THE DEVELOPMENT OF A VULNERABILITY INDEX FOR BEACH EROSION, BASED ON A SEDIMENT BUDGET APPROACH

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Abstract

The present contribution presents an erosion index for the beach zones based on a conceptual sediment budget model; the latter involves the identification of littoral cells, sediment sources, throughouts and sinks of sediment. For the development of the index the aforementioned parameters are ranked in a homogeneous way and interrelated mathematically. The produced index values quantify relatively vulnerability to erosion along the beach zone.

Keywords: Coastal Processes, Erosion, Shoreline Evolution

Introduction

The difficulty to predict coastline changes is due to the range and the frequency of processes that affect coastal areas and the closely coupled links between sea-level rise and other processes driving coastal change. Over the past decade, the Coastal Vulnerability Index has been developed for the assessment of coastline changes due to a potential sea level rise. This index aims to classify the potential effects of sea-level rise on open coasts using the physical characteristics of the coastal system (for details see Gornitz and White, 1992), providing basically a rank-based vulnerability assessment and comparative classification of the various coastal stretches.

The aim of this contribution is the development of an index dedicated to the assessment of vulnerability in the case of beach zones developed in microtidal environment but experiencing significant nearshore hydrodynamics including relative sea level change.

The BVI method

Concept: The proposed beach-zone vulnerability index (BVI) is based on a numerical approach of the parameters governed the sediment budget of beach zone and its evolution. Thus, variables that form the beach vulnerability index includes: (i) long-shore sediment transport; (ii) cross-shore transport; (iii) riverine inputs; (iv) relative sea level change (tectonic and climatic); (v) wave run-up; and, (vi) aeolian sediment transport. It is worth mentioned that the calculation of the aforementioned variables incorporates the estimation of other important parameters, such as granulometry, significant wave height and the gomorphological characteristics of the beach zone, like beach slope, beach profile length

Calculation: For the calculation of each variable the simplest possible available equation has been chosen; these are presented below:

(I). Longshore sediment transport is given by Komar's (1998) equation:

$$Q_1 = 1.1\rho g^{\frac{3}{2}} H_b^{\frac{5}{2}} cos(a_b) sin(a_b) \quad (1)$$

where, Q: potential volumetric longshore transport rate (m^3/day), ρ: water density; g: the acceleration of gravity; H_b: breaking wave height, a_b: wave crest angle at breaking.

(II) Crosshore sediment transport is provided from the Bailard and Inman's (1981) equation:

$$Q_1 = \rho C_D {u_b}^3 \left\{ \frac{\varepsilon_B}{tan\phi} \left(\psi_1 + \frac{2}{3}\delta_u - \frac{tan\beta}{tan\phi} {u_3}^* \right) + \frac{u_b}{w_s}\varepsilon_s \left[\psi_2 + \delta_u {u_3}^* - \frac{u_o}{w_s}\varepsilon_5 {u_3}^* tan\beta \right] \right\} \quad (2)$$

where, ε_B: 0.2; ε_S: 0.025; C_D: dragging coefficient; w_s: sediment fall velocity; φ: the angle of repose; β: the beach slope; u_b:near bed water velocity; ρ: water density; and, ρ_s: density of sediment. δ_u,ψ_1, ψ_2, ψ_1, u_3^* and u_5^* cross-shore velocities depending from the significant wave height (Bailard ,1982).

(III) In the case of data absence, riverine sediment inputs maybe calculated with the use of Hovious' (1998) equation:

$$lnE = -0.416lnA + 4.26 \cdot 10^{-4}H + 0.15T + 0.095T_R + 0.0015R + 3.58 \quad (3)$$

Where, E: sediment weight gr/m^2; H: maximum elevation of the drainage basin; T: mean temperature; T_R: temperature range; and, R: river run off.

(IV) The effect of relative sea level rise variable is calculated from Bruun's (1962) semi-empirical relationship: $R = s\left(\frac{L}{B + h_c}\right)$ (4)

where, S: relative mean sea level rise, in cm; L: profile length; B: berm height; and, h_c:closure depth.

(V) The wave run-up R is given from CERC (1984) in the case of:

breaking waves, $R = 2.32 H_o {\xi_o}^{0.17}$ (5a) and,

non-breaking waves, $R = H_o\sqrt{2\pi}\left(\frac{\pi}{2B}\right)^{\frac{1}{4}}$ (5b)

where, Ho: offshore significant wave height; B: Berm height, and ξ: the Irribaren number.

(VI) The aeolian transport variable is provided by Hsu (1986) equation:

$$q = V_a P_a \left(e^{-0.63+0.91D}\right)\sqrt{\frac{U_x}{gD}} \quad (6)$$

where, *q:* sand transport rate, in gm/cm/s; *u**: shear velocity; *g:* acceleration of gravity; *D:* mean sand grain diameter; *Va:* air kinematic viscosity; and, *Pa:* air mass density.

The index is applied in a beach zone that is divided alongshore into a grid at distances according to the required accuracy. Subsequently, the required data set is obtained either by the use of numerical models (eg. wave heights, breaking height and angle) or by data that are collected by field measurements.

Ranking index variables: It is based on the assumption that the potential maximum value reflects 100% of the variable; this maximum value will be calculated obviously by applying the maximum values for the parameters that are included in the corresponding equations. Numerical values of variables will be also transformed into percentages ranging between 0.00 and 1.00, while those variables that are associated with addition and/or removal of sediment from the beach zone (e.g. cross-shore sediment transport will be signed as either negative or positive.

Output: The index will be calculated as the geometric mean value of the six (6) variables for each grid cell of the beach zone. This will highlight not only the most vulnerable parts of the beach zone to erosion, but also the principal variable being responsible for the highest vulnerability; thus, the physical process(es) mostly responsible for the erosion could be identified.

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