# GEOMORPHOLOGICAL APPROACHES TO STUDY POSIDONIA BANQUETTES AND THEIR EFFECTS ON THE COASTAL FRONT OF SCHINIAS - MARATHON NATIONAL PARK

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**Abstract** – In this study UAV technology with RTK-GPS is used in order to map in detail, the beach morphological characteristics in conjunction with shoreline change investigation with remote sensing techniques, aiming to the impact of the presence of *Posidonia oceanica* beach-cast seagrass litter in the area of Schinias national Park, Marathon, Greece. The principal aim of this research is to evaluate the relation between the banquettes and the sediments, as well as the banquette's significance concerning the beach protection. Field data were collected by performing 4 UAV Missions during one year with a view to: a) identifying spatiotemporal changes in volume, shape and area covered by the banquettes, and b) analysing relations between banquette deposition and sedimentary budget components and changes. Also, remote sensing data covering a period of 76 years was realized at the coastal front of Schinias-Marathon National Park, in order to identify current trends of the shoreline and the reasons for the intense erosion that has been caused. The total area covered by *Posidonia oceanica* beach-cast deposits was 11468.49 $m^2$ (maximum covered area in this research) and the volume of the two different banquettes was approximately 2492$m^3$. Concerning the granulometry analysis the dominant sediment class was the class of fine sand in all seasons. Shoreline differences between 1945 and 2021 in the study site, reveal a loss of land surface mainly due to the operation of the Marathon Dam (1929) causing high coastal erosion rates for the next 40 years. The setback rate is not constant for the entire dataset while also part of sedimentary equilibrium of this coast has probably been gradually restored within the last twenty years. Across the study site, a rather remarkable shoreline accretion is observed for the latest period (2018 - 2021). This, is a rather interesting finding, possibly related with the extensive Posidonia banquettes that have accumulated here, following the no removal strategy adopted by the Management Body of Schinias - Marathon Protected Area, since 2018. Thus, the presence of the banquette on a beach and the fine grained sediment enclosed in the banquettes, mitigates the erosion processes, can contribute to the sediment budget and affect positively the shoreline displacement. Therefore, the decisions of the extraction or not of such a formation must be taken under serious consideration.

## Introduction

Coastal environments and, in particular, beaches are rapidly evolving systems, driven by the continuous interaction of the topography and transport processes with wind,

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wave and tidal forcing. In order to understand and quantify coastal morphodynamics, it is necessary to acquire high-resolution data on beach topographic changes [3]. In the present study the UAV (*Unmanned Aerial Vehicle*) was used in order to map with great detail the beach morphological characteristics, in combination with the study of the shoreline displacement over time with a view to assessing the impact of the presence of *Posidonia oceanica* beach-cast organic material [10] on the coastal front. When in large accumulations, these deposits may develop characteristic formations on the lower shore known as banquettes [2]. Shoreline stability and the recession of the erosional processes, due to the presence of the banquettes on the beach have been studied. The principal aim is to evaluate the relation between the banquettes, their different expansion-volume on the beach, and their significance as a natural protection of the beach against dominant wave dynamics [4].

The study area is the coastal plain of Schinias Bay and it is located in the northeast region of the Attica Prefecture, approximately 50 km from the centre of Athens (Fig. 1). The broader area of Schinias and Marathon is an area of special ecological and socio-economic importance due to the presence of several historical monuments, sports and military facilities, while also of intense agricultural and touristic activities in Attica. Additionally, SMNP is part of the Natura 2000 European Network of protected areas (GR3000016 - Schinias Wetland and GR 3000003 – Schinias-Marathon National Park). The area is part of the southern Euboean Gulf, with an orientation of NE to SW. In particular our test site is located in the northern tip of Schinias Bay. This region is limited by the Kynosoura peninsula to the east and comprises a channel mouth draining a small lagoon. The marine counterpart of the area has been mainly designated for the presence of extensive *Posidonia oceanica* meadows of variable extend form along the beach almost annually at least for the past 4 decades.

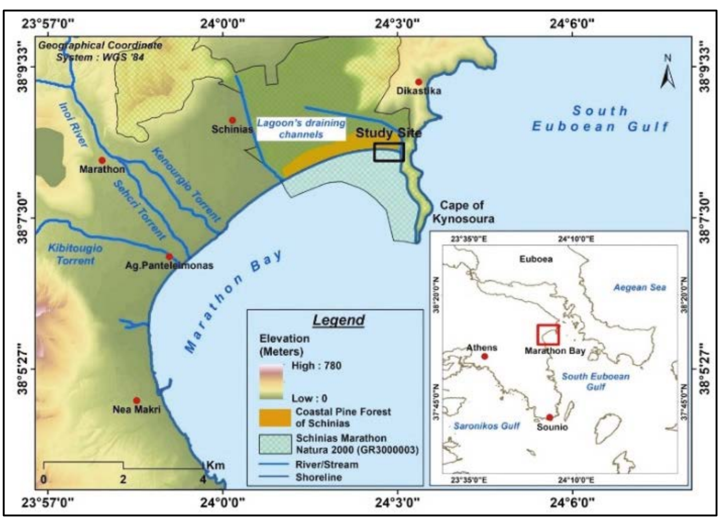



Figure 1 – The location of the study area in Marathon Bay, the physiographic setting of the coastal plain of Marathon, the torrents of the coastal plain and the lagoon's draining channel and also the limits of the Schinias - Marathon National Park. The lower right map also depicts the location of marathon bay in the wider area of Attica peninsula [6].

## Materials and Methods

*UAV data collection and field survey*

DJI Matrice 210 RTK was used for data acquisition. For this survey the sensor Zenmuse X5S was selected. This sensor is CMOS, 4/3”, it can collect RGB images with 20.8MP of effective Pixels. The photo resolutions are in 4:3, 5280×3956 and in 16:9, 5280×2970. It is also equipped with RTK technology, which expands its capabilities as it is extremely steady on flight (±10 cm on air) even with strong winds. Due to the smoothness of the terrain (almost flat as it is a beach front) the flights were horizontal parallel to the ground at a certain height AGL (Above Ground Level) [11]. The sensor of the UAV is pointed in 80 degrees (nadir). The images were taken in a specific overlap, in order to achieve 3D reconstruction of the relief, which led to the volume measurement of the different concentrations of the banquettes onshore. The software used to make the flight plans is the Pix4D capture (v.4.12.1). We use Ground Control Points (GCPs) to increase the accuracy of the UAV imagery to centimeter level [5]. At least 5 GCPs were used for each Mission of his study. They also improve the results from the Structure from Motion (SfM) interpretation of the photogrammetry process [13]. Prior to the flight the GCPs were surveyed with RTK GPS. The results from the RTK GPS survey along with the images collected from the drone flights were interpretated through Pix4D mapper v.4.5.6. in order to produce the orthomosaics, the Digital Surface Models (DSM) and the Digital Terrain Models (DTM), in order to calculate accurately the fluctuations of the volume of the banquettes during different seasons.

*Sediment sampling*

Sediment samples were collected during the photogrammetry missions (July 2020, September 2020, February 2021, June 2021). The sites where the sediments were acquired are in general, on the shoreline and on the shoreline area of the banquettes, forming transects, spaced approximately 50 m apart each other, in order to have a better image of the relation between the presence of the banquettes and the granulometry of the sediments. A GPS device was used to have the exact coordinates of the sampling sites with accuracy of ±3 m. The sampling sites varied during each mission because of the beach morphology and the movement of the banquettes.

The granulometric analyses conducted at the Bio-Geo-Chemical Laboratory (ISO 17025) of HCMR. Firstly, some of the samples taken from the banquettes were wet sieved with Calgon (Sodium Hexaphosphate -(NaPO3)6) (sieve diameter 4mm) to withdraw any grain from the leaves, in order to calculate the total amount/volume of sediments entrapped in the banquette. Then the rest of the samples, along with the sand which had been withdraw from Posidonia leaves, were dried in the oven in 45 °C for two days and they were sieved (sieves from 4 mm to <63 μm). Additionally, the results were interpretated statistically through the Gradistat v. 8.0 [1], in order to define the quality and the quantity of the distinctive sediment classes.

*Shoreline Displacement Analysis*

The survey of long-term shoreline displacements was carried out by comparing historical and contemporary aerial photographs (1945, 1960, 1969, 1988, 1996, 2001, 2010) along with satellite imagery (2012, 2014, 2018) and orthophotomosaic from photographs obtained using Unmanned Aerial Vehicle (2021) covering a period of 76 years (1945 - 2021). The shoreline uncertainty variable for each shoreline was defined as the spatial resolution (cell size) of the corresponding mosaic or image whose shoreline was digitized. Based on this approach regarding the shoreline uncertainty and consequently the error of the results, the accuracy of each shoreline from the available data, with the series mentioned above, was 1 m, 1 m, 0.64 m, 0.67 m, 1 m, 0.49 m, 0.25 m, 0.49 m, 5 m, 3 m and 0.027 m respectively. The satellite images (with a resolution of 3 and 5 m respectively) raise the error of the results. Nevertheless, because the rest of the data is of high accuracy, we can say that the accuracy of the results is of the order of +/- 1 m since we know in each result which shorelines interacted more and we have a fairly good knowledge of the study area. The quantification of long-term shoreline displacements was made with the use of the add-on application of Digital Shoreline Analysis System (DSAS) within the GIS platform ArcMap 10.6 [7]. This was accomplished by assessing 68 transects (every 10 meters), placed perpendicular relatively to the historical shorelines from a stable baseline [12]. At each transect the Net Shoreline Movement (NSM), the Shoreline Change Envelope (SCE), the End Point Rate (EPR) and Linear Regression Rate (LRR) was calculated and analyzed. All distances were calculated in meters, while the rate of change in meters per year (m / y). For a comprehensive overview regarding the trend of the shoreline and the interpretation of the results, the analysis was also applied along the wider area of the Schinias pine forest, i.e., along 3 200 m of shoreline (or hereafter study area).

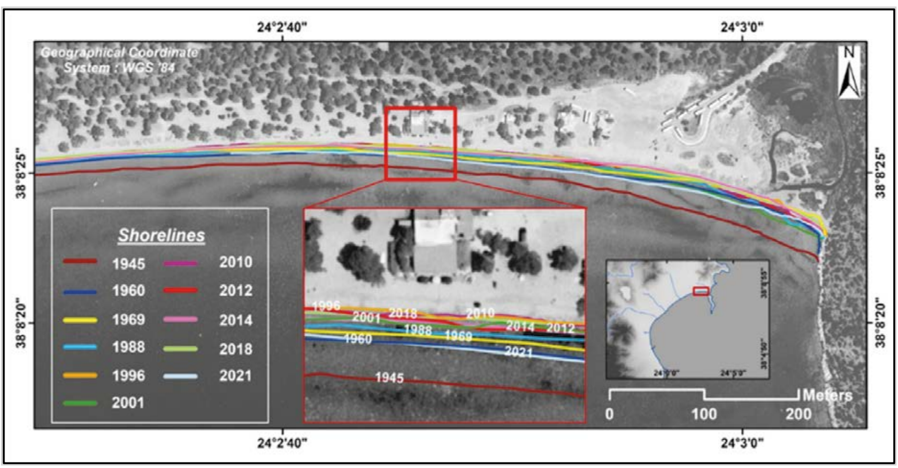
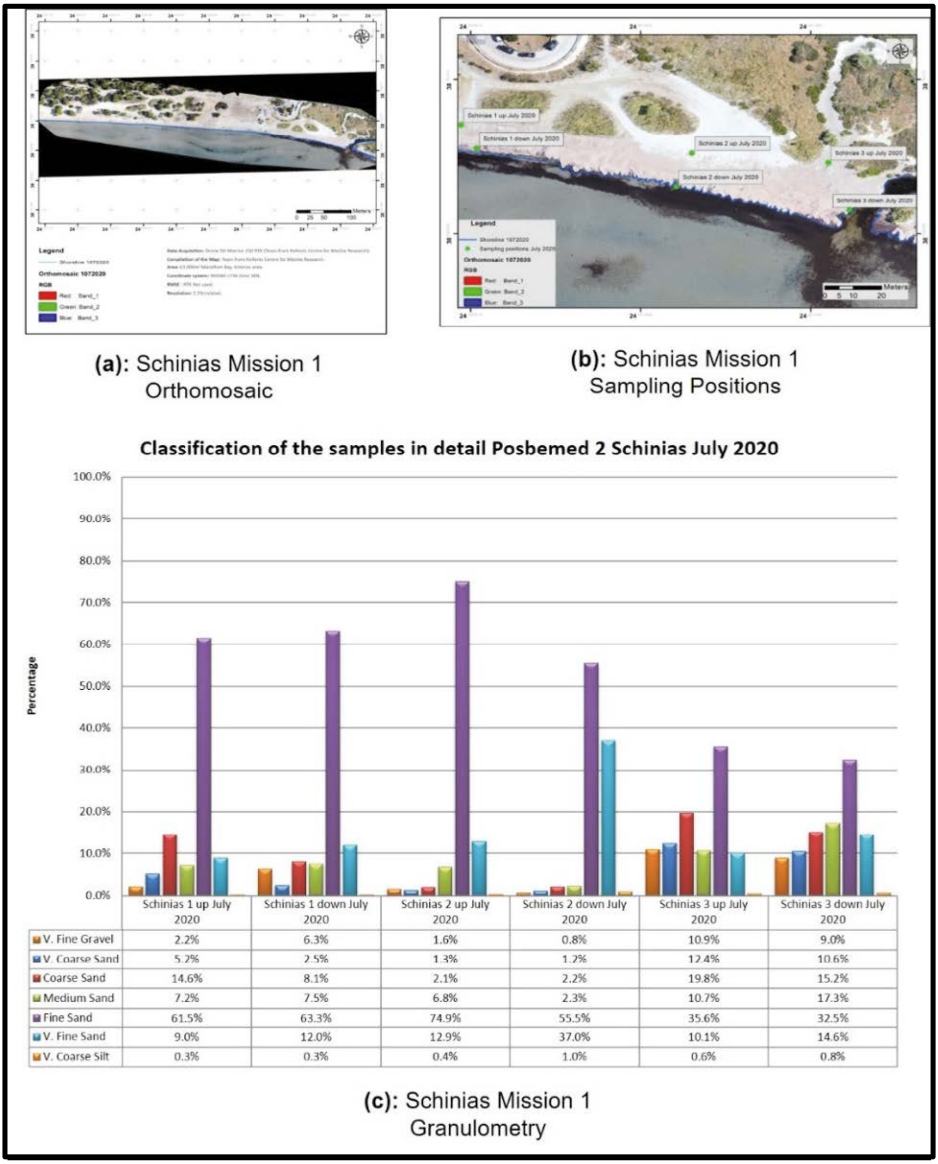



Figure 2 – All the digitized historical shorelines at the study site.

## Results

According to UAV photogrammetry data processing the maximum banquette deposition is encountered during Mission 3 (February 2021). This fact can be explained by




| | Schinias 1 up July 2020 | Schinias 1 down July 2020 | Schinias 2 up July 2020 | Schinias 2 down July 2020 | Schinias 3 up July 2020 | Schinias 3 down July 2020 |
|---|---|---|---|---|---|---|
| V. Fine Gravel | 2.2% | 6.3% | 1.6% | 0.8% | 10.9% | 9.0% |
| V. Coarse Sand | 5.2% | 2.5% | 1.3% | 1.2% | 12.4% | 10.6% |
| Coarse Sand | 14.6% | 8.1% | 2.1% | 2.2% | 19.8% | 15.2% |
| Medium Sand | 7.2% | 7.5% | 6.8% | 2.3% | 10.7% | 17.3% |
| Fine Sand | 61.5% | 63.3% | 74.9% | 55.5% | 35.6% | 32.5% |
| V. Fine Sand | 9.0% | 12.0% | 12.9% | 37.0% | 10.1% | 14.6% |
| V. Coarse Silt | 0.3% | 0.3% | 0.4% | 1.0% | 0.6% | 0.8% |

Figure 3 – Mission 1.

the dead leaves deposition mechanism which is very active during winter. Therefore, this observation enhances this study's results showing that the largest deposition of Posidonia dead leaves occurred between September 2020 (Mission 2 – Fig.4) and February 2021 (Mission 3 - Fig.5). In that period also the maximum volume of the sediment entrapped in the banquette calculated in this study (~161.17 ±2.76 m$^3$ minimum-2 large trucks transporting solid materials and ~1692.26 ±312.52 m$^3$ maximum-16 large trucks transporting solid materials). Both calculations-scenarios (minimum-maximum) indicating the obligation of the proper management (rationally remove or not remove at all the banquettes) in order not to lose all this amount of sediments, that is very difficult to accumulate to the beach since no physical nourishment mechanisms exist. Another significant factor explaining banquette deposition dynamics is their height. It is obvious that the maximum height of the banquette ranging from 1 m Profile A-A' Mission 2 (September 2020), to 0.20 m Profile C-C' Mission 4 (June 2021). Summarizing the banquette's main deposition mostly occurs after autumn, during the final phases of a storm event, when wave energy decreases. During Mission 3 the banquette shows its maximum extension. Other significant results originated from the granulometric analysis of each sample and then in all classes of each Mission separately (Fig. 3, 4, 5 and 6). In all Missions it is observed that the dominant class is fine sand, a fact that clearly reveals the protective role of the banquette. In general, the larger percentage of sediments can be characterized as sand (over 90 %). Deposition of coarser sediments is observed during Mission 1 (July 2020) and Mission 4 (June 2021).

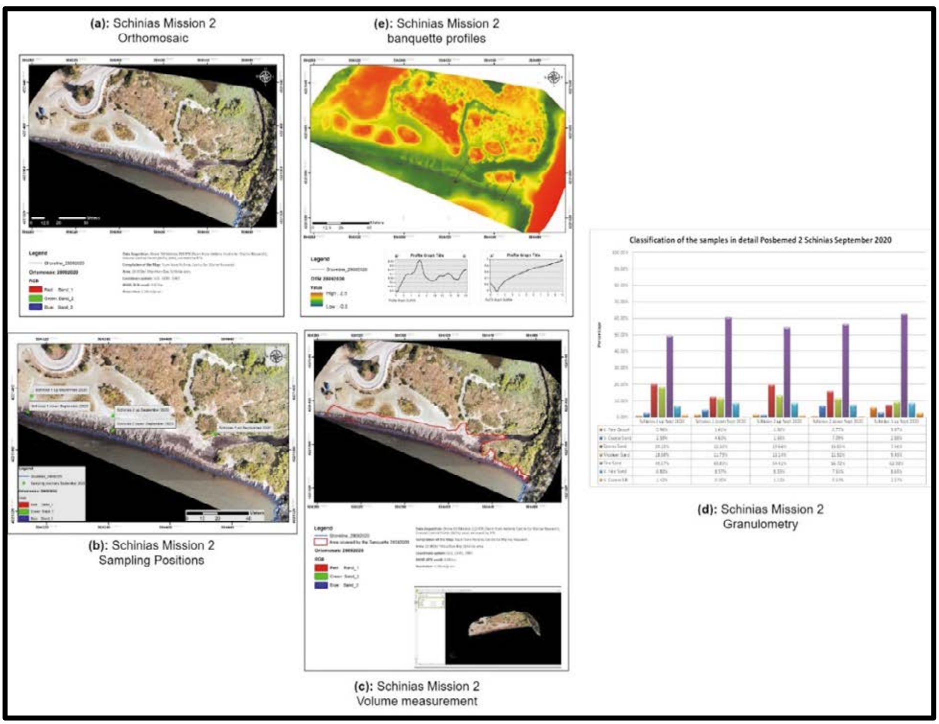



Figure 4 – Mission 2.

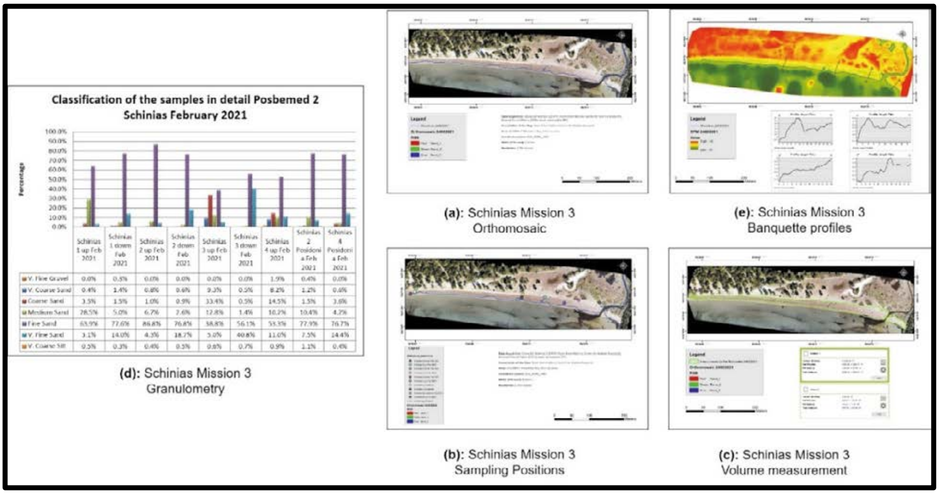



Figure 5 – Mission 3.

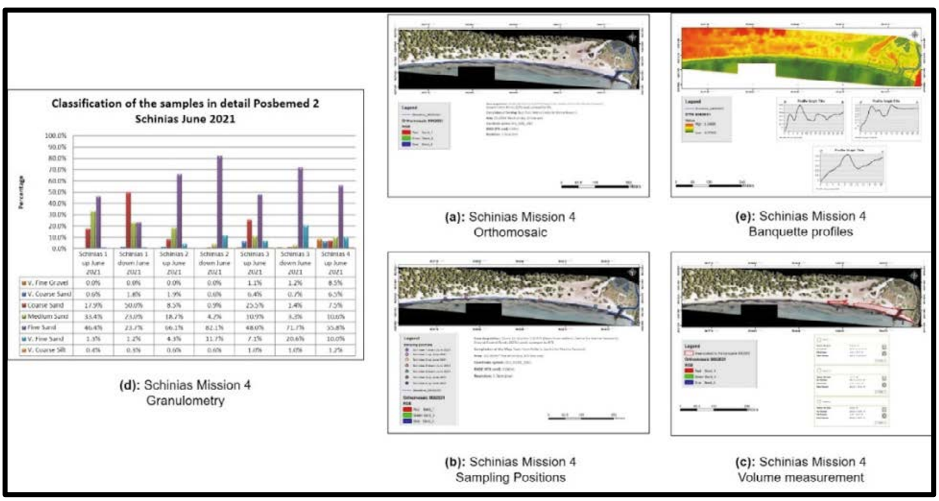



Figure 6 – Mission 4.

The results of NSM shown that the shoreline has undergone retreat in the last 76 years. The largest changes (25 - 30 m) are observed at the eastern part, with the maximum value (-30 m) at transect 3 at the eastern end of the beach. From east to west, values gradually decrease (from transect 30 to 68 values range from -10 to -12.5 meters). The average change of the shoreline across the study site is –15.3 m. The SCE values range from 20 m (transect 61) to 40 m (transect 6). Based on the EPR, the average displacement rate in the study area shows only negative values (shoreline retreat) for the period 1945 – 2021 (Figure 7a). The maximum setback value is found in transect 3 (-0.39 m / yr.) and the minimum in transect 43 (-0.14 m / yr.). The overall average shoreline retreat rate for the study site is 0.2 m / yr. The study of the Linear Regression Rate (LRR) shown that the setback rate has been estimated not to have been constant (Figure 7b, c, d and e): changes from the period 1945 – 1969, where the shoreline is constantly eroding with the higher rates, to the period 1969 – 1996, where erosion rates decreased significantly. Within 1996 advance of the shoreline is first observed, then alternating with periods of setback until 2010. Within 2010 - 2018, shoreline advance becomes more frequent (while again alternating with periods of retreat). Also 2014–2018, milder setback (and even advance) values are generally observed along the study area, particularly pronounced at the easternmost part of beach where the greatest setbacks had been previously detected. Finally, a rather remarkable shoreline accretion is observed for the latest period (2018 - 2021).

## Discussion

The key novelty of this study is not only that static information on the shore of the study area is shown on the different products, but also the accurate estimation of the sedimentary volume entrapped in the banquette is also calculated due to the use and combination of state-of-the-art methods and techniques for the study of the Schinias beachfront. The banquette affects directly the sediment deposition, and consequently the granulometry of the beach sediments, providing a low energy environment as indicated by fine sand accumulated therein. Indeed, fine-grained sediments are more likely to be eroded and transported to the sea during strong winds-waves. Thus, the amount of such sediments entrapped in banquettes in our study area, can contribute to the sediment budget of this coastal zone, highlighting the key role of the banquettes in microtidal embayed Mediterranean beaches. The volume of the banquette varies significantly between seasons and is affected by local weather conditions, especially strong eastern-southeastern winds for the case of Schinias.

Based on the shoreline displacement data, the study area seems to be subjected to coastal erosion since 1945, resulting to a loss of land surface of the order of 10,189 $m^2$. The operation of the Marathon Dam in 1929 severely disturbed the sedimentological balance of the wider coast resulting high rates of shoreline retreat for the period 1945 – 1969. Part of the coastal sedimentological balance was rather restored from the 80's onwards, based on the shoreline analysis which indicated decrease of the retreat rates and periods of shoreline advance began to appear since then. Although the study area appears more sheltered due to Kynosoura cape, it presents higher changes and retreat rates as compared to the western part of Schinias beach. Regarding the correlation of the shoreline with the Posidonia banquettes, noteworthy is the position of the shoreline on 2018, when a non-removal strategy for Posidonia banquettes was set forth by the Management Body of SMNP, presenting lower setback values and even mild advance at the study area, where indeed the greatest setbacks had been previously detected. Moreover, this finding stands out against the general situation characterizing the wider beach of Schinias (beyond the study area), where setback values remain constant for the same period [8]. Also, a rather remarkable shoreline accretion is observed for the latest period (2018 - 2021) across the study area, which could be likely directly related with the extensive Posidonia banquettes that have undisturbed accumulated here this last couple of years.

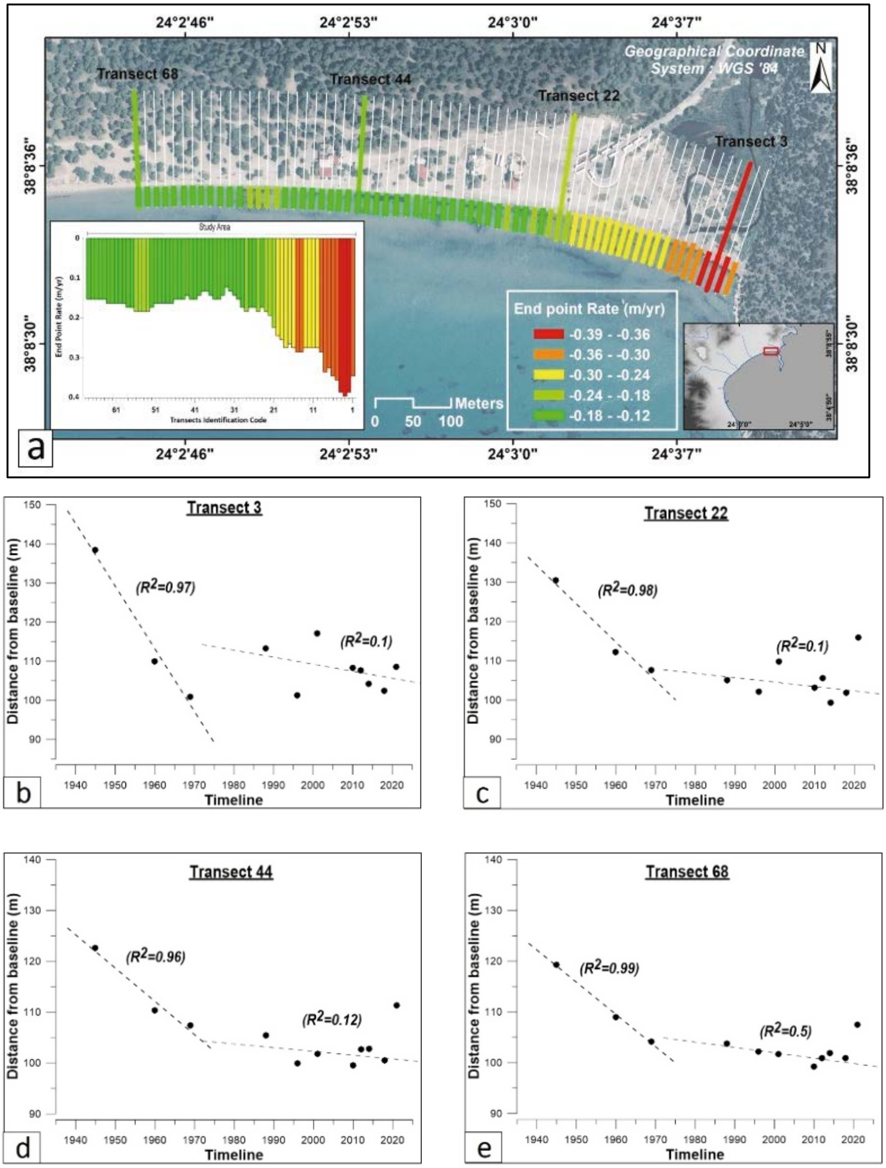



Figure 7 – Representation of the shoreline displacement rate (EPR) at each transect (in meters per year) across the study area, for the period 1945 – 2021(a) and the positions where the representative transect 3 (b), 22 (c), 44 (d) and 68 (e) intersects the shorelines as well as the linear correlation of the points at each transect.

## Conclusion

The fluctuations of the area covered by the banquette, the shoreline displacement and the sediment deposition on shore, along with the geomorphologically sheltered environment, make the role of the banquette particularly significant for our study area. Coastal displacement has been estimated approximately 20 m (erosion) since 1945 [9] and it would only be higher but for Posidonia banquettes accumulation, since the main sediment supply comes from marine and aeolian processes. The draining channel doesn't provide significant amount of sediment since it has not an extensive drainage network. Against the general erosion trend characterizing the wider study area [9], banquette accretion contributed to shoreline advance (~1 m maximum) within the time frame of this study, further indicating the protective role of these natural features; more long-term monitoring is however necessary to better understand long-term trends in this process. High-resolution photos taken from the drone along with the centimetre accuracy performed by the GNSS-RTK (DGPS) provide exquisite data for such surveys. More extensive monitoring, considering both long-term and seasonal changes is required. In this way, coastal trends and spatiotemporal sedimentological changes in direct relation with key environmental factors will be better comprehended, providing valuable input to management planning and decision-making processes for this area of high ecological interest.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