline, because most of these systems have not direct human interventions.

To provide a more detailed view of coastline dynamics, the between the oldest and the most recent coastline (Fig. 1) was compared using the statistical method of EPR. Results are consistent with the question raised above concerning where the greatest losses in beach area have occurred. It is evident from the map that both shoreline indicators have declined sharply, highlighting sectors A, B, C, D, E and F in the red of the study area, which have contributed most to the decline in beach area over the periods considered.

The distance between the oldest and most recent shoreline was calculated between each period studied, obtaining EPRs for each defined profile respectively (Fig. 1). The EPR is reclassified into 5 classes: -34-15 m/y, -15-10 m/y, -10-5 m/y, -5-0 m/y, 0-1 m/y, 1-5 m/y and 5-25 m/y.

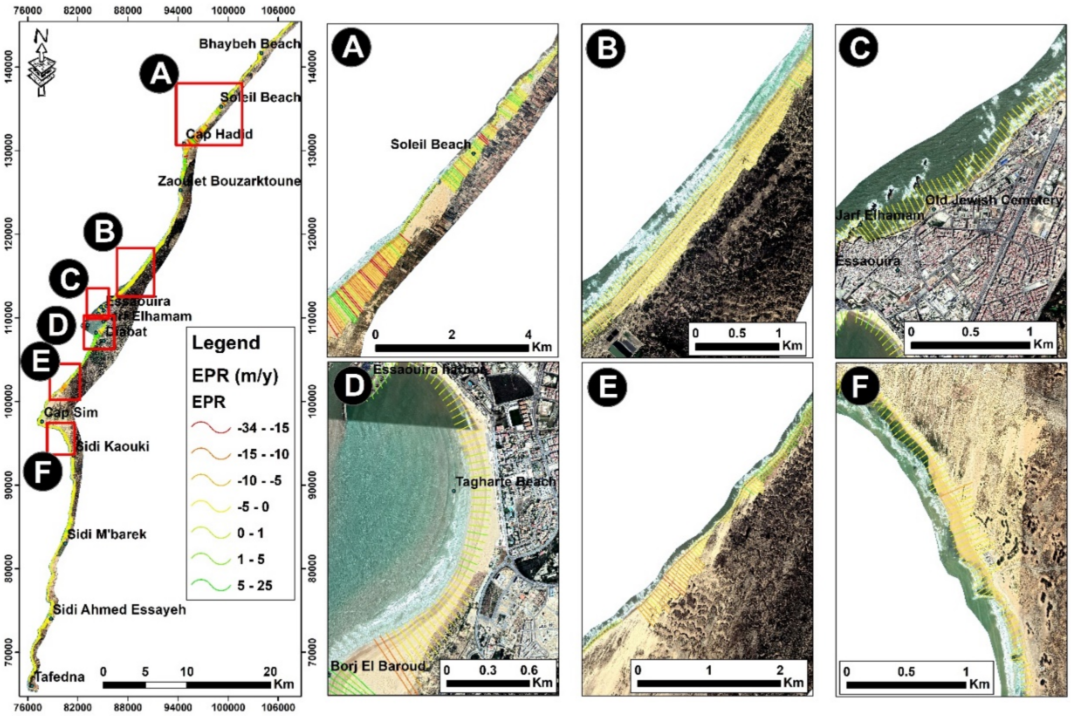

Figure 1. Diachronic variation with End Point Rate in the Essaouira province sandy coast, Morocco. Coastal sectors A to F located by letters in the main map.

By comparing aerial photos from 1975 and 2020 in sector C (Fig. 2-A), we can conclude that the beach next to the rampart of Essaouira's old town has undergone considerable erosion in the last 45 years. This is borne out by a field visit, which revealed that the rampart has been heavily damaged by waves, whereas many old maps show that there used to be a wide beach.

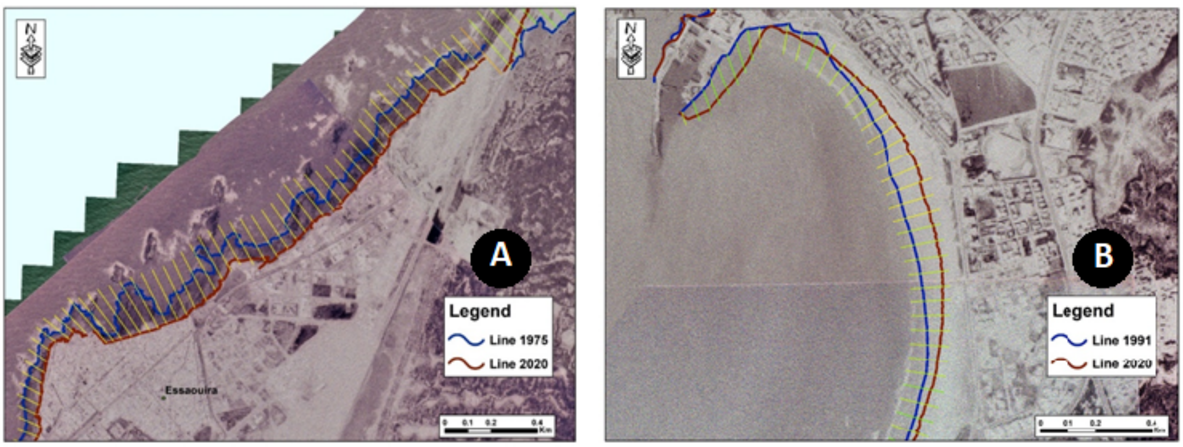

Figure 2. A: Comparing the 1975 and 2020's coastlines in the northern coastal sector of Essaouira C sector. B: Comparing the 1991 and 2020's coastlines in southern coastal sector of Essaouira D sector. Morocco.

As mentioned above, 6 sectors were identified whose average trend showed a decline in the coastline indicator. The rest of the study area varies between very low erosion values and high accretion values, with a maximum of 25 m/y recorded in the extreme south of sector A, south of the "Soleil" beach. As for Tagharte beach (Sector D), the maximum accretion of 1.1 m/y was recorded in the median part of the zone at roundabout level and the extreme north in the area in the shadow of Essaouira port, as also shown in Fig. 2-B, comparing the 1991 and 2020 lines.

These results highlight the absence of anthropogenic influence on the study area, whose changes depend on the natural components that drive the dynamics of the area, except for sectors C and D. In sector D, the influence of the proximity of the anthropogenic zone is remarkable, limiting the size of the beach-dune system and making it more vulnerable to the advancing sea.
As far as Tagharte beach is concerned, and in general and taking into account differences in the local geomorphological context, the results obtained are well below the maximum rates recorded on the sandy coasts of Morocco and Portugal, for example. Hind et al. (2017) recorded an average of 1.4 m/year in the Moroccan Kenitra coast, and, in Portugal, Bettencourt e Ângelo (1992), Pires et al. (2007), and Rocha et al. (2007), mentioned in their research values of coastline recession in Maceda of 12.5 m/year.

4. CONCLUSION

The research focused on examining the morphosedimentary dynamics of the sandy coast in Essaouira province, and it was conducted at both regional and local scales. At the regional scale, an analysis using DSAS was carried out by comparing aerial photos spanning from 1975 to 2020 to study long-term coastline dynamics. This allowed for an in-depth investigation of the coast's behavior over the past four decades and in local scale.
Sector A experienced the most pronounced maximum recession, with a retreat of 34m. Sectors D and E followed with recessions of 13m and 10m respectively. In contrast, sectors B, C, and F displayed smaller recessions, with sector C exhibiting substantial erosion near the rampart of Essaouira's old town when comparing aerial photos from 1975 and 2020. This erosion was observed during a field visit, where the rampart was found to be heavily damaged by waves, indicating the loss of a previously wide beach.
Six sectors showed an overall decline in the coastline indicator, while other parts of the study area exhibited varying levels of erosion and accretion. The southern part of sector A recorded the highest accretion value, reaching 25m south of the "Soleil" beach. Tagharte beach (Sector D) experienced a maximum accretion of 1.1m in its median and northern parts, particularly in the area near Essaouira port. Spatial analysis also revealed small erosion oscillations in certain cliffs in the southern part of the study area. These findings align with the results obtained from rock system modelling, indicating low accretion values along this particular stretch of coastline.
The results suggest that anthropogenic influences have had minimal impact on the study area, which appears to be relatively remote from human activities. The changes observed in the area primarily depend on natural components that drive its dynamics, except for sectors C and D. Sector D, in particular, shows a notable influence from the proximity of anthropogenic zones, leading to a reduction in the size of the beach-dune system and increased vulnerability to sea encroachment.

References

Baig, M. R. I., Ahmad, I. A., Shahfahad, Tayyab, M., & Rahman, A. (2020). Analysis of shoreline changes in Vishakhapatnam coastal tract of Andhra Pradesh, India: an application of digital shoreline analysis system (DSAS). *Annals of GIS*, 26(4), 361-376.

Bettencourt, P., & Angelo, C. (1992). Midwest coastal zone (Espinho-Nazaré): morphological framing and recent evolution. *Geonovas*. A Geologia e o Ambiente, 7-30.

Genz, A. S., Fletcher, C. H., Dunn, R. A., Frazer, L. N., & 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), 87-105.

Khouz, A., Trindade, J., Oliveira, S., El Bchari, F., Bougadir, B., Garcia, R., & Jadoud, M. (2022). Landslide susceptibility assessment in rocky coast subsystem of Essaouira coastal area–Morocco. *Natural Hazards and Earth System Sciences* Discussions, 2022, 1-37.

Lharti, S., Rodríguez, G. S. F., Daoudi, L., el Mimoun, A., & Ali, A. B. (2006). Morfologia y Sedimentologia del complejo playa/dunas costeras de Essaouira (Marruecos atlantico): Modelo de transporte costero. *Geomorfología y Territorio*: Actas de La IX Reunión Nacional de Geomorfología, Santiago de Compostela, 13-15 de Septiembre de 2006, 401–418.

Hind, A., Aïcha, B., Soufiane, H., Mounir, H., Tarik, B., Boko, M., & Bouchaib, M. (2017). Evaluating the impacts of sea-level rise on the Moroccan coast: quantifying coastal erosion and inundation in a Atlantic alluvial plain (Kenitra coastal). Episodes *Journal of International Geoscience*, 40(4), 269-278.

Nassar, K., Mahmod, W. E., Fath, H., Masria, A., Nadaoka, K., & Negm, A. (2019). Shoreline change detection using DSAS technique: Case of North Sinai coast, Egypt. *Marine Georesources & Geotechnology*, 37(1), 81-95.

Pires, A., Vinagre, A., Gomes, A. A., & Chaminé, H. I. (2007). Aplicação SIG ao Ordenamento do Território na frente urbana de Espinho: uma previsão baseada na análise histórica da dinâmica costeira: a prediction based on historical analysis of coastal dynamics. *Plublicações da Associação Portuguesa de Geomorfólogos,* Volume V, APGeom, Lisboa. p. 281-291

Quang, D. N., Ngan, V. H., Tam, H. S., Viet, N. T., Tinh, N. X., & Tanaka, H. (2021). Long-term shoreline evolution using DSAS technique: A case study of Quang Nam province, Vietnam. *Journal of Marine Science and Engineering*, 9(10), 1124.

Rocha, J., Ferreira, J. C., Simões, J., & Tenedório, J. A. (2007): Modelling coastal and land use evolution patterns through neural network and cellular automata integration. *Journal of Coastal Research*, SPEC. ISSUE 50, 827–831,

Simone, Y. C. (2000). *Le Géosystème Dunaire Anthropisé d'Essaouira-Est (Maroc atlantique): Dynamique et Paléoenvironnements.* [PhD Thesis]. Université de Provence-Aix-Marseille I.

Sytnik, O., Del Río, L., Greggio, N., & Bonetti, J. (2018). Historical shoreline trend analysis and drivers of coastal change along the Ravenna coast, NE Adriatic. *Environmental earth sciences*, 77, 1-20.

Thieler, E. R., Himmelstoss, E. A., Zichichi, J. L., & Ergul, A. (2009). *The Digital Shoreline Analysis System (DSAS) version 4.0-an ArcGIS extension for calculating shoreline change (No. 2008-1278)*. US Geological Survey.

Weisrock, A. (1980). Géomorphologie et paléo-environnements de l'Atlas atlantique (Maroc). Thèse d‟état, Paris I, 931 p.

Yasir, M., Sheng, H., Fan, H., Nazir, S., Niang, A. J., Salauddin, M., & Khan, S. (2020). Automatic coastline extraction and changes analysis using remote sensing and GIS technology. IEEE Access, 8, 180156-180170.

ORGANIZAÇÃO:

APGeom

Instituto de Geografia e Ordenamento do Território
UNIVERSIDADE DE LISBOA

APOIOS:

LISBOA
UNIVERSIDADE DE LISBOA

Fundação para a Ciência e a Tecnologia

CEG
Centro de Estudos Geográficos

GEOMORPHOLOGY
GEOMORPHOLOGIE

PUBLICAÇÕES DA ASSOCIAÇÃO PORTUGUESA DE GEOMORFÓLOGOS

ISBN: ????