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Master Plan of solutions to mitigate the risk of coastal erosion in Calabria (Italy), a case study

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ABSTRACT

This paper describes the scientific aspects analysed in the preparatory phase of a Master Plan of interventions to mitigate the risk of coastal erosion in Calabria. The Plan has recently been developed by the regional administration to define in an objective manner a scale of priorities for the planning and intervention of the medium and long-term re-equilibrium of the coastline. The analyses developed in this paper allow us to correctly evaluate, from several points of view, the consequences of possible proposed solutions, and thence to make choices based on accurate documentation and reliable analysis of the physical, environmental, social and economic aspects, all of which are closely interrelated.

Such a Master Plan is necessary in Calabria both because of the geographic shape of the land, characterized by a coastline over 700 km long and which is fundamentally important to the regional economy, and also because of the presence of a significant number of past ad hoc interventions in coastal defence, often carried out by different institutional bodies, as a matter of urgency, and in areas of limited access, generally without sound or effective design or general vision of the problem, the result of which has only served to shift, in spatial and temporary terms, the problem of coastal erosion.

1. Introduction

Coastal areas are one of the most populated territories of the world. Indeed, 37% of the world's population lives within 100 km of a coast, while about 50% are within 200 km (Burbridge, 2004). In this context, the definition of a consistent strategy for the protection of coastal areas is an ingredient required to guarantee safe conditions in areas exposed to both environmental and anthropic actions.

Classical solutions adopted to protect these areas are based on either structural interventions or regulations. Specifically, structural interventions relate to the installation of structures able to interact with the environment in order to stop sediment transport and induce the artificial formation of sediment aggregates. For example, groynes and detached breakwaters are used to limit erosion caused by sea waves and to induce an advancement of the coastal areas (Barbaro and Foti, 2011, 2013). Beach nourishment measures can be categorised as this type of intervention, despite the fact that they do not involve the use of structures, as they are an artificial solution implemented by the dumping of sediments over an area exposed to severe erosion. The second approach, quite popular with public administrations, is the proclamation of regulations controlling the anthropic action in certain areas. Such an approach is quite effective for limiting anthropic effects. Indeed, in several cases, of which an example will be discussed in the following sections, coastal areas become unstable because of the installation of structures (Tomasicchio et al., 2011; Boccotti et al., 2015). In this view, flood risk assessment (Salvadori et al., 2015), sustainable development of coastal areas and engineering design of infrastructures (Salvadori et al., 2013, 2014) have a fundamental role.

This paper describes the characteristics of the Calabrian region from the perspective of coastal safety. This region is located in the southern part of the Italian peninsula (Fig. 1).

From an orographic perspective, hills (49%) and mountains (42%), with only restricted flat areas (9%), characterise Calabria. Given this fact, it is relevant that the region has a remarkable coastal length of over 700 km. The shape of the region is long and narrow, so that few rivers are of any significant length, with most of them classified as torrents. The coasts of Calabria are composed of both sandy and gravel beaches. Furthermore, promontories can be identified in some areas. All areas are quite exposed to anthropic action. Thus, the relevance of the coastal area to the local economy

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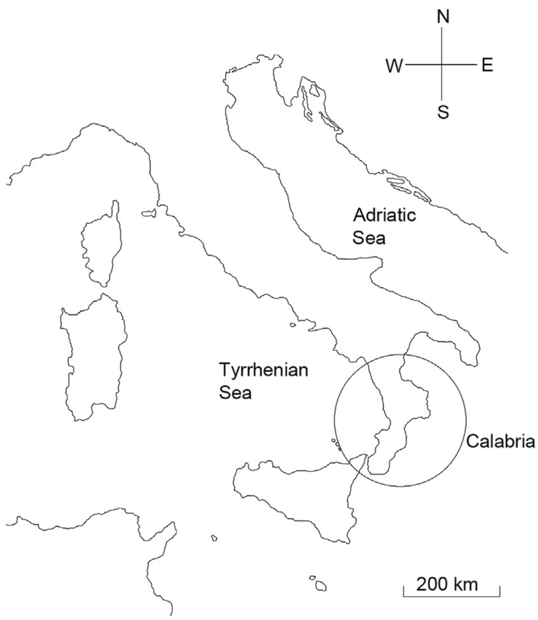

Fig. 1. Location of Calabria region.

is not surprising.

In the last few decades, most of the coast has experienced relevant erosive phenomena due to:

- anthropisation for industrial and tourist purposes;
- reduction of sediment transport from rivers and torrents;
- tectonic subsidence;
- relevant actions of sea storms (Barbaro et al., 2011, 2013; Arena et al., 2013a,b).

Several works were carried out to limit these phenomena. However, in most cases, they were conceived as temporary solutions in quite limited, space-wise, areas. Using this approach, the proposed solutions were implemented without a clear technical view of the situation, with consequent ineffective results.

The Plan has recently been developed by the regional administration to define in an objective manner a scale of priorities for the planning and intervention of the medium and long term re-equilibrium of the coastline. The analyses developed in this paper allow us to correctly evaluate, from several points of view, the consequences of possible proposed solutions, and thence to make choices based on accurate documentation and reliable analysis of the physical, environmental, social and economic aspects, all of which are closely interrelated.

This paper is divided into several parts: the first is an introduction, and to illustrate the importance of the drafting of the Master Plan, describes two case studies of work carried out without a global view of the problem and of the relative effects on the surrounding coastline. In the following part we analyse the scientific considerations in the preparation of the Master Plan, in particular the wave climate and relative index characteristic, the risk quantification and the determination of an intervention priority index.

2. Preliminary considerations on the importance of defining a Master Plan

The importance of a Master Plan is highlighted via two specific examples pertaining to the realisation of two quite different coastal structures: a port infrastructure and a groyne.

The first example is the construction of a port in Saline Joniche, a small town in southern Calabria. This port was constructed in the '70s to serve a nearby industrial area. It was thus conceived for mainly industrial purposes. Such an infrastructure has a remarkable environmental impact, as its presence modifies the shoreline configuration of the surrounding coastal area (Barbaro, 2013a,b; Barbaro et al., 2014).

A simple local approach is inadequate for designing this kind of coastal structure. In this regard, Fig. 2 and Fig. 3 are quite typical. Fig. 2 shows that the port configuration stops the natural movement of sand along the coast. The amount of the longshore sediment transport is so great that over 20 years, the entrance of the port has been totally obstructed such that now it is completely unserviceable. Fig. 3 shows the shoreline change which occurred after the construction of the port. Specifically, the left panel shows that the shoreline experienced a remarkable erosion for several kilometres along its north-west coast. These areas were characterized by quite long beaches, which were very important for the local economy. Nowadays, the situation is as shown in the right panel of Fig. 3, which shows a completely eroded beach. Over 20 years, more than 20 ha of beach has been eroded along a 5 km stretch of coast (see left panel of Fig. 3).

A second example concerns the realisation of a groyne in Lazzaro, located in southern Calabria a few kilometres north of Saline Joniche. The structure was constructed with the objective of restoring the beach on the south side of the structure. In this context, it is seen that, despite the relatively small size of the structure (especially when compared to the previous example), the local based design has induced, significant erosion on the northern side of the structure (see Fig. 4).

These examples emphasise the fact that a global view of the costal processes must be considered when planning solutions to coastal issues. Furthermore, the "size" of the structure is not negligible, as the coastal morphology is greatly affected by its interaction with a structure.

3. Wave climate and characteristic index

To characterise and classify the offshore wave climate, the coasts of Calabria are divided into contiguous study areas. Specifically, 24 areas are identified, whose borders are characterized by relevant variations of the coastal morphology (Fig. 5).

The wave climate has been investigated via the ABRC-MaCRO software developed by HR Wallingford Ltd. This software allows us to obtain time histories of metocean data, starting from the information available at the Met Office database. This database is composed by data reconstructed via the European Wave Model starting from wind field data. The data was gathered from October 1986 to November 2008. Data samples were obtained every 6 h before June 1988, and every 3 h thereafter. The database includes 18 points of the European Wave Model located off the coasts of Calabria, with a grid resolution of 25–30 km. Fig. 6 shows these points and the buoys of the Rete Ondametrica Nazionale (RON) and of the Rete Ondametrica Regionale (ROR) collecting data in Calabria.

The software is based on the HINDWAVE model (Ewing, 1989), which is implemented starting with the following input data: geometric characteristics of the area under investigation and wind velocity field in the area. The calculation is carried out in two stages: first, a table with all the combinations of wave data compatible with the characteristics of the site is defined, then wind records are analysed to identify which wave conditions are better correlated with current records.

The model has been calibrated via the buoy wave data recorded in Cetraro (Tyrrhenian Sea) and Crotone (Ionian Sea). This data is provided by the Rete Ondametrica Nazionale (RON).