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Assessment of the Evinos Delta Recent Shoreline Changes (Gulf of Patras, Western Greece)

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Introduction

River deltas are dynamic and complex depositional landforms, shaped by the competition between marine and fluvial processes (Coleman and Wright, 1975). River deltas crucially depend on sustained sediment supplies in order to maintain delta shoreline position and to balance subsidence. Because they are increasingly starved of sediment trapped behind dam reservoirs, many of the world's river deltas are becoming vulnerable to accelerated erosion, losing large tracts of land and becoming more exposed to flooding and sea-level rise (Ericson et al., 2006). In Greece the most distinctive shoreline changes concern beach zones of low lying coastal plains (mainly river deltas) and are mainly associated with severe decline or even elimination of fluvial sediment discharge due to river damming and uncontrolled sand and gravel mining activities from the lower reaches of the rivers.

The principal objective of this study is to quantify the post 1945 changes of the shoreline of the Evinos River delta in Western Greece using geo-referenced aerial photographs, a detailed Digital Elevation Model (DEM) and Landsat imagery. Quantitative assessment of recent delta shoreline changes is a part of the coastal monitoring that helps significantly in long-term predictions of shoreline positions, which is particularly useful for the design of future shoreline management and development strategies.

Study Area

The Evinos River delta is located on the northern shore of the Gulf of Patras. It covers an area of about 92 km^2 and belongs to one of the most significant ecosystems in Western Greece, the Messologi wetland, which is protected by the Ramsar Convention. According to Galloway's (1975) proposed delta classification it should be classified among those deltas affected by fluvial sediment supply and wave activity.

The formation of the Evinos delta is the result of the combination of suitable conditions for delta formation during the late Holocene. Climatic conditions within the drainage basin (high mean annual precipitation) along with the geology (presence of highly erodible formations) and morphology (relatively steep slopes in the upper reaches) of the catchment are characteristics favorable for weathering and erosion. Large amounts of sediments supplied by erosion are transported down the valley of the river to the coast. In addition, the bathymetry (maximum depth no more than 130 m) and tectonic features of the Gulf of Patras (the rate of tectonic subsidence during the Holocene is 0.4 mm/yr (Ferentinos et al., 1985)) in addition to the extremely low tidal range have permitted sediment accumulation in the area of the river mouth. According to the geomorphological map of the delta, constructed by Maroukian and Karymbalis (2004), the deltaic plain is crossed by four groups of abandoned distributaries. The coastline of the eastern palaeo-lobe consists of low cliffs and gravel beaches while the western coastal zone of the delta is characterized by a series of beach ridges which have built up an oblong area that protects Klisova lagoon from the Gulf of Patras. The Klisova lagoon is the result of the natural compaction of deltaic sediments after the shifting of the main channel to the east. The main channel of the Evinos River crossing the deltaic plain has been artificially aligned since 1959 while a dam has been constructed in the upper reaches of the catchment in 1997 in order to supply Athens with potable water.

Methodology

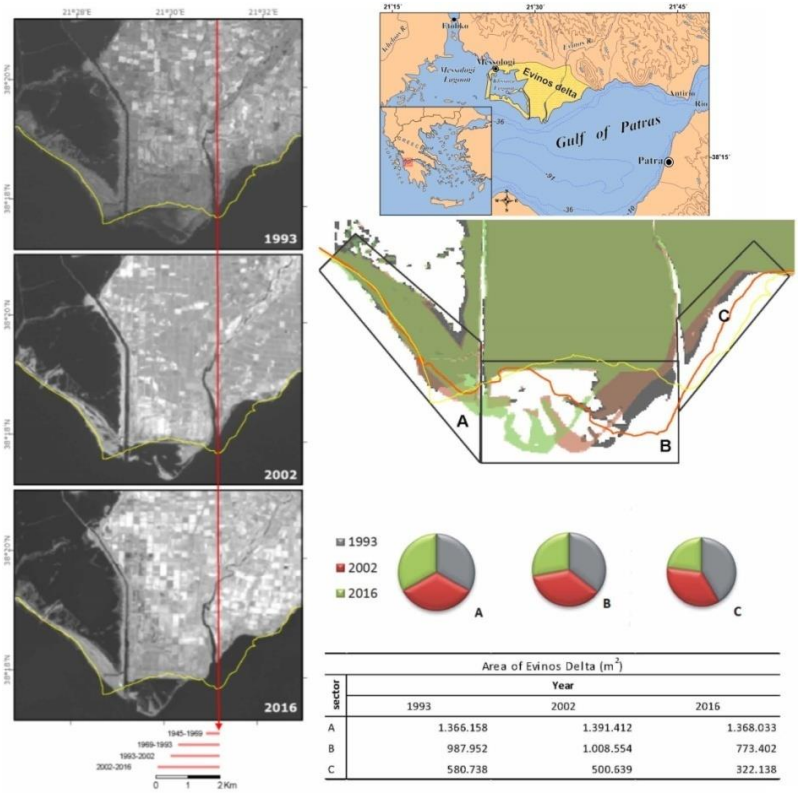
In order to detect and quantify diachronic changes of the Evinos delta shoreline, comparative observations of the coastlines of 1945, 1969, 2016 have been made utilizing GIS techniques. The coastlines of 1945 and 1996 have been digitized from georeferenced aerial photo-mosaic obtained from the Hellenic Millitary Geographical Service (HMGS) while the source for the most recent coastline of 2016 was the detailed DEM of the Hellenic Cadastre. This comparison allowed us to identify areas of progradation and parts of the fan-delta plain that are being eroded as well as to quantify cumulative progradation and erosion for the time periods 1945-1969 and 1945-2016 respectively. Using the 1945 digitized shoreline, 532 measurement sites were created every 50 m using an automated procedure. Coastal retreat or progradation was calculated for the intervals between the dates of the imagery by measuring the distance separating the two shorelines (in vector format) perpendicular to the older shoreline.

Remote sensing is becoming a highly effective and efficient coastline detection technique. Even if the accuracy of the coastline detection depends on the spatial resolution of the remote sensing images, the medium-resolution images such as Landsat TM, have been widely used to detect coastlines (Gens, 2010). Thus in an attempt to quantify land loss and/or

land gain for the time periods between 1993, 2002 and 2018, the broader deltaic area of the mouth of the river was divided into three parts (Figure 1) and three Landsat TM images, acquired on July 1993, August 2002 and August 2018 respectively, with a spatial resolution of 30 m, were collected. Image preprocessing was conducted on these three TM images, including radiometric correction, registration and precise geometric corrections. To distinguish coastal temporal variations, only Bands 5 and 4 of Landsat 5-7 and Landsat 8 images were used respectively.

Results and Conclusions

The comparative analysis of the 1945, 1969 and 2016 delta shorelines shows that the main process along a significant part of the delta front is intense erosion. In particular the coastline of the eastern abandoned part of the delta is retreating since 1945. The coastal geomorphic features of this part of the delta (exposed coastal sections of eroded delta deposits along low cliffs - up to 1.5 m high - and abandoned meandering channels now being eroded) as well as the presence of collapsed shoreline houses are indicative of erosive processes. The main cause of the east delta erosion are the exposition of the shoreline towards the predominant waves and long-shore currents (Piper et al., 1982) in addition to the lack of sediment supply since 1959 after the artificial closing of the river mouth. It is estimated that the area of the pre-1959 mouth has retreated for about 600 m since 1945. The only area where the delta progrades today is west of the present river mouth which consists of dynamic, gradually changing sandy barriers.



Area of Evinos Delta (m^2)

sector	Year		
	1993	2002	2016
A	1.366.158	1.391.412	1.368.033
B	987.952	1.008.554	773.402
C	580.738	500.639	322.138

Figure 1. Land loss and/or land gain for three parts of the Evinos River delta estimated by Landsat TM images.

The comparative analysis of Landsat TM images showed a significant land loss for the broader area of the active delta and the part of the delta east of the present river mouth, especially after 2002 (Figure 1). Land loss is primarily associated with severe decline of fluvial sediment discharge due to the construction of the dam (in 1997) in the upper reaches of the river. Another important reason for the erosion is the uncontrolled sand and gravel mining activity from the distributary channel of the river.

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