USE OF MIXED STUDY TECHNIQUES IN THE EVALUATION OF COASTLINE DYNAMICS - THE "PORTO CESAREO" MPA CASE OF STUDY

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Abstract – In recent decades, the much-discussed climate changes with the consequent variations in sea and weather conditions and the rise of the mean sea level are causing an indisputable set of negative actions on the entire coastal system mainly due to the increase of the erosive phenomenon along the shorelines. These critical scenarios have a major impact even on a local scale, and because of that, we decided to study a well knows tract of rocky/sandy mixed coast, in a highly anthropized area, even if located inside the "Porto Cesareo" Marine Protected Area (MPA) (Ionian Sea, Gulf of Taranto, Puglia Region, Italy). The high naturalistic and archaeological value of this area calls for a greater institutional effort in the study of erosional phenomena. Several historical documents from other studies point out that this coastal area is an ideal place for this kind of research. The effects of coastal erosion and anthropic pressures along this tract of coast require adequate efforts for a consistent and rapid evaluation of the coastal dynamics. The methodologies proposed in this work are based on mixed techniques from different fields of study, integrating recent aero photogrammetry surveys with drones, aerial images acquired by the Italian Military Geographic Institute (IGM), elaboration of paleoshorelines related by underwater archaeological markers and their dating, and finally on the elaboration of satellite products useful for the study of vast areas. The monitoring of coastal areas and the evaluation of shoreline dynamics are core topics in the implementation of managing actions of decision-makers on a local, regional, national, and international scale, above all in places like the chosen one, inside an MPA. Remote sensing through the use of RPAS (Remotely Piloted Aircraft Systems or Drones) has proved to be very useful for identifying phenomena that act on a small spatial scale and in supporting and implementing protective measures according to the adaptive management approach, through multi-year surveys on habitats of conservation interest [18]. For the implementation of fine-scale monitoring actions, we have chosen products from the Sentinel satellite of the Copernicus constellation (European Space Agency - ESA). In this context, the use of satellite products provides a recurrent view of the ground, useful in the short and long-term monitoring of changes in wide coastal areas, and in particular, offers a coastline positioning evaluation in near real-time. Local monitoring actions performed in recent years have already shown an erosive trend in the past decades, and even, negative forecasts for the next decade, so further surveys with mixed methodologies could be crucial in the evaluation of the evolution of this particular coastal area by local authorities.

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Introduction

In recent decades, the much-discussed climate changes with the consequent variations in sea and weather conditions and the rise of the mean sea level are causing an indisputable set of negative effects on the entire coastal system mainly due to the increase of the erosive phenomena. This is particularly true along the Apulian region coastline, as assessed by various studies, one for all the *Piano Regionale delle Coste Puglia* [18], that reports positive erosional dynamics along the Ionian coastal areas. More specifically, between the Torre Lapillo (40.280979° N 17.840503° E) site and the Porto Cesareo town (40.261868° N 17.887420°E), particularly in the last ten years, many environmental emergencies took place, causing a high number of erosional events and pushing the regional authorities to implement a series of intervention in emergency status [1, 2, 3]. The sandy beaches of Porto Cesareo are among the more touristic attractions, with an annual average of at least 300 000 seasonal touristic presences [6], creating an entire economic system. This implies that public concern about the coastal area dynamics on the different types of impacts and risks that affect different matrices is present among the local stakeholders. So, the conservation of these landscapes must be pursued considering the preservation of all the economic assets, such as the sandy beaches, for touristic purposes, and for their intrinsic environmental and ecological value. In addition, the land-sea contact areas are well-known resting sites for archaeological evidence of the past, threatened even after a single extreme event [14, 15]. So, the point is to preserve a comprehensive good environmental status for the local community as a whole, and as an attractor for visitors.

This new wave should be rooted in a more capillary and systematic monitoring action for the definition of management actions to reduce the consequences of extreme events. So, the local governments (Coastal Municipalities and MPAs management bodies) must be more involved in the monitoring actions of the coastal areas, repeated over time, sometimes on vast areas. To cope with these needs, in collaboration with the Porto Cesareo MPA management body, we proposed a reliable and easily implementable methodology for the local operators, easy to use recurrently. We decided to study a well-known tract of rocky/sandy mixed coast in a highly anthropized area, even if located inside the “Porto Cesareo” Marine Protected Area (MPA) (Ionian Sea, Gulf of Taranto, Apulia Region, Italy). The coast of Porto Cesareo municipality falls within a well-identified landscape morpho unit whose limits are represented by the tip of Torre Squillace (40.235144° N 17.909999° E), immediately south of Porto Cesareo and Punta Rondinella (40.464297° N 17.247009° E), near Taranto, sharing the same morphological characters. The stretch of coast, from Porto Cesareo to Marina di Pulsano (40.349174° N 17.374957° E), is characterized by a substantial alternation between a flat, sloping rocky coast and pocket beaches bordered by low rocky promontories. In this morpho landscape unit falls the inflection zone that marks the change of direction of elongation of the Ionian coast of the Salento Peninsula which passes from E - W to NW - SE. The morphological characteristics of this stretch of coast, are classified as pocket beaches, as they do not have large longitudinal extensions and are limited by promontories that break up the various physiographic units, making each sector exclusive with its characteristics mainly linked to the local exposure to wave motion. According to the classification of the beaches of Puglia these beaches individually identify 6 coastal systems of the "stationary barrier" type.

This coastal system consisting of sandy deposits, in some cases extended for kilometres, located in sedimentary traps defined by the particular configuration of the rocky coast and almost totally devoid of sedimentary contribution from the hinterland The main sediment sources can only be indigenous and therefore come from dismantling calcarenite or generally calcareous promontories located in the immediate vicinity without the possibility of replacement or fluvial inputs given the local absence of waterways. The sediment recycling takes place mainly between the emerged beach and the dune, where present, and the submerged beach [10, 11, 13]. The seabed overlooking the stretch of coast of interest degrades with a succession of submerged terraces to a depth of about 30 m and then slowly increasing to a depth of 40 m at about 8 km from the coast. These natural environments have been undergoing severe erosion for some decades as a result of a combination of factors operating on different scales, both natural and human-induced. Natural factors that most affect the erosion phenomena are winds, storms, currents near the beaches, sea-level rise, and soil subsidence.

Man induced factors include the massive use of the coastal strip with wild and rapid urbanization consequent the construction of infrastructures and works for residential and recreational settlements, the use of the soil, the alteration of vegetation, and the works for the regulation of the hydrographic network. Indicatively, it can be assumed that these erosive phenomena, in Porto Cesareo, as in many other Italian areas, have begun to manifest themselves plainly since the sixties of the last century both for natural factors and as a phenomenon induced by the pressures of use on the coastal areas. In the examined area, starting from the 1940s and 1950s, reclamation interventions began in the areas behind the dunes, which allowed the creation of collection basins and a network of connecting canals, which determined the conditions for the beginning of the first coastal erosional phenomena, albeit with a very low intensity. Unfortunately, the Porto Cesareo coastal area has never been a site for monitoring aimed at quantifying the erosive phenomenon.

Therefore, today it is only possible to qualitatively observe the effects of this phenomena that manifest themselves in the progressive and general erosion and dismantling of the dune cords and the progressive and general depletion of sediment from the submerged beach to the retreat of the shoreline in particular in the south-east part of the Torre Lapillo bay. In January 2010, a series of storm surges which triggered serious erosion of the stretch of sandy coast throughout occurred the Salento peninsula. The coastal municipalities that have suffered the most from the negative effects of this phenomenon, including Porto Cesareo, have encouraged the competent offices of the Puglia Region to implement urgent actions to mitigate the damage. In May 2010, the Apulia Region authority responded to the coastal municipalities by launching the first phase of recognition for the erosive phenomenon. The first results of this study showed that the erosive phenomenon resulting from the storms of January 2010 also affected stretches of the coast previously classified as stable [4, 5]. While, as is obvious, in the stretches of sandy coast, already with a historical tendency to erosion, the storm surges of January 2010 further aggravated the stability of the coast and endangered the infrastructures, the natural habitats, and the archaeological heritage. In the Porto Cesareo area, several nowadays submerged archaeological contexts – settlements, shipwrecks, cargos – were investigated in the framework of the UnderwaterMuse project[1] (Programme Italia-Croatia), and seem to be significant markers of sea-level changes and seascapes evolution along centuries. The large

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[1] https://www.italy-croatia.eu/web/underwatermuse

submerged area in front of the Bronze Age site of Scalo di Furno (40.275725° N 17.874066° E) represents the lower terrace of the settlement, showing structures and materials. Between the Torre Chianca (40.271722° N 17.870762° E) and the tip of Belvedere (40.280250° N 17.878912° E), there are other remains of structures and alignments of pole holes with pottery from the Middle Bronze Age, together with portions, partially submerged, of a Roman settlement and necropolis attested by funerary steles and tombs.

The underwater research conducted between the promontory on which the settlement stands and the islet in front has provided an important contribution to the reconstruction of the ancient landscape; in fact, they allowed to recognize a submerged part of the protohistoric village itself: two wall alignments, probably remains of the fortification work and a paved area referable to an open area, very rich in ceramic fragments and animal bones; this sector of the village is today between 2.20 and 3.55 m deep, but in the Bronze Age, as indeed, the entire area between the mainland and the island of Malva must have been completely emerged [7, 8]. In the same area, the wreck of a Roman *navis lapidaria* lays, with a cargo of monumental cipollino marble columns, probably beached when the sea level was lower than the current one of 1.5 m. Other two beached wrecks of the medieval age, in the sites of Bacino Grande (40.280625° N 17.866034° E) and La Strea (40.250065° N 17.898074° E), testify significant coastal seascapes changes, as well as the presence of archaeological material and anthropic deposits on the islets of the Porto Cesareo archipelago, dating from the Archaic to the Roman Age, and the structures partially under the sea level on the Strea peninsula (Medieval age). Also, the quarry of Torre Castiglione (40.289319° N 17.817496° E), brought to the light by the powerful storms of 2019, is a precious testimony of a different ancient coastal landscape. This could make it possible to create a spatially and temporally explicit database that allows rapid consultation of erosion parameters (such as beach depth) and a rapid institutional planning and intervention [19].

Materials and Methods

The proposed monitoring plan provides for the integrated use of different types of data, harmonized through accurate georeferencing. Some of these data already natively contain georeferencing, as in the case of satellite data. Others, such as the historical aerial photogrammetry of the Military Geographical Institute (IGM), and the drone surveys have been corrected with the use of the Global Navigation Satellite System (GNSS), model Topcon HiPer SR. Remote sensing through the use of RPAS (Remotely Piloted Aircraft Systems or Drones) is proving to be very useful for identifying phenomena that act on a small scale and supporting and implementing protective measures according to an adaptive management approach, favouring the creation of a long-term investigation model, through multi-year surveys on habitats of conservation interest and coastal dynamics [12]. Photographic data and their photogrammetric elaboration allow to find a specific “point”, thanks to its georeferencing, which allows evaluating the evolution of certain phenomena being able to extract a large amount of data from the same product, this thanks to the capability of choosing different scales of analysis [16]. In recent years this technique has proved to be extremely effective and interesting in the environmental analysis of a multitude of matrices.

The data georeferencing process, essential for this type of analysis, requires the use of dedicated software for the correction and determination of the positions. Common points were identified between the IGM images and the current territory, such as the vertices of coastal towers, islets, reefs, which have not changed in the past 100 years. Finally, as regards the archaeological surveys, the onboard GPS of the support boats for underwater research was used.

The working group used an RPAS DJI model Phantom 4 Pro, that allows to cover areas from 25 to 35 hectares in a day and to return a multitude of outputs within a short time, like high-resolution orthomosaic, Digital Elevation Models (DEM), contour lines, habitat mapping (habitat identification is based on broad classes that are easily recognized based on ground truth and image analysis by trained operators. In this case, we focused on discriminating the area covered by beaches, which are easily isolated given the large difference with the urban environment behind.), 3D models and, sections and profiles of the beach. The survey sites were identified in the three pocket beaches located in the central area of the protected marine area "Porto Cesareo", the work area falls within the ideal polygon having vertices with coordinates 40.275400° N 17.868497° E, 40.271928° N 17.882110° E, 40.268685° N 17.880147° E, 40.272608° N 17.866113° E (fig. 1).

Figure 1 – Area of work.

The investigated beaches have an extension of about 1528 m within a system that is spread over about 4 km. These beaches have been selected as an elective place for summer tourist visits and installation sites of beach resorts that contribute to the local economy. Furthermore, are areas subject to numerous archaeological finds both on land and in the facing stretches of water that have made it possible to extract a paleoshoreline [7, 8]. Once a geodatabase is created, all aerophotogrammetric images, both historical and recent from drone, are georeferenced with the same reference system in order to compare data.

Finally, as already reported, for the archaeological surveys, vessel-installed GPS were used to support the underwater research activities. The assessment of the coastline dynamics was carried out through the use of the Digital Shoreline Analysis System (DSAS) Version 5.1 tool, distributed for the ESRI ArcGIS platform by the United States Geological Survey (UNGS) Woods Hole Coastal and Marine Science Centre[2].

This tool allows the calculation of statistics relating to the rate of change of coastlines starting from historical data relating to their positioning. For the use of this tool, it is necessary to create a shapefile in correspondence with non-dynamic structures (in this specific case it was decided to use a road infrastructure already present in the 40s) called baseline, and a single shapefile containing all the coastlines for each survey year, by each type of used methodology. These shapefiles represent the necessary inputs to the DSAS tool for the construction of transects that intersect perpendicularly to the baseline and allow the calculation of distance measurements (Shoreline Change Envelope and Net Shoreline Movement) and statistics (End Point Rate, Linear Regression Rate, and Weighted Linear Regression). Once these two shapefiles have been generated and their attribute tables have been appropriately populated, they have been inserted into the project database. Once populated the attribute table of the “Shorelines”, the “Cast Transect” key generates the transect, perpendicular to the “Baseline”, which intercepts the “Shorelines”. Finally, the “Calculate Rates” key generates the output statistics.

This standardized procedure allows processing the outputs from different acquisition methodologies of the same portion of the coast, using the same parameters, to monitor the evolution of the coastal strip. The use of information from different acquisition technologies, as already specified, requires corrections and additions; in our case, the presence of human artifacts dating back to the 16th century made it possible to use these structures, along with other geomorphological features of the area, as an additional tool for calibration and correction in positioning. We used IGM digitized stereoscopic aerial photos, acquired in the years 1943, 1954, 1977, and 1997. These are specifically nadiral frames with photogrammetric characteristics, of variable format, on panchromatic material (B/W), at the approximate scale of 1: 33 000 (variable with the detection altitude). These historical photos cover 79 years, with discontinuous intervals, and have the disadvantage of showing a point-like image of reality, but as a counterpoint, they are also the only validated, objective, and easily available source of information on a now past reality. The images were suitably georeferenced through the GNSS in the EPSG 32633 - WGS 1984 - UTM Zone 33N coordinate format. Specifically, 11 control points scattered in the area of interest were acquired, and the spatially explicit images thus obtained were processed to generate the contour lines necessary for identifying the discontinuity lines in a cross-comparison with other processing of the raster dataset, such as hillshade models, capable of emphasizing elevated structures about the height of the sun (Painted Relief). This algorithm was employed using the acquisition date and time information for every single frame, both for the IGM images and for the aerial photogrammetric images from the drone. This information was included in the freeware SunEarth Tools which allows you to calculate the Solar Azimuth and the Elevation of the Sun for each location by year and time of acquisition.

[2] https://www.usgs.gov/centers/whcmsc/science/digital-shoreline-analysis-system-dsas

The processing of raster files was carried out through the geospatial processing software ERDAS IMAGINE and ArcGIS (ArcMap), these steps allowed for the extraction, comparison, and validation of all the shorelines. Among the various definitions of this structure, we decided to adopt the one reported by the Coastal Engineering Research Centre [9] which defines the shoreline as the "line of contact between the earth and a body of water". The shorelines thus extracted were then exported as a shapefile and loaded into the GIS environment for subsequent processing. The images that made it possible to create the orthomosaics and DEMs relating to the year 2022 were acquired using RPAS, produced by DJI, model Phantom 4 Pro. The acquisition using RPAS took place at a constant altitude of 100 meters, in optimal light conditions calculated based on the absence of cloud cover and at an appropriate time with an appropriate height of the Sun above the horizon, fundamental factors to consider since they can create artefacts in the photogrammetric processing phase. The overlapping of the single images was 80 % to improve the software's matching capacity and, in this case, it was not necessary to create a clip excluding the edges of the area, notoriously areas where important deformations occur, as these areas did not negatively affect the extraction of data of interest.

Using the Agisoft Metashape photogrammetric software, the acquired images were mosaiced and an orthomosaic of the study area was processed. Although the images acquired employing RPAS are natively georeferenced, it has been found that the quality of this positioning does not respect a congruous standard with the use presented here, both for the X, Y, and Z coordinates. For this reason, it was decided to correct the georeferencing and the elevation based on points acquired in the field through GNSS with which the orthomosaic and the final DEM have been correctly calibrated. The images thus corrected were then processed, as the IGM images, for the extraction of the contour lines and the hillshade model, from these two outputs were thus extracted the shorelines for every single survey as shapefiles then loaded into the project database for the final processing. Satellite remote sensing can provide low-cost long-term shoreline data capable of resolving the temporal scales of interest to coastal scientists and engineers at sites where no in-situ field measurements are available. The use of satellite data in the context of this work mainly served to fill the significant information gap that previous data sources intrinsically have in their acquisition protocol. Satellite images fill this gap thanks to their revisit time and the implementation of algorithms for extracting information from easily usable databases.

Initially, the focus was on the use of the "Coastal Erosion Monitoring with Sentinel-1" Training Kit-COAS02 protocol produced by Copernicus Research and User Support (RUS), with data from Sentinel-1 satellites, C-band synthetic aperture radar (SAR) imaging. Unfortunately, this information turned out to be too coarse for our scale of interest, but certainly of undeniable usefulness for larger areas and where information on the field is scarce. For this reason, and also in order not to deny one of the main objectives of this work, namely the use of this "manual", especially for MPA personnel and coastal municipalities, it was decided to use data from Sentinel-2 satellites (Multi-Spectral Imager (MSI) with a resolution from 10 m to 60 m, depending on the bands[3], which allow the extraction of more useful information on our scale of interest. To make the most of the potential of this data and maintain ease of use for each level of expertise, we decided to use the open-source software toolkit, in Python language, CoastSat [20] which allows the user

[3] https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-2-msi/resolutions/spatial

to obtain time-series of shoreline position of any sandy coastline, worldwide from 30+ years (and growing) of publicly available satellite imagery.

The toolkit exploits the capabilities of Google Earth Engine to efficiently retrieve Landsat and Sentinel-2 images cropped to any user-defined region of interest (ROI). The resulting images are pre-processed to remove cloudy pixels and enhance spatial resolution, before applying a robust and generic shoreline detection algorithm. This shoreline detection technique combines a supervised image classification and a sub-pixel resolution border segmentation to map the position of the shoreline with an accuracy of ~10 m. The purpose of CoastSat is to provide coastal managers, engineers, and scientists with a user-friendly and practical toolkit to monitor and explore their coastlines. CoastSat enables the non-expert user to extract shorelines from numerous Landsat platforms and Sentinel-2 images. The shoreline detection algorithm implemented in CoastSat is optimized for sandy beach coastlines, it combines a sub-pixel border segmentation and an image classification component, which refines the segmentation into four distinct categories such that the shoreline detection is specific to the sand/water interface.

The ease of use is also evident from the input data requested from the user, which are restricted to the Region Of Interest (ROI), the time frame to be monitored and the satellite platform to be exploited. As mentioned above, there are some additional parameters that can be modified to optimize the shoreline detection but for more technical details we refer to the GitHub project page[4]. The algorithm uses an image classification scheme to label each pixel into 4 classes: sand, water, white-water, and other land features. As stressed by the developers, this classifier has been trained using a wide range of different beaches, but it may be that it does not perform very well at specific sites that it has never seen before.

To test if this was the case for our survey site, we crossed the information coming from the processing of the lines coming from RPAS surveys and IGM images, as well as the overlap with the orthomosaics and DEMs generated by the same RPAS surveys and the collimation of the related shorelines. The results of this test confirmed the compatibility of this approach and the correct calibration of the tool. Before running the batch shoreline detection, the tool gives the option to manually digitize a reference shoreline on one cloud-free image. This reference shoreline helps to reject outliers and false detections when mapping shorelines as it only considers as valid shorelines the points that are within a defined distance from this reference shoreline. Employing the CoastSat toolkit, 34 lines were extracted for the year 2019, 32 lines for 2020, and 26 for 2021.

The processing of the extracted coastlines provided, once the shapefiles were imported into GIS, the separation of data by year and by month, to create an annual average line through the DSAS tool itself. The annual mean line was calculated from the transects generated by the DSAS tool, specifically through the layer of the points of intersection between the transects, perpendicular to the "Baseline", and the shorelines through the "Mean centre" tool, the midpoints for every single transect, were generated. The use of the Point to line tool then made it possible to generate the relative average coastline, subsequently smoothed through the "Smooth line" tool with "Bezier interpolation" (fits Bezier curves between vertices.

[4] https://github.com/kvos/CoastSat

The resulting line passes through the vertices of the input line. This algorithm does not require a tolerance. Instead of the Polynomial Approximation with Exponential Kernel that calculates a smoothed line that will not pass through the input line vertices). These mean lines were eventually loaded into the database for subsequent final processing.

Results

The proposed monitoring plan provides for the integrated use of different types of data, harmonized through accurate georeferencing. Remote sensing through the use of RPAS (Remotely Piloted Aircraft Systems or Drones) is proving to be very useful for identifying phenomena that act on a small scale and supporting and implementing protective measures according to an adaptive management approach, favouring the creation of a long-term investigation model, through multi-year surveys on habitats of conservation interest and coastal dynamics [12].

Photographic data and their photogrammetric elaboration allow to find a specific "point", thanks to its georeferencing, which allows evaluating the evolution of certain phenomena being able to extract a large amount of data from the same product, this thanks to the capability of choosing different scales of analysis [16]. To display the results, among the various outputs generated by the DSAS tool, it was decided to use the "Net Shoreline Movement" (NSM) which expresses the distance expressed in meters between the oldest and most recent coastline for each transect.

This choice is always to pursue of the main purpose of the project, which is to provide a simple interpretation system for both the operators and the stakeholders of the areas affected by erosion (e.g., coastal municipalities and state-owned concessionaries who each year attend to the effects of the erosive phenomenon tangibly).

Discussion

From the results reported in Figure 2 and Table 1, it is possible to infer that in the 79 years between 1943 and 2022, out of 67 transects with an intermediate distance of 20 meters built in the DSAS tool, 85.0 7% are in an erosive state with an average negative distance of 17.84 meters. On the other hand, 14.93 % of transects result in accretion with an average positive distance of 7.49 meters. The accretional area is localized in the Torre Chianca bay, due to its peculiar morphologic structure working as a sediment trap. The other beaches, instead, are subjected to constant erosion due to their exposure.

Thanks to the underwater archaeological evidence it was also possible to determine the long-term evolution of the same trait of coastline. As reported in Figure 3 and Table 2, the useful information from this elaboration is quite tricky to interpret, so a good compromise could be to rely on the average distance of change reported in 507.36 meters seawards the actual coastline.

Table 1 – Net Shoreline Movement (m), 1943-2022.

Total number of transects	67
Average distance	-14.06
Number of transects with negative distance	57
Percent of transects that have a negative distance	85.07 %
Maximum negative distance	-53.19
Maximum negative distance transect ID	19
Average of all negative distance	-17.84
Number of transects with positive distance	10
Percent of transects that have a positive distance	14.93 %
Maximum positive distance	10.83
Maximum positive distance transect ID	37
Average of all positive distances	7.49

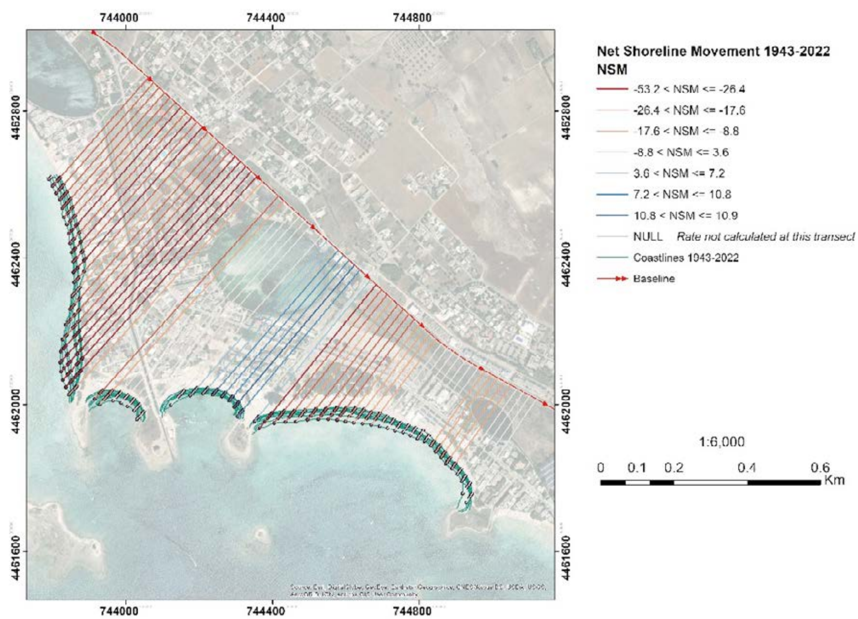

Figure 2 – NSM inferred from 1943-2022 lines DSAS processing.

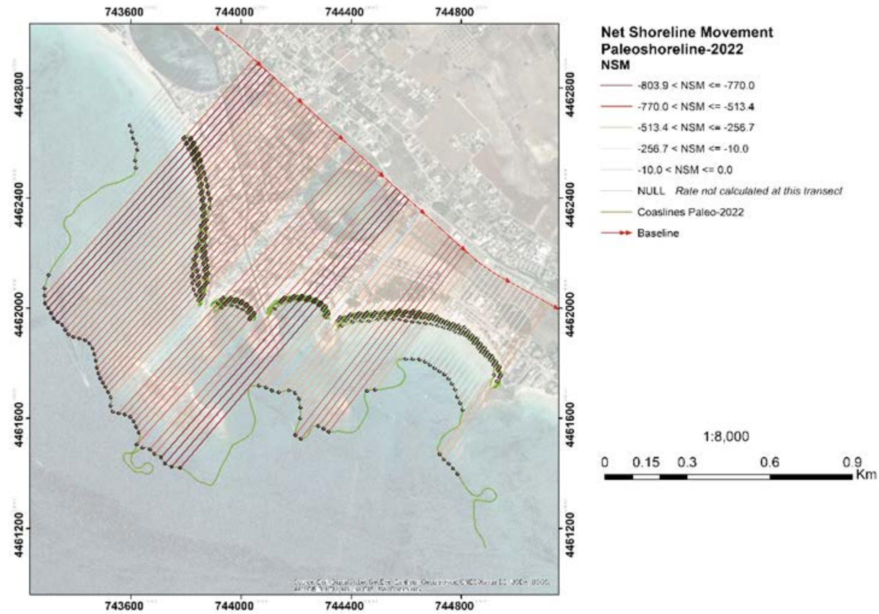

Figure 3 – NSM inferred from Paleoshoreline-2022 lines DSAS processing.

Table 2 – Net Shoreline Movement (m), Paleoshoreline-2022.

Total number of transects	67
Average distance	-507.36
Number of transects with negative distance	67
Percent of transects that have a negative distance	100 %
Maximum negative distance	-803.82
Maximum negative distance transect ID	11
Average of all negative distance	-507.36
Number of transects with positive distance	0

Conclusion

Coastal spaces can be defined as "living organisms", Due to the various factors that influence the dynamics of the coastal environment, this is certainly one of the most complex and fragile habitats, strongly affected by any variation that can be generated even several kilometres away from the place under examination [17]. The purpose of this work wants to highlight the possibility to integrate widely used means, cheap and reliable, freely and easily accessible data, together with the necessary expertise of the personnel of the coastal community authorities, in areas affected by erosional phenomena. The aim is to implement a monitoring system for the acquisition, processing and integration of results in an adaptive management perspective, aiming at a quick and concrete protection and management of the coastal environment. In this specific case, in a marine protected area, in which a large percentage of the local wealth is attributable to the tourist exploitation of coastal areas, the implementation of a constant, reliable, and integrated monitoring system of interactions and criticalities is even more important. Only an in-depth knowledge, at a local level and widespread throughout the territory, of the critical issues of the coastal environment and the ever-increasing threats it faces, could effectively help to prevent and quickly inform the local stakeholders on the actions to be implemented for counteract the risks, such as better design in the use and installation of erosion protection structures, or a more informed assessment in the investment of capital in certain areas rather than others. The methodology presented here, strengthened by a simple approach based on validated tools, is proposed as a further small step for the dissemination of those tools and expertise increasingly necessary at every administrative and management level to address those challenges, once considered future but now contingent if not overwhelming.

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