Change detection and environmental impacts assessment of Tabarka coastal area - North Western of Tunisia

Nabila Halouani(*) , Alberto Marini(**) and Moncef Gueddari(*)

(*) Faculty of Sciences of Tunis, Geochemistry and Environmental Geology laboratory, Campus universities, Tunis 2092, Tunisia. E-mail: nabila.fst@gmail.com
(**) Cagliari University - Earth Sciences Department, "TeleGIS" Laboratory, Via Trentino, 51- 09127 Cagliari – Italia e-mail: marini@unica.it

Riassunto:
La protezione delle aree costiere è una parte vitale di tutti i programmi per uno sviluppo sostenibile: anche in Tunisia i litorali sono soggetti ad una erosione progressiva a lungo termine, che minaccia il patrimonio naturale e culturale. L'erosione litoranea deriva da una combinazione di vari fattori, sia naturali che di natura antropica, basati su modelli che si evolvono nello spazio e nel tempo in maniera differente. La costa di Tabarka, inserita nel litorale tunisino nordoccidentale, presenta un'alternanza di promontori rocciosi e di spiagge sabbiose. Anche se non ancora molto urbanizzato, questo litorale è tuttavia soggetto a degradazione ed a modifiche, particolarmente lungo la line di costa, con erosione significativa in alcuni tratti. Questa ricerca è volta all'analisi dello sviluppo della linea costiera ed alla valutazione del potenziale cambiamento, applicando tecniche di telerilevamento ad una serie di foto aeree e di immagini multitemporali da satellite (Landsat e Quickbird). Lo studio analizza l'intensità delle correnti litoranee ed i tassi di evoluzione della linea di costa col desiderio di fornire un riferimento utile per favorire le autorità locali nelle decisioni circa la gestione futura della fascia costiera. Con la costruzione del porto di Tabarka è stato distrutto l'equilibrio dinamico del litorale ed è stato indotto un significativo cambiamento nell'insieme geomorfologico costiero. L'impostazione delle strutture portuali ha generato da una parte una dispersione del trasporto sedimentario e, da un lato, la diretta modifica della diffrazione delle onde provenienti dal NW. L'interruzione del trasporto costiero causato dal porto di Tabarka può anche innescare l'erosione della spiaggia di El Morjene. Le cause principali per l'erosione delle spiaggie sono da collegare agli attacchi di onde eccezionali, all'asporto di sabbie per costruzioni e all'aumento dell'urbanizzazione costiera.

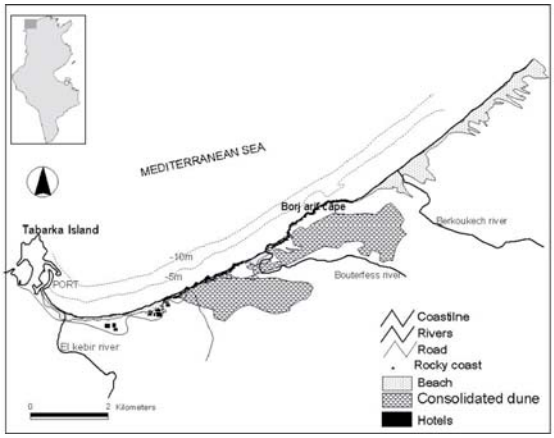

Figure 1: Location map of study area

Abstract:
Protection of marine coastal regions is a vital part in any coastal management program for sustainable development. The Tunisian coasts are subject to long term progressive erosion, which threatens the natural and cultural heritage. Coastal erosion results from a combination of various

factors – both natural and human induced – which have different time and space patterns and have different nature.
The Tabarka coast littoral is a part of the north-western Tunisian coast. It presents an alternation of rocky coasts and sandy beaches. Although not yet very much urbanised, this littoral is still subject to degradation and modification, especially along its shoreline, with significant coastal erosion in some places.
This research aims at applying coastline evolution monitoring and its potential change estimation by applying remote sensing techniques and using multi-temporal satellite images (Landsat and Quickbird). The objectives of the study are measuring and estimating the coastal current hydrodynamics, coastline evolution rates and providing useful reference for the local authorities to make decisions for their future coastal management.
Since the construction of Tabarka Port, the coast dynamic equilibrium has been destroyed and thus a significant littoral geomorphologic change has occurred, which has produced a severe degradation of the littoral and urban environment.
Indeed the implantation of the port generated on one hand a disturbance of the sedimentary transit and, on the other hand, the modification of wave diffraction coming from NW. The interruption of the longshore sediment transport by the construction of the Tabarka Port may also cause the erosion, especially for El Morjene Beach.
The main causes for beach erosion are due to the attacks by strong waves, the interception of sediments by engineering structures (Tabarka Port) and the increase of coastal urbanization.

Introduction
Coastal zone monitoring is an important task in sustainable development and environmental protection. For coastal zone monitoring, coastline extraction at different moments is key; coastline, which has a dynamic nature is one of the most important linear features on the earth's surface (Winarso, *et al.,* 2001).
The coastal areas are currently experiencing intense and sustained environment pressures by a range of driving forces which have been increasing in their intensity over many decades.
The Tunisian coasts are subject to long term progressive erosion, which threatens the natural and cultural patrimony. Beach erosion is often caused by a combination of natural and anthropic factors. The Tabarka littoral is a part of the northern Tunisian coast that is still subject to degradation and modification, especially along its shoreline, with significant coastal erosion in some places. (Paskoff, 1992 and Oueslati, 1994).
Aerial photos are an important and widely available source of information for change detection studies along the Tabarka coast. In general, change detection involves the application of multi-temporal datasets to quantitatively analyse the temporal effects of the phenomenon (Lu et al. 2004).
This paper aims at identifing the major factors responsible for the sedimentary dynamics of the Tabarka coast and its shoreline changes by analysing aerial photography taken in 1963, 1989 and 2001.

Study area
The Tabarka littoral is a part of the north-western Tunisian coast. It extends from Tabarka Port in the west to the mouth of the Berkoukech River in the east (Figure.1). The shoreline morphology, dominated by a wide sandy beach and interrupted by rocky headland, is characterised by the existence of several hard rock outcrops.
The Tabarka coast is 15 km long and the beach is between 30 m and 140 m wide. In the western part of the study area, the back-shore of the beach is limited by urban infrastructure. The beach is straight and open, and the bathymetric offshore contours are almost parallel to the shoreline. An offshore island called Tabarka Island is located at 0.5 km from the coastline and nowadays, the island is connected to the continent by artificial urbanisation. The near-shore slope is around 1,4 %

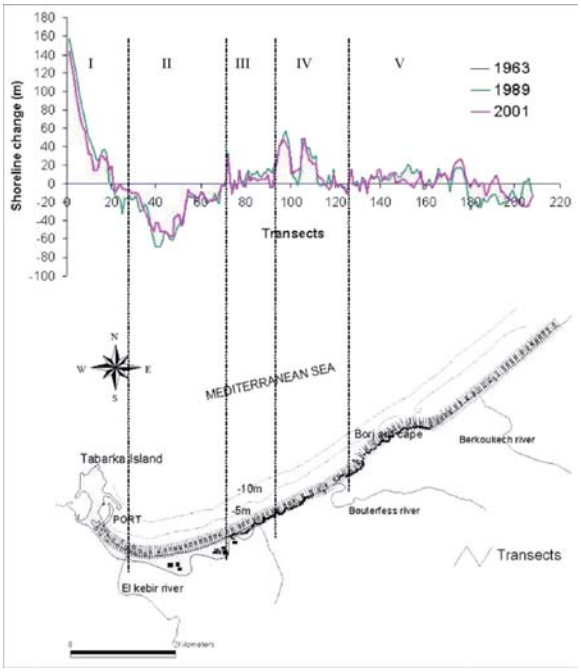

Figure 2. Shoreline change between 1963, 1989 and 2001

with the 5 m depth contour (at an average distance of 350 m from the shoreline), and 1,5 % with the 10 m depth contour (at a distance of about 700 m from the shoreline).

Waves are the main hydrodynamic process along the Tabarka coast, as the maximum tidal variation is less than 0,6 m. The most frequent wave directions occur within the range NE and NW. The estimated annual storm wave heights vary between 4,6 m and 8,3 m and the wave periods are from 11, 2 sec to 13, 5 sec (HP, 1995).

The north-eastern and north-western waves approach the coast respectively with an angle of incidence of 35 and 55 degrees (HP, 1995). The north-eastern waves prevail and are mainly active and more frequent during summer and spring. As eastern waves have higher energy, the net longshore sediment transport is to west (BCEOM/STUDI, 1981).

Sediment supply occurs as a result of longshore drift from eroding headlands, cliffs and other coastal formations (including other beach zones and dune systems), as well as by fluvial sources such as rivers and valleys, and directly via the seabed. El Kébir, Bouterfess and Berkoukech rivers and their tributaries are the main rivers to supply sediments to the sandy coast of Tabarka.

Materials and methods

The space-time evolution of the Tabarka coastline was studied by *GIS* (*Geographic Information System*) using the aerial photographs taken in 1963, 1989 and 2001. The aerial photographs of 1963 and 1989 were georeferenced, orthorectified and assembled by the *ARCMAP GIS* in projection UTM Zone N32 Datum Carthage.

The shoreline change in Tabarka is analysed using the *ARCVIEW* extension entitled *DSAS* (*Digital Shoreline Analysis System*) suggested by the *USGS* (Thieler and al. 2005). A straight, approximately shore-parallel baseline is drawn land-ward of the shoreline. The software creates equally-spaced transects along the baseline and calculates at that location the distance from the baseline for each year shoreline. The software outputs are perpendicular transects of a length and interval specified by the user. The software provides the transect number, the distance from the beginning baseline to each transect, and the distance from the baseline to each digitised shoreline in an attribute table. The attribute table is exported to a spreadsheet, and the distances of the digitised shoreline from the baseline are used to determine the rates of change.

209 transects were created at 50 m along the shoreline and were used to calculate the average annual rate of shoreline change. The largest shoreline position errors were errors of +/- 9 meters (Figure 2).

The thematic map revealed portions of the coastline with positive change seawards (coastline accretion) depicted in green colour and areas of negative changes (coastline erosion) shown in red (Figure 3 and 4). The basic GIS operation we carried out on the thematic map was to extract the identified areas of changes along the coastline, vectorize them into independent polygons and

calculate their areas. The areal information indicate the spatial change (erosion or accretion) within a specific area of interest along the coastline.

Results

The analysis of aerial photographs was used to study the shoreline changes along the Tabarka coast for the years between 1963 and 2001. The variations of the coastline are analysed from 209 profiles drawn perpendicular to the shore.

The Tabarka coast can be divided into five main sections on the basis of beach morphology, morphological behaviour and wave characteristics:

Zone I: El corniche Beach

The first zone comprising El Corniche Beach (P2 to P19) is located between the Tabarka Port and El Kebir River mouth; its shorelines had advanced about 25 to 160 m, at the rate of 0,9 m to 6 m/year between 1963 and 1989, while this zone shows a retreating of its shoreline about 1 to 22 m at the rate of 0,1 to 1,8 m/year between 1989 and 2001 (figure 2).

Zone II: The El Morjene Beach

The second zone situated between El Kebir River mouth and El Morjene Hotel (P20 to P68) had experienced a retreat of more than 69 m in the touristic area between 1963 and 1989, with the rate of 2,7 m/year, but in the 1989-2001 period, the El Morjene Beach has prograded around with an accretion rate of 2,3 m/year (figure 2).*Zone III: Rocky coast*

A third zone located between profiles 69 to profile 78 is characterized by rocky coasts which have been relatively stable during the periods of study.

Zone IV: Bouterfess Beach

A fourth zone, (P79 to P114) comprising Bouterfess Beach, is marked by the sediment input from Bouterfess River (fig.4d). Bouterfess Beach has experienced accretion of about 0,4 to 2, 2 m/year between 1963-1989 periods, or a relative stability in the period 1989-2001.

Zone V: Berkoukech Beach

This zone situated between Borj Arif Cape and Berkoukech River mouth, (P114 to P209) is characterised by developed dunes (Figure 1). The most significant erosion in Berkoukech Beach occurs at the east of Berkoukech River, its shorelines had retreated about 3,76 to 28/ 45 m, at the rate of 0,14 m to 1,09 m/year between 1963 and 1989, while this zone shows a slightly accretion of its shoreline between 1989 and 2001.

Discussion

The coastline variation along the Tabarka coast shows five littoral cells characterised by accretion-erosion-stability-accretion-erosion respectively.

From 1963 to 1989, the accretion recorded in the Tabarka Port (zone I) suggests an interception of a part of the sediment. The progradation of Bouterfess Beach can be explained by the sediments transported from the erosion zone (El Morjene Beach) eastward by the littoral current. This longshore drift repulsed the Bouterfess mouth against the Borj Arif Cape.

From the El Kebir river mouth (divergence point) the sand moves east towards Borj Arif Cape and west towards the Tabarka Port, where the sediments are stopped by jetties.

The shoreline of zone III was not significantly modified; it indicates an equilibrium state. The hard rock outcrops which advance in the sea in this zone probably are playing a role in the stabilisation of this shoreline.

The erosion observed in Berkoukech Beach indicates that along-shore sediment transport is directed to East. The dune destruction caused by the airport construction accelerates the phenomena of erosion.

The accretion recorded at El Corniche Beach between 1963 and 1989, is induced by the construction of the new Port of Tabarka during the 1966-1970 period (HP 1995). Indeed the implantation of the port generated on one hand a disturbance of the sedimentary transit and on the

other hand, the modification of wave diffraction coming from NW.To protect the port, a pier length 557 m has been implemented as solution; however it does not stop completely the sediment transport from East to West (BCEOM/STUDI, 1981).

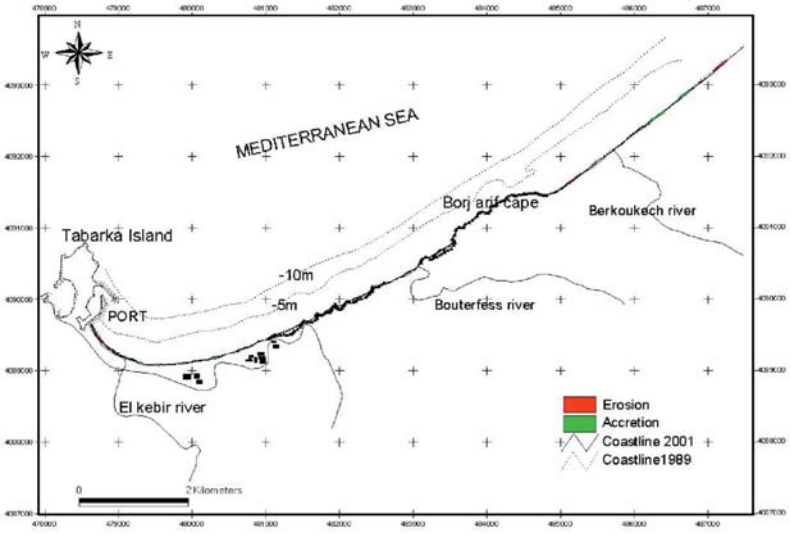

Figure 3: Erosion and accretion areas along the Tabarka coast between 1963 and 1989

The The erosion mentioned on the El Morjene Beach (Figure 3) is notably due to the exposition to NW and NE waves and the fore-dune destruction. El Morjene Beach is the most urbanised zone, therefore beach erosion will probably continue in the following years, with the increasing of coastal urbanisation.

The accretion of the Bouterfess Beach can be linked to its morphology: is it limited by two hard rock outcrops rocks, or is its situation due to the fact that it is in a divergence zone of the waves, or to the contributions of the fluvial sediment input from Bouterfess River mouth and to the sediments brought by westward littoral drift?
The small erosion of El Corniche Beach that occurred between 1989 and 2001 (figure 4) can be attributed to the new physical constraints imposed by the Tabarka Port.
The blockage of longshore sediment transport by the construction of the Tabarka Port may also cause the erosion, especially for El Morjene Beach.
Between 1989 and 2001, the shoreline might have reached an equilibrium state that would not change too much under the regular wave conditions along Tabarka.

Conclusion
The recent coastal evolution of Tabarka littoral, estimated from the aerial photography (1963, 1989 and 2001), has permitted to evaluate the spatial-temporal variability of its shorelines which took place during the last 39 years.
The results have shown a zoning of this coastal fringe, according to the stability, retreating or accreting shorelines. Five zones have been identified: El Corniche Beach, El Morjene Beach, rocky coast, Bouterfess Beach and El Berkoukech Beach.
The coastal evolution analysis shows a general trend of beach erosion along the Tabarka littoral. The El Morjene Beach is characterized by the major erosion trend, and by westward littoral drift, as shown by El Corniche Beach accretion.

El Morjene Beach is the most exposed beach to waves action; consequently it presents a clear erosive process. On the contrary, the El Corniche Beach and Bouterfess Beach show low accumulative rate. Therefore, a main westward and a secondary eastward longshore transport can be defined to explain the behavior of these beaches.
The main causes for beach erosion includes the attacks by strong waves, so wave action controls where erosion and deposition occur along the coastline, the interception of sediments by engineering structures (Tabarka Port) and the increase of coastal urbanization.

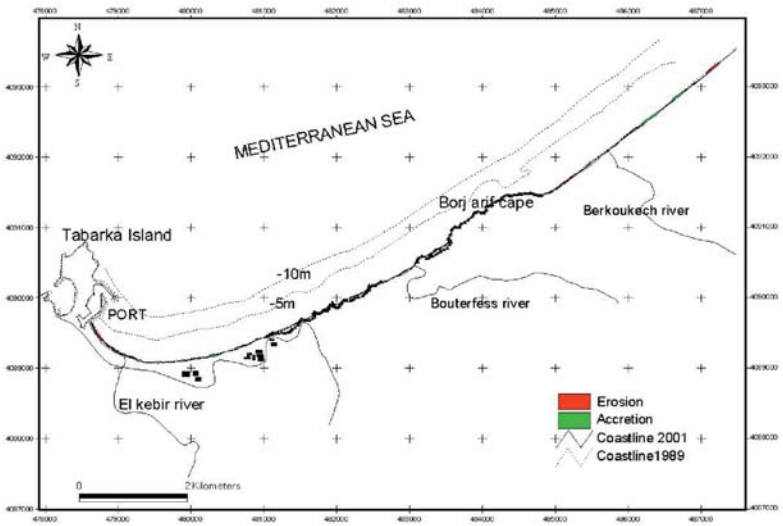

Figure 4: Erosion and accretion areas along the Tabarka coast between 1989 and 2001

References

BCEOM/STUDI. (1981). Etude de l'extension des ports de pêche de Tabarka et Kelibia, problèmes de transit littoral et de sédimentation. 20 p .

HP (Hidrothecnica Portugesa) (1995). Etude générale pour la protection du littoral tunisien. *Rapport I-II-III-IV et V, Ministère de l'Equipement Tunisien*, 300 p.

Oueslati, A., (1994). Les côtes de la Tunisie, recherches sur leur évolution au Quaternaire. *Doctorat Es-Sciences, F.L.S.H.T.,* 402p.

Paskoff, R., (1992). Eroding Tunisian beaches: Causes and mitigation. *Bollettino di Geofisica Teorica ed Applicata,* 10, 2-4, 85-91.

Thieler, E.R., Himmelstoss, E.A., Zichichi, J.L., Miller, T.L., (2005). Digital Shoreline Analysis System (DSAS) version 3.*0;* An ArcGIS extension for calculating shoreline change. *U.S. Geological Survey Open-File Report 2005-1304 (http://woodshole.er.usgs.gov/project-pages/dsas/)*

Winarso, G., Budhiman, S., (2001). The potential application of remote sensing data for coastal study, *Proc. 22nd. Asian Conference on Remote Sensing*, Singapore.