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1 INTRODUCTION

Coastal dynamic studies are important to investigate morphological coastal characteristics. As well known, beaches are economic as well as natural resources. As natural resources, they add beauty to the coast and provide habitats form many living ecosystems. As economic resources, they provide services to people and property that have an economic value. Only few years ago, the scientific community and the managing authorities have started a debate about the assessment of the risk impact on the coastal population. For these reasons the coastal risk management has become a key element in environmental policy and civil protection. As each risk typology, in order to study the coastal risk, we need to collect and homogenize data, to calculate and to analyze the results, and finally to design and to plan the possible intervention works. Coastal erosion risk research should consider both the geomorphologic and hydraulic aspects. The main target of this study is to analyze, with an interdisciplinary approach, the physical processes linked to erosion risk, due to the waves and storm effects. Among of the beaches sections, the swash zone is the most important. This zone is known also as a turbulent layer of water that washes up on the beach after an incoming wave is broken. This swash action can move beach materials up and down the beach, which results in the cross-shore sediment exchange. The scale of the swash zone depends on the type of beach and the wave characteristics. Indeed when the waves approach the shoreline, they are affected by the seabed through processes such as refraction, shoaling, bottom friction and wave-breaking. One large storm, or a series of storms, can cause significant beaches and dunes erosion. Damaging storms usually occur in fall, winter, or early spring months when the “seasonal” beach profile is already relatively lean in shape. Changes observed at the beach are similar to the seasonal changes, with lowering of the beach and extensive loss of the berm. In addition, storm damages usually cause extensive dune erosion, scarping, or complete loss of the frontal dune.

The Sicilian coast, as many Mediterranean coasts, is exposed to erosion and for this reason our research aims to perform a study in an typical Sicilian beach. The selected test site is a sandy beach located in the southern coast of Sicily (San Leone, Agrigento) (fig. 1). This village was originally a small fishing district, today is one of the most beautiful tourist and resorts destinations of this area.

Figure 1: San Leone beach (southern Sicilian coast between the Agrakas and Naro river mouths). The beach is composed by four sectors: 1) the first beach, 2) the second beach, 3) the third beach and 4) the dune beach.

The expansion of the touristic harbour has originated a series of changes in the old beach morphology. The San Leone beaches show significant signs of shoreline retreat and dune erosion, causing concerns for the public administrations and stakeholders. The problem has attracted the attention of local media, especially after large winter storms.

However the perception of the beach erosion by stakeholders might not coincide with real erosional trends, as observed elsewhere. Local beach area loss also increases risk to coastal properties and assets.

In this study, geomorphological and historical shoreline time series, for a period of 36 years, are analyzed in order to obtain evidence of erosional/accretional trends on the sandy beaches of the San Leone coast. Shoreline position change rates are quantified and discussed in relation to the history of the coastal area development. In order to validate the results obtained by the hydraulic and geomorphologic study, we will start up a prototype of a Video-Monitoring System (VMS). This type of monitoring will also help to improve the: 1) defense and preservation of the beach profile; 2) protection of the environmental value, and 3) control of the use of the coast for recreational purposes. Such a monitoring system is a prototype and it will also be adopted in other Sicilian beaches with similar morphological features and hydrodynamic conditions.

2 THE TEST SITE: SAN LEONE BEACH

In order to apply the proposed research method, a dissipative beaches in Sicily was selected. This beach is part of the Agrigento municipality, in particular near at the San Leone holiday area. The beach, is geographically localized on the Sicilian physiographic unit 10 (Capo Bianco head - Lido Rossello) and it is between the Akragas (North-West) river mouth and the Naro river mouth. The San Leone beach is about 5.6 km long and it is a well frequented place. Indeed, San Leone village generally has, in winter, 4,000 citizenry whereas in summer 30,000 vacationers. The coastal area is predominantly urbanized but it is also used for farming and marine activities. The coast zone is characterized by an extended flat plains, delimitated in the landward direction by hills (about 250 m a.s.l.).To facilitate the places location, San Leone beach has been divided into four zones, each with its own reference name.

Looking at the shoreline composition, starting from the Agrakas river mouth to eastward, the first man-made structure is the San Leone harbour. The set up of this structure, has triggered a insufficient sediment supply for the southern beaches creating local shoreline retreats. Going from the west of the east harbour jetty there is a rock armour that absorb the wave energy and hold beach material. In order to protect the beach, beyond the rock armour, several breakwaters where positioned. These structures were built to produce a shoreline advancement and therefore a sediments retention. Near the *Oceano Mare* club, there is a groin which is the last defence structure after the breakwaters. Beyond this groin in front of the club, there are strong shoreline fluctuations. This aspect is also confirmed by hydrogeological studies (http://www.sitr.regione.sicilia.it/pai/) that indicate probable erosion phenomena (on the order of 8 m/year) due to both natural dynamic and influences of man-made structures. The human interventions changed the beach morphology, and in particular the dunes profiles that in the past were higher and wider. In some zones, the seafront road (*Viale delle Dune*) was built on the dunes, thus modifying the old profile.

The sediments are yellowish sands, with smooth out grains, texture opaque and calcitic composition. San Leone beach positioning is NW-SE and it is vulnerable to sea storms due both winds and sea states coming from the 3rd quarter. Manno *et alii*, (2012) assessed about 6.6 m of significant wave height (H_s) in western storm surge, analyzing *Mazara del Vallo* buoy data (closest the San Leone beach). The same authors calculated tide fluctuations (about 0.40 m) on this coast. The latter is a typical value of many Mediterranean coasts.

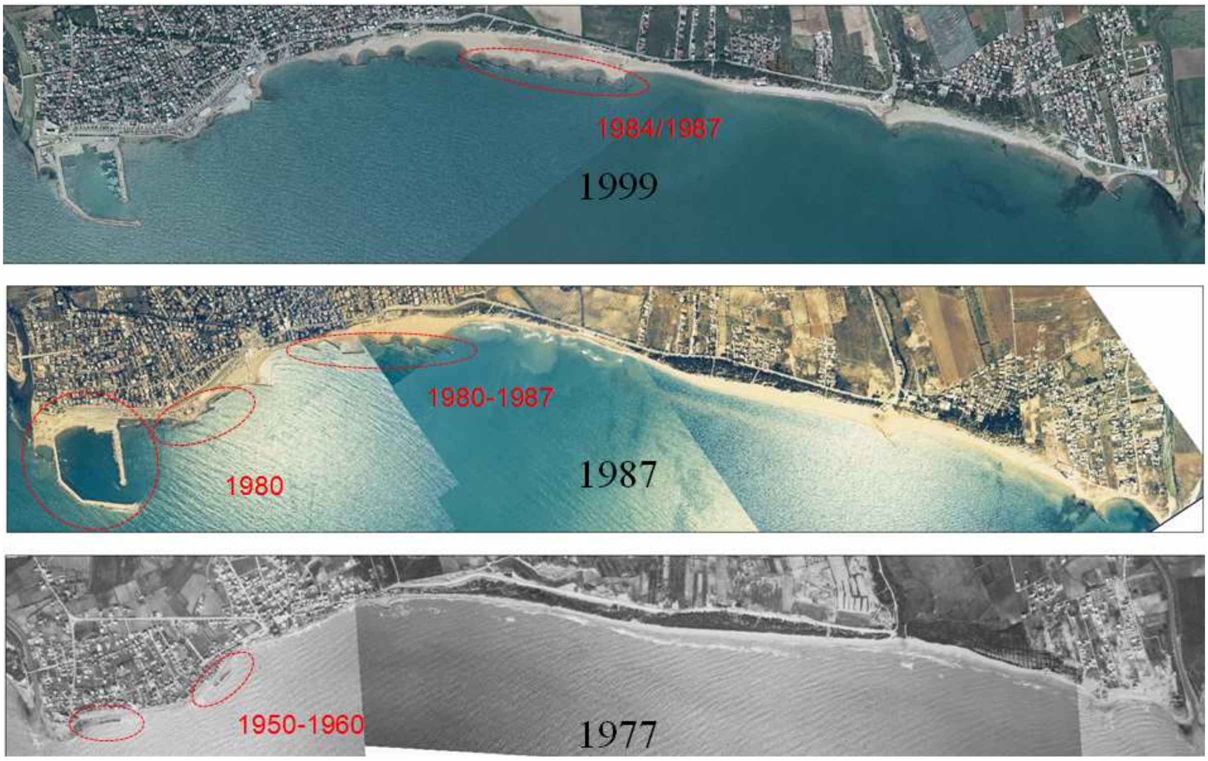


Figure 2: shoreline changing between 1977 and 1999. All the breakwaters in front of the second and the third beach, were built after the harbour construction.

3 METHODOLOGY

In order to study the coastal dynamics of San Leone beach, we a specific study was performed. This study integrates several techniques of various disciplines as topography, geomorphology, geology and hydraulic. With this approach we analyzed the dynamical aspects taking into account several physical aspects (Manno 2012). The analysis started from the data collection (topographical, morphological and geological). At this stage we collected also aerials and satellites imagery.

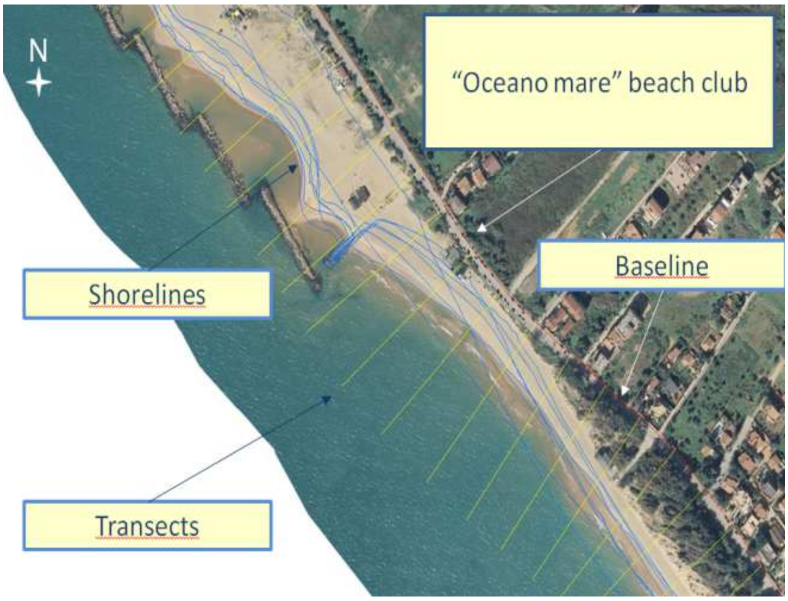
In order to investigate the beach evolution in time, all available data have been georeferenced and then overlapped (fig. 2). The analyzed timeserie rages between 1977 and 2013 (36 years). The diachronic analysis was perform used the wet/dry or maximum run-up line shoreline marker (Boak 2005, Ruggero, 2006). For each year represented by a single image the shoreline was detected and then a statistical analysis was carried out in order to describe advances and retreats of the beach. This analysis was performed using the DSAS (Digital Shoreline Analysis System) software, produced by U.S. Geological Survey. DSAS method is based on measured differences between shoreline positions through time to calculate shoreline rates of change (fig. 3). The reported rates are expressed in meters of change along transects per year. The rate-change statistics were calculated using the Linear Regression Rate (LRR) and the Weighted Linear Regression Rate (WLR) (Manca, 2013). A linear regression rate-of-change (LRR) statistic can be determined by fitting a least-squares regression line to all the shoreline points for a particular transect. The regression line is calculated in a way that the sum of the squared residuals (determined by squaring the offset distance of each data point from the regression line and adding the squared residuals together) is minimized. The linear regression rate (LRR) is represented by the slope of the line. The weighted linear regression gives a more reliable assessment of the dynamic since it weights the points to determine the best-fit line. In the computation of statistics of the rate-of-change of shorelines, a greater weight is given to points for which the position uncertainty is smaller. The weight (*w*) is defined as a function of the variance in the uncertainty of the measurement (*e*) (Genz, 2007):

$$w = 1/\left(e^2\right)$$

where *e* is the shoreline uncertainty value. The uncertainty field of the shoreline feature class is used to calculate the weight.

In order to investigate the historical evolution, a geomorphologic study is going to be performed, allowing us to describe both of the emerged and submerged beach.

To describe the San Leone beach in detail a survey will be performed using a GPS (Global Position System) RTK (Real Time Kinematic). Such technique can be suitable applied to beach, because there are not obstacles (trees, buildings, etc.) that could shield the receivers signal. Another aspect to be highlighted is that this kind of acquisitions are accurate and consistent with a centimetre precision.



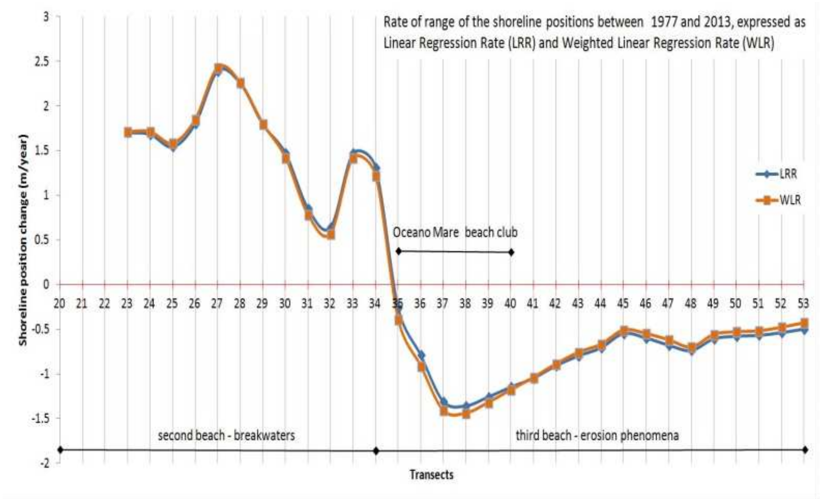


Figure 3: DSAS application in San Leone beach. "Oceano mare" beach club area shows more important shoreline fluctuations.

Coastal dynamics is governed by direct and indirect effects of physical phenomena of hydraulic nature. The so-called “marine hydraulic parameters” are: waves, currents and mean sea level excursions (tides). In the proposed method consider only waves and tides, neglecting the sediment transport and currents.

Wave and tidal data, are collected respectively by wave-meter buoy of Mazara del Vallo and the Porto Empedocle tide-gauge respectively both managed by ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale). The wave-gauge records the vertical displacement within the range of ± 20 m (resolution 0.10 m with an accuracy of 3%) and the direction of origin within a range of 0° to 360° (resolution 1.5° with an accuracy 0.5° to 2°) (Manno, 2010).

Only the significant wave heights (H_s [m]), peak and average wave periods (T_p and T_m [s]) and average direction (D_m [°N]) will be used in this study. The hydraulic study will be divided into two sections: propagation of the waves from offshore to nearshore and tides analysis.

Wavemeter buoy of Mazara del Vallo is not located in front of the investigated beach but in the north-western side, and for this reason it will be necessary to transpose the buoy data. This computation is needed to transpose the data from the measuring point to another "similar" point but located far from of measuring point (Manno, 2012a). In order to overcome this problem we will use the European Centre for Medium-Range Weather Forecasts (ECMWF) dataset (40 years H_s values) obtained by numerical model and simulating a wave meter buoy exactly in front of the San Leone beach (http://www.ecmwf.int).

Once the significant wave heights and the associated return period for each wind sector will be known, a propagation model (SWAN - Simulating Waves Nearshore), will be used to calculate height and period changes of a wave propagating from offshore to nearshore. The outputs obtained will be used for the run-up calculation. To calculate the run-up two different approaches will be used: an empirical formula and a Boussinesq fully non linear numerical model with a lagrangian shoreline boundary condition (Lo Re, 2011). Finally in order to identify the shoreline position, the sea level fluctuations due to astronomical influences will be taken into account. For this reason a tide analysis will be performed using tide observations collected during last decade. Once known the wave and tidal fluctuations a strip of uncertainty around the detected aerial image shoreline will be defined (Manno, 2011).

Furthermore, in order to better understand the forcing and the processes that control the evolution of the San Leone beach, a video monitoring system will be set up. The video system will consist in a system of two cameras mounted on a pole, at 10 m a.s.l. (Viale delle dune "Oceano mare" club area) (Archetti, 2006; Brignone, 2012). This area was selected because the high fluctuation in time and space of this section of the beach. This type of beach monitoring allows the shoreline localization at hourly, daily, seasonal and yearly scales. The images will be acquired by two photo cameras (Canon 18-megapixel, optical zoom of 28-88 mm). The system will acquire both snapshots and averaged images. A snapshot image is a simple photograph of the beach site, where webcams are installed. It is used to simply document site environmental condition as wave motion and beach features (largeness, instantaneous run-up, etc.).

Time Exposure (or timex) will be obtained by a digital average of image intensity over a fixed amount of minutes of images acquisition. Timex will be produced by processing and superimposing snapshot images belonging to the same acquisition cycle. This process eliminates random momentary sea conditions and it removes variability in run-up height. Both the images provide information on: 1) run-up, 2) beach largeness changing, 3) formation and movement of the long-shore bars, 4) water flow and 5) sediment dispersion.

4 CONCLUSION

The proposed research will allow both the analysis of the morphologic dynamics and the erosion assessment of the San Leone beach. The proposed methods will produce significant advantages. In fact, the multidisciplinary approach (geomorphological and hydraulic) will ensure the consideration of the various physical phenomena.

To analyze coastal changes, the shoreline position was chosen as indicator. Usually the shoreline position is extracted from the images not considering the status of the sea (in terms of tide and waves) during the acquisition of the aerial photography. The proposed method evaluates the tides and waves influence on the shoreline position and on the assessment of the beach erosion.

The applied methodology will allow to map the risk of erosion and it will be integrated with a continuous beach monitoring. This method of beach dynamic analysis could be considered as a “prototype” that can be reproduced in other Sicilian beaches with similar characteristics. This will represent and effective support for beach managers and stakeholders. Indeed, both geological and geomorphological studies and run-up assessment (needed to determine the areas exposed to flooding risk, due to storm surge), will be useful in the framework of coastal planning and design.

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