Applied Ocean Research 74 (2018) 205–216

Contents lists available at ScienceDirect

Applied Ocean Research

journal homepage: www.elsevier.com/locate/apor

Modelling the cross-shore beach profiles of sandy beaches with *Posidonia oceanica* using artificial neural networks: Murcia (Spain) as study case

Isabel López [a,*], Luis Aragonés [a], Yolanda Villacampa [b], Rosana Satorre [c]

[a] Dept. of Civil Engineering, University of Alicante, Carretera San Vicent del Raspeig s/n, 03690 Alicante, Spain
[b] Dept. of Applied Mathematics, University of Alicante, Carretera San Vicent del Raspeig s/n, 03690 Alicante, Spain
[c] Dept. of Computer Science and Artificial Intelligence, University of Alicante, Carretera San Vicent del Raspeig s/n, 03690 Alicante, Spain

ARTICLE INFO

Article history:
Received 6 February 2017
Received in revised form 4 July 2017
Accepted 9 March 2018
Available online 15 March 2018

Keywords:
Artificial neural network
Sandy beach
Cross-shore beach profile
Posidonia oceanica

ABSTRACT

This paper presents a model of the cross-shore beach profile taking into account the presence of the seagrass *Posidonia oceanica* whose ultimate objective is to reduce the volume of sand used in beach nourishment. The methodology describes the training, validation, testing and application of models of artificial neural networks (ANN) for computing the cross-shore beach profile of sandy beaches in the province of Murcia (Spain). Eighty ANN models were generated by modifying both the input variables and the number of neurons in the hidden layer. The input variables consist of wave and sediment data and data concerning the *Posidonia oceanica*. To select and evaluate the performance of the optimal model, the following parameters were used: R^2, absolute error, mean absolute percentage error and percentage relative error. The results show a mean absolute error of 0.22 m (0.21 m in training and 0.28 m in test), representing an improvement of 85.1% compared to models that do not use the *Posidonia oceanica* and 69.8% against those that consider it. Although the ANN was developed for beaches with *P.oceanica*, it could be used in areas with other seagrass able to reduce wave energy and consolidate the sand such as *Syringodium filiforme, Thaalassia testudinum, Laminaria hyperborea, Halodule wrightii* and *Zostera marina.*

1. Introduction

The erosion of beaches is an important problem along coastlines at a globally scale [1]. To combat this erosion several coastal replenishment actions are carried out, such as dikes, breakwaters and/or beach nourishments [2,3], for which it is important to characterize properly the morphodynamics of the operating area and the morphology of the cross-shore beach profile [4].

The morphology of a beach is mainly controlled by wave climate, tide and sediment characteristics [5,6]. The prediction of beach profile evolution under the action of waves and currents is one of the most important tasks in coastal engineering because of its influence on coastal erosion [7]. Even though cross-shore sediment fluxes are usually a few orders of magnitude smaller than longshore transport, the cross-shore beach profile has a strong influence on longshore velocity profiles and therefore on longshore sediment fluxes [8]. The beach profile is the result of the trade-off between onshore and offshore fluxes. The direction of the cross-shore fluxes is a key point for predictive tools and is closely related to the nonlinear characteristics of the incoming waves such as asymmetry and velocity skewness [9,10].

Understanding the variability of cross-shore beach profiles is essential for its application to several coastal engineering fields, for instance: i) beach nourishment design [11–14]; ii) coastal defence structure design [15]; and, iii) the delimitation of the active zone for the calculation of nourishment volumes and the estimation of coastal sediment balance [16–18]. The characterization of the morphology of the cross-shore profiles has evolved over the years from simple mathematical equations defining the equilibrium beach profile [19–22], to models (mathematical, numerical, probabilistic, reverse, etc.) for predicting beach profile changes [23,24]. Process-based mathematical and numerical models are one of the main approaches for the prediction of cross-shore beach profile changes. Deterministic process-based models can either be relatively simple or can incorporate sophisticated hydrodynamic models to calculate the hydrodynamics and morphological response over relatively large areas [25]. Using numerical modelling, several models can

* Corresponding author.
E-mail addresses: lopez.ubeda@ua.es (I. López), laragones@ua.es (L. Aragonés), villacampa@ua.es (Y. Villacampa), rosana.satorre@ua.es (R. Satorre).

https://doi.org/10.1016/j.apor.2018.03.004

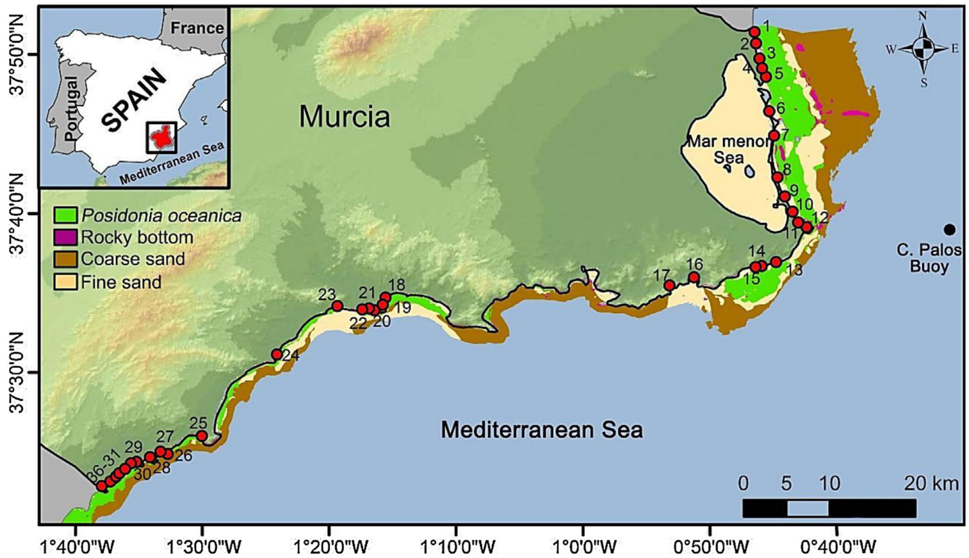

Fig. 1. Location of the studied beaches and composition of the seabed.

be developed and linked to study cross-shore beach profile. For that, a wave model, tidal current model, sediment transport model and finally a morphological model should be developed, validated using field data and linked to each other for a specific study site [25,26]. However, such techniques require considerable computational effort. In addition, there are still compelling discrepancies between model results and measured data [27], which may be due to uncertainties in understanding near-shore processes such as wave breaking, wave reflection, refraction, diffraction and sediment transport [28]. Accordingly, other methods such as Artificial Intelligence (AI) have been introduced in this area, which are less expensive compared with physical-based numerical models [29].

AI, in common with other data-based approaches, makes use of only the measured data, and is a practical tool which can be used to predict changes to the coastline as a response to changes in wave, currents and tidal climates [5]. This tool is particularly useful in coastal application because many coastal engineers are interested in prediction [29]. In recent years, AI techniques such as artificial neural networks (ANNs) have been successfully applied to create models that are useful tools for the coastal engineer, providing data relating to the shape of bay beaches [27]; wind–wave analysis [30,31]; wave prediction [32,33]; coastal water level [34,35]; and location and behaviour of the bars [36,37].

Furthermore, an important factor to consider in modelling a beach profile is the presence of marine vegetation. This paper focuses on studies related to *Posidonia oceanica* given its strong presence of it in the study area, which is the Mediterranean. The three-dimensional structure of rhizomes form a certain reinforcement for the sandy sediment of the submerged beach that, along with the roots and leaves, hinders the sedimentary movements of the seabed, thereby consolidating the sandy substratum and making the submerged beach profile changes much slower than what they would be in the absence of the meadow [38]. In addition, the foliage of the meadow increases the roughness of the bottom, favouring the wave energy dissipation [39]. The absorption of the waves ranges between 30% and 40% of the total energy [40].

The purpose of this study is to investigate the potential of ANN to predict the cross-shore beach profile of sandy beaches with presence of *Posidonia oceanica* in a case study (Coast of the province of Murcia, Spain). To this end, first the variables that may influence the formation of the profile were studied. Some of the considered variables are related to the maritime climate (wave height, period and probability of occurrence), to the sediment properties (median sediment size (D_{50}), real sample density, material density and porosity) and to the biocoenosis of the seabed (presence of *Posidonia oceanica*, studied by the wave damping coefficient K_v). Finally, different ANNs were generated (different input variables and number of neurons in the hidden layer), and the architecture that best represents the cross-shore beach profiles in the study area was selected.

2. Study area

The studied geographical zone is the coast of the province of Murcia, Spain. Murcia is located southeast of the Iberian Peninsula (37°59′10″N 1°07′49″W), and is divided from north to south into two parts separated by a series of mountains that form the so-called Cordillera Sur. These two areas are: i) To the south, the Campo de Murcia is the northern zone of the coastal plain of Campo de Cartagena; and ii) To the north, the Huerta de Murcia formed by a flood plain deposited on the graben. Systems of coastal dunes and beaches, wetlands and coastal marine exist on the coast. The Mar Menor is a littoral lagoon with a semicircular form of salt water from the Mediterranean Sea, and it is separated from this by a strip of sand 22 km in length, and between 100 m and 1200 m in width.

The study was performed on the 36 sandy beaches that are along the 274 km of coast (Fig. 1). The beaches of the province comprise dunes, lagoons, capes and ports. The morphology of the seabed is mostly fine sand, and coarse sand. There is a notable presence of *Posidonia oceanica* meadows in 91.7% (33/36) of the studied beaches (Fig. 1).

Moreover, the study area is a microtidal area where astronomical tides range between 20 cm and 40 cm, and when are affected by meteorological factors, the tide surges can be up to 75 cm [41].

3. Methodology

In the developed methodology, an analysis of the variables that may be related to the formation of the profile (maritime climate, sedimentology and biocoenosis) is provided. Subsequently, the process for the generation of neural networks and the selection of the optimal architecture is described.

3.1. Bathymetric profiles

To obtain the cross-shore profiles, the bathymetry of the “Estudio ecocartográfico de las provincias de Murcia, Almería y Granada