

# Human induced geomorphological changes in the Bay of Vari (SW Attica): Issues of coastal zone management\*

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**ABSTRACT:** The aim of this paper is to examine the qualitative and quantitative morphological and main induced changes of the coastal area of Vari. Qualitative changes include the alterations in land use and coastline evolution that took place in the area of Vari bay during the last hundred years by the comparison of geomorphologic features from recent topographic maps and earlier historical maps which were published in 1885. Quantitative changes, in the same area, were observed and registered by analyzing chronological series of aerial photographs from 1945 to 1987. The implications of these changes to the coastal zone are examined and actions are proposed aiming at the development of this region and its environment protection.

**Key-words:** coastline, GIS, remote sensing.

**ΠΕΡΙΛΗΨΗ:** Ο σκοπός της παρούσας εργασίας είναι να διερευνηθούν οι κύριες ποιοτικές και ποσοτικές μορφολογικές μεταβολές που έχουν προκληθεί στην παράκτια περιοχή της Βάρης. Οι ποιοτικές μεταβολές περιλαμβάνουν τις αλλαγές στην χρήση γης και στην εξέλιξη της ακτογραμμής στην περιοχή του κόλπου της Βάρης και διαπιστώθηκαν μέσω της σύγκρισης πρόσφατων τοπογραφικών χαρτών με παλαιότερους ιστορικούς τοπογραφικούς χάρτες που εκδόθηκαν το 1885. Οι ποσοτικές μεταβολές, στην ίδια περιοχή, παρατηρήθηκαν και καταγράφηκαν με τη μελέτη διαφορετικών χρονολογικών σειρών αεροφωτογραφιών από το 1945 έως το 1987. Επιπλέον, διερευνήθηκαν οι επιπτώσεις των μεταβολών αυτών στην παράκτια ζώνη και προτείνονται μέτρα που στοχεύουν στην ανάπτυξη της περιοχής και στη προστασία του περιβάλλοντος.

**Λέξεις-κλειδιά:** ακτογραμμή, ΓΣΠ, τηλεπισκόπηση.

## INTRODUCTION

During the recent decades, the coastal zone of the southwest area of Attica has been influenced by both natural process and in a greater extent, by human activities. As a consequence, the natural and geographical characteristics in many locations have been altered.

House building and the major technical construction as well as, natural disasters, such as big blazes and deforestation, have impact on the morphology and, particularly, coast (SKILODIMOU, 2002).

The recording and monitoring of the coastline changes is important for the proper management of the coastal zone. A variety of techniques have been used to study the coastline changes. Some researchers compare topographic maps of different periods (GUNASEKERA, 1996; NAIRN & COWIE, 1997; VERIKIOU-PAPASPIRIDAKOU *et al.*, 2004). Moreover, the comparison of the coastline as shown in aerial photographs of different periods of time has revealed the changes of the coastline (BALSON *et al.*, 1996; GORMAN *et al.*, 1998; WATTERS & WIGGINS, 1999; MASON *et al.*, 2000; SKILODIMOU, 2004).

## Geographical Settings

The Bay of Vari is extended along the coastal zone of Attica and is located about 30 km southwest of Athens (Fig. 1). The bulk of the area is flat with gentle slope and altitude fluctuating from 0 - 30 meters, except the eastern and western part. During the last thirty years, the area was urbanized intensely.

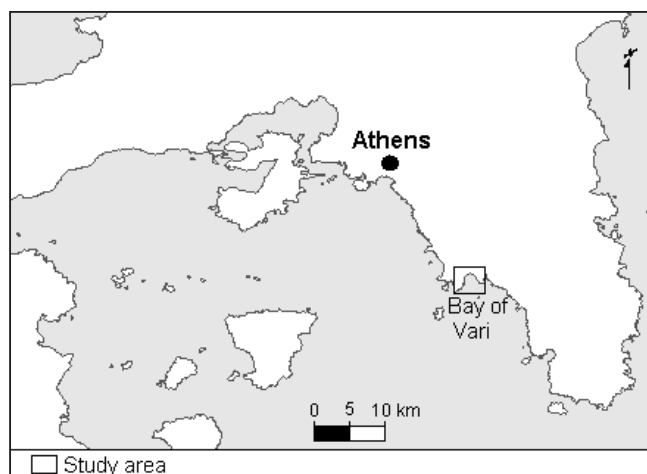


Fig. 1. The location of the study area.

\* Ανθρωπογενείς γεωμορφολογικές μεταβολές στον κόλπο της Βάρης (ΝΔ. Αττική): Προτάσεις για διαχείριση της παράκτιας ζώνης.

## Geological Settings

The general area of Vari is composed by alpine formations, which belong to the relatively autochthonous unit of Attica, and by Neogene and Quaternary formations. Specifically, the lithological formations are given below:

- Lower Marble: these marbles are white or gray-white with some layers of schist and are found in the eastern part of the Vari Bay. They are often fractured (LEPSIUS 1893; MARINOS & PETRASCHECK, 1956; PHOTIADES & CARRAS, 2001).
- Neogene formations are not widespread and consist of Miocene deposits composed of layers of sandstone, marls, loams and conglomerates; these layers are of medium cohesiveness with intercalation terra rossa and travertinoid limestone (HARALAMBAKIS, 1952; KATSAVRIAS & LATSIOUDAS, in press).
- Quaternary formations are widespread in the region and consist of: a) Pleistocene deposits include arenaceous marls, sandstones, breccio-conglomerates, and clastic travertinoid non-layered limestone, b) Holocene deposits made of talus cones with coarse, uneven and angular materials of varied lithologic composition and by alluvial deposits with recent non-cohesive materials, basically sands, clays and gravel (LEPSIUS, 1893; SINDOWSKI, 1949; GAITANAKIS, 1982; KATSAVRIAS & LATSIOUDAS, in press).

The tectonic of the region was due to the plicate activity as well as the relatively recent influence of fault activity. The relatively autochthonous underlying unit of Attica is intensively distorted and has main plicate structures with a direction NE-SW and younger ones with a direction NW-SE (MARIOLAKOS, 1971; MARIOLAKOS & PAPANIKOLAOU, 1973).

## The scope of the study

This paper involves: primarily, the examination of the geology of the Vari region; and secondly, it presents a thorough study of the alterations that occurred. In this context, the use of modern technology such as GIS and remote sensing has supported the methodology of work to economically record, the changes of the coastal environment of Vari. More specifically, the geological formations and the qualitative and quantitative changes in the natural and geographical environment of the coastal zone have been studied. Regarding the qualitative changes, the alterations of the last fifty years have been registered by comparing topographic maps. The quantitative changes include the measurement of the land increase within the last fifty years by comparing the aerial photographs of different years. In this way, the developed GIS database gives information about the geological and tectonic structure of the region and the diachronic changes occurred, as well.

Furthermore, the consequences of the human activi-

ties on the coastal environment are examined and proposals are made for the development and improvement of the coastal zone, as well as the protection of the natural environment.

## DATA USED & METHODOLOGY

As a first step, a new geological map of the broader area was generated based on the existent geological map of Institute of Geological and Mineral Exploration (IGME): sheet "KOROPI-PLAKA", at a scale of 1:50.000. In-situ investigation added information to the study. Besides the fault system of the study area was recorded on the available aerial photographs and has been depicted photogrammetrically on the new geological map. The produced geological map was digitized and saved in the developed GIS database.

The qualitative changes were registered with the help of two survey maps: the topographic map "ATHENS-KOROPI", scale 1:50.000, edited in 1988, of the Hellenic Geographic Military Service and the "VARI" map, scale 1:25.000, edited in 1885, from Royal Archaeological Institute of Germany and republished J.A. Kaupert. After scanning, these maps were checked comparatively using GIS software (TNTmips) capabilities.

To determinate the quantitative changes, aerial photographs from Hellenic Geographical Military Service were examined. The photographs taken between 1945 and 1987 were of different scale:

- Aerial photograph of the year 1945, scale 1:42.000.
- Aerial photograph of the year 1960, scale 1:30.000.
- Aerial photograph of the year 1972, scale 1:40.000.
- Aerial photograph of the year 1987, scale 1:35.000.

Hence, they were adjusted to the projective system EGSA of the survey map of G.M.S. "ATHENS-KOROPI", scale 1:50.000, issued in 1988 with a GeoTiff format. Thus, each aerial photograph is characterized by a geo-reference and geometric correction. Furthermore, the coastline was digitized in each aerial photograph for all the four different data and the recognized changes from 1945 to 1987 were measured by overlaying the digitized coastlines. The processing of the images and the applied GIS techniques occurred using TNTmips software.

The applied methodology produced a new GIS database which may provides information on the geology and the changes that occurred in the coastal environment in the past years. Hence, human interventions and their impact on the region are properly monitored.

## RESULTS & DISCUSSION

### Geological & tectonic observations

Talus cones were observed during field investigation. The talus cones along with the recorded fault system were added to the existing geological map of the area as shown

in figure 2. The prevailing directions of the observed faults (of the geological map, and photo-ling) are: NW-SE, NE-SW, E-W and N-S.

### Coastal geomorphological observations

The comparison between the earlier and the contemporary survey maps is shown in figures 3 and 4. The most important changes of the natural and geomorphologic

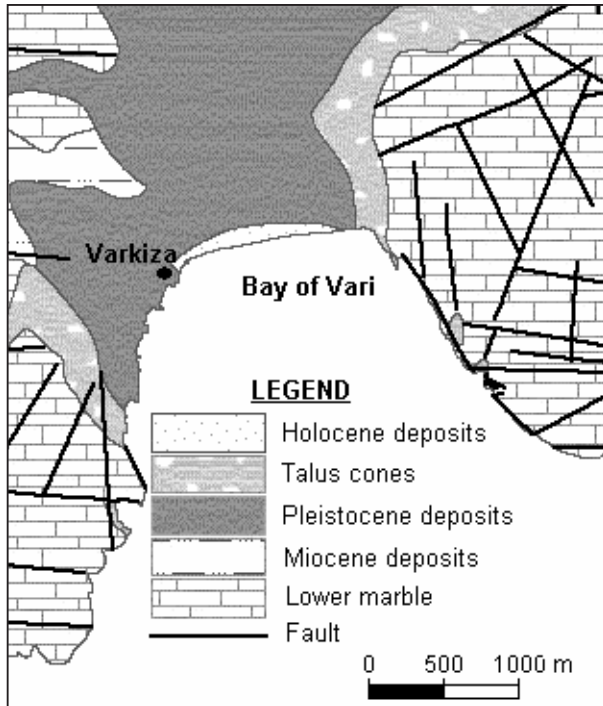


Fig. 2. The geological map of bay of Vari (modified by geological map of IGME).

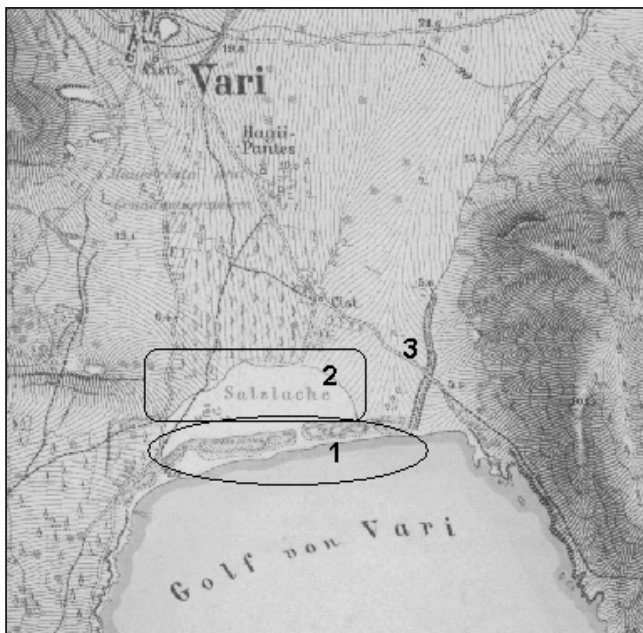


Fig.3. The bay of Vari is shown in the topographic map of 1885.

environment, which have taken place over the last century until today and have been caused by human activity, are:

- Depletion of old dunes extending along the shore of Varkiza coast (location 1, Fig. 3), and of the lagoon (salz lache) located in today's beach constructions of Varkiza (location 2, Fig. 3). Management of the streambed and of its mouth (location 3, Fig. 3).
- Coastal artificial filling and construction of tourist buildings, marinas, recreational areas, and organized beaches; all these have caused the land progradation towards the sea.
- Excessive change in the land use due to housing and roads construction. This has led to the depletion of the greenery and the forestry areas.

The consecutive changes of the coastline from 1945 to 1987 are shown in figure 5. The greatest alterations occurred between the years 1960 and 1972. Particularly, the coasts in the year 1945 and 1960 are approximately at the same level. On the contrary, in 1972 the first results of human intervention are observed due to facilities at the beach of the National Tourist Organization in Varkiza coast. The final interventions occurred in 1987 when new marine works took place in Varkiza as well as a coastal management plan for an organized beach, which is currently used as a recreation area.

The final change of the coastline between 1945 and 1987 is most significant within a zone of 2026 meters in length and width ranging from 16 m to 126 m. Between 1945 and 1987 the encroachment of the land into the sea was 92,557m<sup>2</sup> (Table 1).

TABLE 1

Changes in the coastline during the years 1945 and 1987 in bay of Vari.

Location	Length (in m)	Width (in m)	Area (in m <sup>2</sup> )
Bay of Vari	2026	16 – 126	92,557

### Human Interventions

The housing development of the area and the extensive human interventions in the coastal zone have altered the natural geographic characteristics of Vari Bay and have changed the balance of sediment accretion in the area. The arrangement of the streams and the urbanization of the area have resulted in very small accretions of terrestrial sediment. Thus, the natural formation and change of the coast depend mainly upon the process of marine deposition and erosion.

The area where the lagoon (salz lache) originally occurred as is shown on the topographic map of 1885 (Fig. 3) has been covered by sediments today and is crossed by the Athens-Sounio road. On its west part, housing of part of Varkiza has been developed (Fig. 4).

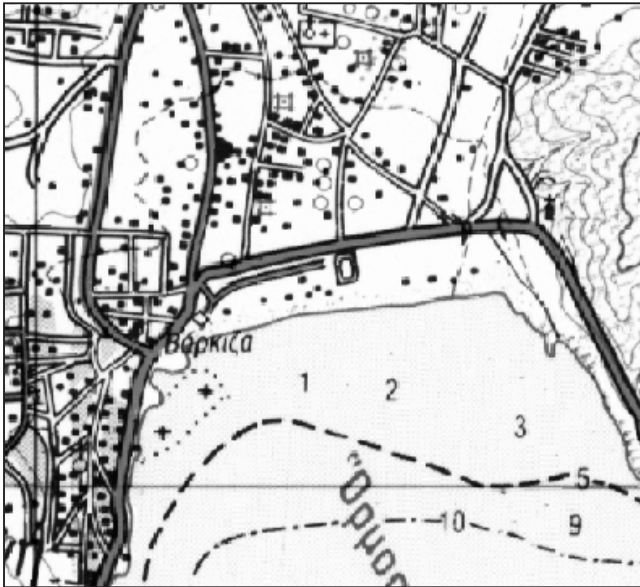


Fig. 4. The bay of Vari is shown in the contemporary topographic map.



Fig. 6. The gray-shaded area is prone to flooding.

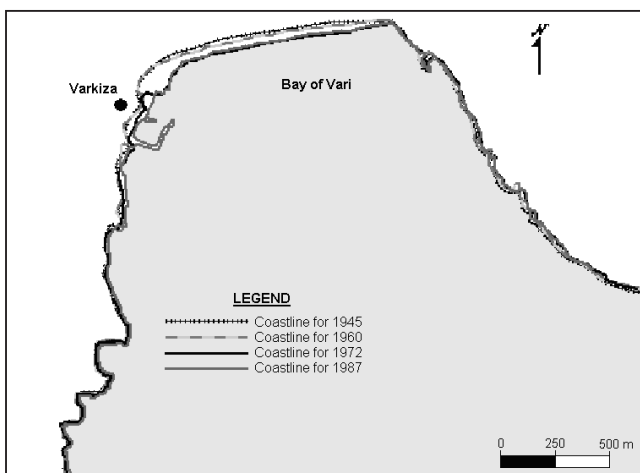


Fig. 5. The consecutive changes on the coastline from 1945 to 1987.

The existence of the lagoon (salz lache) suggests that the specific area is a natural water reservoir. The area extending to its northern part is one of gentle slopes with a low altitude and is a part of the drainage basin of the surrounding area of Vari. This is the main reason of flooding during the months of heavy rain.

The built-up Athens-Sounio road constructed over the old lagoon (salz lache) divides it into two parts: a northern and a southern. Hence, this has produced an artificial obstacle, which does not allow natural water circulation in the northern part into the sea. Combination of inadequate drainage systems, illegal housing development, fires and elimination of forest areas, the extensive landfill without consideration to the natural geographical conditions of the area is cause of flooding.

In figure 6 the area extending to the north of the road appears to show an increased risk of flooding conditions

because of its construction. A special survey should be conducted on the area concerning the natural conditions, which have influence on the area during periods of heavy raining. According to its outcome, the government should make appropriate technical works to deal with the problems of the area.

A series of proposals to deal with the problems can be applied to the study area as well as to other regions with similar problems. Such proposals are mentioned below:

- Continuous monitoring and assessing of human interference in the coastal zone that led to its degradation.
- Restriction of the uncontrolled interference with the coasts and the beaches followed by a framework of coastal planning and land use.
- Maintenance of the natural riverbed and prohibition of the uncontrolled earth filling and construction.
- Construction of a complete drainage system and proper service to control imminent flooding.
- Protection of forestry areas and reforestation.

## CONCLUSIONS

The most significant changes have occurred along the coastal zone of bay of Vari in areas underlain by Quaternary formations and with gentle slopes.

Comparing topographic maps of different periods of time has identified the qualitative and the quantitative changes on the coastal zone of Vari bay. More specifically, extensive housing construction and changes of the land use have resulted in the following effects:

- Destruction of almost all old dunes along the coast in the investigated area, elimination, draining up and earth filling of the old brackish lagoons.
- Technical arrangement of the coast and streams in the examined area.

The changes in the bay of Vari were quantified by comparing aerial photographs of different periods of time. Particularly, for the years 1945 – 1987, artificial expansion of the land against the sea was recorded and land filing over an area of 92,557 square meters in a length of 2026 meters and width of 16 – 126 meters.

The investigatory method applied can procure fast, economic and reliable results as regards the monitoring of the coastal zone and the environment, in general. Authorities involved in coastal management may use the continuous monitoring of the past and current interventions on the coastline.

An additional consequence resulting from the increased human activity in the region of the Vari bay is the flooding events caused by the landfill of the old lagoon (salz lache) and by the construction of the raised coastal road which now acts as a dam impeding water flow.

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