Ocean and Coastal Management 163 (2018) 232–239

Contents lists available at ScienceDirect

Ocean and Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Multi-decadal assessment of shoreline changes using geospatial tools and automatic computation in Kenitra coast, Morocco

Mounir Hakkou[a], Mehdi Maanan[b,*], Tarik Belrhaba[c], Khalid El khalidi[d], Driss El Ouai[a], Aïcha Benmohammadi[c]

[a] Scientific Institute, University Mohamed-V, Rabat, Morocco
[b] Earth Sciences Department, Faculty of Sciences Ain Chock, University Hassan II, Casablanca, Morocco
[c] Earth Sciences Department, Faculty of Sciences, University Ibn Tofail, Kenitra, Morocco
[d] Earth Sciences Department, Faculty of Sciences El Jadida, University Chouaib Doukkali, Morocco

ARTICLE INFO

Keywords:
Shoreline evolution
Beach and dune erosion
Hazard mapping
Anthropogenic impacts
Geospatial technique
Spatial analyst

ABSTRACT

This study investigates a long-term process of shoreline change along the coastal stretch of the Kenitra coast using geospatial techniques and automatic calculations. A DSAS over a three quarter-centennial period of 78 years (1936–2014) was used. Measurements of shoreline variations were undertaken for three beaches aligned from North to South in Chlihat, Mehdia city, and Sidi Boughaba. The study reveals highly disparate results. Indeed, the maximum recorded coastal erosion/accretion kinematics are +4.7 m/yr, −3.2 m/yr, and −1.97 m/yr respectively for Chlihat, Mehdia and Sidi Boughaba beaches. Noteworthy, are the two 500 m parallel dykes established in 1932 that protect the inlet of the Sebou river stretching from the shore to the ocean. These coastal structures interrupt the long-shore sand movement resulting in accretion on the north drift side and erosion on the south drift side. In addition, the establishment of a dredging platform at the Sebou mouth, has considerably reduced the sedimentary stock, and generated negative impacts on coastal dynamics in the southern part (Mehdia and Sidi Boughaba beaches).

1. Introduction

Coastal zones provide important ecosystem services and high biological and ecological productivity, that have been traditionally the source of wealth for many municipalities that were mainly dedicated to the fishing and aquaculture industry. The beach acquiring great relevance as a place for rest and leisure. Since then, the coast has been subjected to an intense exploitation aimed at offering progressively more demanding tourist services (Rodríguez et al., 2009).

For coastal zone monitoring, shoreline detection of change in time is important. Genz et al. (2007) defined the shoreline as the position of the land-water interface at one point in time. Shorelines are dynamic and observed changes give an indication for either coastal erosion or accretion. Shoreline changes occur over a wide range of time scales from geological to short lived extreme events. These changes are mainly associated with waves, tides, winds, periodic storms, sea level change, and the geomorphic processes of erosion and accretion, as well as human-induced activities (Van and Binh, 2008). Shoreline position changes are considered one of the most dynamic processes in coastal areas (Boak and Turner, 2005; Mills et al., 2005; Maiti and Bhattacharya, 2009; Maanan and Robin, 2010). It has become in recent years, one of the major environment problems affecting the coastal zones worldwide. Indeed, nearly 80% of the world's coasts are eroding, with rates ranging from 1 cm/year to 10 m/year (Pilkey and Hume, 2001). Globally, qualitative and quantitative analysis of shoreline temporal and spatial variations has been subject of several earlier studies (Addo et al., 2011; Kabuth et al., 2013; Tahri et al., 2017; Thi et al., 2014; Murali et al., 2015; Moussaid et al., 2015; El-Sharnouby et al., 2015; Masria et al., 2015; Maanan et al., 2018; Bheeroo et al., 2016; Nandi et al., 2016; Kermani et al., 2016; Jonah et al., 2016a,b; Ozturk and Sesli, 2015; Guneroglu, 2015; Micallef et al., 2017; Neelamani, 2018; Ramakrishnan et al., 2018; Fang et al., 2017; Zuzek et al., 2003; Maiti and Bhattacharya, 2009).

Coastal areas are subject to a wide variety of phenomena, such as sea level variations, storm surges and wave energy, tidal inundations, tectonics and land subsidence, sediment budget changes and human activities that continually modify and play fundamental roles in coastal development and exposure risk to coastal erosion (Satta, 2014; ETC-CCA, 2011; Acciarri et al., 2016; El Mrini et al., 2012). Coastal erosion is associated with important environmental implications, often

* Corresponding author.
E-mail address: mehdi.maanan@univh2c.ma (M. Maanan).

https://doi.org/10.1016/j.ocecoaman.2018.07.003
Received 4 January 2018; Received in revised form 15 February 2018; Accepted 3 July 2018
0964-5691/

influencing hundreds of kilometres of shoreline. Coastal erosion represents a serious socio-economic problem not only at the local level, affecting the residents of coastal towns and the tourism industry, but also at the regional level, influencing potential regional progress due to significant economic losses, social problems and ecological damage (Aiello et al., 2013). An improved understanding of shoreline change trends is a necessary step for the environmental control and management of coastal areas (Mills et al., 2005; Addo et al., 2011; Ozturk and Sesli, 2015; Anfuso et al., 2013; Rangel and Anfuso, 2015).

Coastal construction, land reclamation, beach nourishment and port construction, all of which involve dredging, are increasingly required to meet the growing economic and societal demands in the coastal zone worldwide. In many cases, dredging operations affect not only the site itself, but also surrounding areas, through a large number of impact vectors (e.g. turbid plumes, sedimentation, resuspension, release of contaminants, and bathymetric changes) (Authority, 2011; Wolanski and Gibbs, 1992). Effects can be immediate or develop over a longer time frame and they may be temporary or permanent in nature. Consequently, most large-scale dredging projects require environmental impact assessments (EIAs) and active management when underway. The environmental and management issues associated with dredging and construction around ports and harbours have recently been reviewed and guidelines produced for monitoring, management, and mitigation (Anfuso and Del Pozo, 2005; Foster et al., 2010).

Mapping the shoreline with least percentage of error is always uncertain due to its variable and the dynamic nature, that are greatly influenced by the various short time effects like tides and long-term effects like the sea level rise. Thus, to calculate historic change rate of shoreline and predicting the change of the shorelines in future with greater accuracy is least possible. For the past seven decades the science of shoreline mapping had been changed, due to various technological advances (Addo et al., 2008).

In Morocco, a country with a long coastline that stretches on the Atlantic coast from Cape Spartel to Lagouira (≈3500 km), the coastal area contributes substantially to the economic development of the country. In 2000, already 50% of the Moroccan population lived on the coastal area, putting additional pressure and accelerating coastal degradation. Given this situation, we must expect a significant worsening of coastal degradation due to littoralisation phenomenon, that is the process of population and activities being concentrated on the coasts (e.g. increasing in populations, urbanization, development activities and industry).

Vulnerability to erosion hazard combined with human pressure motivated several researches on the regional sedimentary dynamics and evolution of the shoreline on the Moroccan Atlantic coast (Ahizoun et al., 2009; Hakkou et al., 2011, 2015; Tahri et al., 2017; Moussaid et al., 2015; Maanan et al., 2018). Remote sensing approaches provide a means for compiling shoreline positional information, which enables estimating historical rates of change. This study analyzes shoreline changes for a period of 78 years (1936–2014), using geographic information systems (GIS) and Digital Shoreline Analysis System (DSAS).

The main objective of this work is (1) to map and quantify the erosion and accretion areas, (2) to evaluate the long-term rates of shoreline changes along the Kenitra coast and (3) to assess the effect of anthropic activities on the coastal evolution, especially that of the dyke construction and dredging operations.

2. Study area

The sandy meso-tidal coast of Kenitra (10 km long) is located on the Atlantic Moroccan coast aligned about 30° on a North-South direction. The mouth of river Sebou has two jetties that extends approximately 500 m seaward from the low tide level shoreline subdivides this coasting into two sedimentary compartments, separated by a 500 m dyke stretching from the land into the ocean creating contrasting dynamics (Fig. 1). The Northern compartment, which includes Chlihat beach is characterized by a 300 m wide foreshore and a gentle foreshore slope of 1%. The Southern compartment which includes the beaches of Mehdia and Sidi Boughaba is characterized by a narrower foreshore (below 150 m) and steeper but still moderate slopes (3%–5%). The beaches are bordered by 5–15 m high eolian dunes with consolidated backing from 3 to 5 km. This configuration is essentially inherited from ecstatic sea level changes that have shaped a wide continental shelf during the Upper Pliocene (Aberkan, 1989). The morphodynamic of these beaches which sediment grain size is ranging between 200 and 370 μm is intermediate in the south and dissipative in the north (Hakkou et al., 2011).

The Sebou River discharges large quantities of sediments at a rate of about 9.106 T/year (Snoussi et al., 2002). But this discharge use to be much higher (ca. 34 109 T $year^{-1}$ observed from 1940 to 1970), prior to the construction of several dams upstream of the Sebou river inlet to supply drinking and irrigation water (Snoussi et al., 2002). This constitutes a major loss of sediment supply to the Kenitra littoral system at the exit of the river. Sediments flow symmetrically spread to the northeast and to the southwest (SOGREAH, 2011).

The Kenitra coast is exposed to high-energy waves traveling roughly from the NW sector, which is generated by W–E tracking subpolar, deep, low-pressure systems over the North Atlantic Ocean and are therefore strongly seasonally modulated. Substantially higher waves are observed during the December–March winter period. The significant wave heights can exceed 8 m during severe storms (Hakkou et al., 2011). According to SOGREAH (2011), velocities of wave-induced currents are between are between 0.15 m/s and 0.25 m/s for an average annual swell (Hmo = 1.96 m), and can reach 0.5 m/s for a strong swell (Hmo = 4.5 m). The tide is of meso semi-diurnal type (Idrissi et al., 2004) with a tidal range of 2.2 m on average, which can vary from 0.9 to 3.5 m during neap and spring tide, respectively. Prevailing winds are westerly (56%), particularly during the summer period, while northeasterly winds are observed during winter (SOGREAH, 2011).

The mouth of the Sebou is extended by two parallel walls built in 1932 which extremities are at −7 m ZH depth. These dikes which are 500 m long seaward were extended by 50 m in 2007 following a severe storm in 2003 that damaged the pier head (SOGREAH, 2011).

The navigation channel is maintained by dredging. The volume extracted annually at the entrance and inside the mouth are on average 460,000 m^3 (SOGREAH, 2011). Besides, the dredging of the sand dunes north of Chlihat beach (ca. 4.106 m^3/year) furthered the erosion process (Ahizoun et al., 2009).

3. Materials and methods

Shoreline evolution can be assessed by different analytical methods. The interpretation of aerial photographs and satellite images, map analysis (topographical, bathymetric, geological), field surveys and interviews of local people are all sources of information to study the shoreline over relatively large timescales (Grenier and Dubois, 1990). In this paper, the study of the shoreline mobility is established firstly by iconographic analysis using old and recent topographical maps representing a period between 1936 and 2005. Secondly, treatment of aerial photographs from 2002 to 2010 and a shoreline survey by GPS in April 2014 provided recent trends explained by natural and anthropogenic factors (Table 1).

The treatment of images was conducted by means of geometric correction of aerial photographs using polynomial georectification and the choice of a reference line, digitization of the shoreline and estimation of errors, and determination of shoreline rates of change (Durand, 2002; Moore, 2000; Dehouck, 2006; Hughes et al., 2006; Kumar et al., 2010; Maanan et al., 2014; Moussaid et al., 2015; Avinash et al., 2013; Maanan et al., 2013, 2015). These steps were carried out by using ArcGIS Version 10.2 developed by ESRI, using the Lambert Conformal Conic Zone 1 Datum Merchich Spheroid Clarke 1880 projection.