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COASTAL PROTECTION

Considerations on coastal protection and management

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Abstract
As a contribution to the 2019 World Water Day, the Accademia Nazionale dei Lincei promoted a symposium on "Coastal protection and management". A selection of the papers presented at the meeting have been assembled as a Topical Collection. Costal zones are densely populated due to their morphological, climate, economic and recreational opportunities, but are exposed to the adverse effects of the sea action, in the recent decades worsened by growing human impact and sea level rise. Both erosion and accretion change the shoreline and the coastal zones, with the first prevailing today. Different estimates have been produced of beach erosion at a global or national level. In Italy more than 40% of the low coasts are presently eroding, despite decades of expensive beach defence works. In addition, high coastal infrastructures and settlements recently became more frequently exposed to storm surges. The papers collection deals with (a) monitoring studies of natural and man-induced shoreline changes, (b) hard and soft shore protections projects, (c) littoral hazards as tsunami, extreme high waters and storm surges, (d) protection of cultural heritage threatened by sea. General considerations on the challenge posed by the sea-level rise and possible solutions, i.e. defence, adaptation or managed retreat, are briefly summarized.

Keywords Climate change · Coastal erosion · Coastal management · Littoral hazard · Sea level rise · Shore protection

On March 21, 2019 the Accademia Nazionale dei Lincei promoted a meeting on "Coastal protection and management". This subject was proposed by Prof. Michele Caputo, chairman of the "Environment and Natural Disasters Commission", as a contribution to the 2019 World Water Day.

The purpose of the meeting was to draw attention to a problem that has been of great interest and socio-economic significance for many decades to the countries facing the sea and that climate change and increased human impact further increased. The long and narrow Italian peninsula (with its islands) is particularly exposed to adverse effects of the sea action on the coasts.

At the meeting the discussion concerned: long-shore erosion, coast evolution and impact on socio-economic resources, human pressure on the Italian coasts, techniques of coastal protection, tsunami and extreme weather and meteo-marine events. A selection of the papers presented at the meeting has been assembled as a Topical Collection, under the heading "Coastal Protection". Seven papers were published on Issue 1, March 2020 of Rendiconti Lincei—Scienze Fisiche e Naturali; three others are presented in this issue.

The coast, especially that bordering alluvial plains, is a very dynamic environment, prone to erosion, subsidence, tsunami and flooding from the sea and the land (Nicholls 2002). Nevertheless, an increasingly percentage of the world population lives in a narrow strip parallel to the shore, thanks to the economic, social and recreational opportunities here available (Goldberg 1994).

Approximately 90% of the sediments forming world beaches are produced by land surface erosion and is delivered by rivers to the sea (Pethick 1984). This volume changes following landcover variation, climate changes, human activity within the watershed. Deforestation to

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increase pasture and agriculture surfaces, increases soil erosion and coastal progradation, whereas hillside stabilization, dam construction, land reclamation, and riverbed quarrying trigger coastal erosion (Williams et al. 2018). In addition, sediments are no longer free to move alongshore because of harbours, jetties and coastal protection structures.

In most of the countries, the whole human activity is producing a negative beach sediment budget, which is the main reason of beach erosion. In addition, sea level rise, which has been a minor factor in the last century, will soon become a more important one, exposing coastal population, and national economies, to more severe beach erosion (Nicholls and Cazenave 2010).

Assessing the percentage of eroding beaches is not easy, for the lack of reliable and synchronous data, and the intrinsic variability of the shoreline, which in few hours can migrate inshore and offshore more than its long term (years, decades) trend.

Bird (1985), via interviews done to 200 colleagues in 127 countries, estimates that 70% of the world beaches are eroding; and this value is reported in thousands of scientific papers. Recently, Luijendijk et al. (2018) comparing millions of satellite images and using artificial intelligence to train the software to classify sea–beach–inland surface, found that Bird's value should be reduced to 24%. Mentaschi et al. (2018), again using satellite data, evaluate in 28,000 km^2 the land surface lost between 1984 and 2015.

According to EUROSION (2004) 15% of the 100,925 km of European coast analyzed is eroding, notwithstanding that 3% is protected; another 5% is stable thanks to shore protection works.

In Italy, out of 3951 km of low coast, 1657 km (41.9%) are eroding, even if several coastal sectors are intensively protected, with seawalls, groins, detached breakwaters, often doubling the structure, to have more than 2 km of defences for each kilometre of coast (Pranzini 2018).

In several countries, the negative beach sediment budget is being opposed via artificial nourishment, firstly with aggregates excavated on the riverbed, in alluvial plains or produced crushing quarry rock; further, nearshore and continental shelf sediments were dredged. The latter source nowadays provides the largest part of the sediment used for beach nourishment. In The Netherlands, 21.5 M m^3 of sand were used for a single project in order to create a sediment source which will naturally feed the coast for several years (Stive et al. 2013); it's approximately the same volume ever dredged along the Italian coast for beach nourishment, an activity started at the end of the 1990s with the work to defend the barrier island closing the Venice lagoon. Large volumes were than used in Lazio and Emilia-Romagna, but environmental constrains (and recently economic ones) limit the use of this resource along the Italian coast.

Alternative methods for shore protection have been developed, tested and adopted in several countries, from beach dewatering to artificial reefs (Armono 2004; Pilkey and Cooper 2012; Mariani and Turner 2013) from oyster reefs (Scyphers et al. 2011) to seagrass planting (Ondiviela et al. 2014), but effective results are far from arriving.

It seems that we need a Copernican revolution in this field to have a new way to look at the processes and find new ways to sustainable solutions.

With the sea level rising at an accelerated rate, humans cannot wait for a new Copernicus to keep their position along the coast, and the concept of managed retreat is making its way.

Actually, retreat has been forced till now, following a continuous coastal erosion, like at Galerazamba (Colombia; Correa and Gonzalez 2000), or after a catastrophic event, like in Normandy after the 2010 storm Xynthia, where several hundred houses have been relocated (Anthony and Sabatier 2013).

If researchers evaluate in different way the percentage of world coast presently under erosion, even more complex is the forecast for the future scenarios, and the discussion, if not conflict, among scholars is carried on in conferences, media and scientific papers. Recently, the forecast of the disappearance in 2100 of 50% of the world beached done by Vousdoukas et al. (2020) has been heavily challenged by Cooper et al. (2020) for the methods and models applied.

Actually, despite the plethora of studies carried out on coastal plains, beaches and continental shelves, where the Holocene sea level rise left important records, a comprehensive model of coastal response to SLR is not available, and painting maps in blue all what is below the water level as some IPCC scenario gives, demonstrates the lack of knowledge we still have.

Even without a framework on which there is agreement among researchers and decision makers, the increase of coastal erosion and flooding is a fact that everyone accepts. Equally accepetd is that invaluable or vital goods, e.g. Venice and New York, must be defended while for lower value sites a managed retreat (Rulleau and Rey-Valette 2017; Siders et al. 2019) can be considered.

Adaptation to climate change and sea level rise is the challenge present and future generations must face, finding technical, economic and social solutions (Hinkel et al. 2018). This means developing new sustainable defence strategies, possibly flexible to conform to future unforeseen conditions, and adapt the present coastal settlement to face higher sea levels and more intense storms. Significant examples are carried on, e.g. in Boston (City of Boston 2016) Hong Kong and Singapore (Chan et al. 2018).

In other sites, especially scattered built areas, undeveloped coasts and natural/agricultural areas, managed retreat is

environmentally, economically and socially more sustainable (Kousky 2014; Lincke et al. 2020).

Anticipating such events, convincing the population that we are not retreating but advancing in a different direction (Ewing 2019) is a very hard political task (Gibbs 2016), also because the effectivenes of this decision generarly comes (if it comes) after the forthcoming elections; to win them it is more convincing to show new seawalls, detached breakwater, groins and, at best, some more sand on the beach.

Within this framework, the papers presented at the the Accademia dei Lincei meeting "Costal protection and management" showed that Italian research is facing many of the problems above mentioned, from beach nourishment (Vecchi et al. 2020) to the behaviour of pebbles in coastal defence with artificial coarse clastic beaches (Bertoni et al. 2020), through monitoring studies of natural or man-induced shoreline changes (Di Paola et al. 2020; Carranza et al. 2020; Pellicani et al. this issue). There is a growing interest in extreme events, from exceptional high tide flooding to destructive sea storms on high coasts and human structures, possibly with increased magnitude and frequency due to climate change and sea level rise (Foti et al. 2020; Morucci et al. 2020). The evaluation of the instability of coastal cliffs facing touristic beaches, buldings and infrastructures is another problem along many high energy coasts (Esposito et al. this issue). In addition, a part of the Italian coasts is exposed to the risk of tsunami, as shown by geologic evidence (Scardino et al. this issue). Finally, a field of study most peculiar to Italy is that of the protection of cultural heritages threatened by sea, from the city of Venice (Foti et al. 2020) to historic and archeologic monuments (Mattei et al. 2020).

Works presented range from regional to local scale, but they are always framed within the global issues analysed before, and benefit from the close connections Italian single researchers, universities, research institutes have with their international counterparts, most of them within European projects.

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