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Present evolution and future predictions for the deltaic coastal zone between the Sulina and Sf. Gheorghe Danube river mouths (Romania)

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ABSTRACT

Human activity has modified the natural evolution of coastal areas to a considerable extent and has arguably been the most important factor controlling the evolution of the coastal zone in recent decades. These interventions have drastically changed the natural evolution trends of the coastal strip between Sulina and Sf. Gheorghe Danube mouths, where the highest erosion and substantial accumulation rates can be observed compared to the entire Romanian Black Sea coast. In addition, various scenarios of the rate of sea-level rise suggest a general coastline retreat ranging from 30 to 150 m by 2030 for the coastal strip between Sulina and Sf. Gheorghe. The implications for the study area were examined using two possible scenarios: the first in which there is no intervention to protect against coastal erosion, and the second in which new human interventions are taken into account. The predicted coastal evolution under the first scenario is essentially a projection of present-day coastline evolution influenced by projected climate change, whilst for the second scenario the results are more complex and difficult to assess at present due to a lack of information concerning future coastal management plans.

1. Introduction

Several researchers have studied coastal retreat phenomena along the coastlines of major river deltas around the Mediterranean, including those of the Rhone (Bird, 1988), Ebro (Jimenez et al., 1997), Nile (Fanos, 1995), and Po (Simeoni and Bondesan, 1997). Such studies have concluded that a decrease in sediment supply, transported to the sea by rivers, appears to be the most important factor controlling (coastal) retreat. Poulos and Collins (2002) have shown the importance of the presence of dams in reducing Mediterranean riverine sediment fluxes and the implications for the evolution of Mediterranean deltas. Moreover, man-made constructions along coastlines have caused extended shoreline displacements by altering nearshore sediment transport and/or by modifying littoral sediment budgets (e.g. Finkl, 1994; Komar, 1998).

The delta of the Danube River, in common with most deltas of large, continental, rivers has experienced extended erosion, with average rates of coastline retreat of up to 20 m/year for the period 1900–1988 (McManus, 2002). The purpose of this study is to investigate the current and future evolution of the deltaic coastal zone between the mouths of the Sulina and Sf. Gheorghe, the two main distributaries of the Danube River. For this reason, the existing knowledge concerning the current geo-environmental status is reviewed briefly. In addition, human influences on the evolution of the coastal zone under investigation, are summarised using existing information. These influences fall into two categories: the reduction of sediment fluxes, and coastal engineering works. The future evolution of the coastal zone is then examined in association with predictions for sea-level rise due to global climatic change by the application of Bruun's rule (Bruun, 1962); although the latter method has received a lot of criticism (e.g. Cooper and Pilkey, 2004) it is still in use. In this study, the results predicted using this method are presented as gross estimates and not as absolute values. Finally, future trends for the evolution of the coastal plain are discussed against different socio-economic scenarios.

2. Physical setting of the study area

The Danube River is Europe's second longest river, after the Volga, with a total length of 2857 km. The source of the river lies in the Black Forest (Schwartzwald) Mountains in Germany, and the river flows into the North Western part of the Black Sea through three main mouths. The Danube drainage basin covers 15 Central and Eastern European countries and has a total area of 817 000 km^2. The channel of the Danube first divides into two distributaries: Chilia and Tulcea. The former bifurcates into a series of smaller branches, forming the Chilia Secondary Delta, which is situated within the Ukraine, whilst the latter splits into the Sulina and Sf. Gheorghe distributaries (Panin, 1998).

The coastal zone between the Sulina and Sf. Gheorghe mouths is situated entirely within Romania, and is approximately 34 km long with a general North–South orientation. The zone consists of beaches composed of well sorted fine sand, mostly quartztic, and in places

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enriched in heavy minerals, as the main sedimentary source is the alluvium derived locally from the Danube.

The coastal zone delimited by the Danube's Sulina and Sf. Gheorghe mouths can be divided from North to South into three sectors, characterised by different styles of coastal evolution; these are (Fig. 1): (i) the *Sulina Sector*, with a total length of about 7 km, situated in the northern part of the study area between the Sulina Canal Jetties (to the north) and the beach of Sulina town (to the south); (ii) the *Imputita–Casla Vadanei Sector* with a length of about 14 km, which is a coastal depression consisting of numerous lakes, marshes and channels and (iii) the *Casla Vadanei–Sf. Gheorghe Sector* representing the southern 13 km of the study area that extends to the Sf. Gheorghe mouth. Moreover, about 10 km to the south of the Sulina Canal southern jetty, a secondary Danube outlet, named Canalul cu Sonda, was active until 1996, when it experienced sedimentation.

The Sulina–Sf. Gheorghe coastal zone is exposed to winds stronger than 2 m/s, for 80% to 90% of the year, with the northern winds being the prevailing and stronger ones (40–50%, annually) (Bondar et al., 1973; Panin, 1998). The wave regime is characterised by wave heights <0.2 m (49.1%), whilst 33% are wind waves and 17.9% are swells (Cristescu, Diaconu, 1980 in Panin, 1999). The wind waves are predominantly from a NE direction (Cristescu, Diaconu, 1980 in Panin, 1999), whilst the associated longshore currents along the Romanian coastal zone are mainly directed to the south. This reflects the predominant wind regime and the morphological configuration of the Black Sea basin. Surface velocities during periods of low wind speed are 3–50 cm/s, while during N and NE strong winds (14–15 m/s) velocities may reach 1 m/s on the surface and 0.2–0.3 m/s near the sea bed (Bondar and Roventa, 1967). Local disruptions of the general southward oriented longshore current are generated by anthropogenic structures, localized alterations in coastline orientation and nearshore bottom morphology. In terms of tidal range, the study area, as the entire Black Sea coastal zone, is micro tidal (average amplitudes of 7–11 cm) and semi-diurnal (Bondar et al., 1973). Relative changes in sea level during the past century have varied between 2.7 and 3 mm/year of which 1.28 mm/year has been attributed to eustacy (Malciu, 2000) and 1.5–1.8 mm/year to natural subsidence of the deltaic plain (Panin, 1999).

3. Human intervention

Anthropogenic influences can be considered to be the most important factors controlling the coastal evolution between the Danube mouths of Sulina and Sf. Gheorghe in recent decades. These influences fall into two main categories: those related to changes of riverine water/sediment fluxes and those induced by engineering works.

3.1. Changes in the Danube River water and sediment discharges

The first human interference in the natural flow of the Danube River dates back to the second half of the 19th Century, when the

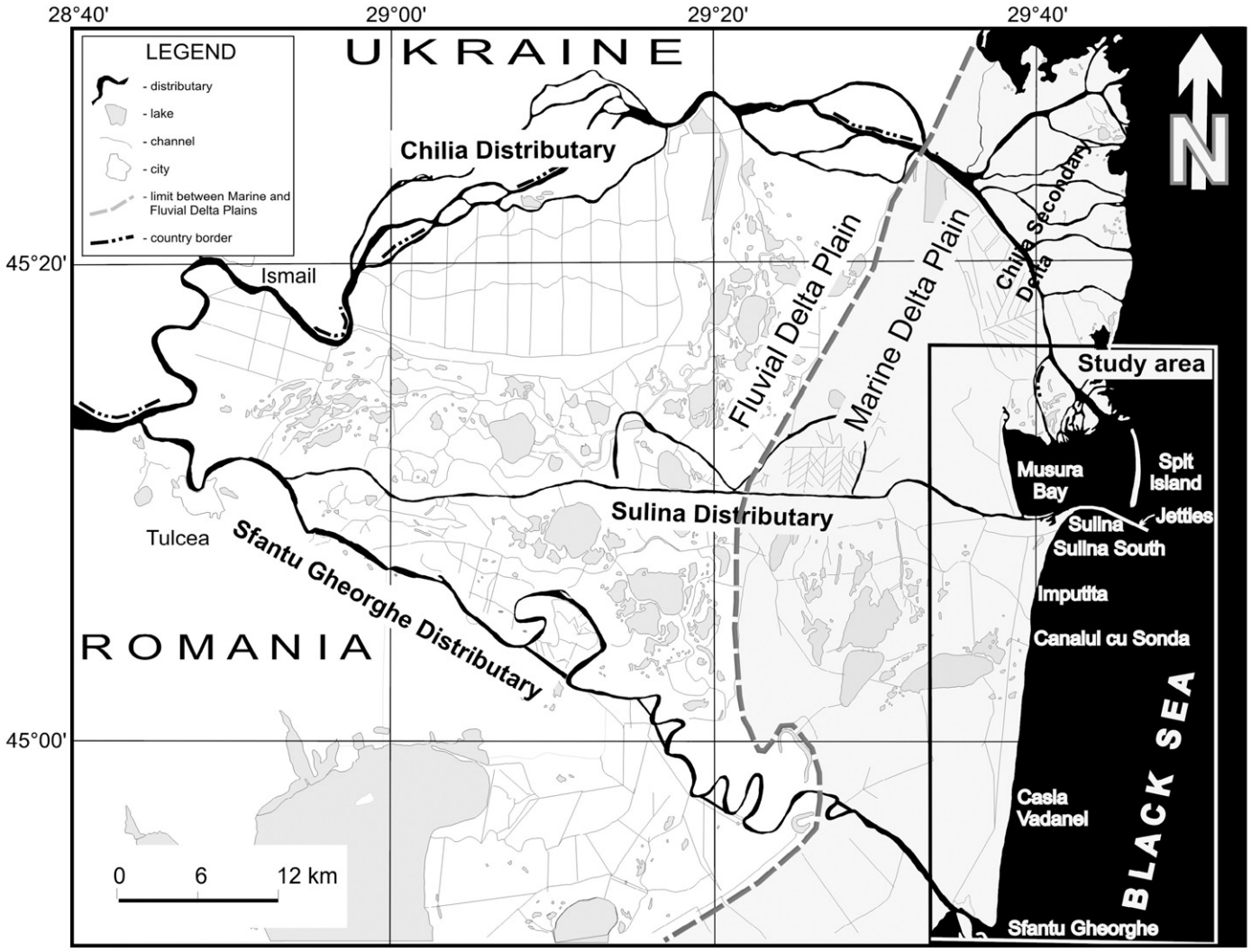

Fig. 1. Danube Delta and the littoral between Sulina and Sf. Gheorghe.