

Indicator	
27	Natural, human and economic assets at risk.
Measurement	
27.3	Value of economic assets in an ‘at risk’ zone.
What should the measurement tell us?	
<p>As a result of climate change, some areas on the coast may disappear due to coastal erosion, may become permanently inundated by the rise in sea level or temporally flooded due to an increasing incidence of terrestrial and/or marine storms. The first two threats are of importance because they potentially lead to a loss of a rich coastal ecosystem, while the latter (flooding by rivers) can be considered as an event that has shaped the protected habitat.</p> <p>It is difficult to express the damage that threats related to climate change may cause in the coastal zone in monetary terms, even if for this consideration only, the threats are reduced to flooding, coastal erosion and sea level rise. A second simplification is to value only the economic assets in an ‘at risk’ zone instead of the total potential damage. The main difficulty for the valuation is to provide a value for all assets inside a large area: how much does a square meter of a protected area or a beach cost? Moreover, not all assets that are located in an area are identified in available databases, for instance residential or industrial equipment.</p> <p>The valuation of this measurement is obtained by calculating the proportion of the economic assets that are located in an ‘at risk’ zone, from all the assets in a wider area (the coastal zone or the reference one). The considered assets are land use categories. These categories of human activity give us an idea of assets included (buildings, infrastructures, crops, etc.). The proportion of threatened areas of certain land use categories can provide an approximation of a valuation in economic terms.</p>	
Parameters	
(i)	Extension of the area by land use categories within an ‘at risk’ coastal zone by RSLR, coastal erosion river flooding, marine storms flooding or any of these.
(ii)	Percentage of the area by land use categories within an ‘at risk’ coastal zone by RSLR, coastal erosion river flooding, marine storms flooding or any of these on the areas of respective land use category in the wider reference area.
(iii)	Percentage of the area by groups of land uses within an ‘at risk’ coastal zone by RSLR, coastal erosion river flooding, marine storms flooding or any of these on the areas of respective land use category in the wider reference area.

Coverage	
Spatial	Temporal
Coastal municipalities strip ¹ .	Currently.
Data sources	
<p>The incidence of climate change on the coastal zones has been evaluated by the Intergovernmental Panel on Climate Change (IPCC) http://www.ipcc.ch/. Chapter 6 of ‘Climate Change 2001: Impacts, Adaptation and Vulnerability’ focuses on Coastal Zones and Marine Ecosystems. Moreover, the particularity of each continent is specified (Chapter 13 for Europe).</p> <p>This reference provides criteria for the establishment of the area at risk but, in general, they are not specific enough to be directly applied for delimiting the area at risk.</p> <p>RSLR: The IPCC has established the evolution of the sea level throughout the century in different scenarios (parts 3.6.2-3.6.6). It presents a common estimation for all seas but the relative rise must incorporate any local component due to vertical displacement of land such as subsidence.</p> <p>Inundation by river floods: Many countries have produced assessments of the areas at risk of river flooding linked to a defined return period (period with a high probability of registering the incidence that causes the risk one time). On 18 January 2006, the Commission adopted its proposal for a Directive of the European Parliament and of the Council on the assessment and management of floods (COM(2006)15 final of 18.1.2006). The directive will impose the implementation of flood risk management plans in which the first step is to take into account the areas affected. Areas likely to be inundated by river floods will be estimated from existing studies from regional/national agencies. In order to follow the proposal of the Directives, it is recommended to use the delineation of area to be inundated by the flood of 100 year return period.</p> <p>Coastal erosion: In a few countries, there is an estimation of the area affected by coastal erosion. A typical example is <i>National Appraisal of Assets at Risk from Flooding and Coastal Erosion</i> (http://www.defra.gov.uk/environ/fcd/policy/NAAR1101.pdf) produced in 2001. That report computes ‘annual average damage’ differentially caused by coastal erosion, sea and tidal flooding and fluvial flooding under different scenarios such as, do nothing, improve defences to current standards and improve to enhanced standards. Information is presented for a NUTS 2 geography but is compiled from local data which it should be possible to obtain. Areas subjected to erosion as well as the extension of the erosion (erosion rates) will be taken from existing studies by regional/national agencies.</p> <p>Inundation by coastal storms: As in the case of river floods, the area ‘at risk’ is related to a specified return period. The water level must include the contribution of storm surges and wave run-up. For this calculation, long time series of wave and water level data are required. When they are not available, they can be substituted by simulated and/or hindcasted data.</p> <p>Finally, once the vertical data (projected inundation levels) have been obtained, it will be necessary to define a digital terrain model (DTM) of the area of study to estimate the extension of the affected area.</p> <p>Finally, the land use cartography of reference is the CORINE land cover, which is easily accessible. Its coverage is all of Europe. The territorial administration may have land use cartography with higher resolution.</p>	

Methodology		
	Steps	Products
1	Obtain the most recent and precise cartography (in GIS format) on land uses and calculate statistics of the extension of different land uses in the wider reference region.	Cartography and <u>Areas of land uses in the wider reference region.</u>
2	Clip the integrated cartography of land uses (f.i. CLC) with the coastal coverage (in this case, coastal municipalities) and obtain statistics on the land uses categories at level 2 (15 items) ² .	Cartography and <u>areas of land uses in the coastal zone.</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 year 2100, which is 0.5m ³ modified by local level of vertical land displacement, if it is known.	Cartography (GIS layer preferably) of the area below RSRL in 2100 at best guess.
4	Delineate the area likely to be inundated by a river flood of 100 year return period (or take this from already existing analysis).	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 run-up 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 in land.	Cartography (GIS layer preferably) of the area below sea water level associated to a coastal flood of 100 year return period.
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 period). In defended areas (e.g. urban zones) where coastal retreat is limited, this erosion will not be considered for the analysis.	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 cartography of coastal European, national and regional land uses with the different affected areas evaluated in points 3, 4, 5, 6 and 7. Obtain statistics of the extension of each category of land use 'at risk' by each factor and any of them.	Extension of <u>each land use class in coastal zone at risk by each process and any of them.</u>

9	Divide the extension of each coastal land use at risk (it includes the area of any risk) and in all of the coastal zone by the extension of each coastal land use in the wider reference area and multiply by 100%.	<u>Percentage of each land use class in coastal zone 'at risk' on the wider reference area.</u>
10	Add averages of different land uses categories into 4 groups: 1. Artificial surfaces 2. Agricultural areas 3. Forests and semi-natural areas 4. Wetlands 5. Water bodies	<u>Percentage of groups of land use in coastal zone 'at risk' on the wider reference area.</u>

Presentation of the data

Map 1	Map representing land uses in the coastal municipalities and the 4 different areas at risk by means of complementary plot.	
Graph 1	Stacked bar chart: Columns showing the extension of each land use at risk zone: RSLR, coastal erosion, river flooding, marine storm flooding, the union of them and the area in the coastal zone (6 stacked columns).	
Graph 2	Bar chart: Columns of the percentage of each land use group on its respective group in the wider reference coverage. Each 5 columns (one for each risk evaluated) are grouped by groups of land use (5 groups).	

Adding value to the data

Different risk areas might be considered according to different previsions (more probable or less probable). Moreover, a risk zone might be defined on account of future protection structures. Results can be calculated using a coastal buffer of 1km or 10km as coastal coverage.

Aggregation and disaggregation

With the aim of simplifying the graphs, an aggregation of different categories is proposed. Graphs can be made without these groups but complexity would rise.

Notes

¹ This administrative coastal coverage has been taken for maintaining the same coverage as the previous measurement of this indicator: population inside the area 'at risk'. For that measurement some steps of calculation needs use the inhabitant in each coastal municipality

² The nomenclature of Corine Land Cover differentiates the categories of land used at 3 levels (More information in <http://reports.eea.europa.eu/COR0-part2/en>). The categories of land use that is considered here is the 2nd level:

- | Level 1 | Level 2 |
|-----------------------------|---|
| 1. Artificial | 1.1. Urban fabric
1.2. Industrial, commercial
1.3. Mine, dump
1.4. Artificial non-agricultural |
| 2. Agricultural | 2.1. Arable land
2.2. Permanent crops
2.3. Pastures
2.4. Heterogeneous |
| 3. Forests and Semi-natural | 3.1. Forests
3.2. Shrub and/or herbaceous
3.3. Open spaces with little vegetation |
| 4. Wetlands | 4.1. Inland wetlands
4.2. Coastal wetlands |
| 5. Water bodies | 5.1. Inland water bodies
5.2. Marine water bodies (Not for this calculation) |

In the last step of methodology is the aggregation in the 5 groups of 1st level.

³ The Intergovernmental Panel on Climate Change (IPCC) forecasts that by 2100 the sea level will have risen by 20-90 cm around the world. The best guess (more probable situation) is 38 cm. The option that has been taken for this methodology is the level of 50cm instead 38cm, because we do not use a level of precision of cm. In addition to absolute sea level modification, there is a vertical displacement of land, with local values.

⁴ The wave run-up is the temporary elevation of sea level rise when the wave reaches the land and progresses on it. 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 run-up is exposed 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 run-up. *Coastal Engineering*, 53, 573–588.

The elevation of run-up 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 run-up, 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 $gT_0^2/2\pi$ [Stockdon et al., 2006].

(This equation is extracted from *of the* Abstract of 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 Run-up and Setup*, p.83

<http://ir.library.oregonstate.edu/dspace/bitstream/1957/1930/1/stockdonPhdThesis2006.pdf>.)

For calculating the run-up 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 return period. These values must therefore be previously estimated from an existing extreme wave climate in each tide gauge available in the coastal region of the coverage. The extreme wave climate is an analysis that provides the probabilistic Weibul function, which relates return periods with wave heights.

In most cases it will be sufficient 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 run-up. To do this, we shall need a simultaneous water level (ξ) time series of a joint storm-surge wave distribution to associate a probability with each pair of H and ξ , but this is complicated. The value of H used in Stockdon's run-up 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 run-up.