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Editorial

Coastal Vulnerability and Mitigation Strategies: From Monitoring to Applied Research

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Abstract: This paper intends to offer the readers an overview of the Special Issue on Coastal Vulnerability and Mitigation Strategies: From Monitoring to Applied Research. The main focus of this Special Issue is to provide the state-of-the-art and the recent research updates on the sustainable management strategies for protecting vulnerable coastal areas. Based on 28 contributions from authors from 17 different countries (Australia, China, Ecuador, Germany, Greece, India, Italy, Mexico, The Netherlands, New Zealand, Poland, Spain, Sri Lanka, Taiwan, United Arab Emirates, UK, USA), an ensemble of interdisciplinary articles has been collected, emphasizing the importance of tackling technical and scientific problems at different scales and from different point of views.

Keywords: coastal vulnerability; coastal defense; coastal monitoring; wave climate; coastal morphodynamic; coastal management; coastal ecosystem

1. Introduction

Coastal management in the 21st century will require us to face multiple issues including climate change and impacts of sea level rise. Conservation of coastal systems and ecosystems requires multidisciplinary inputs as well as integrated studies and approaches.

In view of this, the following research topics deserve greater attention to speed up the development of suitable coastal management strategies:

(a). relationship between coastal ecosystems and hydrodynamics;
(b). climate change effect on coastal areas;
(c). coastal morphodynamics;
(d). coastal vulnerability;
(e). integrated coastal management.

2. Contributions

This Special Issue provides food for thought on each of these topics.

2.1. Relationship between Coastal Ecosystem and Hydrodynamics

Coastal lagoons and river deltas are complex environments where hydrology and coastal dynamics work together for the ecosystem functioning. Management and environmental policies of such coastal areas are extremely difficult because of continuous conflicts between conservation and development. Modelling is crucial for supporting the analysis of management scenarios. So many research efforts have been made to understand the relationships of coastal hydrodynamics with biotic and abiotic elements of the ecosystems.

Christia et al. [1] developed an integrated environmental assessment methodology on Western Greece coastal lagoons (Rodia, Tsoukalio and Logarou—Amvrakikos Gulf, Kleisova—Messolonghi-Aitoliko, Araxos) demonstrating the link between macrophyte assemblages and abiotic factors typical of coastal lagoon systems. Their results emphasize the crucial impact of the sea water intrusion on the relative abundance and distribution of macrophyte species, as described in other Mediterranean coastal lagoons. The proposed methodology is broadly applicable, since it is based on important parameters affecting coastal lagoon ecosystems, and the provided links between macrophyte assemblages and abiotic factors are of critical importance to improve environmental policies.

Tran Anh et al. [2] combined different models to simulate the hydrodynamics and salinity distributions in the Hau (Bassac) River estuary of the Mekong Delta, southern Vietnam. A combination of 1D and 2D hydrodynamic models were calibrated and applied to simulate future hydrological changes under multiple scenarios of upstream inflow changes, climate change and sea level rise for the 2036–2065 period. The model simulations indicate that a combination of upstream discharge reductions, rainfall changes and rising sea level will substantially exacerbate salinity intrusion.

Interaction between mangrove vegetation and hydrodynamics plays an important role in many coastal tropical and sub-tropical intertidal environments, including coastal protection. Coastal vegetation is effective in dissipating incident wave energy during storm conditions, which offers valuable protection to coastal communities.

Montgomery et al. [3] explored the influence of channelization on mangrove flood attenuation comparing high water events in two contrasting New Zealand mangrove forests. The degree of channelization and, therefore, the capacity of mangroves to reduce flooding depends on the elevation of the vegetation. Observations from sites with the same vegetation type suggest that mangrove properties are important to long wave dissipation only if water transport through the vegetation is the dominant mechanism of fluid transport.

Tan et al. [4] investigated wave propagation and turbulence characteristics through vegetation with different stiffness by means of a physical model in a laboratory wave flume. The results showed different patterns in wave propagation turbulence intensity in different canopies; such knowledge may support the selecting of vegetation species with suitable stiffness for coastal protection purposes.

Yao et al.'s [5] technical note provides a practical set-up to derive both time-varying and period-averaged vegetation drag coefficients following the direct measuring method. Standard force sensors are applied to compose four synchronized force–velocity measuring systems in the current experiment. The newly-developed synchronized force–velocity measuring systems and the automatic realignment algorithm offers information for future experiments on vegetation–wave interactions for better understanding and prediction of vegetation-induced wave dissipation.

Tripepi et al. [6] investigated hydrodynamic forces induced by tsunami-like solitary waves on a horizontal cylinder placed on a horizontal seabed by means of 2D laboratory experiments. An overall good agreement found between analytical solutions and laboratory tests has led, in conjunction with the measurement of experimental forces, to the calibration of the hydrodynamic coefficients in the Morison and transverse equations.

2.2. Coastal Climate

Extreme sea and weather events (in terms of storm waves, tsunamis, sea level rise, air temperature, wind and atmospheric precipitation) in coastal areas have highlighted the destructive effects that can occur from hazards of marine origin. Many geomorphological and coastal engineering scenarios require robust estimates of wave climate and design wave height with a certain return period and incorrect estimates can have dramatic effects on the flood risk analysis or on the structural design of maritime structures.

Dentale et al. [7] proposed a procedure based on integrating significant wave height time series generated by model chains with those recorded by wave buoys in the same area (North Atlantic Spanish Coast, South Mediterranean Italian coasts and Gulf of Mexico) in order to provide better estimates of extreme values. A general procedure is provided to improve the reliability of model data for the extreme values analysis; such a procedure can also be used to evaluate the suitability of a given model data archive to the estimation of the probability of extreme sea states.

Molina et al. [8] analyzed a 35-year wave climate dataset concerning four positions equally spaced along the Mediterranean coast of Andalusia (south of Spain). A total of 2961 storm events were recorded and classified as a function of their associated energy flux. In particular, nine stormy years, i.e., years with a high cumulative energy, were recorded.

Hamza et al. [9] investigated the wave climate offshore Saadiyat island situated in the Gulf within the Emirate of Abu Dhabi. They compared the measured ADCP data and propagation results of the NOAA offshore wave dataset by means of the Simulating WAves Nearshore (SWAN) numerical model, the NOAA and ECMWF wave datasets at the closest grid point in shallow water conditions, and the SPM '84 hindcasting method with the NOAA wind dataset used as input have been carried out. They showed that the SPM '84 hindcasting method might be very accurate in shallow water conditions.

Contestabile et al. [10] carried out a multi-comparison between wave propagation model data and direct measurements at Bagnoli-Coroglio bay (central Tyrrhenian Sea, Italy). A non-conventional triple-collocation-based calibration of a wave propagation model is described. GPS-buoy, ADCP data and model virtual numerical points allowed an implicit reciprocal validation of the different data source. The results suggest that numerical model calibration based on short term wave buoy measurements can be easily applied in different areas where detailed wave data are not available.

Tylkowski et al. [11] determined the threshold values for extreme sea and weather events on the Polish Baltic coast. The threshold values presented can be used to forecast changes in climatic and hydrological conditions (maximum and average daily air temperature, daily sum of atmospheric precipitation and maximum and average sea level) in the Baltic coastal zone.

Hydrometeorological conditions especially favorable to the intensification of aeolian processes are the main determinants of geomorphological changes in the coastal zone. Hojan et al. [12] presented the temporal and spatial variability of hydrometeorological conditions conducive aeolian processes on the Southern Baltic coastal zone in Poland. In periods between storms, coastal wind is seen to decrease the balance of beach sediments and lowers the beach area.

2.3. Coastal Morphodynamic

Extreme storms may significantly affect the coastal environment, especially in terms of erosion and sediment transport. They can provoke disastrous consequences such as sediment transport beyond the surf zone to unusual depths [13]. The swash zone is that part of the beach alternately covered and exposed by uprush and backwash. It is characterized by strong and unsteady flows, high turbulence levels, large sediment transport rates and rapid morphological change, and it represents arguably the most dynamic region of the nearshore [14].

Riefolo et al. [15] analyzed experimental data from large scale wave flume under the project SUSCO (Swash zone response under grouping Storm Conditions) founded by EC Programme HYDRALAB III. The authors highlighted the effects of wave grouping and long-wave short-wave combination regimes on low frequency wave generations and clarified their influence on morphodynamics. Some evidence of the influence of low frequency waves on runup and transport patterns are shown. In particular, the generation and evolution of secondary bedforms are consistent with energy transferred between the standing wave modes.

Saponieri et al. [16] analyzed short term morphodynamic response of a beach nourishment protected by a standard and an innovative beach defense system. The 2D physical small-scale models were carried out to study a rubble-mound detached submerged breakwater and a Beach Drainage System deployed together. The Beach Drainage System influenced swash zone hydrodynamics and morphodynamics in the presence of the submerged breakwater while a reversal of the prevalent direction of the net sediment transport seaward was reported offshore from the sheltered region.

Medellín et al. [17] studied the shoreline resistance and resilience associated to a transient disturbance (a temporary groin) by means of field observations and numerical modelling. The study site is a micro-tidal sea-breeze dominated beach located in the northern Yucatan Peninsula. A new one-line numerical model of beach evolution is calibrated with the field surveys, reproducing both the sediment impoundment and subsequent beach recovery after the structure removal. Results suggest that beach resistance associated to the presence of a structure decreases with increasing alongshore sediment transport potential, whereas resilience after structure removal is positively correlated with the alongshore diffusivity.

Torres-Freyermuth et al. [18] investigated beach morphodynamics behind low-crested detached breakwaters build on a micro-tidal sea-breeze-dominated beach located in the northern Yucatán Peninsula in the Gulf of Mexico. Three study sites were monitored trough beach survey (RTK-DGPS), UAV flights, freeboard elevation and breakwater length, waves and sea level measurements. Observations suggest the high sensitiveness of beach morphodynamics to breakwater transmissivity.

2.4. Coastal Vulnerability

Coastal vulnerability is a spatial concept that identifies people and places that are susceptible to disturbances resulting from coastal hazards. Hazards in the coastal environment, such as coastal storms, erosion and inundation, pose significant threats to coastal physical, economic, and social systems. [19].

The Coastal Vulnerability Index (CVI) is a popular index in literature to assess the coastal vulnerability of climate change.

Pantusa et al. [20] presenting a case study proposed a CVI formulation to make it suitable for the Mediterranean coasts. The new formulation considers ten variables divided into three typological groups: geological, physical process and vegetation. For the case study presented in this work, the most influential variables in determining CVI are dune width and geomorphology. The transects presenting a very high vulnerability were characterized by sandy and narrow beaches (without dunes and vegetation) and by the absence of Posidonia oceanica.

Kantamaneni et al. [21] reviewed the existing coastal vulnerability assessment studies along the coastal Andhra Pradesh region in India with the aim to mitigate the existing shortcomings in the assessment techniques used previously in that area. Their study shows that very little was done so far in the area to assess the overall coastal vulnerability, with only a few of the CVI parameters being accounted for and based on relatively low-resolution data. So, this study significantly improved the assessment.

Garcia-Ayllon [22] presented an innovative methodology for analyzing the coastal vulnerability based on the GIS evaluation of the spatial statistical correlation of long-term anthropic impacts and the distribution of current risks. The geo-statistical analysis carried out for the Mar Menor Mediterranean lagoon reveals that the urbanization processes being developed in the last decades have generated imbalances. The proposed approach seems promising to better understand the relationship between territorial transformations on the coast and the current coastal vulnerability of this area.

Favaretto et al. [23] presented a novel 2D model for the inland flood propagation and an approach for the assessment of coastal flooding vulnerability. Hazard maps of two stretches of the Venetian littoral (Northern Adriatic Sea, Italy) were produced, showing the probability of failure in each point of the coast for a given inland inundation level.

Gaeta et al. [24] implemented a coupled wave-2D hydrodynamic simulation by means of the open-source TELEMAC suite in the coastal area of the River Reno mouth (eastern coast of Northern Italy). Past (1971–2000) and future climate change (2071–2100) scenarios showed that flooding hazards and changes in littoral hydrodynamics at the selected site are nowadays already significant, especially during extreme events and are expected to further increase in the future. The highest contribution to the coastal vulnerability of the studied beach is due to the relative rise of sea level, especially when this is combined with extreme sea storms.

2.5. Coastal Management

Coastal management in the coastal zone includes nature conservation, recreational activity, habitat and species restoration and coastal defense (protection from coastal pollution, coastal erosion and flooding).

Ruol at al. [25] described the recent Coastal Plan of the Veneto Region (Italy) proposing erosion mitigation criteria. The authors provided practical guidelines on how to interpret coastal monitoring analysis, select when, where and what mitigation measures should be adopted, and suggest a methodology for assigning a priority level to any action. The criterion used takes into account erosive tendency, existing coastal flooding hazards, coast value, environmental relevance, tourist pressure, urbanization level, the presence of production activities and cultural heritage.

Coastal management criteria based on the coastal risk map for the Yunlin Coast (Taiwan) was drawn by Huang et al. [26]. The results showed vulnerability and potential hazards and proposed design criteria for coastal defense and land use for the various kinds of risks faced. The safety of the present coastal defenses and land use was assessed, and coastal protection measures for hazard prevention were proposed based on the generated risk map. The coastal hazards are constituted mainly by storm surge and ground subsidence and, therefore, an implementation of both engineered and non-engineered control measures is proposed.

Giardino et al. [27] presented an implementation and application of the Bayesian belief network (BBN) for coastal erosion management at the regional scale along the entire Holland coast. The effects of different sand nourishment designs on two pre-identified coastal indicators (i.e., dune foot and momentary coastline position) were assessed at 604 cross-shore transects and spanning a period of over 50 years. BBN provides a very powerful tool to bridge the existing gap between the needs of coastal managers and the currently available data and numerical models.

Coastal pollution is also a significant element of vulnerability. The assessment of pollution sources is critical for support management and if needed remediation actions.

Giglioli et al. [28] analyzed the contaminants' concentrations (i.e., heavy metals and hydrocarbons) in seabed sediments through a statistical multivariate approach in a post-industrial area, Bagnoli (Gulf of Naples, Southern Italy). The main contamination source was found related to anthropogenic activities but, concerning Arsenic and other metals, it was reported that the existence of multiple anthropogenic and geogenic sources might originate from the volcanic rocks present in the area.

Mestanza et al. [29] presented an historical analysis (17th to 19th centuries) of the shore protection works performed at Callao (Peru) as defense from storm waves and tsunamis. The analyses put in evidence that most of the physical processes of coastal dynamics and shore protection were qualitatively understood. The main difference with the modern approach is that new materials to build structures as physical and numerical models to design them are now available. A strategic retreat as the most sustainable solution with respect to the forecasted sea level rise and increased storminess, was even considered.

Pranzini et al. [30] analyzed a long time series (from 1878 to 2017) of data on shorelines and shore protection structures along the Northern Tuscany coast. The presented case studies allow identification as to how shore protection structures are designed to counteract beach erosion. This study shows how sediment bypassing could have been implemented at most important harbors and how softer solutions might have been adopted starting from stable sectors and moving towards eroding areas. However, the authors point out that such strategies would have required a long-term strategy, which in many cases is incompatible with the lifetime of political decision-makers.

Cioffi et al. [31] developed a methodological modeling approach to assess the reliability of hydraulic infrastructures in controlling risks of flooding in a lagoon area in the south of Italy. This zone has an elevation equal to or lower than the mean sea level. The modeling study shows that the carrying capacity of the hydraulic network downstream of the pumping system is insufficient to cope with future sea level rise and intensification of rainfall.

3. Conclusions

The research contents examined in this Special Issue highlight that several stressors affect the coastal zones, determining new challenges to minimize coastal vulnerability through mitigation strategies.

Most papers give us greater insights and open new frontiers to handle risks in coastal zones. Innovation in management tools for coastal managers and applied research in the topic of coastal zone management have been proposed. Several studies have thoroughly investigated specific hydrodynamic and morphodynamic processes in costal zones. An overview of mitigation strategies against flooding and erosion, also in the perspective of climate change effects, is also provided. Moreover, the Special Issue is completed by several contributions concerning ecological coastal defense and innovative monitoring techniques.

The ensemble of interdisciplinary articles collected in this Special Issue emphasizes the importance of tackling technical and scientific problems at different scales and from different points of view.

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