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INDICATORS FOR INTEGRATED COASTAL ZONE MANAGEMENT (ICZM) : *Methodological Factsheets in support of comparable measurements and an integrated assessment in coastal zones*

The **ICZM Protocol for the Mediterranean Sea** (the 'ICZM Protocol'), signed in Madrid on 21 January 2008 and ratified on 24 March 2011, represents a milestone for the implementation of ICZM in the Region and can serve as a blueprint for the implementation of ICZM in other Regional Seas. The **PEGASO project** builds on existing capacities and develops common approaches to support integrated policies for the Mediterranean and Black Sea Basins in ways that are consistent with the ICZM Protocol.

The PEGASO project has developed **a core set of indicators** that are instrumental in measuring the implementation of ICZM policies and programmes. The core set of ICZM indicators addresses the specific requirement of Article 27 of the Protocol to '*define coastal management indicators*' and '*establish and maintain up-to-date assessments of the use and management of coastal zones*'. In doing so, the PEGASO project has widely built on previous and existing indicator sets developed by different institutions and projects, and which are duly acknowledged (see '[Methodological paper for the selection and application of PEGASO ICZM indicators](#)' for further reading and background material)

The present Methodological Factsheet is part of a set of 15 factsheets that are made available to end-users. This set of factsheets is conceived to support a harmonized approach to calculate ICZM indicators at different spatial scales in the Mediterranean and Black Sea regions.

Name of the Indicator	
<p>Risk assessment (considering sea level rise scenario's and return periods of storm surges)</p> <ul style="list-style-type: none"> - Economic assets in the 'at risk area' of storm surges and coastal flooding - Biological diversity (habitats/species) in the 'at risk area' of storm surges and coastal flooding - Population living in the 'at risk area' of storm surges and coastal flooding 	
Objective of the indicator	
<p>Floods are natural phenomena which cannot be prevented. However, the increase in human activities (urban sprawl, increase in human settlements and economic assets in floodplains, the reduction of the natural water retention due to soil sealing) and the increase in probability of hazards due to climate change, contribute to an increased likelihood and adverse impacts in case of flood events. Science-based climate scenarios (e.g. Intergovernmental Panel on Climate Change) suggest that with the current predictions, climate change will probably result in a further increase in flood events combined with erosion, in many European regions. Particularly the low-lying coastal areas are subject to flooding due to sea level rise, accelerated coastal erosion and increased frequency of storm surges.</p> <p>Part IV of the Mediterranean ICZM Protocol specifically relates to risks affecting the coastal zone including coastal erosion and natural hazards. Moreover, vulnerability and hazard assessments of coastal zones are obligations for the contracting parties. This indicator therefore attempts to measure the extent to which economic assets, biological diversity-natural value and population are at risk of storm surges and coastal flooding, and to assess the impact of mitigation and risk prevention strategies and plans.</p> <p>At this moment, no coordinated and concerted action to valuate these measures exists across both the Mediterranean and Black Sea countries. The option taken for valuation therefore relates to coordinated reporting obligations in the framework of the European Floods Directive (Directive 2007/60/EC). Member States MS had to assess the watersheds and coastal areas that are at risk of flooding, by 2011. Furthermore, MS need to map flood hazards and flood risks in river basins and coastal areas by 2013. Flood <u>hazard</u> maps will cover the geographical areas which could be flooded according to different flood scenarios with low, medium and high probability and will give information on the flood extent, water depths/level, flow velocity or relevant water flow. Risks are defined as the probability of a hazard occurring, multiplied by the impact it may cause. Flood <u>risk</u> maps show the potential adverse consequences associated with the different flood scenarios and expressed in terms of (a) the indicative number of inhabitants potentially affected, (b) type of economic activity of the area potentially affected (c) installations which might cause accidental pollution in case of flooding and potentially affected protected areas (d) other information which the Member State considers useful such as the indication of areas where floods with a high content of transported sediments and debris floods can occur. Before the end of 2015, MS need to establish flood risk management plans with special attention to prevention and protection against floods. The subsequent reporting follows a six-year cycle.</p>	
Policy context	
ICZM Policy Objective	To prevent damage to the coastal environment, and appropriate restoration if damage already occurred
ICZM Protocol Article	Article 6: <i>General principles of ICZM</i>
	Article 22: <i>Natural hazards</i>
	Article 23: <i>Coastal erosion</i>
	Article 24: <i>Response to national disasters</i>
UNEP-MAP Ecological Objective	Objective 7: <i>Alteration of hydrographic conditions does not adversely affect coastal and marine ecosystems.</i>

	Operational objective 7.1: <i>Impacts to the marine and coastal ecosystem induced by climate variability and/or climate change are minimized</i>
INSPIRE ANNEX I-III Data Theme (34)	Annex I 8 Hydrography Annex III 5 Human health and safety 12 Natural risk zones

CALCULATION OF THE INDICATOR

Spatial consideration	
Coverage	Resolution – Reporting unit(s)
The coastal zones of the Mediterranean and Black Seas (art. 3.1 ICZM Protocol)	Areas for which potential significant flood risks exist, or might be considered likely to occur (see art. 4, 5.1 and 6.1 of the Floods Directive). For the purpose of the present objective the risk is defined for a 100-year return period (floods) and a sea level rise of 0.5m, with delineation on a digital terrain model (DTM).
Temporal consideration	
Period	Resolution (time interval or unit)
2013, 2019, ...	Every 6 years
Parameter(s)	
(i)	Flood risk maps showing the potential adverse consequences expressed in terms of the <u>indicative number of inhabitants</u> potentially affected for the defined flood scenarios
(ii)	Flood risk maps showing the potential adverse consequences expressed in terms of the <u>type of economic activity</u> of the area potentially affected for the defined flood scenarios
(iii)	Flood risk maps showing the potential adverse consequences expressed in terms of <u>biological diversity (extent of protected areas habitats/species)</u> potentially affected for the defined flood scenarios
Calculation method	
Steps	Products
<p>The reporting follows the output in the framework of the European Floods Directive, at the level of the Mediterranean and Black Seas, see Floods Directive Reporting Sheets</p> <p>(see also the alternative calculation method, described below)</p>	<p>Relevant products relating to the indicator as formulated above:</p> <ul style="list-style-type: none"> - Flood risk maps showing the potential adverse consequences expressed in terms of the <u>indicative number of inhabitants</u> potentially affected for the defined flood scenarios - Flood risk maps showing the potential adverse consequences expressed in terms of the <u>type of economic activity</u> of the area potentially affected for the defined flood scenarios - Flood risk maps showing the potential adverse consequences expressed in terms of biological diversity <u>activity</u> of the area potentially affected for the defined flood scenarios

Current monitoring		Data sources ¹	
EU Floods Directive: every six years all Member States have to assess the watersheds and coastal areas that are at risk from flooding and need to map flood hazards and flood risks in river basins and coastal areas.		Data (will become) available on: European Environment Information and Observation Network (EIONET) ; Water Information System for Europe (WISE) ; European Floods Portal	
Assessment context			
Use of the indicator in previous assessments/initiatives	Mediterranean Strategy for Sustainable Development (MSSD) The DEDUCE project The SAIL project		
DPSIR framework	Impact. (the indicator can also be indicative of Response as effects of mitigation)		
Link to anthropogenic pressure			
Sustainability target or threshold	No targets/thresholds available		
Link with other assessment tools			
Example of integrated assessment			
Scope for future improvements			
The visualization of flood risk maps under the EU Floods Directive (2007/60/EC) is currently ongoing. A basin wide assessment of flood risks requires data from both EU and non-EU Mediterranean and Black Sea countries gathered in a coordinated and concerted manner in order to be able to make comparisons and regional conclusions. As this indicator requires the use of preexisting maps (inundation, risk) it is necessary to identify these maps and to define a common scale of digitalization.			
Indicator references (i.e. UNEP, EEA, ...)			

ALTERNATIVE CALCULATION METHOD

The approach indicated above is the preferred method because of its consistency with EU policies which will be mandatory for all EU Member States in the context of the Floods directive. However, this approach will not be ready for reporting within the scope of the PEGASO project, and/or it does not have a legal basis or mandatory character in non-EU countries. Considering the formal character of this reporting, and considering the legal and other consequences of producing 'flood risk maps', this matter must be approached with care. An alternative calculation method is to follow the one that was developed within the DEDUCE project, and which is not explicitly linked to the EU (Floods) directive.

¹ Fully INSPIRE-compliant reporting formats may not be operational for the 1st cycle of reporting of flood hazard maps and flood risk maps. Member States have to implement the system to the reporting of the second cycle (March 2020) at the latest, although reporting should as far as reasonably possible be INSPIRE compliant in the first cycle. Depending on the developments under the implementation of INSPIRE, this reporting sheet or other related document may need to be revised. For the first cycle, Member States can report either in an INSPIRE-compatible format (decentralised system), or if not fully implemented in that Member State, hyperlinks to maps available in digital format, with geo-referenced hyperlinks which enables access to a certain area identified within WISE. For the second cycle, reporting formats/schemas shall aim at being fully INSPIRE compliant.

1	Overlap the most recent map of urban occupation ² with the coastal municipality (NUTS 5) cartography and obtain statistics of the extension of residential areas by municipalities.	Residential land use area by each coastal municipality.
2	From the most recent census, obtain the population living at the coast by NUTS 5, the population living at the coast (total value) and the population of the wider reference area.	<u>Population living in coastal municipalities (the total value and also the value of each municipality) and population living in the wider reference area.</u>
3	Using a digital terrain model (DTM), delineate the area with direct connection to the sea, located below the elevation of relative sea level rise (RSLR) in 2100, which is 0.5m ⁽³⁾ modified by the local level of vertical land displacement, if it is known.	Cartography (GIS layer preferably) of the area below RSRL in 2100 at best estimate.
4	Delineate the area likely to be inundated by a river flood of 100-year return period (or take it from already existing analyses).	Cartography (GIS layer preferably) of the area affected by a river flood of 100-year return period.
5	Using a DTM, delineate the area with direct connection to the sea located below the wave runup ⁴ of 100-year return period. The tide elevation might be combined with the run-up for a more exact value of sporadic sea water elevation on land.	Cartography (GIS layer preferably) of the area below the sea water level associated to a coastal flood of 100-year return period.

² There is specific GIS cartography that contains the location of residential areas or building locations. Its level of precision is very high. If detailed cartography on urban nuclei is not available, the categories of continuous urban fabric (CORINE, 111) and discontinuous fabric (CORINE, 112) from the map of land uses could be used.

³ The Intergovernmental Panel on Climate Change (IPPC) forecasts that in 2100 the global sea level will rise 20-90 cm. A more probable scenario is 38 cm. The option that has been taken for this methodology is the level of 50 cm instead of 38 cm, because we do not use a level of precision in cm. In addition to absolute sea level modification, there is a vertical displacement of land, with local values.

⁴ The wave runup is the temporary elevation of sea level rise when the wave progresses on land. It is the sum of setup, the time-averaged water-level elevation at the shoreline due to waves (excluding tides and surge), and swash, the time-varying, vertical fluctuations about the temporal mean.

The most correct parameterisation of the runup is described in "Predicting the Longshore-Variable Coastal Response to Hurricanes" - Stockdon, H.F., Holman, R.A., Howd, P.A. & Sallenger Jr, A.H. 2006. Empirical parameterisation of setup, swash, and runup. Coastal Engineering, 53, 573–588.

The elevation of runup maxima has been shown to be dependent on deep-water wave height (H_0), wave period (T_0) and the foreshore beach slope (β_f). The elevation of the 2% exceedence level for runup, R_2 , can be calculated using the empirical parameterisation:

$$R_2 = 1.1 \left(0.35 \beta_f (H_0 L_0)^{1/2} + \frac{[H_0 L_0 (0.563 \beta_f^2 + 0.004)]^{1/2}}{2} \right)$$

where L_0 is the deep-water wavelength, defined as $gT^2/2\pi$ [Stockdon et al., 2006].

(This equation is extracted from of the Abstract of the dissertation of Hilary F. Stockdon for the degree of Doctor of Philosophy in Oceanography presented on April 5, 2006. More information in part 4.4.3.3. Estimation of Wave Runup and Setup, p.83 <http://ir.library.oregonstate.edu/dspace/bitstream/1957/1930/1/stockdonPhdThesis2006.pdf>.)

6	Obtain values of coastal erosion rates (m/year). Project these rates to estimate the retreat in 2100 (the process is simplified by assuming that erosion rates will be constant during such a period). In protected areas (e.g. urban zones) where coastal retreat is limited, this erosion will not be considered for the analysis (Not necessary for the measurement of population ⁵).	Cartography (GIS layer preferably) of the area at coastal erosion risk for a return period of 100 years.
7	Add the risk areas associated with each process (four): coastal flooding, river flooding, coastal erosion and RSLR to obtain the area affected by any risk.	Cartography (GIS layer preferably) of area to be affected by any risk source.
8	Overlap the most recent map of urban occupation with the coastal municipality (NUTS 5) cartography and the different affected areas evaluated in points 3, 4, 5, 6 and obtain statistics of the extension of residential areas 'at risk' by each and any agent and by municipalities.	Extension of residential areas 'at risk' by each and any agent and by municipalities.
9	For each coastal municipality, divide the residential area of the 'at risk' zone by the residential area of the coastal municipality.	Proportion of residential areas in the 'at risk' zone in each coastal municipality. We assume that this is a better estimation for the <u>proportion of the population 'at risk'</u>
10	Multiply the portion of residential areas 'at risk' zone of each coastal municipality (obtained recently) by its population.	Estimated population living in the 'at risk' zone by municipalities.
11	Aggregate the population of the 'at risk' zone of each coastal municipality.	<u>Coastal population living in an 'at risk' zone by each and any agent/process.</u>
12	Divide the population 'at risk' (this includes the area of any risk) and the population of the coastal zone by the population of the wider reference area and multiply by 100%.	<u>Percentage of coastal population 'at risk' in the wider reference area</u>

For calculating the runup for a return period of 100 years, the values of two required features of waves must be used: deep-water wave height (H_0), wave period (T_0) related to such a return period. Therefore, these values must first be estimated from an existing extreme wave climate in each tide gauge available in the coastal area covered. The extreme wave climate is an analysis that provides the probabilistic Weibull function, which relates return periods to wave heights.

In most cases, it will be adequate to calculate the equation with two slope characteristics of the beaches of the selected area: one for reflective, steep and coarse sediment and one for dissipative, mild and fine sediment.

It would be necessary to consider the contribution of the meteorological tide to the runup. To do this, we will need a simultaneous water level (ξ) time series of a joint storm-surge wave distribution to associate a probability to each pair of H and ξ , but this is complicated. The value of H used in Stockdon's runup equation might be the sum of both components: height of wave and tide elevation. The procedure to include this component to the previous one will be simply adding the value associated with the selected probability to the estimated runup.

⁵ If we have to do calculations using the GIS of land uses, because it is the only one available, we initially have to obtain two different coefficients from an 'at risk' zone: one for urban fabric and the other for a discontinuous fabric 'at risk zone'. From both coefficients, we will obtain the portion of population in the 'at risk' zone from the population of each coastal municipality. For this purpose we have to consider that the density of population in the urban fabric category is higher than the density in the discontinuous fabric category. We therefore apply a factor for a weighted average. It consists of multiplication of the urban fabric coefficient by x , aggregation of the discontinuous fabric coefficient and division of all by $x+1$. A suggested value for x is 4.

Comment: in the absence of real terrain data, numeric modelling can be developed (see experiences of MHI in Sebastopol Bay)