Assessment of Maritime Erosion Index for Ionian-Lucanian Coast

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Abstract

It is assumed worldwide that the assessment of coastal erosion and induced risk can be carried out through concise indexes which take into account both morphological and anthropic characteristics of littoral system as well as energy intensity of wave climate. The classic literature proposes different indicators in order to describe erosion/progradation activities along the coast and climate wave conditions, generally expressed by wave energy. This means that the physical strength for coastal erosion is commonly assumed to coincide to the annual storm intensity and treated like an independent variable. In the present paper, the *maritime erosion index* has been proposed to be employed in risk assessment induced by continuous nearshore wave modelling and storm events corresponding to different boundary conditions. Such an index takes into account both erosion power and climate wave power. Sensitivity analysis has been carried out with reference to the case study of Ionian-Lucanian coast (Southern Italy) through the comparison with commonly used *storm intensity and exposure index*.

Keywords

Risk analysis • Erosion index • Wave climate • Coastal erosion

8.1 Introduction

The use of indexes and indicators is a synthetic and powerful tool in coastal planning and management as well as to define possible inundation scenarios in terms of both ordinary and extreme events and mitigation actions. Coastal inundation and erosion risks are strongly related: as erosion increases, inundation hazard increases as well due to the reduction of self-defence capability. The analysis of coastal erosion is generally made considering a set of synthetic indexes which take into account morphological, geological and sedimentological properties of the coastal system, short, medium and long term wave climate and socio-economic development and infrastructure layout. These indexes are also differentiated in driving force, pressure, state, impact and response (DPSIR) (OECD 2002). In such a conceptual model, wave climate intensity and erosion coastal rate play the role of independent variables listed in the set of cause and effect respectively, while the mutual interaction is obviously consistent. General assumption refers to, indeed, possible direct dependence between erosion rate and wave energy budget allowing us to consider decreasing erosion as the energy wave decreases and vice versa. The *storm exposure and intensity index* adopted by Ranieri (2010) works in such a way giving an assessment of wave climate activities here assumed as stress. Further, the energy wave

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G. Lollino et al. (eds.), *Engineering Geology for Society and Territory – Volume 4*,
DOI: 10.1007/978-3-319-08660-6_8,

assessment is evaluated orthogonally to the shoreline neglecting the longitudinal components even though they are responsible for the sediment transport processes; hence, the index seems not to be able to give an exhaustive view of coastal erosion dynamics.

In the paper, a new physically based index, named *maritime erosion index*, has been proposed in the vulnerability rank analysis for coastal risk assessment. Index evaluation is performed on two homogeneous datasets referred to a relevant number of observations available for a 60 year time interval. Such data sets consist of hindcasting data and shoreline change data, observed on the Ionian-Lucanian coast. For the available data, both indexes have been computed and compared.

8.2 Maritime Erosion Index

The shoreline change is basically related to physical processes of erosion, transport and deposition of sediments, meteorology and wave climate. It also regards the energy of the wave field acting during storm events and/or a medium period.

The "maritime erosion index" considers the energy stress affecting the shore area, which characterizes the territorial system state and is finalized to vulnerability assessment. It is defined by the way of maximum annual erosion, T_E, and surface-wave parameters (H, T wave height and period respectively) corresponding to a specific physical condition, i.e. morphological, maximum, mean and/or with respect to a return period.

$$\vartheta = \frac{T_E}{\sqrt{[3]\frac{gH^2}{T}}} \tag{8.1}$$

The resulting coefficient, ϑ, is formally dimensionless, even though expressed in (s/year). T_E is the velocity of shoreline displacements (erosion or progradation) assumed positive when representing erosion. The denominator represents the *unit wave power* corresponding to the *mean available wave energy* per year from which the transport rate variations in the study area depends on. The more ϑ increases the less system integrity decreases leaving system vulnerability increasing as well.

Maritime erosion index, indeed, allows us to draw natural variation of sediment erosion, transport and deposition as well as shore protection system effectiveness, by referring to a mean annual wave climate or a morphological one.

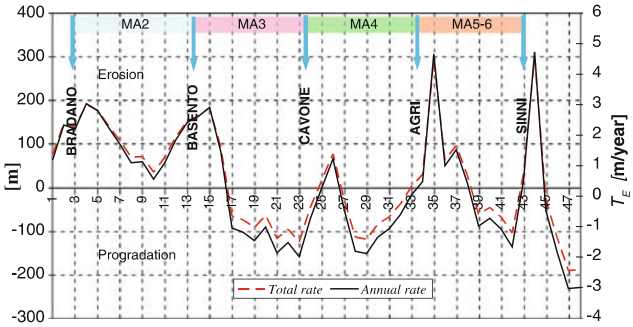

Fig. 8.1 Total rate (*left axis*) and annual erosion/progradation velocity, T_E, observed along the study littoral for the time interval 1949–2012

8.3 Study Area

The study area is located in Southern Italy and quite precisely inside the Taranto Gulf located in the middle part of the Mediterranean Basin. Such an area, corresponding to the Lucanian littoral, is included into a single physiographic unit and exhibits a coastline orientation at 30° N direction with quasi-parallel bathymetry. The coast is delimited by the Bradano River (NE) and the Sinni River (SO), and can be divided in 4 macro-areas (MAs), corresponding to physiographic sub-units. The observed mean annual erosion (or progradation) velocities, for the period 1949–2012, have been estimated through a multisource and multi-temporal approach (Guariglia et al. 2006) based on change detection analysis of satellite imagery and cartographic, aerial and LIDAR data. Figure 8.1 reports the observed erosion/progradation rate evaluated on 48 georeferenced transects along the coast (sorted from NE to SW) both in terms of mean annual velocity, T_E and cumulative values at 2012.

In detail, Fig. 8.1 gives information about the territorial vulnerability degree in terms of erosion for the whole study area apart from MA 3. Such a phenomenon principally depends on local river dynamics and sediment transport changes due to extensive land defence and river settlement interventions made over 30 years (1960–990), whose effects are still going on.

8.4 Estimation of the Maritime Erosion Index

Due to the absence of way buoy data, wave climate analysis has been performed by means of SMB hindcasting updated method (Greco et al. 2004). Meteorological and wave

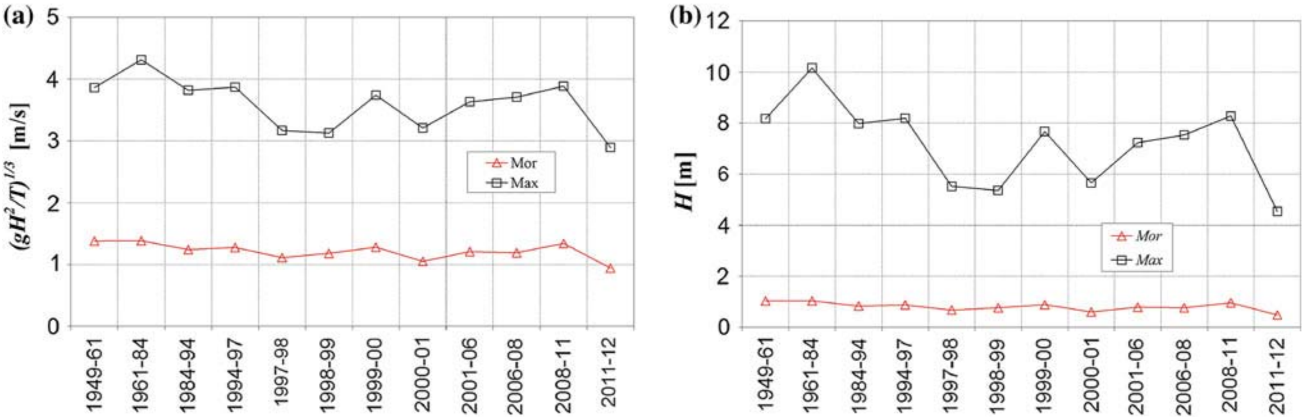

Fig. 8.2 Unit wave power (**a**) and wave height (**b**) referred to morphological and maximum wave conditions

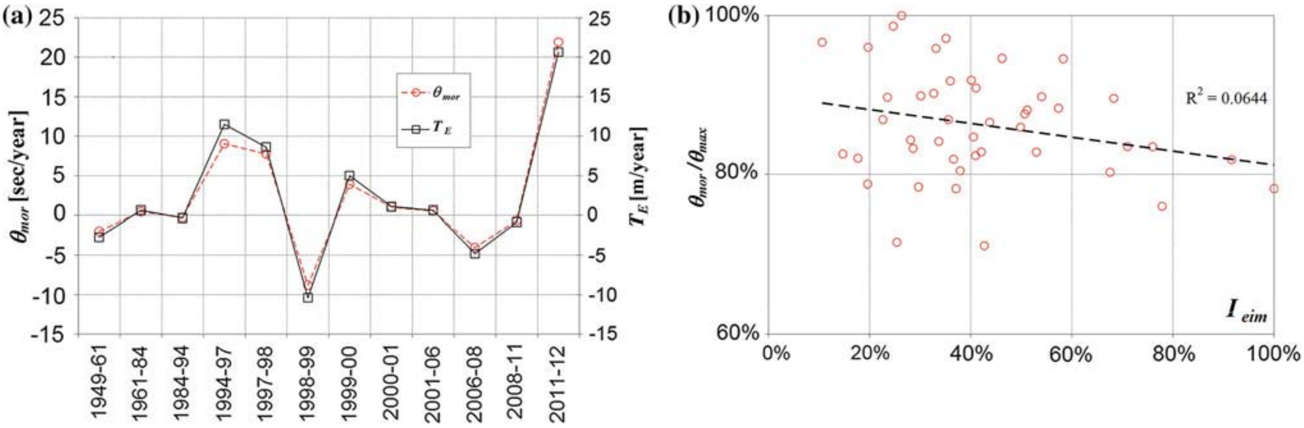

Fig. 8.3 Temporal variation of T_E and ϑ_{mor} (**a**) ($\vartheta_{mor}/\vartheta_{max}$) versus ($I_{eim}$) (**b**)

climate analyses have been performed with wind direction and speed data set in the time interval 1968–2012, collected at Marina di Ginosa meteorological station (id. N. 325 of the CNMCA network—National Center for Aeronautic Meteorology and Climatology of Italian Air Force) located in the Northern Taranto Gulf and representative of the study area wind climate.

Figure 8.2 synthetically shows the results of wave climate analysis for the whole dataset period expressed in terms of deep water morphological (*Mor*) and maximum (*Max*) unit wave power values (a) computed by morphological (H_{mor}) and maximum (H_{max}) wave heights (b).

Time distribution of the maritime erosion index (ϑ) all over the time interval as well as the observed rate T_E are reported in Fig. 8.3a. It shows a uniform time distribution which jointly read with Fig. 8.2a proves a slightly increasing erosion rate. On the other hand, from the combined reading of the Figs. 8.2b and 8.3a, a general decay of coastal erosion self-defence arises presenting an almost constant erosional trend versus a decreasing wave energy rate, that is the littoral has an increasing vulnerability.

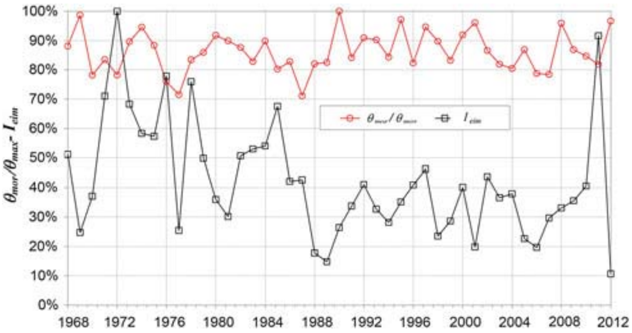

Fig. 8.4 Annual variation of ($\vartheta_{mor}/\vartheta_{max}$) and ($I_{eim}$) indexes

Moreover, comparison analysis between the proposed ϑ index and the *storm exposure and intensity index* (I_{eim}) (Ranieri 2010), defined by the ratio between the mean annual energy, *E*, and maximum one, E_{max}, is reported in Fig. 8.3b.

The distribution $[(\vartheta_{mor}/\vartheta_{max}) - I_{eim}]$ sketches a general absence of physical dependence among the indexes. In fact, time comparison between the two index distributions

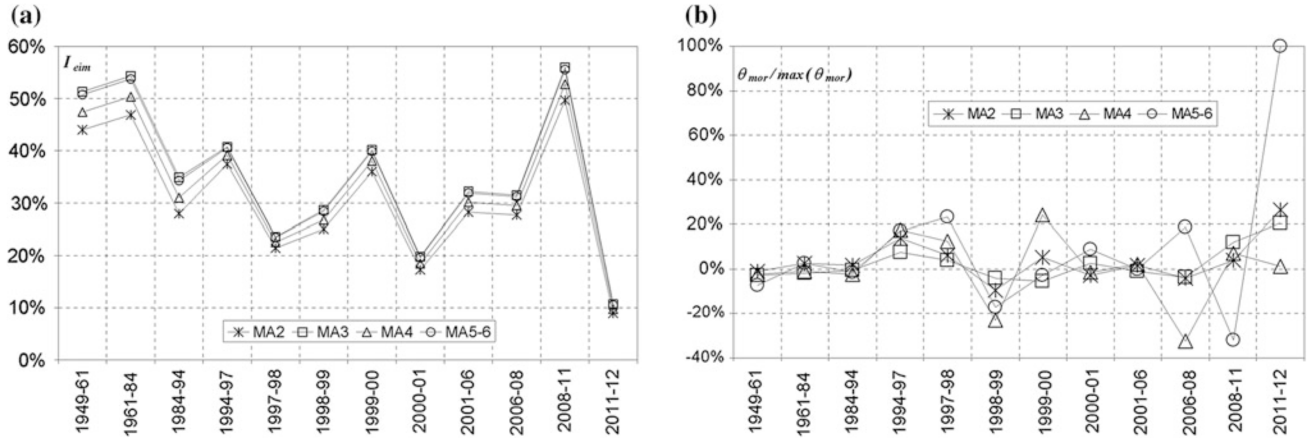

Fig. 8.5 Temporal variation of $(\vartheta_{mor}/\vartheta_{max})$ and (I_{eim}) per macro-area

(Fig. 8.4) presents a time variation of both indexes, in the observation period. The plot outlines a wide variation of I_{eim}, showing a smooth decreasing trend which supports a decreasing intensity of climate wave, versus a "quasi" homogeneous behaviour of the maritime erosion ratio which allows us to assume a steady unit wave power among the observation periods.

Furthermore, I_{eim} refers to a wide variability with respect to $(\vartheta_{mor}/\vartheta_{max})$ and I_{eim} spikes generally do not correspond to erosion rate excesses, outlining a limited capability to select critical conditions or events.

Finally, Fig. 8.5 underlines how ϑ_{mor}, normalized by the maximum one, seems to be more stable than I_{eim} even in terms of effects on shoreline, with reference to the average value of T_E observed per macro-area. In other words, the quasi-steady conditions of the $(\vartheta_{mor}/\vartheta_{max})$ (Fig. 8.4) clearly expresses the weakness of the functional relationship between the Ionian-Lucanian coastal erosion process and the wave climate variability, thus the vulnerability degree and local criticality depend principally on constraining elements external to maritime driving factors.

8.5 Conclusions

The vulnerability rank estimation in coastal areas can be expressed by indexes depending on wave climate parameters. The Authors recognize the *storm exposure and intensity index* (I_{eim}) as representative for the wave climate effects on the coastal dynamics and propose an alternative index named *maritime erosion index* (ϑ).

Such indexes and the comparison between them have been evaluated on a significant coastal area of the Ionian-Lucanian coast in Southern Italy.

The results outline a wide variation of the (I_{eim}), showing a smooth decreasing trend in time which supports a decreasing intensity of the climate wave, versus a "quasi" homogeneous behaviour of the maritime erosion ratio which allows us to assume a steady unit wave power among the observation periods.

The $(\vartheta_{moh}/\vartheta_{max})$ ratio seems to be more stable than I_{eim}, even in terms of effects on the shoreline. In other words, the quasi-steady conditions of the $(\vartheta_{mor}/\vartheta_{max})$ ratio clearly express the weakness of the functional relationship between coastal erosion processes and wave climate variability, considering the vulnerability level not directly affected by maritime driving factors.

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