Spatio-temporal changes to the coastal zone of Vari (Greece), using remote sensing and GIS techniques

HARIKLIA SKILODIMOU[1], GEORGE BATHRELLOS[2], DIONISSIOS KALIVAS[3], PANAYOTA MAKRI[4], & EFTHIMIA VERIKIOU-PAPASPIRIDAKOU[5]

[1] *National and Kapodistrian University of Athens, Zografou, 157 84, Gr. (e-mail: hskilodimou@euof.uoa.gr)*
[2] *National and Kapodistrian University of Athens, Zografou, 157 84, Gr. (e-mail: gbathrellos@geol.uoa.gr)*
[3] *Agricultural University of Athens, Athens 118 55 Gr. (e-mail: kalivas@aua.gr)*
[4] *National and Kapodistrian University of Athens, Zografou, 157 84, Gr. (e-mail: pmakri@geol.uoa.gr)*
[5] *National and Kapodistrian University of Athens, Zografou, 157 84, Gr.*

Abstract: The aim of this paper is to examine the spatio-temporal, qualitative and quantitative changes in the natural environment and morphology of the coastal area of Vari, a suburb of Athens, Greece. The changes were studied using maps, aerial photographs and GIS techniques. Qualitative changes including man-made alterations that took place in the area of Vari bay during the last hundred years were detected by comparing the geomorphologic characteristics portrayed by recent topographic maps with those visible on old maps (edition 1885). Quantitative changes, in the same area, were noted, registered and assessed in terms of surface changes by interpreting aerial photographs taken between 1945 and 1987. The results showed that intense housing construction associated with the urban 'sprawl' of Athens in the south-west coastal zone have resulted in the following effects:

- Destruction of almost all the former dunes,
- Draining and earth filling of the former salt-lagoons and
- Artificial re-arrangements to the coast and stream systems.

New actions are proposed for the development of this region, with a view to the better protection of its natural environment.

Résumé: Ce document examine les changements spatio-temporels de l'environnement naturel et de la morphologie de la côte de Vari, banlieue d'Athènes, en Grèce. Ces changements ont été étudiés à l'aide des cartes topographiques, des photographies aériennes et des Systèmes d' Information Géographique (GIS). Les changements qualitatifs qui eut lieu a la région du golfe de Vari pendant les cent dernières années ont été investigués par la comparaison des caractéristiques géomorphologiques des cartes anciennes (édition 1885) et contemporaines, à la fois. Les changements quantitatifs de la même région ont été calculés par l'étude et l'interprétation des photographies aériennes, émises aux années différentes de 1945 a 1987. Les résultats de l'étude des photographies et des cartes, ont identifié que l'urbanisation de la région a provoqué:

- La destruction des dunes
- Le dessèchement et le remblayage des lagunes
- La gestion artificielle de la côte et des ruisseaux.

Afin de protéger l'environnement et développer la région, quelques suggestions ont été soumises.

Keywords: geomorphology, shorelines, geographic information systems, remote sensing

INTRODUCTION

During recent decades, the coastal zone in the southwestern area of Attica has been influenced by natural causes and, to a greater degree, by human activities. As a consequence of this, the natural and geographical characteristics in many parts of the area have been altered. The construction of houses and various other infrastructure has constituted one agency of change, as have natural disasters, such as extensive fires and deforestation; both of these in combination have affected the geomorphology and, in particular, the coastal configuration.

This study involves firstly, an examination of the geology of the region of Vari in the Southwestern coastal zone of Attica, and secondly, a thorough study of the changes that have occurred. Comparisons of aerial photographs taken at different times have revealed changes to the shoreline in many previous studies (Gunasekera 1996, Balson *et al.* 1996, Watters & Wiggins 1999, Mason, Gurvey & Kennett 2000).

The use of remote sensing and GIS technology has enabled changes to the coastal environment of Vari to be more efficiently recorded (Skilodimou 2002). More specifically, the geological formations and the qualitative and quantitative changes to the natural and human environment of the coastal zone have been studied in an effort to more closely relate these parameters. The qualitative changes taking place over the last fifty years have been documented by comparing topographic maps published at various times. Quantitative changes to the land surface have been estimated by comparing aerial photographs taken at different times over the last fifty years. A GIS database has been created, which gives information about the geological and tectonic framework of the region as well as the temporal changes that have occurred.

The impact of human activities on the coastal environment is also examined, and proposals will be made about measures that can be taken regarding both at the development and improvement of the coastal zone, as well as protection of the natural environment.

DATA AND METHODOLOGY

Study area

The Bay of Vari is located about 30 km southwest of Athens (Figure 1). With the exceptions of the eastern and western parts the area is characterized by a subdued topography, with gentle slopes and altitudes ranging from sea level to 30 m. Urbanization has taken place over the past thirty years.

Figure 1. The study area

Data used

The following data has been used:

- Geological map sheet “KOROPI-PLAKA”, scale 1:50.000, of the Institute of Geology and Mineral Exploration (IGME).
- Topographic map sheet “ATHENS-KOROPI”, scale 1:50.000, edited in 1988, of the Hellenic Geographic Military Service (HGMS)
- Topographic map sheet “VARI”, scale 1:25.000, edited in 1885, of the Royal Archaeological Institute of Germany; republished by J.A. Kaupert
- Aerial photograph for 1945, scale 1:42.000, of the HGMS
- Aerial photograph for 1960, scale 1:30.000, of the HGMS

- Aerial photograph for 1972, scale 1:40.000 of the HGMS
- Aerial photograph for 1987, scale 1:35.000 of the HGMS
- Fieldwork carried out in 2001.

Methodology

As a first step, the main geological formations were characterized. The observations made, which included in-situ field investigations, were integrated with the existing geological map to produce a new map. This was digitized and stored in the GIS database developed at the same time.

The qualitative changes were registered by using the two topographic maps edited in 1988 and 1885. After these editions had been scanned and digitized, comparisons were made and the changes documented using GIS software (ArcGIS and TNTmips) capabilities.

Aerial photographs were used to detect the quantitative changes. They were flown between 1945 and 1987 and the images were printed at different scales necessitating adjustment to the projection system (EGSA) of the topographic map "ATHENS-KOROPI" (details above), with a GeoTiff format. Geo-referencing of the photographs was achieved by establishing common points between each photograph and the relevant parts of the topographical base-map. Further processing of the images utilized the software TNTmips; it included digitization of the shorelines portrayed by each aerial photograph and overlaying of the different layers in a GIS.

These methodologies have resulted in a new GIS database to provide information both on the geology and the changes that have occurred to the coastal environment over the past years. This database will facilitate the monitoring of human interventions, and their impact on the region.

RESULTS

Geological and tectonic settings

The broader area of Vari is composed of formations related to the Alpine orogenic system, specifically those belonging to the relatively autochthonous unit of Attica, as well as by Neogene and Quaternary formations. The principal lithological units are as follows:

- Lower Marble: these are white or greyish white marbles with some schist layers; they crop out along the eastern part of Vari Bay. They are commonly faulted and fractured (Lepsius 1893; Marinos & Petrascheck 1956; Photiades & Carras 2001).
- The Neogene formations are patchily developed. They comprise Miocene sequences of sandstone, marl, loam and conglomerate; strata are of medium cohesiveness, with intercalations of terra rossa and travertinoid limestone (Haralambakis 1952; Katsiavrias, & Latsoudas in press).
- The Quaternary formations are widespread. The Pleistocene sequences consist of arenaceous marl, sandstone, breccio-conglomarate, and massive, travertinoid, clastic limestone. Holocene deposits consist of talus cones composed of coarse, poorly sorted, angular material of varied lithology, and unconsolidated alluvial material consisting of sand, clay and gravel (Lepsius 1893; Sindowski 1949; Marinos & Petrascheck 1956; Gaitanakis, 1982; Katsiavrias, & Latsoudas in press). Talus cones were also encountered during in site investigations and these were included in the new geological map of the region (Figure 2).

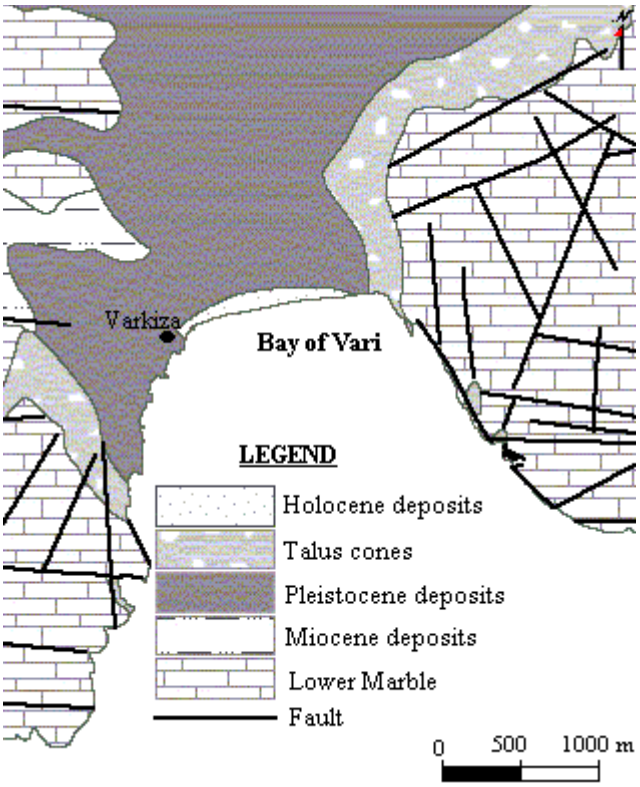

Figure 2. Geological map of the Bay of Vari.

The present tectonic features of the region are the result of thrusting, in addition to more recent fault activity. The relatively autochthonous underlying unit of Attica is intensely dismembered by major thrusts with NE-SW transport directions, and by younger translational structures with NW-SE directions (Mariolakos 1971; Mariolakos & Papanikolaou 1973).

The network of faults crossing the study area has been recorded from the available aerial photographs and depicted photogrammetrically on the new geological map (Figure 2). The prevailing directions of the faults are: NW-SE, NE-SW, E-W and N-S.

Qualitative changes to the coastal zone

A comparison between previous and contemporary survey maps is shown in Figure 3. The most important changes to the natural environment and geomorphology over the past century or so have been caused by human activities, and are as follows:

- Disappearance of the dunes that formerly extended along the shore of Varkiza (location 1, Figure 3), and of the lagoon (salz lache), replaced by modern beach constructions at Varkiza (location 2, Figure 3). The stream channel and its mouth have been remodelled (location 3, Figure 3).
- Coastal filling-in and the construction of tourist buildings, marinas, recreation areas, and organized beaches have resulted in the artificial encroachment of the land towards the sea.
- Changes in the land use due to housing and road construction has led to the disappearance of green fields and forestry areas.

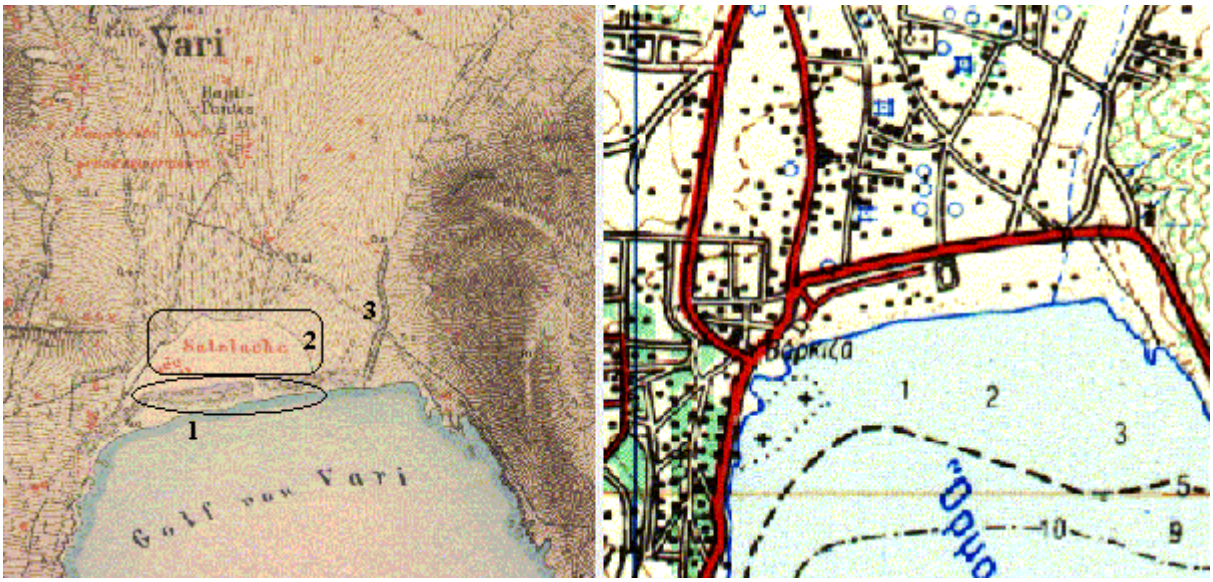

Figure 3. Vari Bay shown in two maps dated 1885 (left) and contemporary (right).

Quantitative changes to the coastal zone

Successive changes to the shoreline from 1945 to 1987 are shown in Figure 4. The most noticeable changes occurred between the years 1960 and 1972, whereas the coastal configurations for 1945 and 1960 are approximately similar. In 1972, major human intervention commenced with construction work along the beach carried out by the National Tourist Organization in Varkiza. In 1987, the final phase of these developments involved new marine works in Varkiza as well as coastal management resulting in the beach that is currently used as recreation area.

Figure 5 demonstrates the most recent shoreline change, between 1945 and 1987. This change has affected the shoreline along a length of 2026 m and a width fluctuating from 16m to 126m. The total area of land that has been added between 1945 and 1987 is approximately 92,557m^2 .

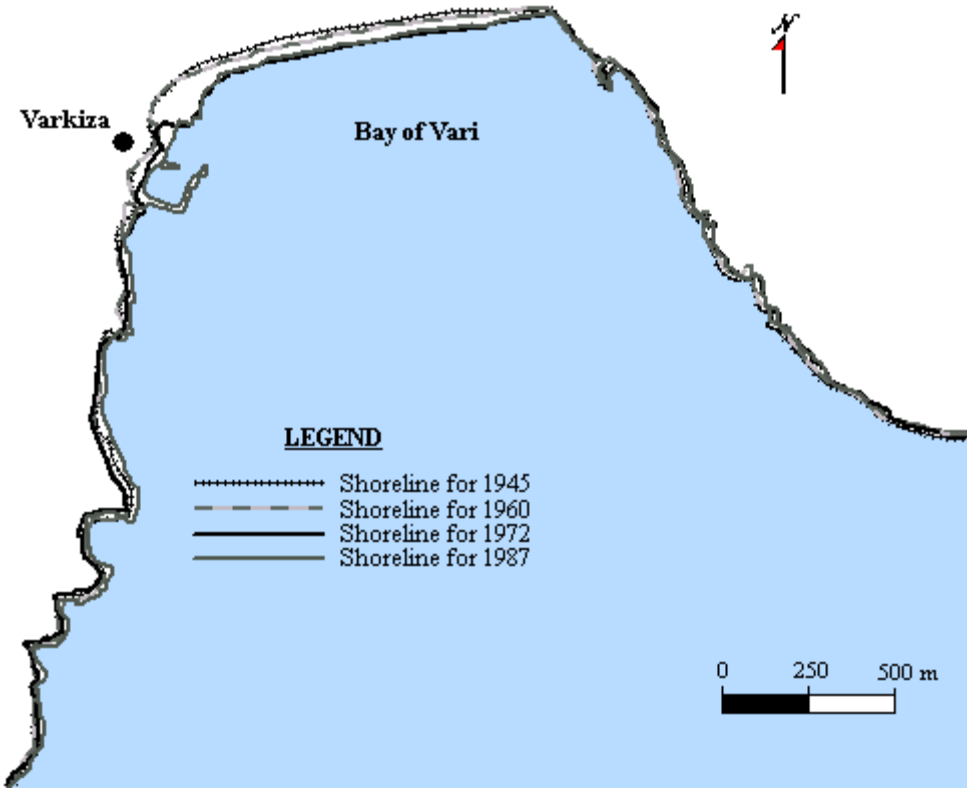

Figure 4. Progressive changes to the shoreline from 1945 to 1987.

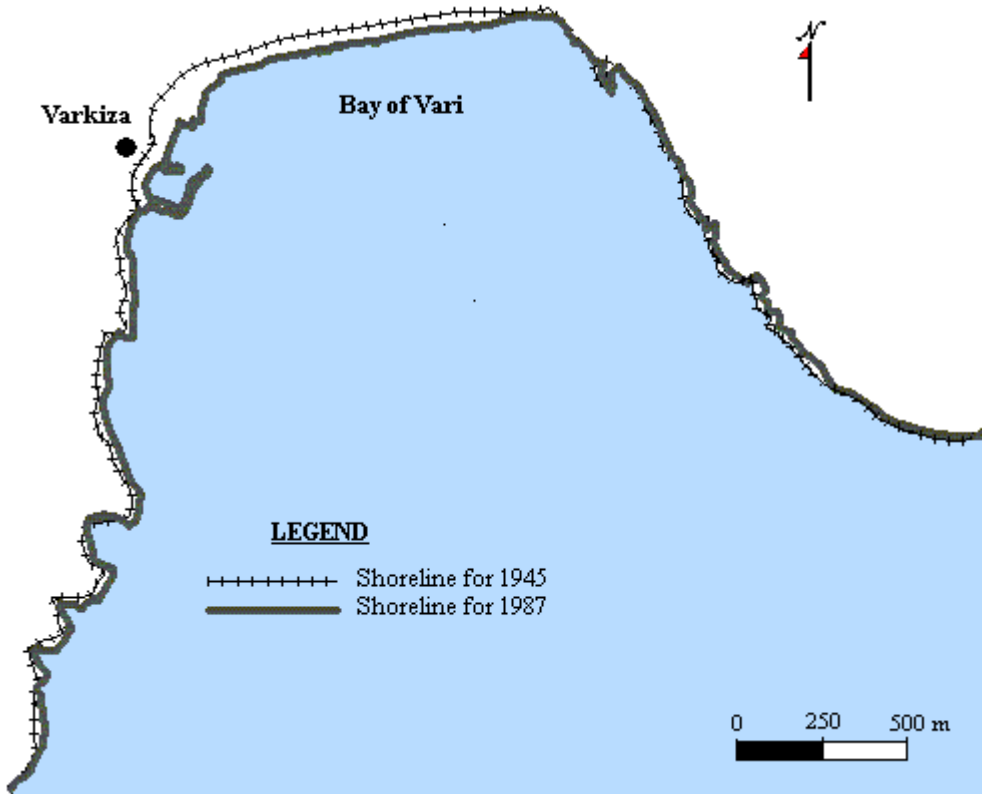

Figure 5. Comparison of shoreline configurations, 1945 and 1987.

The impact of human interventions in the coastal zone

Housing development in the area, and extensive human interventions in the coastal zone, have altered the natural geographic characteristics of Vari Bay and have changed the balance of sediment accretion. The realignment of streams and the urbanization of the area have resulted in very small increases in the amount of terrestrial sediment deposited. Thus, naturally induced changes to the coastal configuration remain dependant upon processes of marine deposition and erosion)

The area formerly occupied by the lagoon (salz lache) is depicted on the topographic map for 1885 (Figure 3), and is today filled by made ground, which includes the Athens to Sounio road. Its western part has also been encroached upon by the urban sprawl of Varkiza. The former presence of the lagoon (salz lache) nonetheless suggests that this area remains prone to natural water accumulation. To the north of it is low-lying terrain, with gentle slopes, which forms part of the drainage basin occupied by much of Vari. This area is similarly prone to flooding during periods of high rainfall.

The embanked Athens to Sounio road separates the site of the former lagoon into northern and southern compartments. It thus acts as an artificial obstacle to drainage, preventing the natural conveyance of water from the northern compartment to the sea. The combination of an inadequate drainage network, illegal housing developments, burning and elimination of forest areas, and the construction of extensive earth fills without regard to the natural physiography of the area have all resulted in the increased risk of flooding.

Figure 6 shows an area to the north of the road that is inferred to have an increased risk of flooding, due to inappropriate construction. This area needs further investigation in order to assess the potential for flooding due to runoff from the surrounding terrain at times of elevated rainfall, and to make recommendations for the possible construction of flood defences.

Figure 6. Area considered to be flood-prone (grey shading).

CONCLUSIONS AND PROPOSALS

The results of this investigation have shown that the most significant changes to the area have occurred on ground underlain by Quaternary formations, both along the coastal zone of the Bay of Vari and in the adjacent, gently sloping terrain.

Comparisons made between topographic maps for different periods of time have identified both qualitative and quantitative changes along the Bay of Vari coastal zone. In particular, the intense housing construction and accompanying changes to land usage have resulted in the following effects:

- Fundamental alteration of the natural environment
- The removal of dune fields that originally extended along the coast, together with the filling in of the former salt lagoons.
- Diversion and remodelling of the coastline and streams in the study area.

These changes were quantified by comparing aerial photographs taken at different periods of time. These show that during the 1945-1987 period, construction resulted in the encroachment of dry land across areas formerly occupied by the sea. This was achieved by the introduction of earth fill over an area of 92.557m^2, extending along the coast for 2026 m as a narrow strip of new ground between 16 and 126 m wide.

The methodologies used here can produce rapid, economical and reliable results for monitoring the changes that have occurred to the coastal zone and the natural environment. Moreover, all competent authorities involved in land management can adopt similar practices to monitor the effects of past and current interventions on the shoreline configuration.

An additional factor, that is directly related to increased human activity in the Bay of Vari region, is the potential for flooding caused by the infilling of a former lagoon (salz lache) and the construction of an embanked coastal road.

A series of proposals to deal with these potential problems is advanced, which are relevant not only here but also to other regions with similar histories of development. These are:

- Continuous monitoring and assessment of human interference patterns that have significantly degraded the coastal zone.
- Restriction of uncontrolled development of the coastal and beach zones, pending the completion of planning guidance and land use documentation for these areas.
- Maintenance of natural watercourses and runoff channels, and a moratorium on inappropriate earth filling and constructional activities.

- Construction of a drainage network and relevant services to mitigate the imminent danger of flooding.

Corresponding author: Dr Hariklia Skilodimou, National and Kapodistrian University of Athens, Panepistimiopolis, Zographou, Attiki, 157 84, Greece. Tel: +30 210 7274262. Email: hskilodimou@euof.uoa.gr.

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