Morphological evolution of the Evros River Deltaic shoreline

D.I. Giannouli, A. Karditsa, S.E. Poulos and E. Vassilakis

Faculty of Geology & Geoenvironment, National & Kapodistrian University of Athens, Panepistimioupoli-Zografou, 15784, Attiki, Greece

Abstract

The present study aims to map, analyze and identify the recent morphological changes along the deltaic coastline of R. Evros, using a time-series of historical aerial photographs, elaborated with photogrammetric and GIS software. The development of its delta is being controlled, by both natural and human induced factors, and especially those related to water and sediment fluxes. Since the 1950s, anthropogenic activities have been responsible for the hydrological and morphological changes in its delta region. The coastline of the Evros river mouth area has subjected to significant changes between 1960 and 2000, as indicated by shoreline retreat of up to 600 m locally, although the contemporary mouth seems to be nowadays relatively stable, after its initial prolongation soon after the artificial relocation of its lower course in 1950's.

Keywords: shoreline retreat, human intervention, aerial photographs

Introduction

Deltas are sensitive coastal systems with significant biodiversity but also vulnerable to any natural and/or human change. The climatic changes and the anthropogenic pressure in the last 100 years (for agriculture, irrigation, tourism) have transformed the majority of river / deltas hydrosystems. The anthropogenic interference has changed significantly riverine fluxes (Poulos and Collins, 2002), resulting in changes in freshwater fluxes and shelf sedimentation patterns. Dams have a major effect on the composition of the transported material, as they trap a high proportion of the solid load and enable only some clay particles to move downstream (Palanques et al., 1990). The aim of this study is to map, analyze and identify the recent morphological changes along the deltaic coastline of R. Evros, using four datasets of aerial photographs (1960-1985-1991-2000) elaborated with photogrammetric software for ortho-rectification and combined in a GIS platform.

Study area

The mouth area of the R. Evros debouches at the Gulf of Alexandroupolis, which belongs to the NE Aegean inner continental shelf (Figure 1). Evros River drain an area of approximately 52,500 km^2 having a length of its main course of 515 km total length. The Evros River discharges annually approximately $3.2x10^6$ tonnes of sediment (Pehlivanoglou, 1989) and 9.5

km^3 /year of freshwater (Sari and Çağatay, 2001). The climate of Evros River catchment area is characterized, according to Koppen's classification, as humid continental (Cfb) with no dry season and warm summers (temperatures ≥40°) (Flokas, 1997). Measurements in Evros River catchment area in Plovdiv and Pleven (Bulgaria) for the period 1970-1994 showed that there is an average decrease of the precipitation between 8% and 16% of the climatic norm (Vassilev & Georgiev, 1996).

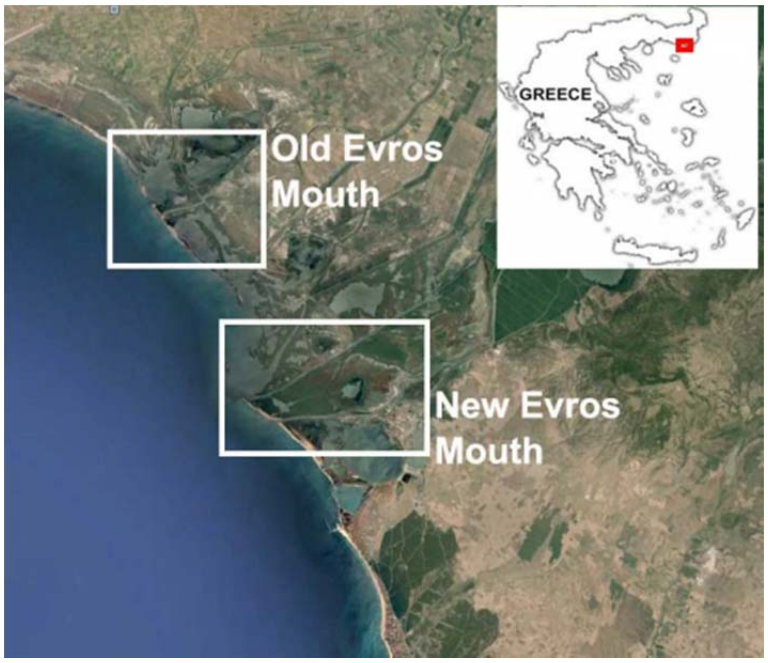

Figure 1: Presentation of the Evros River mouths

Alexandroupolis Gulf is essentially a tideless environment with astronomical tidal range <10 cm (Tsimplis, 1994). However, occasionally sea level may increase up to 0.80 m (HHS, 2005) due to meteorological forcing associated with southerly winds. In terms of wind-induced waves, the coast of the Gulf is predominately exposed to waves approaching from the SW (4.8%), S (1.8%) and SE (0.8%).

The overall offshore water circulation in Alexandroupolis Gulf is mainly controlled by the fringes of the Samothraki anti-cyclone, which implies an eastward circulation in the offshore waters of the Gulf (Zervakis & Georgopoulos, 2002; Olson et al., 2007).

Evros Delta covers an area of 188 km^2 and is characterized by its multifarious morphometry; almost 90% of the delta belongs to Greece and 10% to Turkey. Most of the deltaic front and the prodelta area are being covered by fine grained (silt and clay) material of terrigenous origin.

The Evros River delta and its deltaic shore zone is of great ecological significance being one of the most important wintering areas for birds in the Mediterranean, hosting four permanent lagoons (Laki, Drana, Paloukia and Nimfes). Thus, its Greek part has been designated as a Ramsar Site, a Special Protected Area and Natura 2000 site (UNECE, 2011) and of extreme

touristic interest. The latter applies not only to the coastal part of its deltaic plain, but also to associated sandy beaches.

The development of its delta is being controlled, by both natural and human induced factors, and especially those related to the water and sediment fluxes. Since the 1950s, anthropogenic activities have been responsible for the hydrological and morphological changes in its delta region. Draining and irrigation works in conjunction with the alignment and settlement of the lower part of the Evros river course, approximately 7 km southern from its natural mouth, in 1950s have regulated its flow. Human intervention to Evros River, includes, also, the construction and operation of more than 20 major dams, for hydroelectric power and irrigation, during the past decades which influenced significantly riverine fluxes (Karditsa & Poulos, 2014). Finally, human activities within the transboundary Evros River catchment are closely related to industrial waste, urban sewage and agricultural discharge increasing its content in organic and inorganic matter, nutrients and several trace elements (Angelidis and Athanasiadis, 1995).

Methodology

The inter-annual changes of the coastline position were studied with the use of a series of analog aerial photographs acquired during the years 1960, 1985, 1991, (obtained by the Hellenic Military Geographical Service (HMGS)) and 2000 (obtained by the Ministry of Public Works and the Environment). The aerial photographs were scanned with large format scanner in high resolution (1,200 dpi) producing raster images which, in turn, were geometrically corrected, in order to produce high accuracy ortho-mosaics for each year of acquisition (Faik, 2010), with the use of photogrammetric software. The geometrical correction of the aerial photographs included the ortho-rectification of each scene, initially by using a 25 m Digital Elevation Model, extracted from the contours and the elevation points on topographic maps of 1:5,000. The produced datasets were imported in a GIS environment and, after being digitized, compared in order to identify areas of erosion/accretion.

Results and Discussion

The coastline of the Evros river mouth area has suffered significant changes between 1960 and 2000 (Figure 2). Along the entire old river mouth coastline, retreat is considered to be the dominant process. The mouth area has retreated more than 600m since 1960; the loboid formations appearing in the coastline of 1960 have been eroded and elongated beach ridges have been created to northwards under the influence of the wave-induced longshore sediment transport. The biggest changes have occurred from 1960 to 1985, where shoreline retreat reached ~400m; this extensive retreat is attributed primarily to the alignment and relocation of the active river mouth ~7km southern and, secondarily, to the construction and operation of more than 20 dams along the Evros river tributary channels. During the same period a small progradation of ~150m is observed in the shoreline northern of the old Evros river mouth (Figure 3), due to reworking, removal, transport and deposition of the sediment material existing proximal to the mouth area.

Between 1985 and 1991 the system is in equilibrium and no significant changes seems to have taken place in the morphology of the old mouth area, except from the formation of elongated beach ridges, towards the north and up to a distance of 200m. Since sediment inputs did not increase during this period, it is assumed that the material for the formation of the beach ridges produced by the hydrodynamic induced erosional processes to the shallow waters of the old mouth neighboring area.

The whole area seems to underlie a thorough erosion between the years 1991 and 2000, during which the old mouth retreats more than 100 m, to the north shoreline retreated some 50 m, while pre-existed beach ridge eroded, while some small barrier islands are formed.

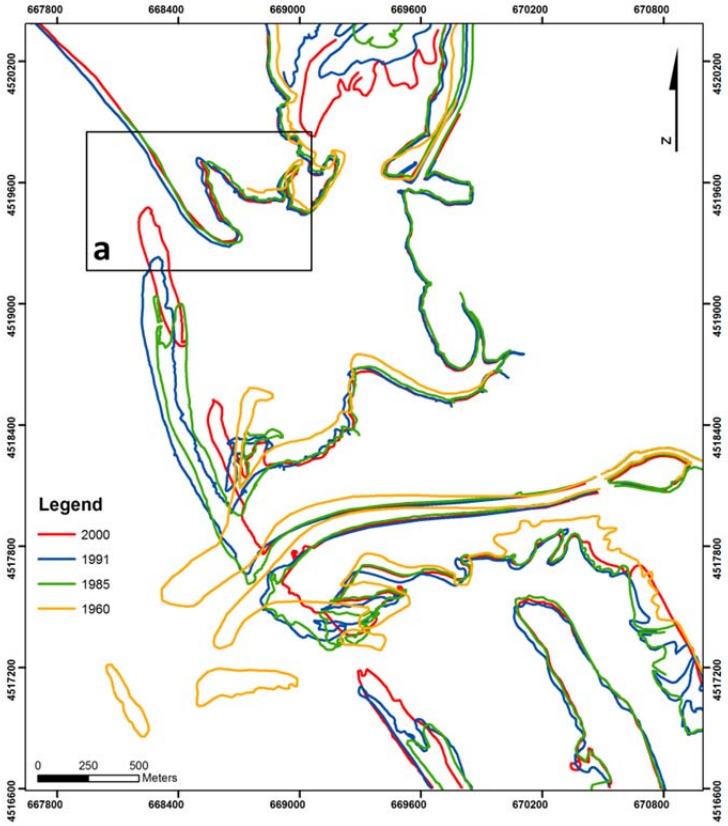

Figure 2. Shoreline evolution between years 1960 and 2000.

Figure 3. Satellite image (Google Earth 2010) of the area “a” of figure 2.

Regarding the new (southern) river mouth (Figure 1), there is not adequate information in order accurate conclusions to be made, since new Evros river mouth constitutes the boundary line between Greece and Turkey territory and, therefore, aerial photographs are not available by the HMGS. However, Satellite image observations (Google Earth 2010) lead safely to the assumption that river mouth relocation (in 1950s) is associated with a period of progradation, creating loboid formations in the new river mouth area. Yet, since 2000 the area of the active mouth seems to be relatively stable. The overall trend in the orientation of the recently formed sedimentary bodies indicate a generalized northward sediment transport.

Conclusions

Evros old river mouth indicates a gradual erosion of the old river mouth since 1960, which led to a shoreline retreat (locally) up to 600m, following the relocation of its lower route and the reduction of sediment influx due to dam presence. Therefore, Evros old river mouth turned from river dominated to become rather wave dominated. On the other hand, Evros current mouth, after an initial phase of progradation in response to relocation of the main course, seems to be relatively stable, indicating a kind of equilibrium between the longshore transport and fluvial input processes.

Aknowledgements

The study is supported by the project BEACHTOUR (11SYN- 8-1466) of the Operational Program Cooperation 2011, Competitiveness and Entrepreneurship" co-funded by the European Regional Development Fund (ERDF) and the Ministry of Education and Relegious Affairs.

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