Granulometric Indices Mapping in Relation to Hydrodynamic Factors for Beach Characterization and Monitoring with Very High Spatial Resolution

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***Abstract*—The objective of this article is the spatiotemporal monitoring of coastline and beaches in relation to hydrodynamics and sediment dynamics. Since the study area is local, it is important to carry out a very high spatial resolution study. To achieve our goal we used satellite images with a spatial resolution of 0.2 m on the one hand and the high-resolution SWAN model on the other hand. We have transformed satellite images into coastlines. For the diachronic study we used ArcGIS to create a mosaic of images, to rectify these mosaics and to calculate the distances separating the coastlines taken on different dates. We observed the presence of erosion/accretion on several beaches. This evolution can be explained by the effect of the maritime structures and the contributions of the wadis. Wave energies are distributed unevenly along the coast due to the bathymetry of the area and the orientation of the coastline. The study of the sedimentary dynamics based on the granulometric study of the surface sediments and the extrapolation of the different granulometric indices under ArcGIS allowed us to show the distribution of different sedimentary facies on the surfaces of the studied beaches. We noticed a concordance between the distribution of wave energies and the evolution of the coastline. On the other hand, the combination of the results obtained and the granulometric analysis allowed us to explain the distribution of sedimentary classes.**

***Keywords*—Beaches, Coastline, Hydrodynamics, GIS, Granulometry**

I. INTRODUCTION

Resilience capacity of beaches make that there is an alternation between erosion and fattening allowing beaches as much as possible to be rebalanced [1]. The coastline is dynamic that is undergoing frequent short and long term evolutions caused by hydrodynamic changes, geomorphological changes and other factors [2]. In addition to the variability of natural phenomena, the structures that develop there directly affect the coast through changing its shoreline and direction [3]. To all these actions can be added the degradation of the dunes bordering the coast due to the extension of tourist and seaside urbanization at their level and the disturbance of sedimentary transit following port developments and the installation of protective structures [4]. For understanding the spatio-temporal evolution of the coastline, it became obvious the recourse to satellite images. For this part, we have been interested in answering the following question: What is the contribution of very high resolution remote sensing for the diachronic study of beaches and coastline kinematics?

The present contribution is with a view to territorial planning and sustainable development of this coastal zone. It is based on the combination of coastline kinematic study and beach evolution using very high-resolution remote sensing data and GIS, as well as very high-resolution hydrodynamic modelling using the SWAN model. Then, the coastline of these regions is under increasing anthropic pressure, in particular due to sedimentary inputs from the wadis and fattening following the installation of protective structures. For this purpose, this work also aims at determining these negative impacts on the sediment dynamics and the natural equilibrium of the two beaches khaloufi and corso based on the granulometric characterization of the superficial sediments, including the factors that control the sediment dynamics in relation to their size and their spatial repartition. In trying to answer the question: Is it possible to characterize the sedimentary facies by extrapolation of the different granulometric indices on the beach surface?

II. STUDY AREA

The study area is spatially located between longitudes 2°20'00"E in the west to 3°50'00"E in the east. It includes: Zemmouri Bay, Algiers Bay, the rocky coastline, El Djamila Bay and Bou Ismail Bay. Given the extent of the study area and the large mass for the output results, we have mapped these results by coastal commune (Fig. 1). This paper is aimed at deepening our knowledge of two regions, one to the east and the other to the west of the study area, in terms of coastline retreat and advance, their response to changes in hydrodynamic conditions and to estimate the impacts of developments on the beaches' morpho-sedimentary aspects.

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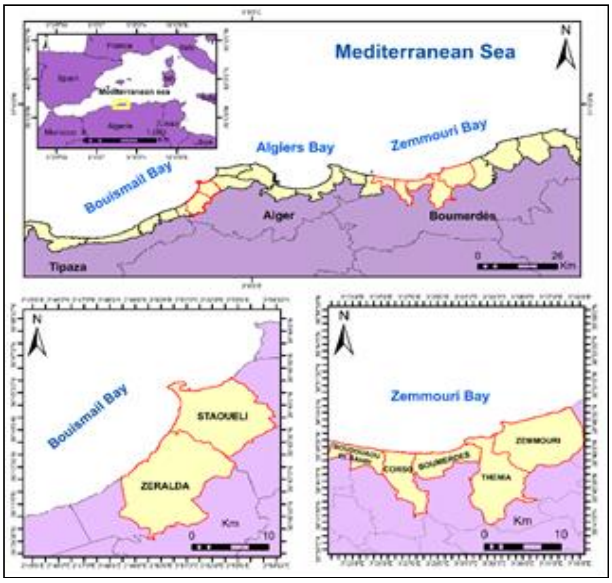

Fig. 1. Geographic location of the study area.

A. Selection of sampling sites for granulometric analysis

We have chosen two beaches that are targets of both erosion and accretion phenomena. So, the khaloufi beach located at Bou Ismail bay and the corso beach located at Zemmouri bay were analysed to verify the consequences of coastal evolution on the dispersion of the superficial sediments of these beaches as they show an evolution over a temporal series between 2002 and 2019 according to the very high resolution diachronic study.

B. Field trips

The fieldwork, carried out during the year 2019, consisted of taking 54 GPS-assisted superficial sediment samples from each beach. The samples were taken in a precise manner using radials oriented perpendicular to the shoreline. The length of Khaloufi Beach is 800m and is the same for Corso Beach. The spacing between two juxtaposed radials is about 50m and the spacing between three successive samples on the same radial depends on the width of the beach. (Fig 2, 3)

Fig. 2. Location of sampling points for khaloufi beach.

Fig. 3. Location of sampling points for Corso beach.

III. Methodology

A. Database

The present work proposes to realize a coastal erosion cartography for the monitoring of coastal dynamics at a precise scale. Then it is necessary to have appropriate tools for data acquisition, their processing and their analysis.

Our objective consists in creating a database of very high-resolution satellite images covering the entire study area.

Several sources of satellite images can be exploited to extract the shoreline, for this study we have chosen to work on Google Earth Pro images. This is an open-access software offering an image historical record over seventeen (17) years or so of very high-resolution satellite images [5].

Mosaicking consists of assembling the Raster images of the littoral zone into a single image. We proceeded to a rectification to eliminate the spatial shift between old and recent images. From the fact that our application is interested in the study of the coastline, the choice of the wedging points is extremely important, whose, it is necessary to select vectors projected over the 0 m level. [5]

After the acquisition of the coastline surveys, we have proceeded to a diachronic analysis to evaluate the dynamics of the beaches and its evolution. This analysis consists in determining the distances of evolution (Advance/Retreat) for the coastline, and the affected linear per beach and then per littoral commune. To do this, there was recourse to the Digital Shoreline Analysis System (DSAS) extension integrated in the ArcGIS 10.2 environment. [5] This tool allows to realise a statistical calculation of distances and evolution rates from different shorelines [6].

B. Sediment Granulometry

There are wide variations in sediment texture depending on the relative proportion of sands, silts and clays which they contain [7]. Granulometric analysis is used to describe the sediment using different mineral fractions grouped into classes [8].

Determination of the fine fraction

The determination of the fine fraction content is based on the difference in the dry weight of the sediment estimated from the granulometric analysis before and after wet separation on a sieve from 80µm [9].

Granulometric analysis of the coarse fraction

The sediments were dry sieved on a series of AFNOR type sieves. For each coarse fraction (>80µm), histograms of the mean grain distribution, frequency curves and semi-logarithmic cumulative curves were plotted. From the analysis results under GRADISTAT v8.0. Granulometric indices and numerical ranking orders were determined. This will allow us to compare the samples, determine the graphical parameters and cartography of the different granulometric indices.

Granulometric indices

The logarithmic method of Folk and Ward (1957) was chosen for the present study, which appears to be the most robust for comparing various sediments [10]. This method offers the opportunity to convert parameter values into descriptive sediment terms.

C. Hydrodynamism

The waves generated by the winds are in reality under a complex, these waves disperse in the sea with different wavelengths and speeds [11]. Wave heights generally depend on the wind speed and its persistence. Then, the energy of offshore waves is higher than that of coastal waves [12], but coastal areas do not have the same energy potential; [13], [14] the distribution of this hydrodynamic energy depends on several factors, including coastal morphology [15].

TABLE I. VARIATIONS OF THE SIGNIFICANT HEIGHT OF WAVES FOR THE EIGHT STATIONS IN THE WESTERN REGION

Stations	Min	Max	Moy
S1	0.094	6.481	1.002
S2	0.075	5.825	0.888
S3	0.057	5.124	0.743
S4	0.084	6.203	0.94
S5	0.066	5.49	0.808
S6	0.024	2.864	0.563
S7	0.071	5.928	0.825
S8	0.02	1794	0.497

TABLE II. VARIATIONS OF THE SIGNIFICANT HEIGHT OF WAVES FOR THE FOUR STATIONS IN THE EASTERN REGION

Stations	Min	Max	Moy
S1	0	6.9204	0.9581
S2	0	6.9666	0.9551
S3	0	6.8931	0.9300
S4	0	6.2787	0.8576

Our area of interest is mainly affected by significant heights, the western part of which is very exposed to the swell, unlike the eastern part where the installation of protective structures on a considerable line has modified the coastal hydrodynamics; this concerns the western region. Most of the shores of the eastern region are affected by waves of significant height almost identical for all the stations.

IV. RESULTS AND INTERPRETATION

The results of the analysis of changes in shoreline position under the ArcGIS environment and the DSAS 4.3 extension of our area of interest were carried out along 1437 transects, for the western region and 1478 transects for the eastern region. These transects were spaced 10 metres apart and resulted in the realisation of the coastal erosion maps.

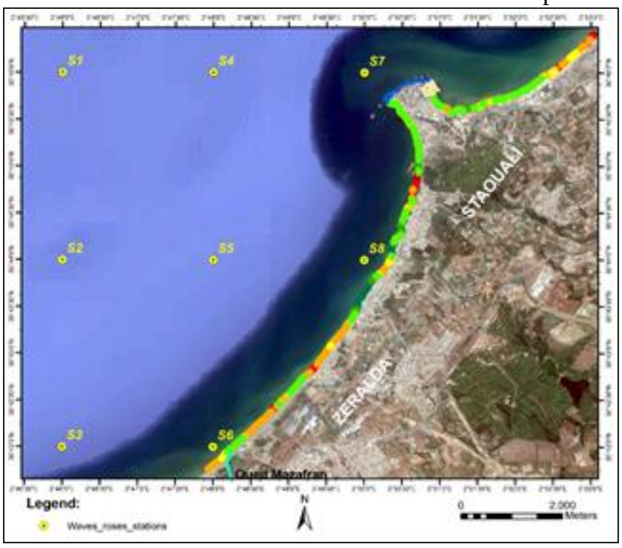

Fig. 4. Representation of coastline evolutions between 2002 and 2019 for the western region.

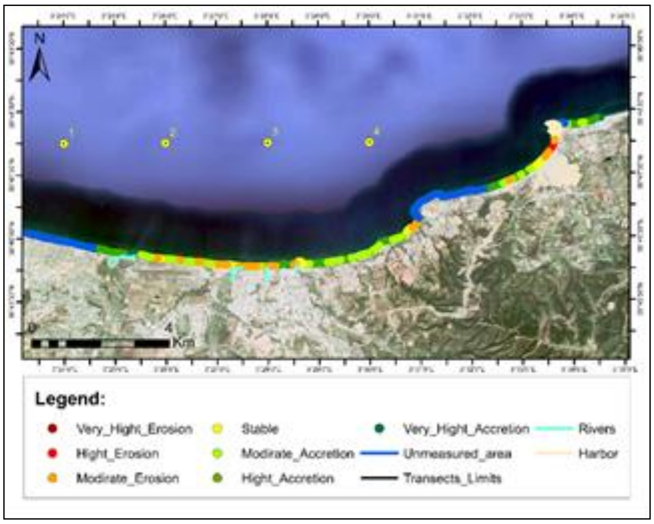

Fig. 5. Representation of coastline evolutions between 2003 and 2019 for the eastern region.

A. Shoreline evolution analysis

Our study area has several different beaches in relation to the evolution of the coastline. Both regions are located near the wadis that have an influence on the coastline evolution.

Khaloufi Beach

Presents a coastline marked by an evolution of different amplitudes. During this period, 45 transects showed accretion, while 35 transects showed recession. The mean distance (NSM) of shoreline evolution at Khaloufi Beach is 2,189 m. With a mean shoreline erosion rate (EPR) of 0.12 m / year.

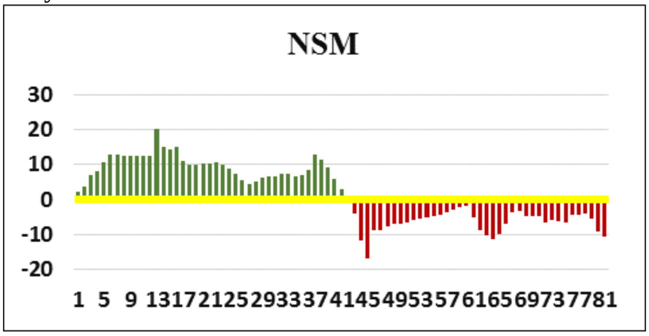

Fig. 6. NSM (Net Shoreline movement) of khaloufi beach transects

The coastline of the western part near the mouth of the Wadi Mazafran is very dynamic, we observe a significant accretion probably due to its high debit and the sediment inputs, moving away from the mouth we observe an erosion in the eastern part of the beach. 80 transects spaced 10 m apart on the khaloufi1 beach show an erosion which varies between a maximum of -16.8 m and a minimum of -1.87 m, the accretion in the area oscillates between a minimum of 0.44 m and a maximum of 20.39 m with an estimated average accretion of 8.6832 m.

Corso Beach

Presents an alternation of the three phenomena; erosion, accretion and coastline stability over a time series between 2003 and 2019. So 30 transects show accretion, 29 show erosion and stability on 21 transects. The mean distance (NSM) of coastline evolution of this beach is 2.64 m. (Fig.18) and a mean rate of shoreline erosion (EPR) of 0.162 m / year.

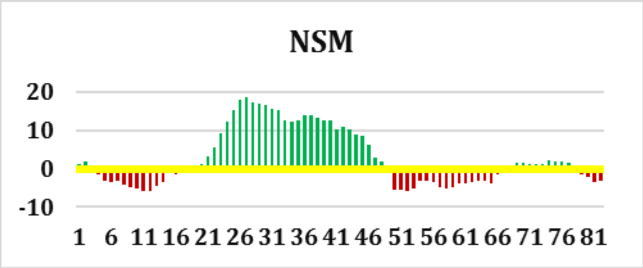

Fig. 7. NSM (Net Shoreline movement) of Corso beach transects

The coastline in front of the mouth of the Wadi Corso presents an accretion of an average of 10.5 m, due to sediment inputs, and areas of erosion far from the mouth of an average of -4.15 m.

B. Granulometric analysis of the fine fraction

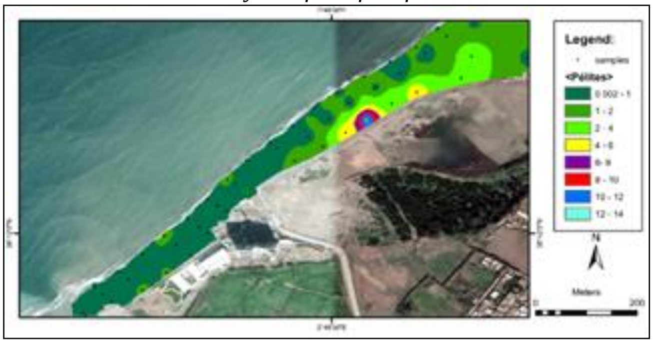

Fig. 8. Map of spatial variation of the pelite rate for khaloufi beach

We observe that the grade of the fine fraction generally increases from west to east. The sediments sampled at the coastline of the eastern part are essentially made up of a coarse fraction. While the samples taken at the beach backshore have more or less content of the fine fraction. The western part of the beach is characterised by a coarse fraction caused by beach accretion and sediment deposition due to the contributions of the Mazafran wadi.

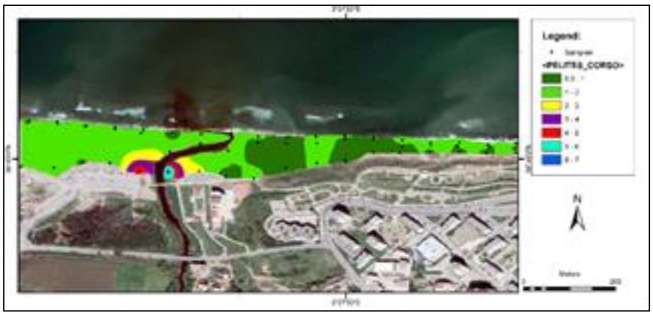

Fig. 9. Map of spatial variation of the pelite rate for Corso beach.

We observe that the fine fraction content is higher in the western part of the beach while the eastern part is characterised by a low fine fraction content. The sediments sampled at the back beach on both sides of the Wadi Corso have more or less important fine fraction contents contrary to the stations sampled at the coastline.

C. Granulometric analysis of the coarse fraction

Graphic parameters

The median

The Q50 corresponds to the diameter of the average grain whose intercept is 50% of the total weight of the sediment. The mean of the median thus shows that the composition of the surface sediment of the khaloufi beach and the corso beach is mostly medium sand. The very small differences in the median values are indicative of the identical conditions under which they were deposited. [16]

The mode

The mode is the diameter of the sieve which corresponds to the dominant sedimentary fraction [9]. Three curves can be distinguished.

1- Unimodal: represents a dominance of a single sedimentary stock;

2- Bimodal: represents the dominance of two sedimentary stocks.

3- polymodal: represents the dominance of several sedimentary stocks.

These parameters show us the proportion of coarse and fine sediments in a sample. In the case of a well-classified sediment, it is possible to note a good symmetry in the frequency curve.

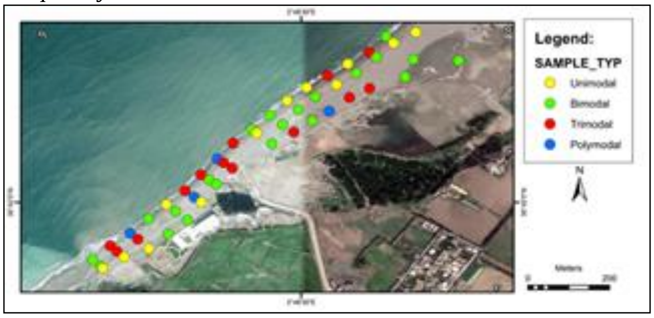

Fig. 10. Map of mode repartition for khaloufi beach.

The sediments of the eastern part of the Khaloufi Beach are for the most part unimodal and bimodal in distribution. For some samples, on the contrary, we find several "peaks" on the frequency curves. Thus these samples show several modes characterizing in fact several sedimentary stocks. The sediments of the western part of the khaloufi beach often show bimodal to polymodal distributions, as they are mainly composed of a mixture of gravel and sand.

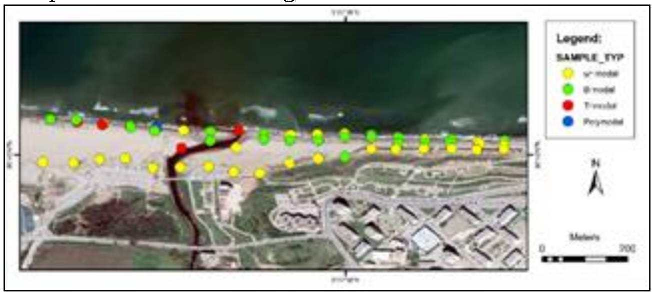

Fig. 11. Map of mode repartition for Corso beach.

The backbeach sediments are largely unimodal in distribution. Most of the samples collected near the coastline have bimodal distributions and only 5 samples have trismodal to polymodal distributions.

Cumulative curves

We will describe the essential features of the cumulative granulometric curves of the sediment samples analyzed by the different granulometric indices. These cumulative curves of total sediment are generally of several aspects spread out, symmetrical and straightened and reflect mixed facies. Coarse and fine fractions stand out well on the frequency curves.

Granulometric indices

The granulometric indices are expressed in Phi (Ø). The Phi scale is defined by the following relation:

$$\emptyset\,(X) = [\,-log\,(qx)] * 3.3219$$

With qx: the grain size (mm) which corresponds to x % of the cumulative weight.

The average grain

The average defines the mean grain size [17]

$$\mathrm{Mz}\,(en\ Phi) = \frac{(\mathrm{Q16} + \mathrm{Q50} + \mathrm{Q84})}{3}$$

It allows individualizing the following facies:

- Coarse sand and gravel: Mz < 1Ø (Mz > 500 µm)
- Medium sands: 1Ø < Mz < 2Ø (250 < Mz < 500 µm)
- Fine sands: 2 Ø <Mz < 3 Ø (125 < Mz < 250 µm)
- Silts and clays: Mz > 4 Ø (Mz < 63 µm)

The values of the average for all samples are comprised between -1 and 3 Ø, indicating coarse sands, medium to fine sands.

Fig. 12. Spatial variation map of the mean grain for khaloufi beach.

The average sediment size of the khaloufi beach generally decreases from west to east of the beach. Sand diameters show a refinement of the coastline towards the backbeach.

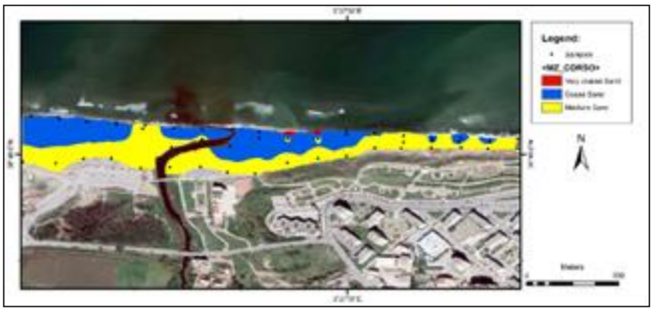

Fig. 13. Spatial variation map of the mean grain for Corso beach.

Sediment grain size decreases from coastline to backbeach. There is, therefore, a sorting of grain size at the coastline carried out by the swell currents.

Classifying index (S0)

The sorting (Standard Deviation) indicates the dispersion of sediment sizes relative to the median. It is calculated by the following equation:

$$\sigma\,(en\ Phi) = \frac{(\mathrm{Q84} - \mathrm{Q16})}{4} + \frac{(\mathrm{Q95} - \mathrm{Q5})}{6.6}$$

Depending on its value according to the logarthmitric method of Folk and Ward, several types of sands can be distinguished:

Very well sorted sands: σ < 0.35 Ø

Well sorted sands: 0.35 Ø < σ < 0.5 Ø

Moderately well sorted sands: 0.5 Ø < σ < 0.7 Ø

Moderately sorted Sands: 0.7 Ø < σ < 1 Ø

Poorly sorted sands: 1 Ø <σ < 2 Ø

Very poorly sorted sands: 2 Ø <σ< 4 Ø

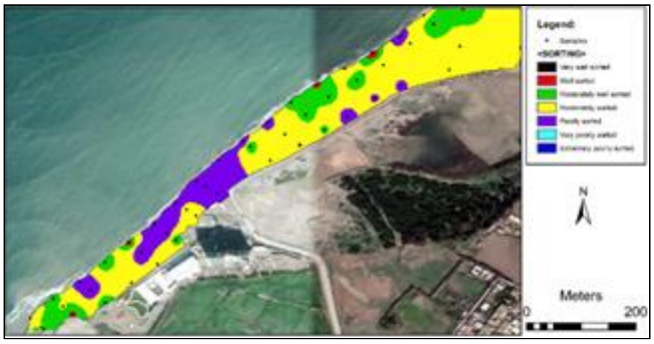

Fig. 14. Spatial variation map of the sorting indice for khaloufi beach.

The majority of the sands sampled at the shoreline in the western part of the beach are characterized by largely misclassified sediments, and those near the border dune in the eastern part of the beach at stations 13-3 14-3 and 15-3 and station 16-1 sampled at the shoreline have a standard deviation of 1 to 2 Ø. These sediments are poorly sorted. there is therefore a granulomeretic sorting from west to east.

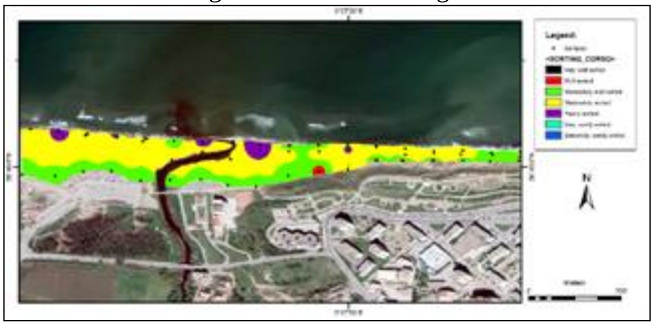

Fig. 15. Spatial variation map of the sorting index for Corso beach.

At the backbeach, most of the sediments sampled are moderately well sorted. There is a back beach to coastline sorting where most of the sediments are well classified with the exception of some stations that have poorly classified sediment.

Skewness Indice (Ski)

The asymmetry informs the predominance, or not, of fine or coarse particles compared to the average grain of the sample. It contributes to the characterization of the deposition milieu. It allows the determination of granulometric curve deviation compared to the Gauss curve. It is given by the following expression :

$$SKi\ (en\ phi) = \frac{(Q16 + Q84 - 2Q50)}{2(Q84 - Q16)} + \frac{(Q5 + Q95 - 2Q50)}{2\,(Q95 - Q5)}$$

According to its value, one distinguishes:

-1 Ø < Ski <-0.30 Ø : Very coarse skewed curve.

-0.30 Ø < Ski < -0.10 Ø : Coarse skewed curve.

-0.10 Ø < Ski < 0.10 Ø : symmetrical curve.

0.10 Ø < Ski < 0.30 Ø : Fine skewed curve.

0.30 Ø < Ski < 1 Ø : Very end skewed curve.

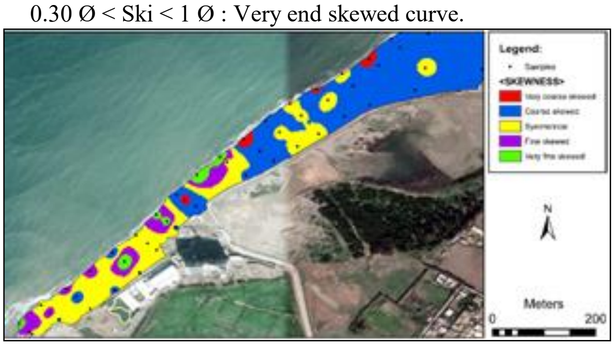

Fig. 16. Spatial variation map of the skewness index for khaloufi beach.

The western part of the khaloufi beach is dominated by cumulative curves showing asymmetry and asymmetry towards the fine particles so the coarse fraction is very spread out, except for the radial 8. The asymmetry index for the samples of the eastern part is higher than 1 which makes the grading maximum on the coarse side while the fine fraction is spread out.

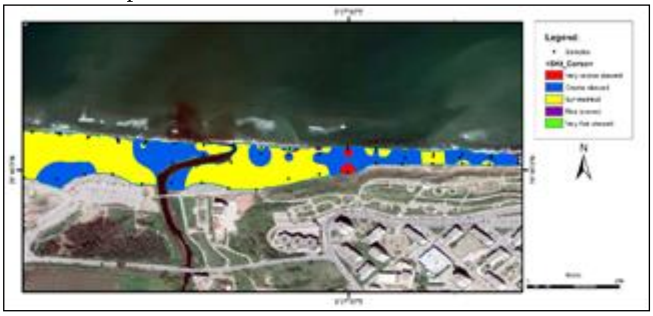

Fig. 17. Spatial variation map of the skewness index for Corso beach.

Three types of cumulative curves can be distinguished for Corso Beach surficial sediments where the eastern side and the surface near Wadi Corso show asymmetry index values greater than one, so the grading is highest on the coarse side and the fine fraction is spread out. The western part of the beach shows cumulative curves with asymmetry over almost all of the surficial sediments of this beach.

Kurtosis index (KG)

It is calculated by the following formula:

$$KG\ (en\ phi) = \frac{(Q95 - Q5)}{2.44(Q75 - Q25)}$$

This index describes the shape of the granulometric curves in relation to the Gauss curve.

KG <-0.67 Ø : Very platykurtic curve.

0.67 Ø < KG <0.90 Ø curve platykurtic.

0.9 Ø < KG <1.11 Ø curve Mesokurtic.

1.11 Ø < KG <1.5 Ø curve Leptokurtic.

1.5 Ø < KG <3 Ø Very Leptokurtic.

KG > 3 Ø curve Extremely Leptokurtic.

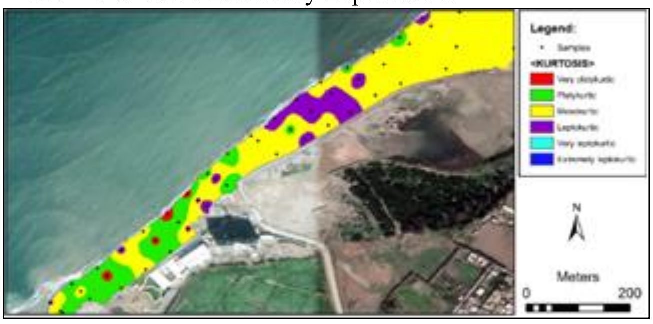

Fig. 18. Spatial variation map of the kurtosis index for khaloufi beach.

The majority of the cumulative sediment curves in the western part are platykurtics and very platykurtics, while the cumulative curves in the eastern part are largely mesokurtics and steeply sloping leptokurtics.

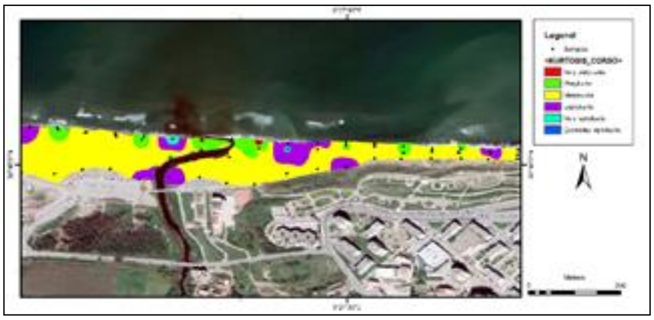

Fig. 19. Spatial variation map of the kurtosis index for Corso beach.

The cumulative surficial sediment curves for this beach are almost mesokurtics and steeply sloping leptokurtics with the exception of a few stations sampled at the coastline, which have platykurtics and very platykurtics curves.

Uniformity coefficient (U)

The uniformity coefficient U is defined by the following equation:

$$U = \frac{d60}{d10}$$

With: d60: grain size (mm) corresponding to 60% of the cumulative weight

d10: grain size (mm) corresponding to 10% of the cumulative weight

It allows to qualify the granulometry of sands:

U < 2: uniform granulometry

U > 2: varied granulometry.

Fig. 20. Map of spatial variation in the coefficient of uniformity for khaloufi beach.

The coefficient of uniformity is less than 2 for samples collected near the coastline in the eastern part of the Khaloufi Beach, so these sediments have a uniform granulometry. Whereas sediments collected near the border dune in this part of the beach have a varied granulometry. The uniformity index for the western part of this beach is greater than 2 for the most part, so the sediments from these sampling points are of various granulometry.

Fig. 21. Map of spatial variation in the coefficient of uniformity for corso beach.

The coefficient of uniformity is less than 2 for samples taken from the backbeach, so these sediments have a uniform granulometry. Sediments sampled near the coastline, on the other hand, have a various granulometry.

D. Triangular diagram and granulometric facies

The granulometric facies are determined on a triangular diagram according to their content of gravel, sand and silt. The fractional contents are defined according to the standards adapted for the granulometric description of the facie.

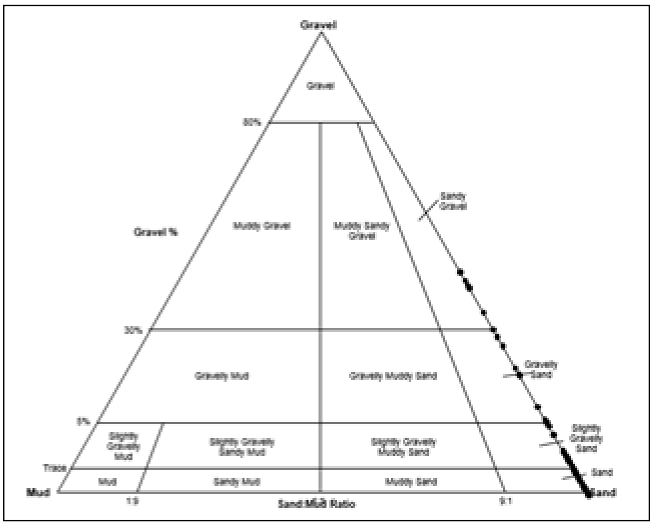

Fig. 22. Spatial variation map of the kurtosis index.

All the samples represented on the diagram let appear three main categories of typical granulometric facies: sand gravel, gravelly sand, lightly gravelly sand and sand.

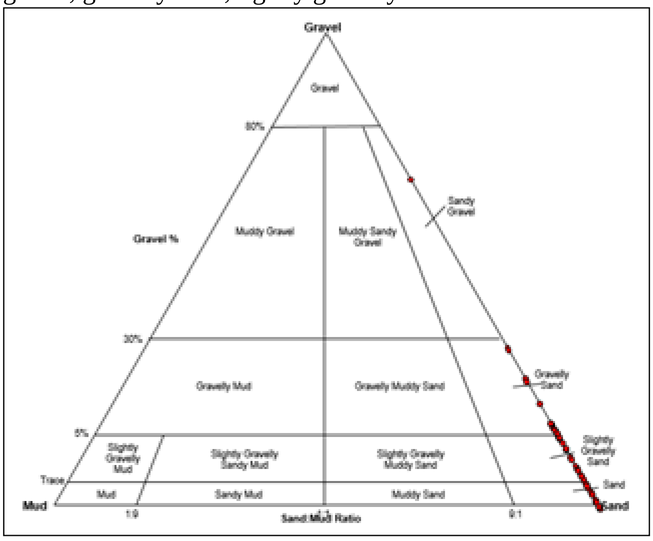

Fig. 23. Spatial variation map of the kurtosis index.

The majority of the samples taken from Corso Beach are sand, slightly gravelly sand and gravelly sand. With the exception of sample 10-1 which is sand gravel.

Except for some differences in the distribution of the samples on the Folk and Ward triangular diagram, both beaches have the same granulometric facies.

V. DISCUSSION

Coastal erosion cartography based on the careful analysis from the Google Earth pro images under ArcGIS and the DSAS 4.3 extension allowed us to select the most dynamic beaches for the studied area.

Then, the geodatabase developed during the study of hydrodynamics made it possible to explain the phenomena of marine erosion and submersion and to determine the coastal vulnerability in the studied area.

This study also focuses on the analysis of the morpho-sedimentary aspects of the beach by extrapolating granulometric indices.

The evolution of coastal positions over a time series between 2002 and 2019 indicates that the entire coastal zone studied is very dynamic. This is due to the exposure to waves from different directions in addition to the coastal morphology and bottom roughness of each part of the coastline.

These changes were measured according to four dates 2002, 2008, 2013 and 2019 for Khaloufi Beach and three dates 2003, 2011 and 2019 for Corso Beach. The study revealed very disparate results spatially and temporally.

The coast of this region is invaded by strong pressures and considering the complexity of this geosystem, the highlighting of the historical evolution of the coastline and the identification of the zones of evolution due to the different processes mainly hydrodynamics allowed us to observe that the three phenomena accretion, erosion and stability are sometimes observed over a small distance.

Moreover, the hydrodynamic activity along this coast has considerably affected the sedimentary stock and has generated impacts on coastal dynamics. The wave roses of the studied stations show that the mean significant height is higher for some areas than others, this allowed us to identify areas with high energy potential and the interpretation of the coastline dynamics and beach evolution.

Under wave conditions and longshore drift current, shoreline morphological changes are observed over a 17-year period on a large area. On the other hand, the mouth of the mazafran wadi and the coso wadi are very dynamics, which is why the beaches studied are in evolution. The results obtained further confirm that there is a significant correlation between the dynamics of the beaches and the hydrodynamic factors.

In addition to natural factors, anthropogenic activities can also influence the change in the coastline. Around some coasts, beach nourishment projects and coastal protection structures are constructed to prevent coastal erosion [18]. This is the case for beaches located near marine structures because the impact of harbor installations, groins and breakwaters on sediment transport and the modification of coastal hydrodynamics is manifested by the appearance of artificial accretion zones.

The beaches studied show both erosion and accretion of the coastline and were chosen as sampling sites. The granulometric analysis of the surface sediments for these beaches presents a sandy facies. The fine fraction content generally increases from west to east for Khaloufi Beach and from the backbeach to the coastline for Corso Beach. This can be explained by the proximity of the coastal dune and the contributions of the wadis, which are partly responsible for this distribution, by the important depositions near the mouth.

From the granulometric curves, a large number of statistical parameters can be generated, in order to optimize comparisons between sediments and to interpret the results obtained in terms of sedimentary processes. An approximation of the parameters can be established from the representations of the frequency and cumulative frequency distribution curves. Alternative statistical parameters were also calculated to differentiate between sediment, median grain D50 and mode.

GRADISTAT v. 8.0 provides a structural description of the samples according to the statistical parameters of Folk (1954) and Folk and Ward (1957). The maps developed under ArcGIS display the results of the parameters and granulometric indices of the raw samples by extrapolating the values of the indices over the entire study area, which allowed us to visualise easily the granulometric evolution of the beach.

VI. Conclusions

The methodology developed for the study of shoreline changes along the studied coast is of major interest for the numerical quantification of erosion. This study found that detection of shoreline changes can be done using very high resolution Google Eath Pro images. The methods developed for rectifying them in this study have proven to be effective for the detection and assessment of shoreline position changes.

Thus, the geodatabase developed during the hydrodynamics study made it possible to explain the phenomena of marine erosion and submersion and to determine the coastal vulnerability in the study area.

However, human interventions to correct certain erosion trends in this coastal zone have disrupted the sediment budget and again threaten the natural balance of sandy beaches and the stability of the border dunes. making the coast more vulnerable. Indeed, the presence of mouth points, the location of protective structures near beaches, coastal morphology and direct exposure to wave forces are the main factors that govern the sediment dynamics for the majority of the beaches in this region.

The granulometric study of the samples taken shows that the sediments have an average size between -1 and 2 Ø. Sediments collected along the coastline are generally coarse to medium sands, however, sediments collected near the dune bordière are medium to fine sands. This is a grading process carried out from west to east

From a methodological point of view, the highlighting of historical coastline variations through the combination of rectified Google Earth pro images of very high resolution, geospatial techniques (ArcGIS software), automatic calculation code (DSAS), high-resolution SWAN model and the results of the granulometric analysis provided information on coastal morpho-dynamics in order to monitoring, valorising and qualifying beaches.

From an applied point of view, the results obtained are useful for the coastal zone management, in order to maintain a certain balance between natural and anthropic factors on the one hand and the preservation of these geo-systems on the other.

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