Application of Coastal-Area Morphodynamic Models

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Human activity has become an important force in coastal and estuarine morphological changes. Understanding the morphodynamic impact of these human activities has attracted the attention of scientists as well as coastal and estuarine managers. From the perspective of ecosystem conservation and restoration, scientists and managers require modelling approaches to assess and predict the impact of anthropogenic activities on coastal and estuarine morphogenetic evolution.

human activities modelling

1. Introduction

Coastal and estuarine morphogenetic evolution has been affected by anthropogenic activities over the last few decades, e.g., [1]. Thus, human activities have become an important external force for the future prediction of morphogenetic evolution. Human activities, such as land reclamation, have destroyed ecosystem health. For example, the loss of tidal flats due to land reclamation causes damage to the habitat of tidal wetlands, fishing and nursery grounds, and other ecosystem functions [2][3]. Other noticeable human activities are dam construction and reduced sediment supply to the coast and the estuary [4]. Estuarine regulation and management activities, such as in the Modaomen estuaries, have turned the Modaomen embayment into a channel [5]. Human activity has become an important force in coastal and estuarine morphological changes. Understanding the morphodynamic impact of these human activities has attracted the attention of scientists as well as coastal and estuarine managers. From the perspective of ecosystem conservation and restoration, scientists and managers require modelling approaches to assess and predict the impact of anthropogenic activities on coastal and estuarine morphogenetic evolution. Observational data must always be processed for scientific analysis and modelling. Thus, modelling tools, including data-driven modelling, are crucial for scientific studies and management.

There are many review papers about the modelling approaches of coastal and estuarine evolution, but there is a lack of a review about modelling anthropogenic impacts on morphological evolution. [6] reviewed models for coastal and estuarine evolution at decadal-to-centennial scales based on generalised Exner equations. Sediment fluxes and their gradients are critical for the coastline and for submarine morphological evolution. These morphogenetic models could generate results that deviate from reality owing to uncertainties in the prediction of sediment fluxes and incomplete or simplified boundary forcing. Recently, machine learning techniques for artificial intelligence have emerged because of the increasing amount of available observational data and the advancement of artificial intelligence techniques [7]. As anthropogenic forcing has been widely recognised to be non-negligible during the last decades, how to incorporate the modelling of anthropogenic activities in morphological evolution remains a challenge. To date, few studies have attempted to provide a synthesis review of modelling approaches to the impacts of anthropogenic activities on morphological evolution.

2. Application of Coastal-Area Morphodynamic Models

The most common modelling approaches are coastal-area morphodynamic models such as Delft3D [8] or Telemac modelling system [9] models. The Xbeach model is frequently applied for simulating short-term processes for the beach, dune and barrier due to storm impacts [10]. Direct modelling of human activities and their impacts on morphodynamic evolution is rare in the published literature. Often, the impacts of human activities on the initial and boundary conditions are utilised to run morphodynamic models. For example, the exploratory simplified model of barrier island evolution was applied to a real-world coast with human modifications to topography and sediment fluxes [11]. This approach does not simulate human activities directly, but it uses the observed values of terrain information such as barrier height, island width, and back-barrier depths in human-modified coastal sections. Modelling approaches provide long-term (decadal-to-millennian) evolution with the impacts of human activities.

For the engineering and management timescale, the Delft3D model was applied to simulate morphological changes at different time intervals: the accretion period (1958–1978), erosion period (1986–1997), and accretion period due to human activities (2002–2010) [12]. The first two periods were mainly due to a human-induced reduction in riverine sediment supply, whereas the third period can be attributed to estuarine engineering projects [13]. Anthropogenic-induced sea-level rise can serve as a boundary input for developed coastal-area morphodynamic models [14]. IPCC scenarios of sea-level rise and human activities can be added as boundary forcing for the process-based models for simulating estuarine morphodynamic evolution [15].

Unlike long-term modelling, short-term modelling requires a high accuracy due to short-term morphological changes being small. Furthermore, short-term processes are rapid and instantaneous. For example, the nearshore numerical Xbeach model can simulate the short-term processes of dune erosion, overwashing, and breaching [10]. The Xbeach model has advanced the modelling approaches for dune erosion [16][17] to incorporate vegetation effects for natural-based solutions [18]. Beach-dune systems are often observed at most beaches in the world. However, human influences have strongly modified the natural landscape of the beach-dune systems [11][19]. For example, the existing portions of dune habitat are subjected, particularly during the summer, to intense trampling and degradation due to the uncontrolled access of tourists. Problems with disruption of vegetation cover commonly arise where pedestrians' and vehicles' beach access are poorly managed. Furthermore, infrastructures are built behind the beach for tourism. Thus, it is evident that there is an urgent need to preserve such valuable ecosystems from erosion. Therefore, the coastal community is paying attention to finding new environmentally friendly solutions for dune restoration. In this respect, the Xbeach model that includes the simulation of vegetation effects is useful for engineering and management activities. Regarding the short-term impact of human activities on morphodynamic evolution, artificial dunes are incorporated by modifying the initial bathymetry to large elevations at the dune location for the implementation of the Xbeach model [20].

The coastal morphodynamic model is a process-based model that can simulate coastal morphodynamic changes caused by storm events and relative sea-level rise. Human modifications such as hard structures can be simply added by changing the topography, which usually requires a high grid resolution that can reflect hard structures such as jetties. Beach nourishment acts as an additional sediment source for coastal morphodynamic models. These human activities do not require modification of the primitive equations and internal formulas of the model. This implies that no further development of the model is required. Human activities are reflected in the implementation of the model. These approaches are effective in the case of hard structures and available data representing human activities. Also, these human activities can be accounted for by using their impacts on the boundary forcing or the initial setting of the models. The computation methods of sediment fluxes need to be modified [6][21] because of human activities such as vegetation effects. Biological effects on morphodynamic evolution can also be incorporated, such as benthos, in tidal flats [22].

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