Supplementary Materials

Assessment of Climate Change Impacts in the North Adriatic Coastal Area. Part II: Consequences for Coastal Erosion Impacts at the Regional Scale

Valentina Gallina [1,2], Silvia Torresan [1,2], Alex Zabeo [1,2], Jonathan Rizzi [1,2,3], Sandro Carniel [4], Mauro Sclavo [4], Lisa Pizzol [2], Antonio Marcomini [1,2] and Andrea Critto [1,2,*]

[1] Centro-Euro Mediterraneo sui Cambiamenti Climatici (CMCC), Risk Assessment and Adaptation Strategies Division, via Augusto Imperatore 16, 73100 Lecce, Italy; valegallina@yahoo.it (V.G.); silvia.torresan@cmcc.it (S.T.);

[2] Department of Environmental Sciences, Informatics and Statistics, University Ca' Foscari Venice, Via Torino 155, 30172 Venezia Mestre, Italy; alex.zabeo@unive.it (A.Z.); lisa.pizzol@unive.it (L.P.); marcom@unive.it (A.M.)

[3] Norwegian Institute of Bioeconomy Research (NIBIO), Division of Survey and Statistics, Department of Geomatics, Postboks 115, 1431 Ås, Norway; jonathan.rizzi@nibio.no (J.R.)

[4] CNR-National Research Council of Italy, ISMAR-Institute of Marine Sciences, Castello 2737/f, 30122 Venice, Italy; sandro.carniel@ismar.cnr.it (S.C.); mauro.sclavo@ismar.cnr.it (M.S.)

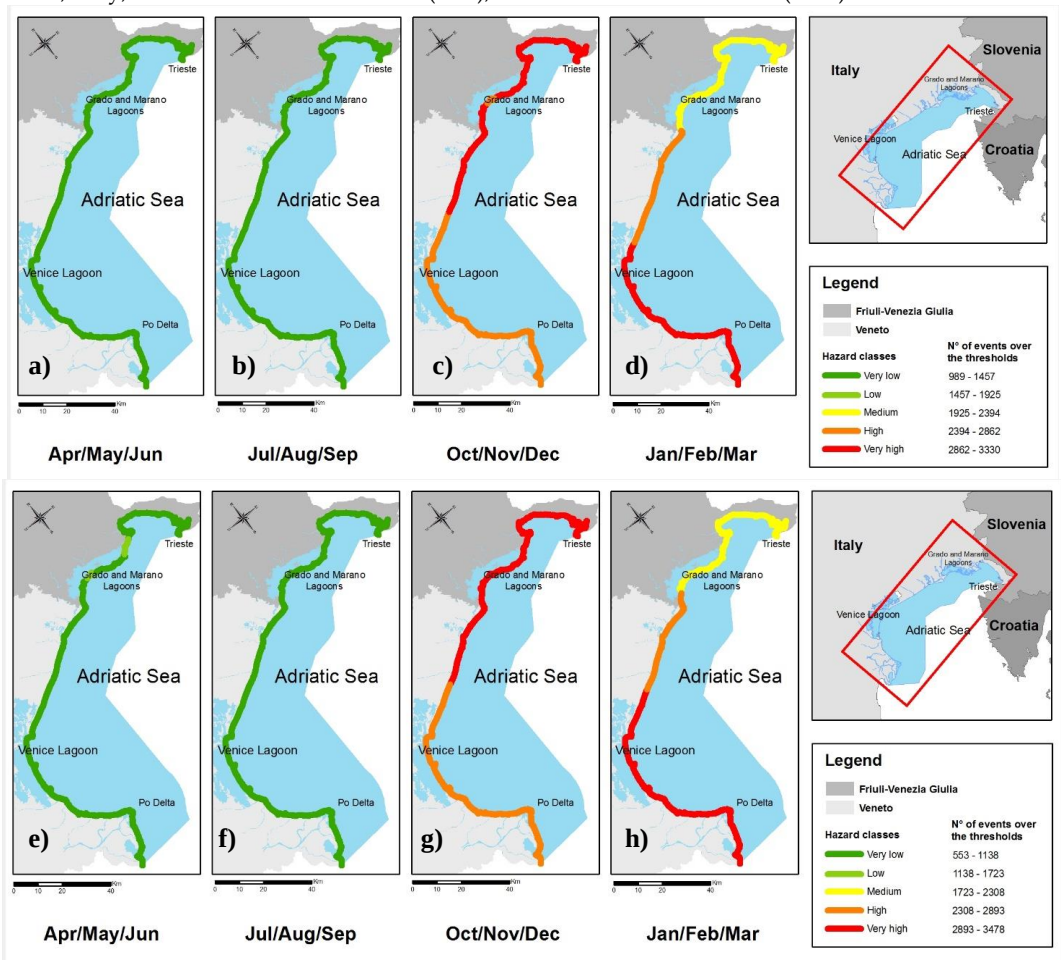


Figure S1. Hazard Maps representing the number of events exceeding the wave height threshold of 0.97 m (**a**–**d**); and the number of events exceeding the bottom stress threshold of 0.15 N/m^2 (**e**–**h**) in the future scenario 2070–2100 in the four seasons (April/May/June, July/August/September, October/November/December, January/February/March). Adapted from Torresan et al. [1].

Table S1. Exposure equations applied in the Exposure function.

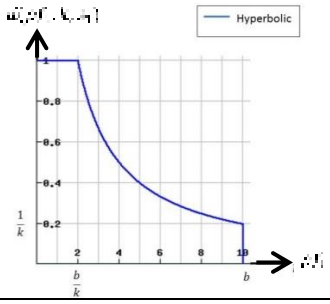
Equation	Description
1. "Probabilistic or" function [2]. $\bigotimes_{i=1}^{4} [f_i] = f_1 \otimes f_2 \otimes f_3 \otimes f_4$ $f_{1 \otimes f_2} = f_1 + f_2 - f_1 f_2 = F_1$ $f_{1 \otimes f_2} = f_1 + f_2 - f_1 f_2 = F_1$ $f_{1 \otimes f_2} = f_1 + f_2 - f_1 f_2 = F_1$ Where: f_i= i-th generic factor f	The process can be repeated until evaluating all operands. If just a factor (f) assumes the maximum value (i.e. 1) then the result of the "probabilistic or" will be 1. On the other side, f with low scores contributes in increasing the final "probabilistic or" score: the more is the number of low factor scores, the greater is the final score.
2. Attenuation function. $At_{ce} = af_1$ Where: At_{ce}= attenuation determined by the presence of artificial protections; af_1= value of the attenuation factor related to artificial protections: 0 (i.e. no attenuation) and 1 (i.e. maximum attenuation).	If the presence of artificial protections (af_1) assumes its maximum value (i.e.1), At_{ce} will be 1, and the exposure will assume the score of zero (i.e. the cell is not impacted by the coastal erosion as the attenuation is maximum). Otherwise, if the attenuation factor af_1 is minimum (i.e. 0, absence of artificial protections), At_{ce} will be 0 and the exposure function will assume its maximum score.
3. Distance function. $d(pf_3, k, s_1) \quad \min\left(1, \frac{s_1}{pf_3 \cdot k}\right)$ Where: pf_3= distance of the center of the cell from the sea (cm); k= constant that defines the slope of the hyperbolic function (in the application is settled at 1 cm); s_2= represents the distance of the center of a cell from the sea which represents the Radius of Influence of Coastal Erosion (RICE).	Graphical representation of the hyperbolic distance. 

Table S2. Classes and scores associated with the hazard metrics identified in the hazard matrix for the coastal erosion impact in the North Adriatic coast. Each class represent a range of wave height and bottom stress events exceeding the thresholds identified in the reference period (i.e., 0.97 m and 0.15 N/m^2 respectively).

Hazard metric	Class	Score
Wave height	989-1457	0.2
	1457-1925	0.4
	1925-2394	0.6
	2394-2862	0.8
	2862-3330	1
Bottom stress	553-1138	0.2
	1138-1723	0.4
	1723-2308	0.6
	2308-2893	0.8
	2893-3478	1

Table S3. Qualitative evaluations supporting the expert/decision maker in the assignation of relative scores to vulnerability and hazard classes (source: [3]).

Linguistic Evaluation	Scores
Most important class	1
Weakly less important class	0.8
Rather less important class	0.6
Strongly less important class	0.4
Least important class	0.2
No vulnerability/hazard	0

Table S4. Classes and scores associated with the susceptibility factors identified in the vulnerability matrix for the coastal erosion impact in the North Adriatic coast.

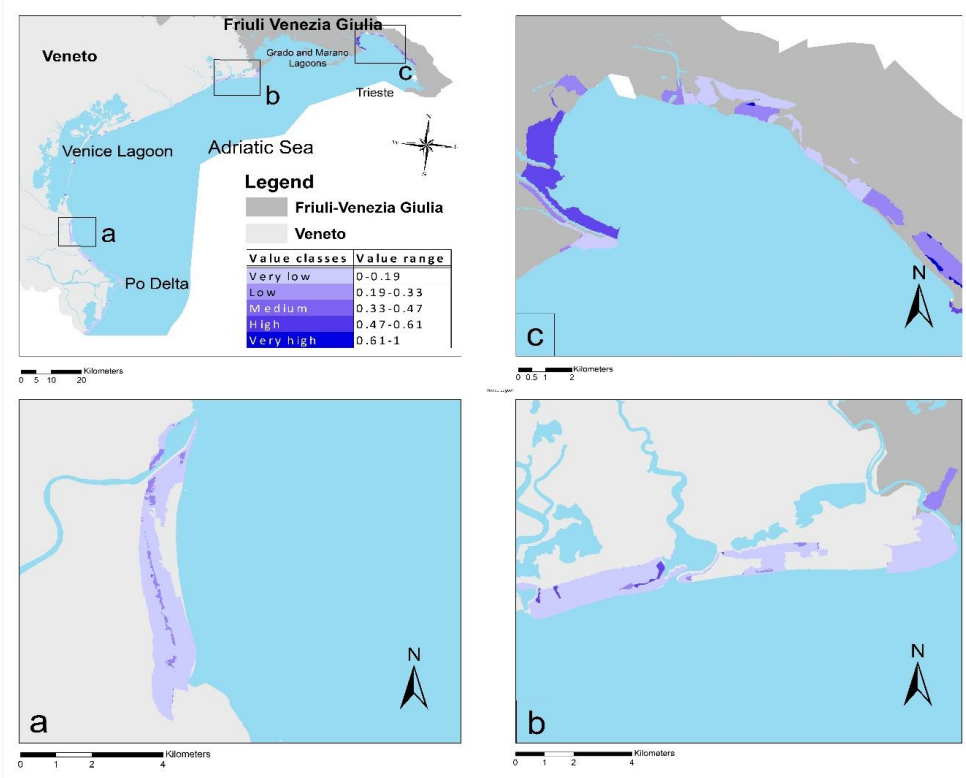
SUSCEPTIBILITY FACTOR	CLASS	SCORE
Vegetation cover	Poor vegetation and meadow	1
	Vegetation with shrubbery	0.5
	Forest	0.2
Coastal slope (degrees)	0 – 1.78	0.2
	1.78 – 3.56	0.4
	3.56 – 5.36	0.6
	5.36 – 7.16	0.8
	7.16 – 8.97	1
Geomorphology	Muddy (non consolidated) coast	1
	Sandy coast	0.5
	Rocky coast	0.2
Dunes	Absence	1
	Presence	0.2
Shoreline variations	Advancing coast	0.2
	Stable coast	0.5
	Coast in erosion	1
Mouth-river typology	Estuary	1
	Delta	0.2
Wetland extension (km^2)	0 – 19.9	1
	19.9 – 39.8	0.8
	39.8 – 59.8	0.6
	59.8 – 79.7	0.4
	79.7 – 99.6	0.2
% of urbanization	< 5% of the land occupied by urban and industrial areas (per municipality)	0.2
	5% and 10% of the land occupied by urban and industrial areas (per municipality)	0.5
	> 10% of the land occupied by urban and industrial areas (per municipality)	1

Table S5. Weights associated with the susceptibility factors identified in the vulnerability matrix for the coastal erosion impact in the North Adriatic coast.

SUSCEPTIBILITY FACTOR	WEIGHT
Vegetation cover	0.6
Coastal slope (%)	0.8
Geomorphology	0.8
Dunes	0.6
Shoreline variations	0.8
Mouth-river typology	0.5
Wetland extension (km^2)	0.5
% of urbanization	0.4

Table S6. Classes and scores associated with the value factors identified in the vulnerability matrix for the coastal erosion impact.

VALUE FACTOR	CLASS	SCORE
Protection level	Nature 2000 area	0.2
	Regional area	0.5
	National area	1
Population density	< 100 inhabitants per municipality	0.2
	100-300 inhabitants per municipality	0.5
	> 300 inhabitants per municipality	1
Agricultural typology	Arable	0.2
	Stable	0.5
	Permanent	1
Urban typology	Infrastructure	0.2
	Commercial	0.5
	Residential	1



d)

	Case study area within the RICE area (km^2)			
Class	Beaches	Protected areas	River mouths	Wetlands
Very low	9,00	57,73	6,19	0,37
Low	2,23	11,79	10,72	9,07
Medium	0,15	4,56	15,51	10,02
High	0,04	0,48	0,41	0,64
Very high	0,00		0,15	1,21

e)

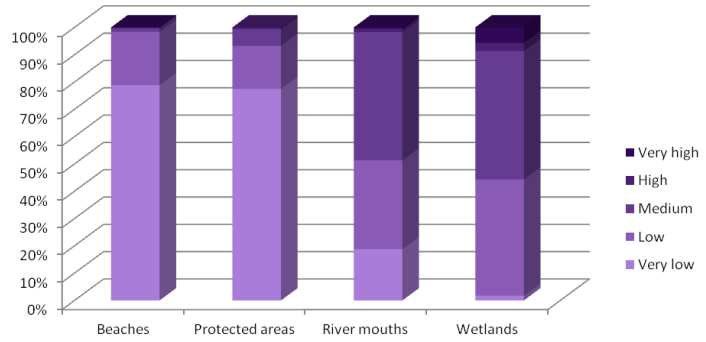


Figure S2. Value map for three selected protected areas (a–c) within the RICE area for the North Adriatic coast for the coastal erosion impact; and distribution of the territorial surface (km^2) (d) and of the percentage of surface (e) that is associated with each value class for the receptors located in the North Adriatic coasts within the RICE area for the coastal erosion impact.

Table S7. Surface (km²) and percentage of Nature 2000 and Regional protection areas for the municipalities interested by damage in the North Adriatic coast within the RICE area for the coastal erosion impact (for the first semester of the thirty-year future scenario).

		Jan/Feb/Mar/Apr/Jun/Jul			
		Nature 2000 area		Regional area	
Municipality	**PROV.**	Km²	%	Km²	%
Monfalcone	GO	0.78	100	0	0
Lignano Sabbiadoro	UD	0.63	100	0	0
Marano Lagunare	UD	2.56	100	0	0
San Michele al Tagliamento	VE	5.16	100	0	0
Eraclea	VE	0.71	100	0	0
Caorle	VE	5.63	100	0	0
Jesolo	VE	0.49	100	0	0
Venezia	VE	1.44	100	0	0
Cavallino Treporti	VE	2.48	100	0	0
Trieste	TS	5.23	97.02	0.16	2.98
San Canzian d'Isonzo	GO	0.40	95.94	0.02	4.06
Porto Viro	RO	4.76	92.94	0.36	7.06
Chioggia	VE	0.29	82.04	0.06	17.96
Duino Aurisina	TS	3.26	81.21	0.76	18.79
Grado	GO	0.49	77.37	0.14	22.63
Rosolina	RO	4.11	57.57	3.03	43.43
Porto Tolle	RO	9.81	52.90	8.74	47.10
Ariano nel Polesine	RO	0.19	18.01	0.86	81.99
Staranzano	GO	0.22	5.85	3.53	94.15

References

1. Torresan, S.; Gallina, V.; Gualdi, S.; Bellafiore, D.; Umgiesser, G.; Carniel, S.; Sclavo, M.; Benetazzo, A.; Giubilato, E.; Critto, A. Assessment of climate change impacts in the North Adriatic coastal area. Part I: A multi-model chain for the definition of climate change hazard scenarios. *Water* **2019**, *11*, 1157. doi:10.3390/w11061157.
2. Kalbfleisch, J.G. *Probability and Statistical Inference: Volume 1: Probability*; Springer Science & Business Media: Berlin, Germany, 1985.
3. Pasini, S; Torresan, S; Rizzi, J; Zabeo, A; Critto, A; Marcomini, A Climate change impact assessment in Veneto and Friuli Plain groundwater. Part II: A spatially resolved regional risk assessment. Sci Total Environ 2012, 440:219–235.