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Impact of Human Interventions on the Morphological Evolution of the Offshore bars System of Coastal Nador Barrier Island.

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Abstract

The coastline of the Nador barrier island is a microtidal and high energy environment characterized by a well-developed system of offshore bars presenting a variety of morphology in interaction with the environmental characteristics and human interventions on the site.

This study, based on field observations and interpretation of aerial photographs helped to show the relationship between human interventions and the morphological evolution of the offshore bars system of the Nador barrier island.

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Introduction

Offshore bars represent the main expression of changes in hydrodynamic processes and sediment transport. They provide a natural protection against erosion and marine submersion. Indeed, the offshore bars represent stocks of sediments, which make them a central element in the functioning of the beach [1-2]. Consequently, the morphological evolution of offshore bars may influence the whole of the sedimentary and hydrological processes of the coastal environment [3]. Thus, some part of the current research on coastal environments focuses on the identification of links between the states of beaches, the morphological changes of offshore bars and environmental parameters. However, current knowledge on the impact of development on coastal offshore bars is very limited. Most of the works are coastal engineering studies which focused on modeling currents and sediment transport in the vicinity of ports with the aim of avoiding the accretion of the outer harbour [4- 5- 6- 7- 8].

The coastline of Nador barrier island is characterized by its high wave-energy and the dominance of a microtidal tidal range. This coastline is characterized by a well-developed offshore bars system in continuous interaction with changes in hydrodynamic parameters, sedimentary flows and human interventions on the site (installation of jetties, urbanization, harbour construction, etc.). These latter have an impact on the morphology and organization of offshore bars system at the site. The aim of this original paper is to show the impact of human interventions on the evolution of the offshore bars system of Nador barrier island.

Study area

Nador lagoon is considered as the largest lagoon of Morocco with a surface of 115 km^2 and a bathymetry which doesn't exceed 8 m in its central part. It is separated from the Mediterranean Sea by a barrier island of 25 km and an average width of 400 m, which reaches approximately 2 km on its SE part. Its overall altitude is very low, except on the central part

where it reaches approximately 20 m. This barrier is marked by many washover fans due to storm waves [9- 10- 11- 12].

The water exchanges between the lagoon and the Mediterranean Sea are currently provided by a single artificial inlet opened in 2011. Marks of at least five relic inlets and inlet A stabilized in 1993 can be noticed on the barrier island. This suggests that the position of the active inlet has often varied over the time [9- 11- 12] (Fig.1).

The hydrodynamic regime of Nador Bay coastline is microtidal. In high tide, the tidal range doesn't exceed 0.50 m at Melilla and 0.35 m at the entrance of Nador lagoon [13]. This hydrodynamic regime is dominated by swells from NE to ENE and W to NW and by violent storm waves [9- 11- 12- 14]. The frequency and characteristics of waves have been reconstructed from the wind data. Theoretical calculations lead to periods of 7 to 11 s and amplitudes of 5 m (annual maximum) to 7.5 m (exceptional maximum) [15].

Currently, this part of the Mediterranean coastline of Morocco experiments a significant socio-economic development with the MarchicaMed project which aims to develop seven touristic sites on the whole of the Nador lagoon system.

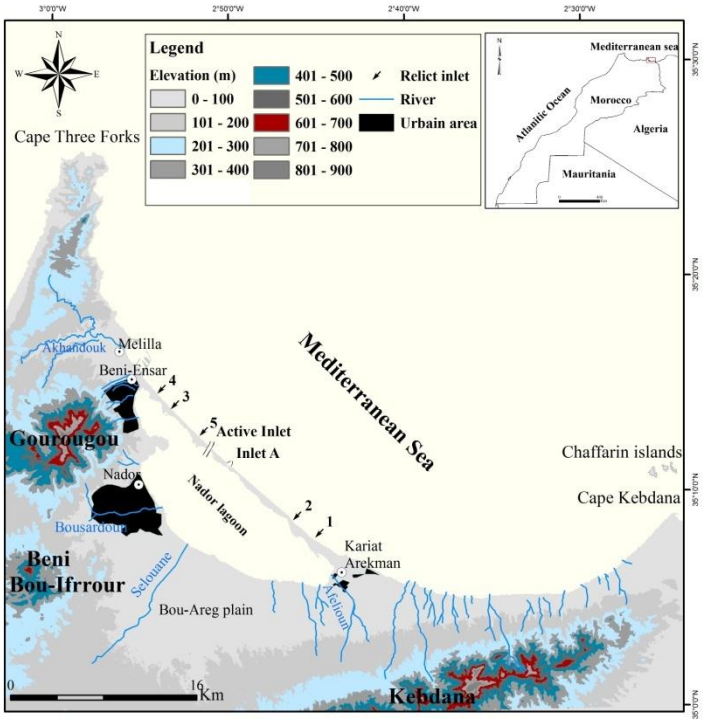

Fig. 1 Location map of study area

Materials and methods

To study the functioning and evolution of coastal ecosystems, one can proceed by regular field monitoring or geo-historical study through comparison of old and new maps, or aerial photos [16-17]. The present study is based on field observations and interpretation of aerial photos taken before and after human interventions (1958 (1/50000), 1988 (1/40000), 1995 (1/20000), 2003 (1/30000). These aerial photographs were geo-referenced to the 1/50000 topographic map of Nador using the Arc Gis 9.3 software.

Results and discussion

1. Initial State of System

Aerial photographs are very popular in the study of the dynamics of evolution of offshore bars system. An analysis of some aerial photographs taken between 1958 and 1988 before human interventions on Nador barrier island coastline shows the presence of a system of linear offshore bars on a distance of 25 km (Fig.2). The presence of a well-developed offshore bars system on the coast of Nador barrier island at that time can be explained by the abundance of sedimentary flows from rivers and cliffs erosion at its NW and SE extremities. This first description corresponds to the initial state of the system before human interventions.

2. *Evolution of System after the Stabilization of Inlet* A

The analysis and interpretation of some aerial photos taken in 1995 after the stabilization of the inlet A by two jetties (a jetty of 350 m at NW and a jetty of 657 m at SE), show that the morphology of the offshore bars system on both sides of these jetties has changed from linear to crescentic (Fig.3). It should be noted that, the offshore bars system has almost completely disappeared when one moves away from the SE jetty of the inlet. However, the system returns to its original morphology (linear morphology) when on moves away from the NW jetty of the inlet (Fig.4).

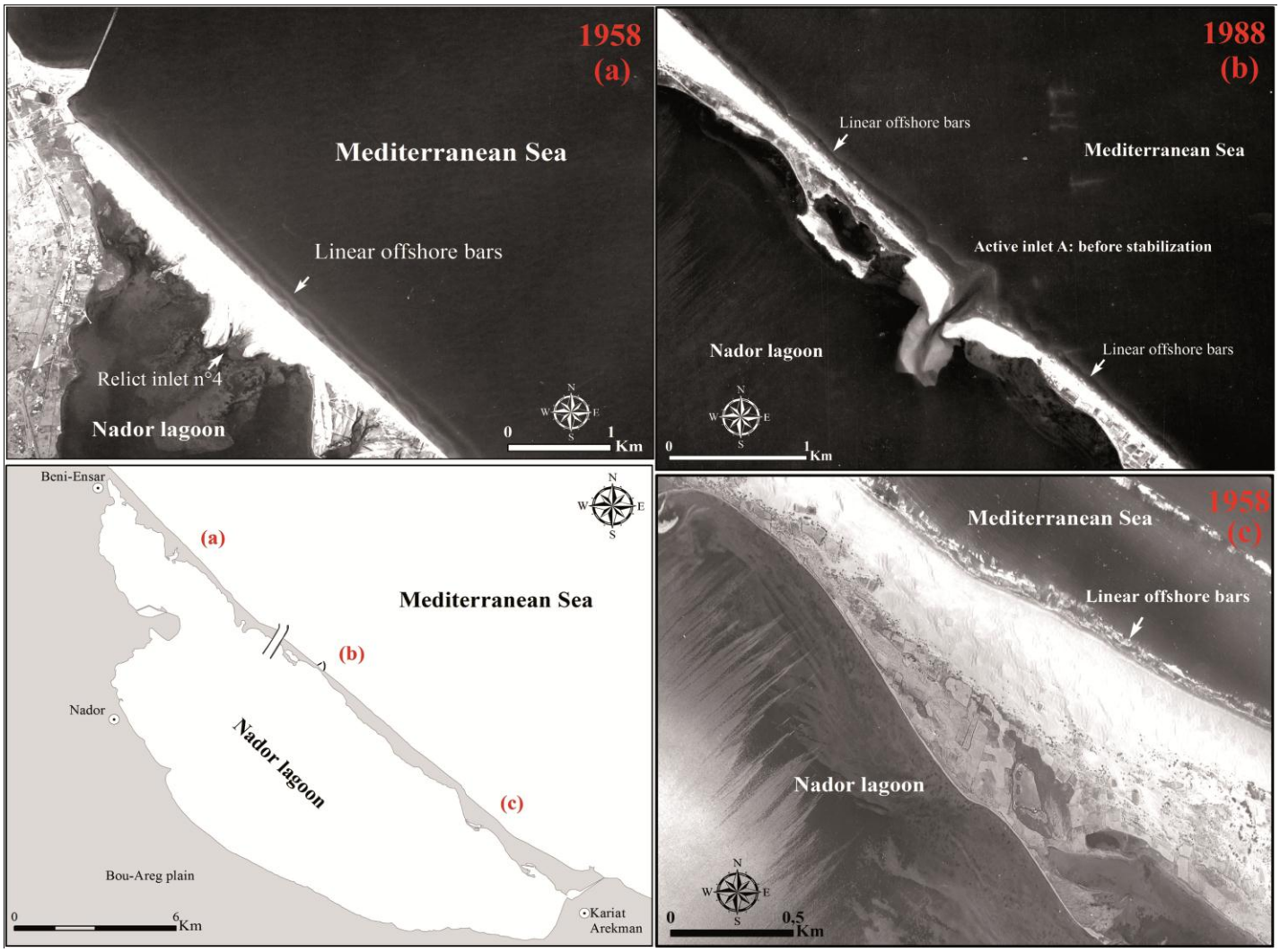

Figure 2: Aerial photos show initial morphology of offshore bars system of Nador barrier island

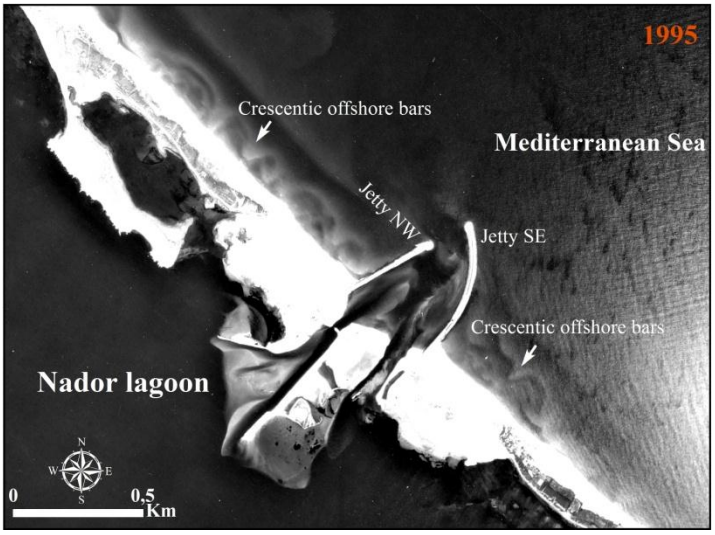

Figure 3: Aerial Photo shows crescentic morphology of offshore bars system of Nador barrier island after stabilization of inlet A

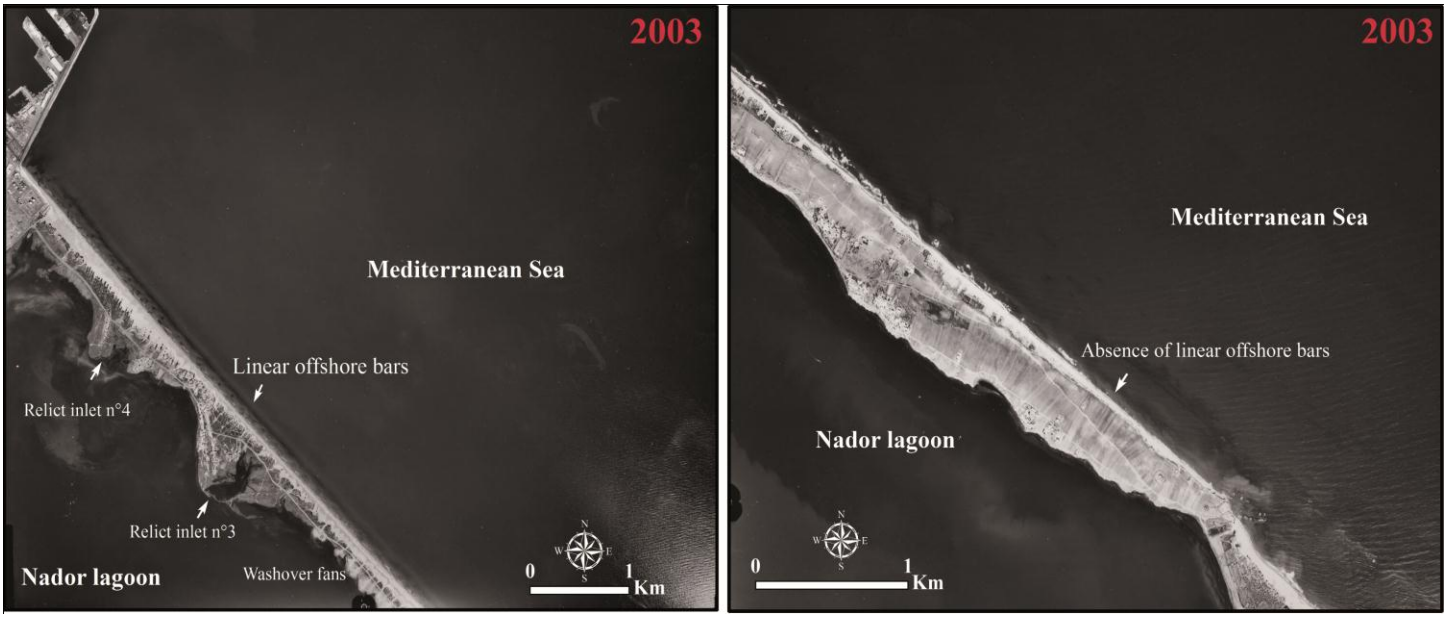

Fig 4: Aerial Photos show evolution of offshore bars system of Nador barrier island after human interventions

Morphological changes observed in the offshore bars system at the coastline of Nador barrier island after stabilization of the inlet A can be explained by a change in the currentology and important changes in sediments supply.

Note that all the studies on the dynamics of offshore bars show that hydrodynamic changes, sediment supply changes and human interventions are the main causes of morphological changes of offshore bars system [18- 19- 20- 21- 22- 23- 24].

At the coastline of Nador barrier island, the appearance of the crescentic morphology of offshore bars on both sides of the jetties of inlet A is due to the formation of rip currents against the jetties.

The disappearance of the offshore bars system far from the SE jetty is probably due to a decrease in sediment supply caused by stabilization of inlet A and coastal urbanization of Kariat Arekman coastline. Indeed, NW jetty blocks the sedimentary transit NW-SE [9- 11- 12]. In addition, multiple buildings at this coastline prevent the sedimentary exchanges between watersheds, barrier island and the beach. This is confirmed by the disappearance of the offshore bars and submersion of several houses at the coastline of Kariat Arekman [9- 11- 12] (Fig.5). It should also be noted that, the SE coastline of the Nador barrier island is characterized by powerful storms capable of transporting the sediment to out sea [9].

The restoration of the balance of the offshore bars system (linear morphology) in NW side is due to the presence of sediment supply and the presence of hydrological conditions favoring the construction of offshore bars.

Fig 5: An example of beach erosion caused by urbanization in Kariat Arekman.

Conclusions

Human interventions in coastal areas have an important influence on sediment transport, hydrodynamics and consequently the morphology of beaches and offshore bars system.

The results of this study clearly show the impact of human interventions on the dynamics and morphology of offshore bars system. These interventions can create significant changes in the currentology as shown by the important rip currents visible at the jetties of the inlet A. These results also show that the evolution of the offshore bars system is in dynamic equilibrium with the natural dynamics of the

environment. Thus, any intervention on the system must take into account not only this dynamics but also the fact that this zone is currently subject to several development projects.

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