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Historical Evolution of the Shoreline of Reggio Calabria

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Abstract. The urban development in the last century was characterized by a depopulation of the mountains and a concentration of the population in urban areas, most of them are located near the coast. This factor increased significantly the problems and risks connected to coastal erosion. Thus, it implied a stricter monitoring activity in order to protect the coast and the population, as well. This paper discusses the historical variation of the shoreline in Reggio Calabria.

Introduction

Shoreline evolution is influenced by a great number of factors (weather, wave climate, morphodynamic characteristics of the site, presence or absence of river mouth and of anthropic structures) [1]. Therefore, an holistic view, supported by a robust mathematical modeling, is necessary to predict the possible evolution of the system [2].

Shoreline evolution can be investigated in simplified manner by mathematical models, which usually are distinguished as static [3] or dynamic [4], or through complex numerical models [5]. However, reliable solutions can be obtained even by means of the static models, especially if the wave climate at a certain region is stable during the year [6-8].

The main factors influencing shoreline evolution are the movement of the sediments [9-11], which can be parallel to the shoreline (long-shore transport) or orthogonal to the shoreline (cross-shore transport). The most popular formula in practical applications to evaluate long-shore transport is the CERC formula [12]. Recently, Tomasicchio et al. [13] developed a model suitable for gravel as well as for sandy beaches, which is based on the assumption that the beaches can be considered like a dissipative structures.

Coastal erosion can be limited by two different approaches: soft intervention (beach nourishment [14]) and hard intervention (use of structures such as breakwaters and groins [15-17]). Obviously, the reliability of any intervention must be assessed not only in the context of simplifying assumptions, but also in realistic situations involving irregular wave dynamics [18] and, if appropriate, their interaction with structures [19-23].

The coastal dunes play an important role in the coastal processes since they represent a natural reservoir of sand, which dissipates the wave energy during a storm and protects the inner areas [24]. Many studies confirms that it is important to protect them and that set-up [25,26], run-up [27], the duration and the intensity of the sea storm are the principal causes of their erosion [28-30].

Case study: Reggio Calabria, Italy

Site description. Reggio Calabria is the most populous town in Calabria with about 180,000 inhabitants and is located in the southern part of the region. This is a particular area because it is close to Sicily and at end of the Italian peninsula. So that, there are fetch of a few kilometers, towards most directions, with low energy wave climate. Indeed, the most part of recorded sea states have a significant wave height of few decimeters, while exceptional waves are slightly over one meter. The most intense sea states propagate from the south-west and south–east. However, most of the coast is oriented such as to act as a natural protection to the direct action of the swell from the south-east.
Finally, the district area is quite large (236 km^2), it is divided into a number of villages and it extends considerably both along the coast, for more than 32 km, as well as inland, passing from a 0m level to a 1803m level in the Aspromonte mountain (Fig. 1).

Fig. 1. Location and limits of Reggio Calarbia.

Methodology. The analysis of the historical evolution of the shoreline in Reggio Calabria is conducted as part of an agreement between the DICEAM Department of the Mediterranea University of Reggio Calabria and the Basin Authority of the Calabria region [31]. The objective of the agreement is the identification of most exposed areas in Calabria, which possess a coastal erosion risk in order to propose appropriate coastal defense.

For the analysis we used the map provided by ABR (cartography of the Cassa del Mezzogiorno of 1958; the Military Geographic Institute IGM cartography of 1985; orthophotos of the Calabria region of 1998; orthophotos of the Calabria Region in 2008). The coast lines of 1958, 1985 and 1998 were also provided by ABR while the coast line in 2008 was traced using open source software Quantum GIS 1.8.0 " Lisboa " (Fig. 2). At this purpose, the shoreline has been distinguished in beaches, cliffs, rocky coasts and anthropogenic beaches. Moreover, a database containing information about ports, coastal structures (breakwaters, groins, mixed structures etc.) has been created. A particular layer has been created for each mentioned element and each one has been associated to the town where it is located.

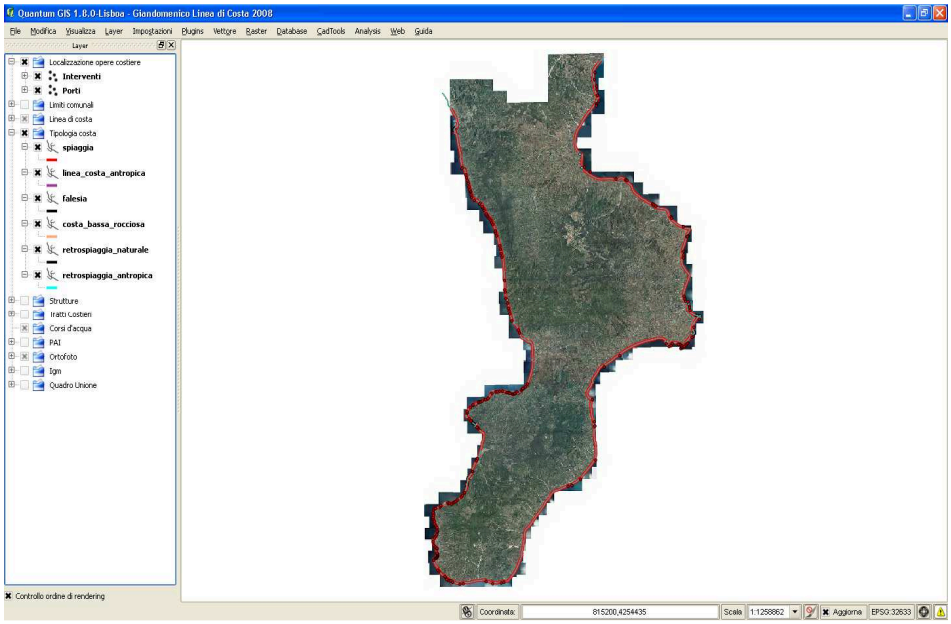


Fig.°2. General view of Calabria through Quantum GIS 1.8.0 'Lisboa'.

Results and discussion

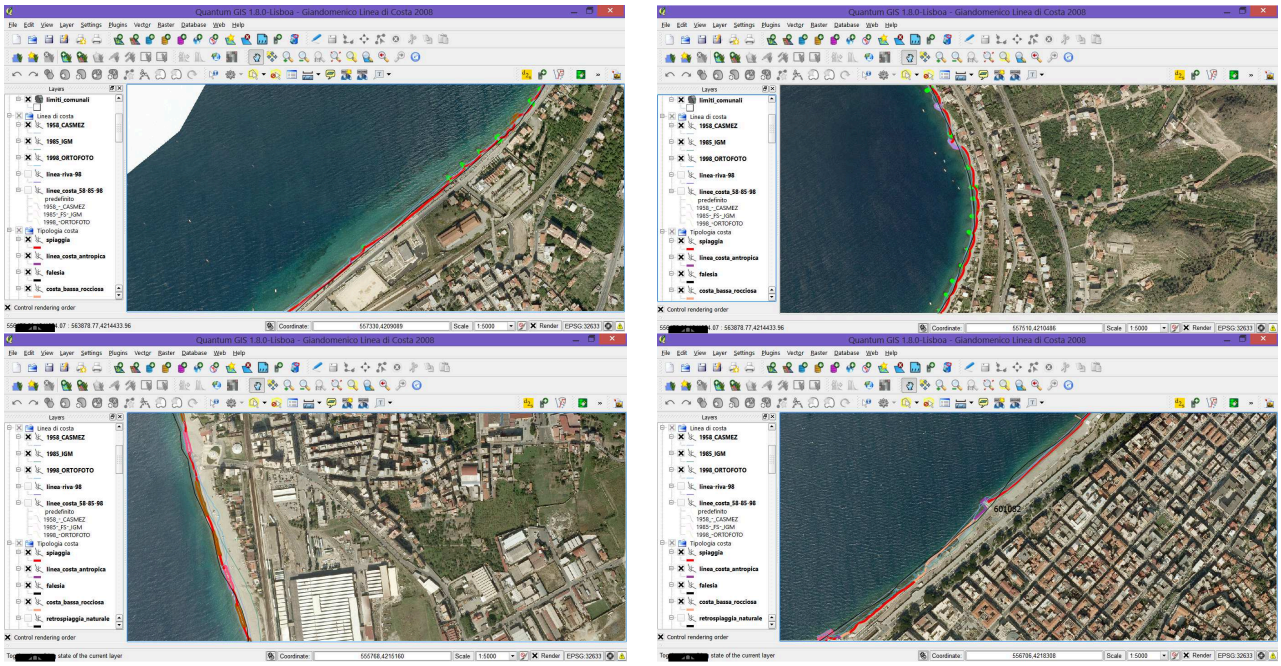
By the mentioned analysis, it is seen that Bocale, a village that is located over 3 km of coasts, alternated beaches in erosion and in accretion until 2008, with wide beaches between 20 m and 50 m. During the last years, about half of the coastline is exposed to a severe erosion, with an almost total loss of the beach. The coast of Pellaro has been dramatically eroded during the time interval 1985-2008 (with a maximum of 20m), with an almost complete destruction of the beach requiring the realization of groins in the last decade. The shoreline of Occhio di Pellaro has experienced a

significant erosion as well. Indeed, it has lost almost all of the 20m beach present in 1958, despite the construction of groins in the last decade. A similar situation has been found in San Gregorio, where a 30m beach has been lost since 1958 and despite the construction of barriers. The shoreline in the south area of Reggio Calabria is slightly increasing thanks to the construction of barriers, and now the amplitude is between 30m and 50m. The area in front of the promenade has a shoreline between 20m and 30m, which is in equilibrium since 1998, but is in erosion if compared to the period 1958-1998 (with erosion up to 20m). The construction of the port in the north side of the town has not influenced significantly the adjacent coastal areas. Indeed, the port was built by exploiting the natural configuration of the shoreline. Further, the area does not involve remarkable sediment transport phenomena, because of the low energy sea states in the Strait of Messina. At the north of the city is located the village Gallico, whose coastline is subject to erosion with loss of almost the entire beach, despite the use of a number of barriers. At the mouth of the Gallico torrent, the coastline has been eroded for more than 100 m since 1958. Catona is subject to significant erosion, with a loss of more than 50 m compared to 1958 and more than 20 m compared to 1985 at the mouth of the broad stream Catona. Finally, the coast near the border with Villa San Giovanni (RC) is subject to significant erosion, with maximum erosion of about 100 m compared to 1958 and to 1985.

In addition, note that more than 130 coastal defense works (about 60 groins, 40 seawalls and 30 barriers) have been constructed in the municipality of Reggio Calabria, with an average of more than 4 interventions / kilometer.

The analysis showed the presence of erosion along almost the entire municipality, with a high percentage of beaches of amplitude not exceeding 20 m. In addition, most of the erosive trends occurred in the period 1958-1985, in conjunction with the phase of development and anthropization of the coastal areas. Finally, it is seen a significant erosion at the mouths of several rivers, especially at the mouth of the Gallico torrent.

Therefore, it is possible to identify a significant correlation between human intervention, both near the coastline and the catchment areas related to a coastal zone, and the erosion of shoreline. This correlation, in the case of Reggio Calabria, is more significant as the location is exposed to a modest wave climate.



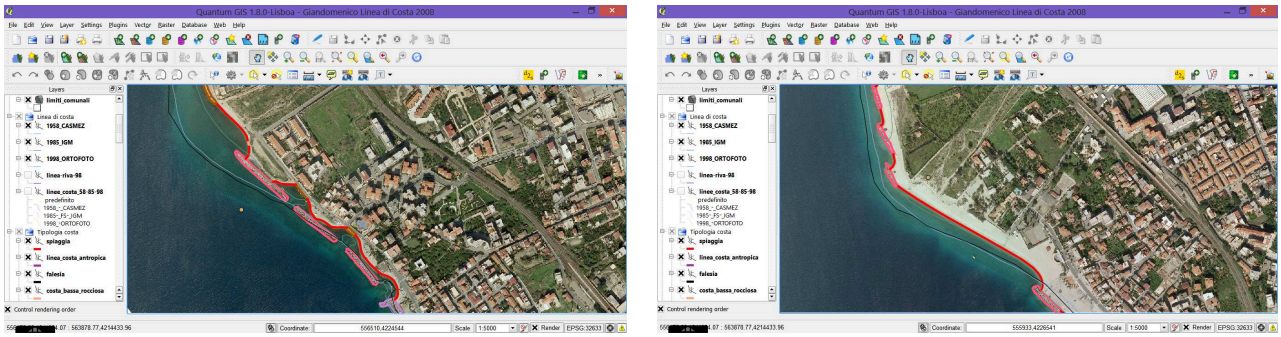


Fig.°3. Reggio Calabria: Pellaro shoreline (upper left panel), Occhio di Pellaro (upper right panel), South area (centern left), promenade (center right), Gallico (bottom left) and Catona (bottom right).

Conclusions

In this paper the historical variation of the shoreline was analyzed in Reggio Calabria. The main causes of the coastal erosion were also investigated.

For the analysis we used the map provided by ABR (cartography of the Cassa del Mezzogiorno of 1958; the Military Geographic Institute IGM cartography of 1985; orthophotos of the Calabria region of 1998; orthophotos of the Calabria Region in 2008). The coast lines of 1958, 1985 and 1998 were also provided by ABR while the coast line in 2008 was traced using open source software Quantum GIS 1.8.0 "Lisboa".

The analysis showed the presence of erosion at almost all the entire municipality, with a high percentage of the beaches of amplitude not exceeding 20 m. In addition, most of the erosive phenomena occurred in the period 1958-1985, in conjunction with an increased development and anthropization of the coastal zones. Finally, it is seen a significant erosion at the mouths of several rivers, especially at the mouth of the Gallico torrent.

Therefore, it is possible to identify a significant correlation between human intervention, both near the coastline and into the catchments area related to the coastal area, and the erosion of coastlines. This correlation, in the case of Reggio Calabria, is remarkable as such a location is exposed to a modest wave climate.

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