

Mapping and assessment of Coastal Erosion Susceptibility using MARS-based modelling

Grazia Azzara^{1*}, Giorgio Manno², Francesco Raffa³, Chiara Martinello¹, Claudio Mercurio¹, Viviana Bellomo¹, Giulia Di Frisco¹, Pietro Scala², Antonio Tozzi³, Giuseppe Ciraolo², Edoardo Rotigliano¹

¹Department of Earth and Sea Sciences (DiSTeM), University of Palermo, Palermo, Italy

²Department of Engineering (DI), University of Palermo, Palermo, Italy

³Institute of Geosciences and Earth Resources, National Research Council, Pisa, Italy

* Correspondence to: Grazia Azzara; e-mail: grazia.azzara@unipa.it

In this study, we propose a methodology for assessing and mapping the natural susceptibility to coastal erosion using MARS (Multivariate Adaptive Regression Splines) – based modelling. The method has been tested for the entire coast of Tuscany. A set of physical and environmental variables was selected as predictors in the models, including coastal slope, geomorphology, number and energy of detected storms, distance of the closure depth from the coastline and direction of drift. A value for all these variables was assigned to each transect (50 m equally spaced) in which the coastline was partitioned.

By comparing the coastline changes of the periods 2000-2010, 2011-2021 and 2000-2021, three independent inventories of retreating (erosion) and advancing (accretion) transects, were used to train and test the predictive models (M2000_2010, M2011_2021 and M2000_2021, respectively). These inventories were binarized, assigning 1 to erosion and 0 to accretion, once coastline variations within the range of -4 and 4 meters (estimated resolution) were excluded.

Model validation was carried out through two validation schemes: a self-validation, involving a random partition of each balanced inventory into a calibration (70%) and a validation (30%) subsets, and a grand-validation, where the models calibrated with 100% of the subsets were used to predict the not-extracted ones. To allow for the estimation of the model performances in terms of precision and reliability, 100 replicates were computed for each validation procedure by randomly multi-extracting different calibration and validation datasets.

The performance of the MARS models was assessed by computing the Area Under the Receiver Operating Characteristics Curve (AUC). All the tested models produced largely acceptable AUC values, as revealed in the results. In particular, the models show an AUC mean value above 0.8, 0.77 and 0.78 for M2000_2010, M2011_2021 and M2000_2021, indicating strong predictive performance.

Finally, a Natural Coastal Erosion Susceptibility Map was created to identify areas that are likely to be more susceptible to coastal erosion. The map was obtained from the model M2000_2021 by averaging, for each transect, 100 estimates of probability value and classifying the susceptibility scores using the Youden Index cutoff. The results showed an accuracy of 74.45%, indicating a good overall classification capability and a precision of 73.39% suggesting that most predicted erosion cases were correct.

These results demonstrate that MARS-based modelling can be a reliable tool for assessing and mapping coastal erosion susceptibility. At the same time, those coastal sectors where the models do not fit the retreat/advance can be interpreted as being controlled by anthropogenic factors (e.g., inland slope/fluvial erosion/sediment transport, coastal protection structures, and nourishment).

KEYWORDS Coastal Erosion Susceptibility, GIS, MARS, Tuscany, Italy