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Towards integrated modelling of Watershed-Coast System morphodynamics in a changing climate: A critical review from a coastal engineering perspective

Achilleas G. SAMARAS

Department of Civil Engineering, Democritus University of Thrace, PC 67100, Xanthi, Greece
email: achsamar@civil.duth.gr

ABSTRACT

1. Introduction

The term Watershed-Coast Systems (WACS), coined by Samaras and Koutitas (2014a), refers to the entities consisting of watersheds of rivers/natural streams and the areas adjacent to their outlets where sediment delivery from the upstream is critical for the balance of the coastal sediment budget, thus playing a key role in long-term evolution of coastal morphology. The study of such systems in a changing climate emerges as an issue of major concern nowadays, as the shift in climate pressures will affect both watersheds and coastal zones, and implications will extend from morphological to ecological and socio-economic ones, threatening ecosystems, cultural heritage, settlements, infrastructure, as well as human life.

From this standpoint, the physical problem in question can be divided into four basic components: (A) climate change; (B) watershed dynamics; (C) coastal dynamics; and (D) integration of the Watershed-Coast System (Fig. 1). Components (B) and (C) have been studied in detail over the years; the last few decades so are (A) and the impact of (A) on (B) and of (A) on (C). Numerical models have been proven essential in the above, with various models and modelling systems currently available which are able to represent natural processes at different scales in space and time. However, the critical component (D) – which independently of (A) defines the essence of the WACS concept – has not been analysed to the extent one would expect to, considering its importance for coastal evolution modelling.

2. Coastal morphodynamics and WACS: Concepts and Modelling

The evolution of coastal morphology has been studied extensively by many researchers, starting from purely theoretical concepts for the systemisation of empirical knowledge and observational understanding, up to entire methodological frameworks for the implementation of modelling tools of varying types and complexity in order to simulate natural and human induced geomorphic processes at different spatial and temporal scales.

Nevertheless, even the works that stand out in literature (e.g. Cowell et al., 2003; Peckham et al., 2013; Payo et al., 2017) do present one or both of the following essential limitations when it comes to the study of WACS: (a) the not-integrated study of the terrestrial and coastal fields as an entity and (b) the scales in space and time at which they have been successfully implemented. The first limitation has its basis in the – admittedly extremely complex – interplay between processes taking place in watersheds, coasts and the coastal zone. The second limitation derives from considering how the aforementioned scales relate to actual case-studies of importance for watershed/coastal management and engineering purposes.

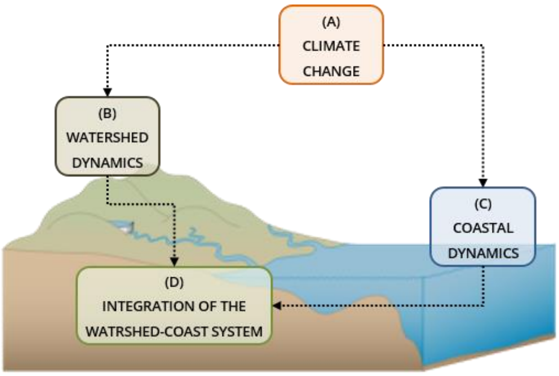

Fig. 1. The physical problem in question.

Approaches that have attempted to overcome these limitations have been proposed by two groups: by Samaras and Koutitas (2012, 2014a, 2014b), later adopted by Malara et al. (2020), and by the group led by Prof. Ranasinghe from IHE Delft (works from Ranasinghe, 2016 up to Bamunawala et al., 2021), who also suggested the term Catchment-Estuary-Coastal (CEC) for these systems. Both approaches present certain advantages and disadvantages; at this stage, it can be said that the second approach is better systematized and presented.

3. Towards the integrated modelling of WACS for management and engineering purposes

Climate crisis and its observed impacts highlight the need for urgent action in order to mitigate and adapt to climate change in view of a dire future (IPCC, 2022). This action requires bold steps towards translating existing scientific knowledge into policy and practice, a task unlikely to succeed unless a pragmatic approach with focus on real-life applicability is followed. The coastal engineering community must rise to the challenge, as coastal zones – located at the land-sea interface and hosting about two thirds of the world's population – will undoubtedly be at the forefront of all relevant attempts.

In this context, the review presented in this work will first identify the critical issues that need to be addressed moving towards the integrated modelling of WACS for management and engineering purposes in a changing climate, and then evaluate relevant literature on the basis of these aspects. Figure 2 presents a general methodological framework for such an approach. The left part of this flowchart, especially regarding (A), (B), and (C), has been theorised by few other researchers to various extents. However, it is the incorporation of the right part of the flowchart that introduces many of the major challenges ahead.

Accordingly, modelling approaches should be formed and/or evaluated based on the following: (i) inclusion of all four components described in Section 1 and Fig. 1; (ii) consideration of projected climate change-induced changes in management practices and engineering works in both fields (terrestrial, coastal) when defining future scenarios; (iii) applicability to scales suitable for watershed/coastal management and engineering purposes; (iv) adaptability to methods for addressing ecological/socio-economic implications and stakeholders engagement. The model validation aspect in panel (D) of Fig. 2 is also critical from a methodological point of view and will be further analysed.

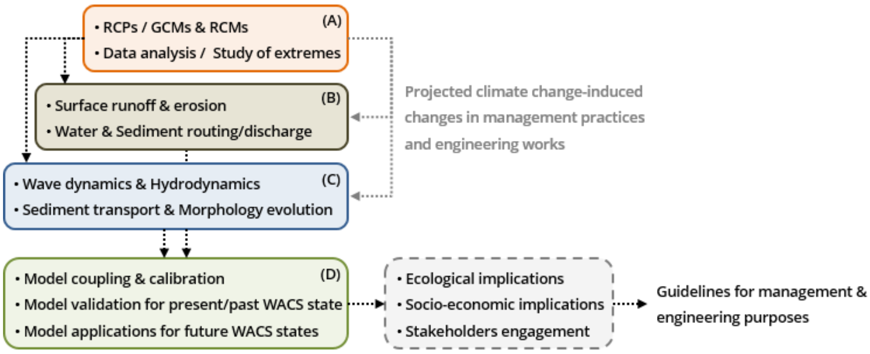

Fig. 2. General methodological framework for the integrated modelling of WACS morphodynamics in a changing climate (A, B, C, D with reference to Fig. 1; RCP: Representative Concentration Pathways; GCM/RCM: Global/Regional Climate Models).

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