Session 1:

Sea level rise risk assessment and mapping at the regional scale: the case study of the North Adriatic coast

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CLIM-RUN Winter School

Trieste, 5 December 2013

Outline

- **Presentation of the case study area of the North Adriatic coast;**

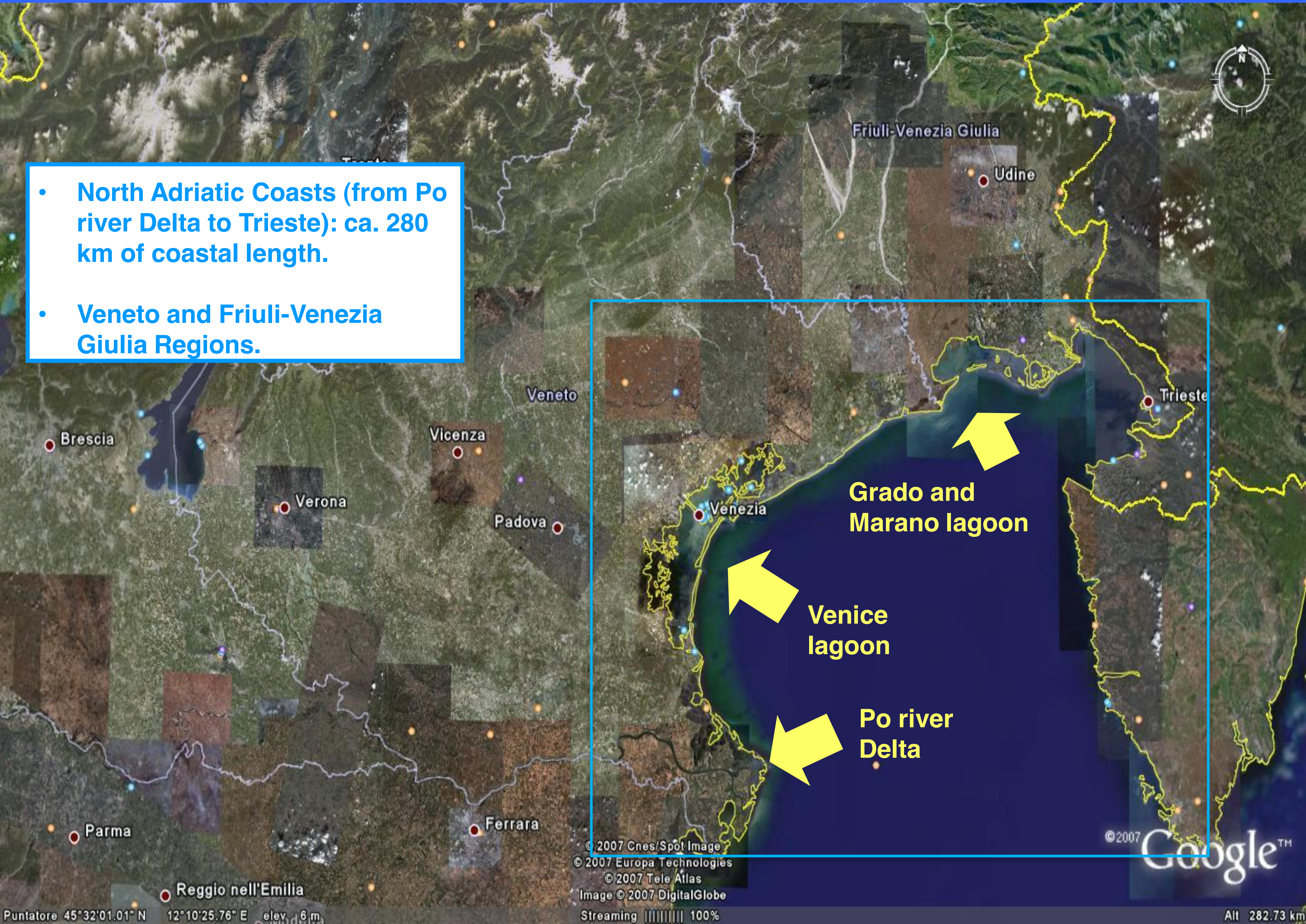
- **DESYCO input data (vulnerability and hazard matrix) for the assessment of sea level rise risk;**

- **DESYCO main outputs produced for the assessment of sea level rise risk in the north Adriatic coast:**
  - ✓Exposure maps;
  - ✓Susceptibility maps;
  - ✓Risk maps;
  - ✓Value maps;
  - ✓Damage maps.

- **Introduction to the next session**

DESYCO CASE STUDY AREA: The North Adriatic coast.

- North Adriatic Coasts (from Po river Delta to Trieste): ca. 280 km of coastal length.
- Veneto and Friuli-Venezia Giulia Regions.







Environmental issues

Relative sea level rise causes an increase of **high tide events** that flood the city of Venice which is a very important international monument.

Relative sea level rise in the last 100 years: 1,2- 2, 5 mm/year
(Antonioli et al., 2007)

30 high tide events ≥ 110 cm from 2000 to 2009.
(Municipality of Venice, 2008)

Erosion has ... or and on the beach since ... especially after 1960 (Bonde...
ca... ding.

Climate change could increase the intensity and frequency of all these issues.

Coastal areas located below sea level and affected by natural or man-induced **subsidence** are very frequent.

Po Plain subsidence: 1-2 mm/year. (Carminati and Martinelli, 2002)

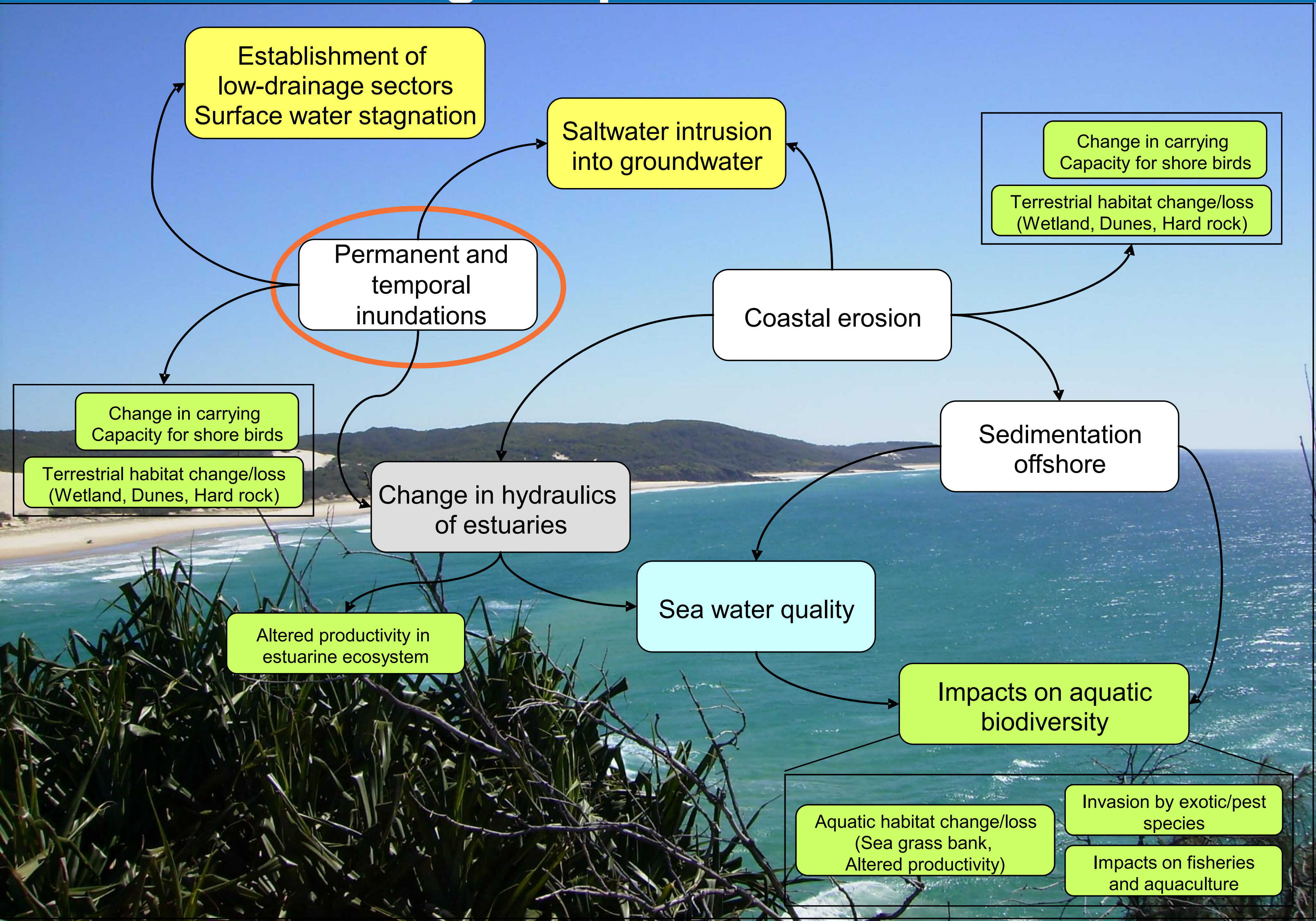
Venice subsidence: 1,3 mm/year. (Carbognin et al., 2009)

Trieste subsidence**:** 0,25 mm/year. (Furlani et al., 2010)

Changes in **wetland** extent, position and type can be expected as accelerated sea-level rise increases forcing on wetland system (McFadden et al., 2007).

2,242 km^2 Ramsar areas.

Climate change impacts on coastal zones



Stakeholders needs

PARTECIPATIVE PROCESS

Stakeholders needs for sea level rise:

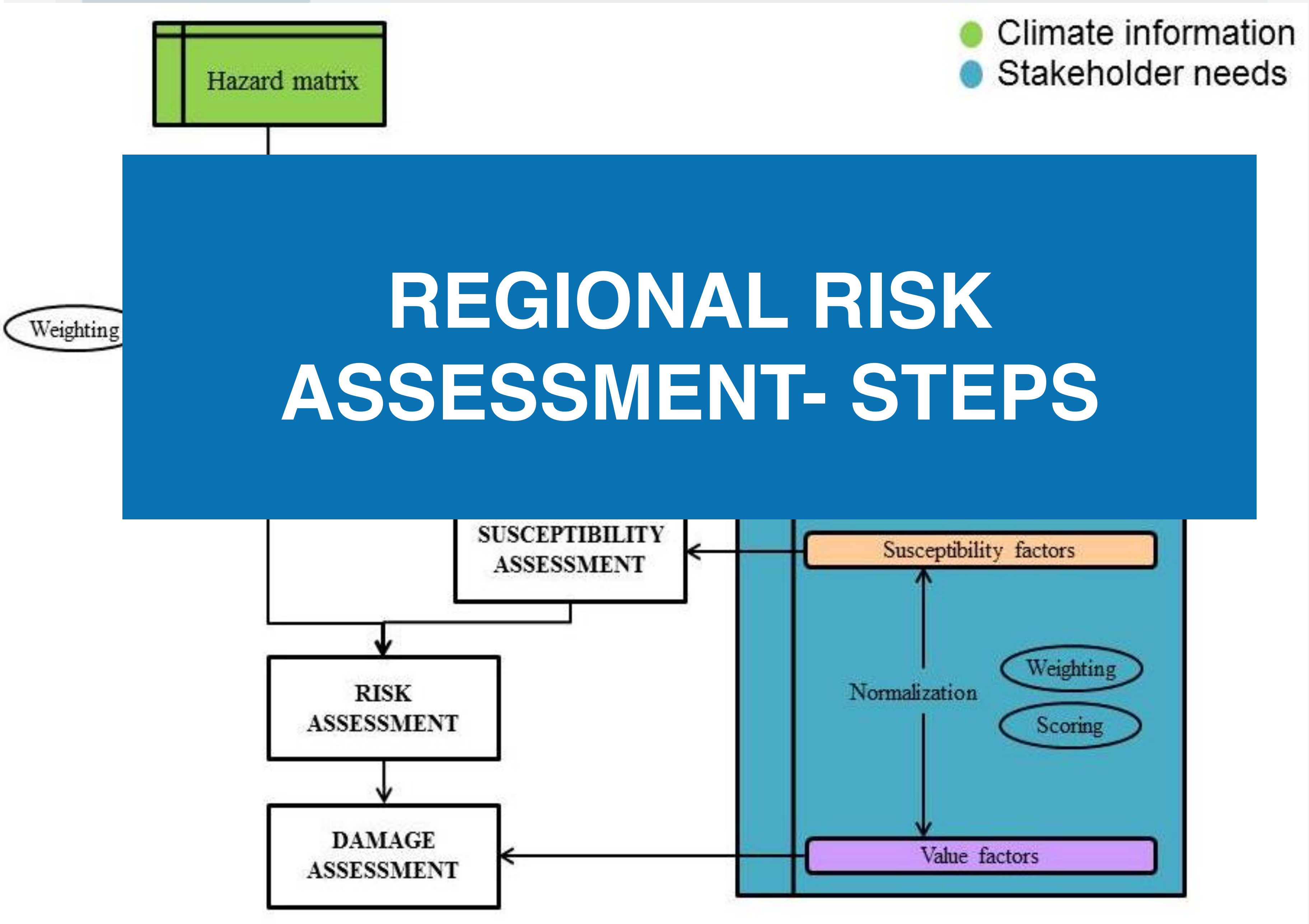
- To know future sea level rise trends;
- To know areas and elements which will be most affected by sea level rise in order to set priopritiesfor adaptation strategies;
- Collect data on sea level rise to answer citizien information requests.

How to deal with sea level rise inundation impact?

Can we provide some tools to stakeholder and end users in order to answer to their requirements?

Regional Risk Assessment and DESYCO

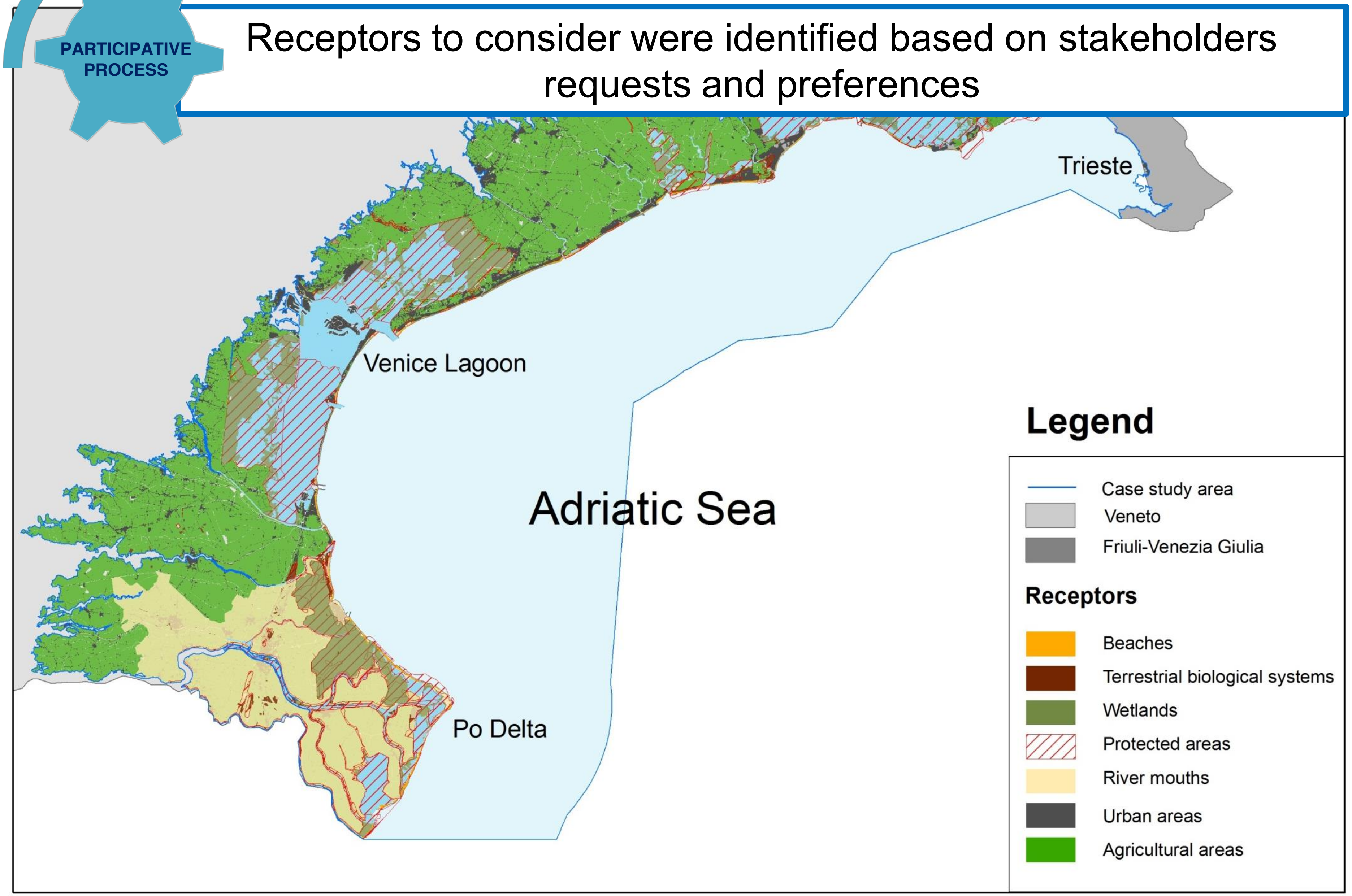
REGIONAL RISK ASSESSMENT- STEPS



STUDIED RECEPTORS: NORTH ADRIATIC COAST

PARTICIPATIVE PROCESS

Receptors to consider were identified based on stakeholders requests and preferences



REGIONAL RISK ASSESSMENT- INPUT DATA

RECEPTORS

VULNERABILITY MATRIX

RECEPTORS / IMPACTS	BEACHES	RIVER MOUTHS	WETLANDS	TERRESTRIAL BIOLOGICAL SYSTEMS	PROTECTED AREAS
	- Population density	- Population density	- Population density	- Population density	- Population density
	- Vegetation cover	- Vegetation cover	- Wetland extension		- Vegetation cover

Pathway factors: physical characteristics of the receptors which contribute in determining the possibility of contact with climate change hazards and therefore potential exposure areas.

Attenuation factors: factors able to attenuate the intensity of the hazard associated to an impact (e.g. artificial or natural structures able to reduce the intensity of a storm surge).

Susceptibility factors: geo-physical or ecological factors which determine the degree to which a receptor could be affected, either adversely or beneficially, by climate-related stimuli.

Value factors: identify relevant environmental and socio-economic values of the receptors that need to be preserved for the interest of the community

Pathway factors	Attenuation factors	Susceptilbity factors	Value factors

REGIONAL RISK ASSESSMENT- INPUT DATA

Construction of the hazard matrix using climate information provide by climate models and observations

CLIMATE INFORMATION

HAZARD MATRIX

STRESSORS

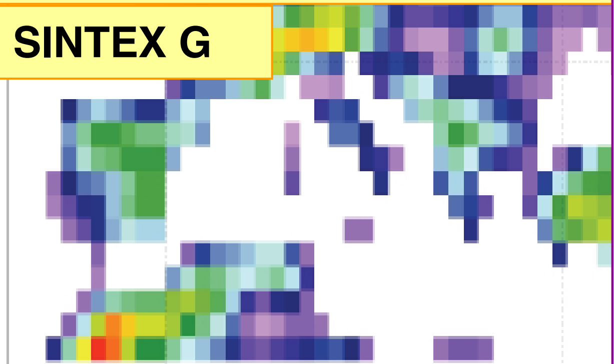
HAZARD METRICS

BOTTOM STRESS	EXTREME STORMS SURGE	SEA LEVEL RISE	WAVE	CLIMATE CHANGE IMPACTS
				HYDRODYNAMIC
		Projected water level		SLR Inundation
		Projected water level		RSLR Inundation
Bottom stress		Projected water levels	Height	Coastal erosion

1) HAZARD SCENARIO ASSESSMENT

Global climate simulations (A1B SRES IPCC)

SINTEX G



Atmosphere: 120 km
Ocean: 200km

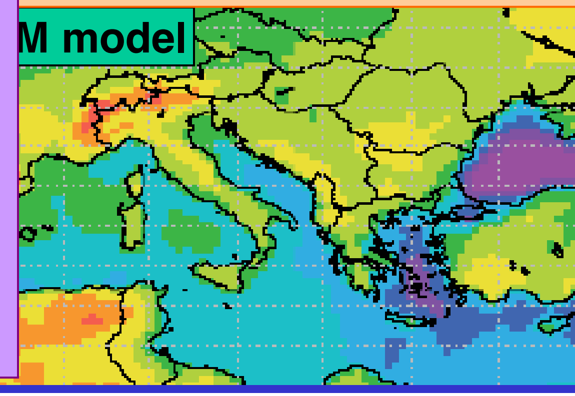
Output EBU-POM (2070-2100):

__Climate factors__:

- Air/sea temperature;
- Rainfall;
- Winds;
- Atmospheric pressure;
- Relative humidity;
- Cloudiness;
- Salinity.

Mediterranean climate simulations

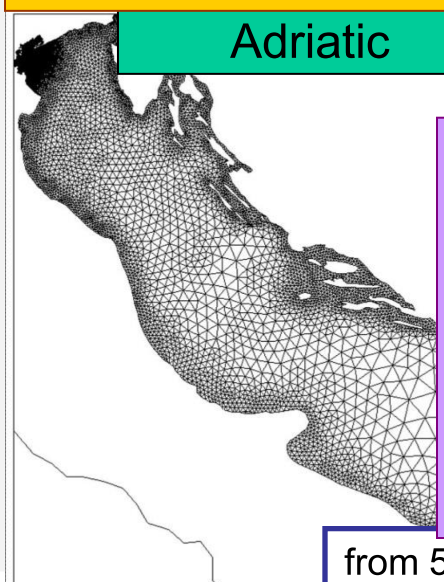
M model



Med scale: 28km

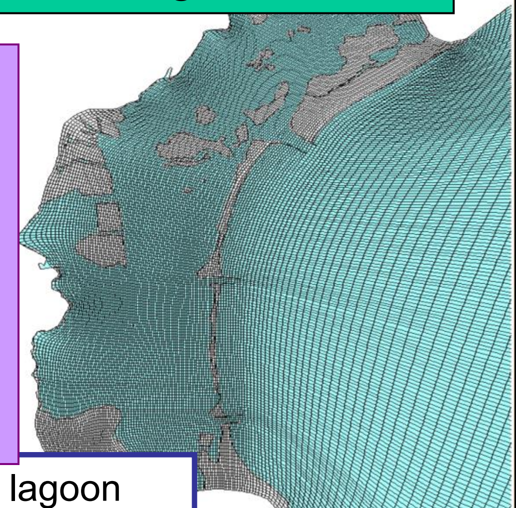
High resolution models:

Adriatic



North Adriatic

Lagoon



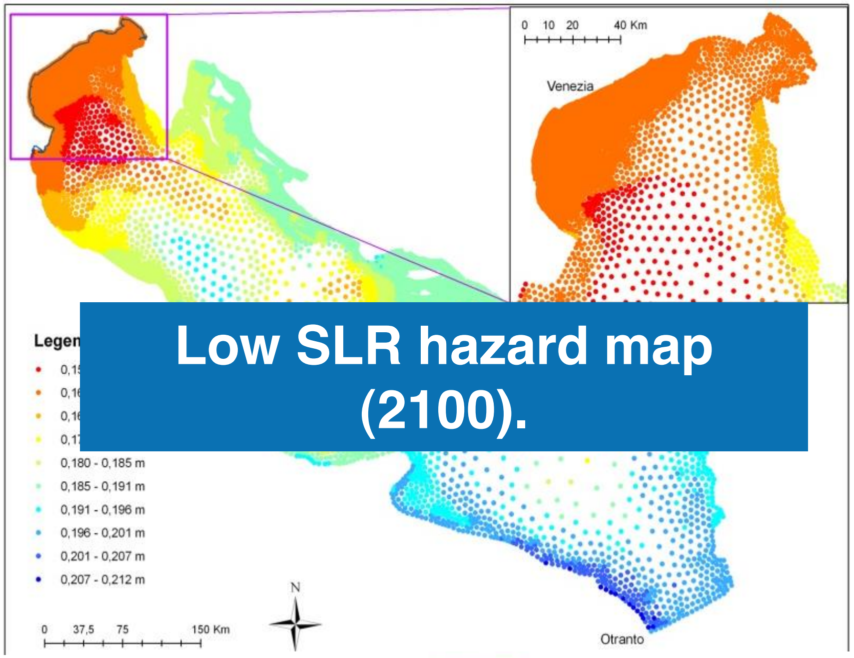
Output SWAN, ROMS, SHYFEM (2070-2100):

__Hydrodynamic factors__:

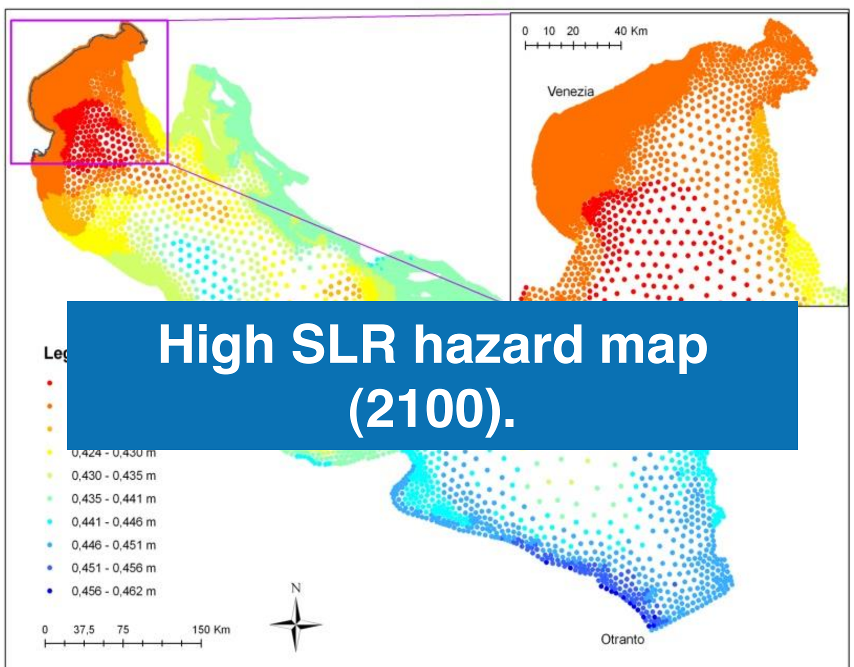
- Water levels
- Wave climate (height, period, direction and energy);
- Nearshore circulation patterns (water velocity);
- Sediment transport and bottom stress;
- Estuarine hydrology/morphology/submerged areas.
- Sea temperature
- Salinity.

from 5-2 km in the open sea to 50 m inside the Venice lagoon

1) HAZARD SCENARIO ASSESSMENT FOR SLR (2070-2100)



Low SLR hazard map (2100).



High SLR hazard map (2100).

SHYFEM SIMULATIONS:

<u>Climate forcing:</u> EBU-POM simulations (wind, pressure, temperature and precipitations) in the Adriatic region. Emission scenario A1B for the period 2070- 2100.

<u>Boundary conditions:</u>
A1B IPCC global SLR scenarios at 2070, assuming linear trend up to 2100.
Low scenario:
20 cm SLR at Otranto.
High scenario:
45 cm SLR at Otranto.

2 SLR hazard maps for the year 2100 (worse conditions of the thirty-year period) in the North Adriatic Region.

1) HAZARD SCENARIO ASSESSMENT FOR SLR

Spatial analysis of SHYFEM shoreline projections at 2100 (North Adriatic region):

Scenario	Minimum value (cm)	Mean value (cm)	Maximum value (cm)	Range (cm)	Standard deviation (cm)
Low Sea Level Rise	16,73	16,84	16,97	0,25	± 0.04
High Sea Level Rise	41,73	41,82	41,96	0,23	± 0.04

The maximum value of projected water levels was selected as the more conservative value for the exposure assessment phase.

The selected **hazard metrics' statistics** correspond to:

- **17 cm** for the **low** sea-level rise hazard scenario for the year 2100.
- **42 cm** for the **high** sea-level rise hazard scenario for the year 2100.

2) EXPOSURE ASSESSMENT FOR SLR

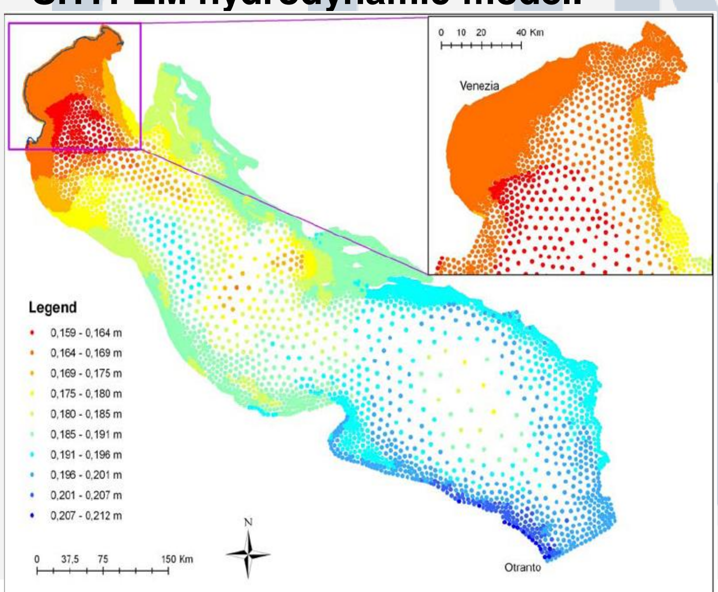
The **exposure assessment** for the sea level rise inundation impact aggregates **data** provided by regional **hydrodynamic models** forced with climate change scenarios with **topographical data** coming from Digital Elevation Models in order to calculate coastal areas and targets potentially exposed to inundation.

$$E_{slr,s} = min\left(max\left(\frac{h_{slr,s} - pf_1}{s_1}, 0\right), 1\right)$$

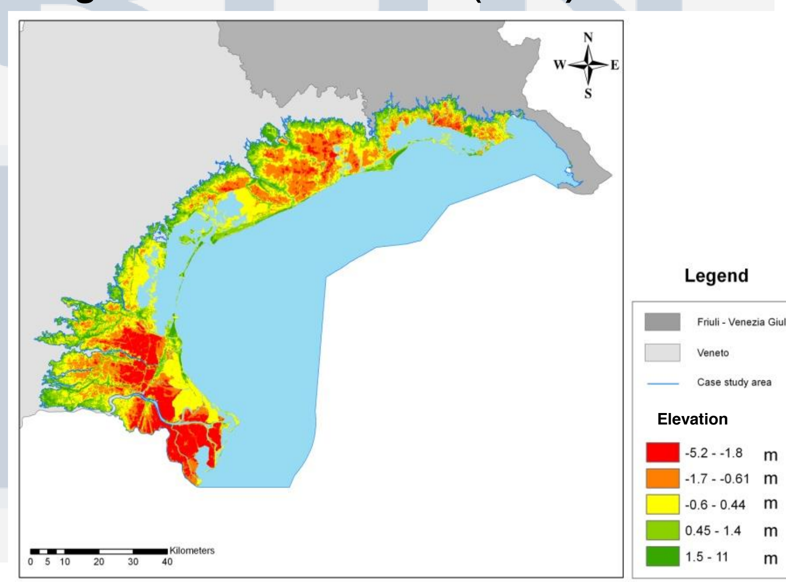
$E_{slr,s}$ = exposure score in a scenario *s;*
$h_{slr,s}$ = height of sea level rise according to scenario *s;*
pf_1 = height of a cell;
s_1 = threshold representing the amount of water above a cell which generate the maximum impact.

North Adriatic data sources:

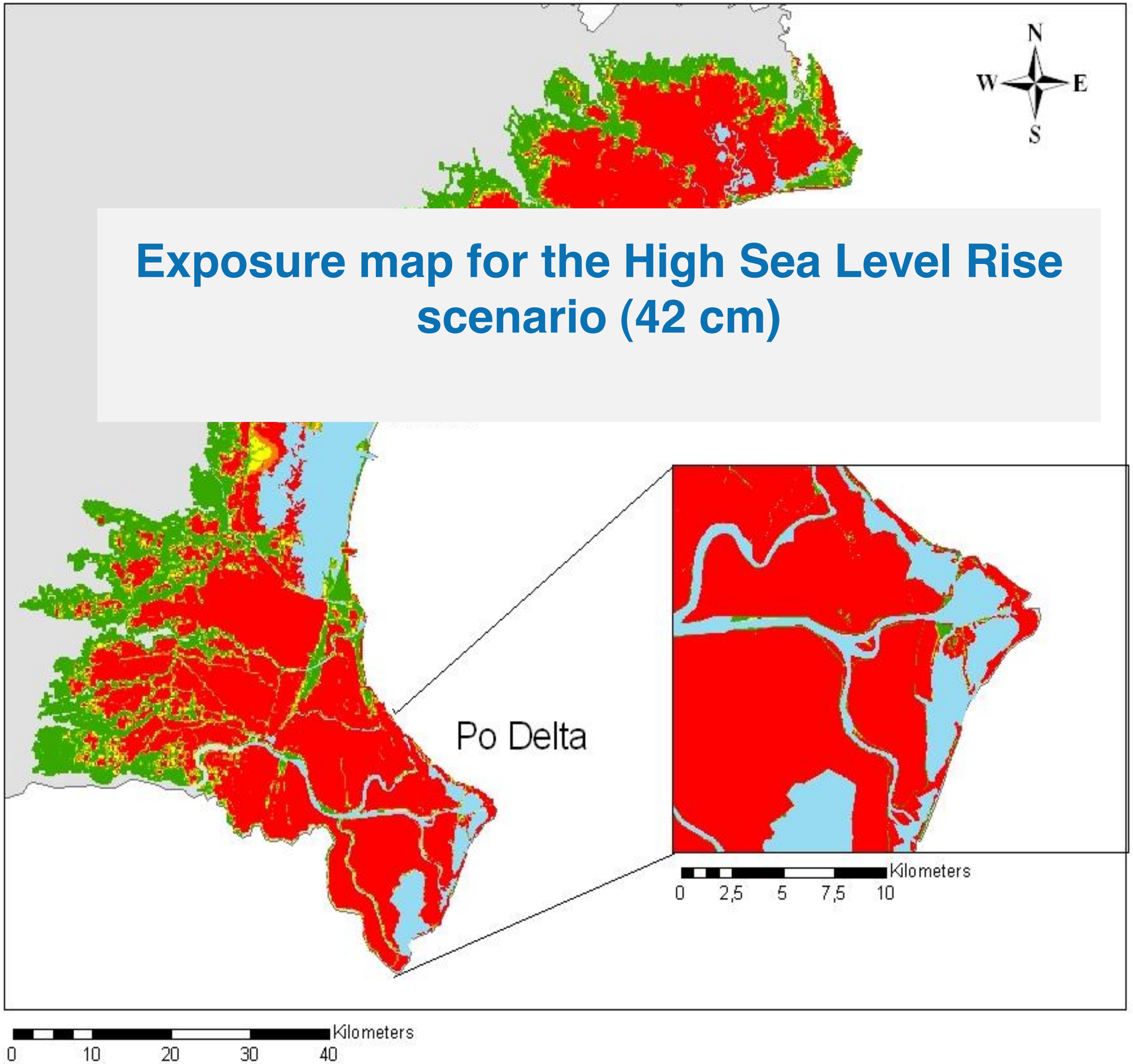
SHYFEM hydrodynamic model.



Digital Elevation Model (DEM) 25



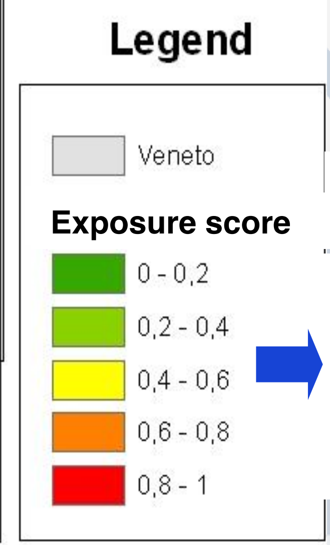
2) EXPOSURE ASSESSMENT FOR SLR



Exposure map for the High Sea Level Rise scenario (42 cm)

Risk scenario: based on SHYFEM MODEL (emission scenario A1B for the year 2100).

Low scenario: 42 cm along the shoreline.



Inundation level (cm)

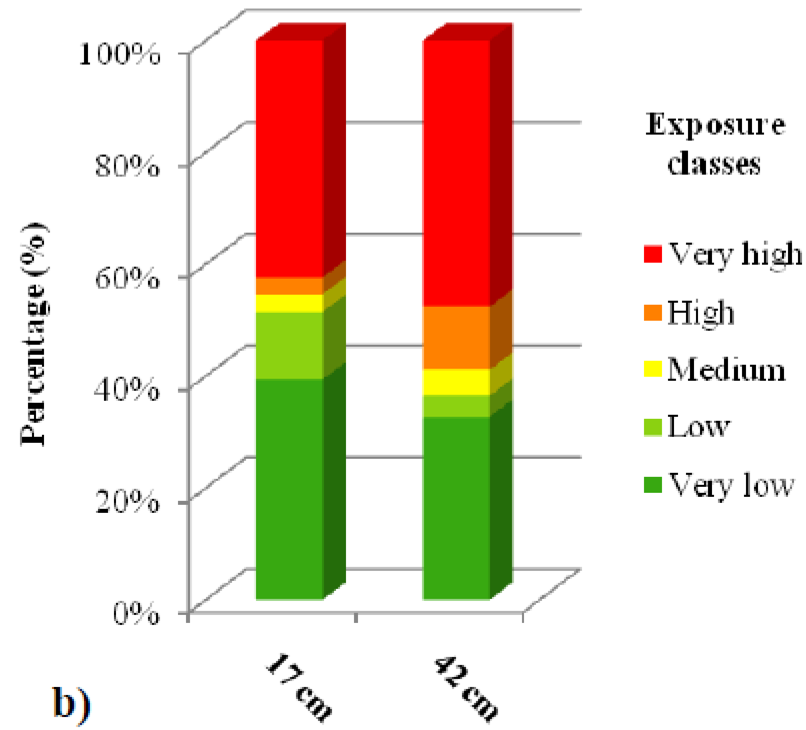
0 – 12
12 – 24
24 – 36
36 – 48
> 48

2) EXPOSURE ASSESSMENT FOR SLR

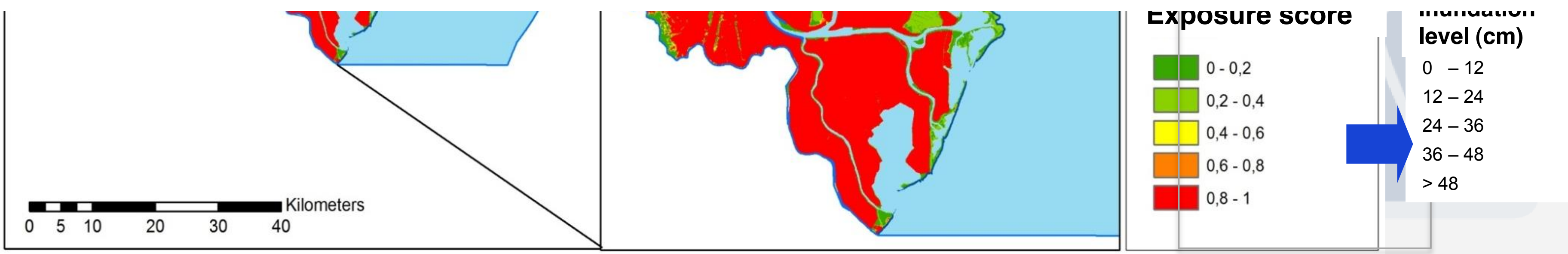
Exposure map for the Low Sea Level Rise scenario (17 cm)

	North Adriatic coasts	
	SLR low scenario (17 cm)	SLR high scenario (42 cm)
Class	Km^2	Km^2
Very low	1138,96	946,08
Low	349,99	108,69
Medium	90,71	134,58
High	88,03	325,69
Very high	1224,62	1377,26
tot	2892,31	2892,31

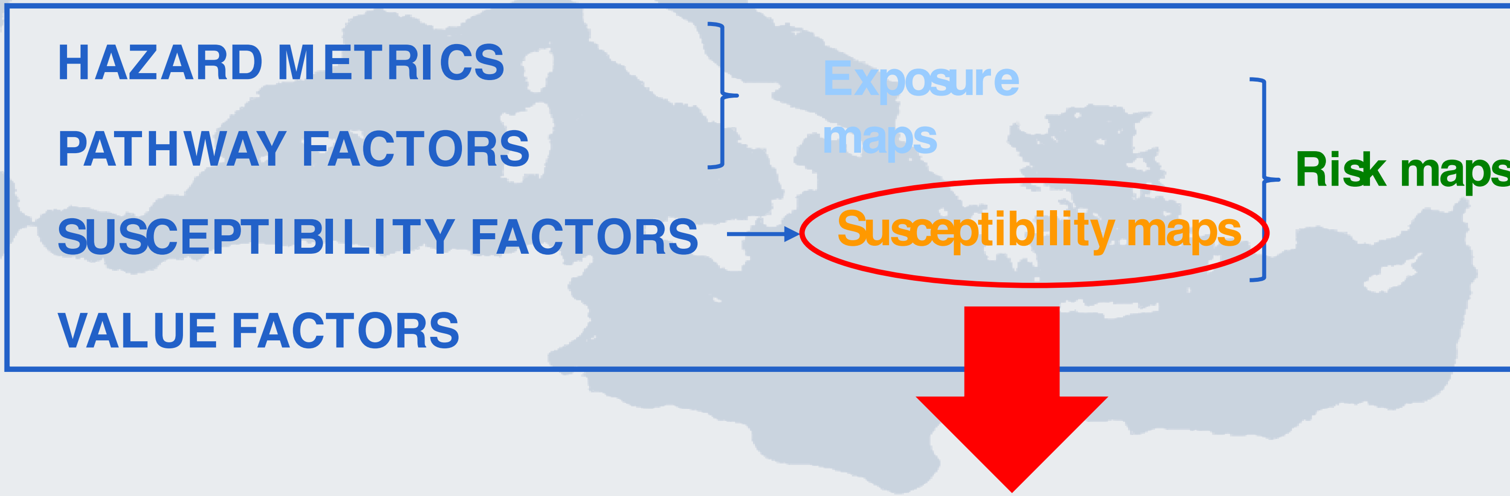
a)



b)



3) SUSCEPTIBILITY ASSESSMENT FOR SLR

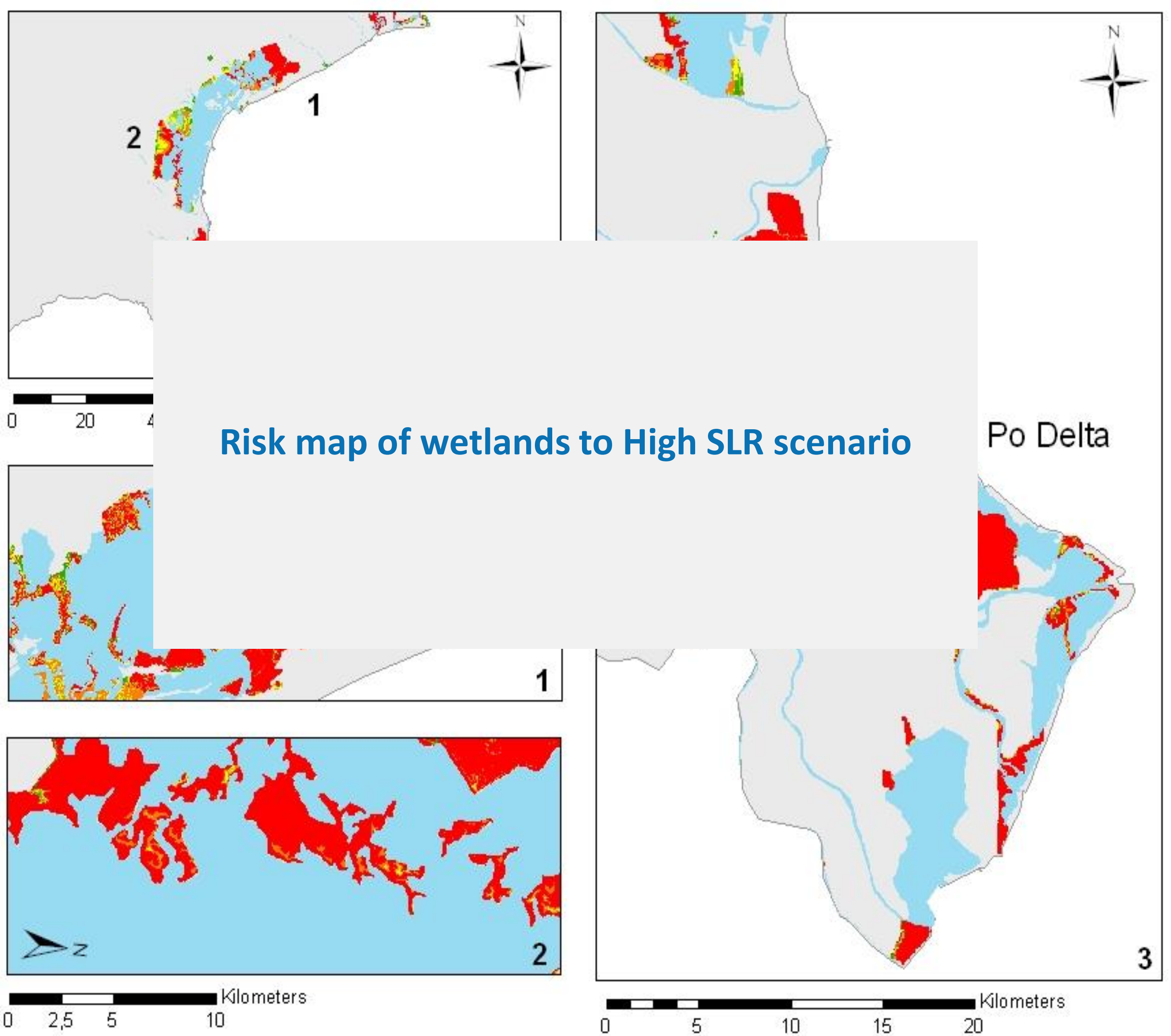


A SLR inundation event affect all the receptors in the same way, causing a **permanent loss of receptors' sub-areas** based only on the elevation of the cells.

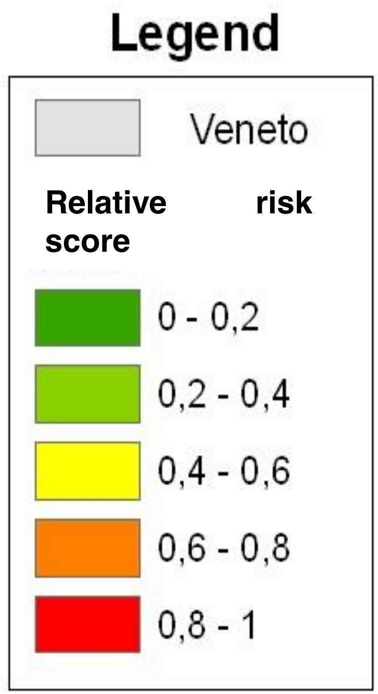
Each **cell of the territory** was considered to have the same **maximum susceptibility** to SLR impact.

Susceptibility score equal to 1→ homogeneous susceptibility map for the investigated area.

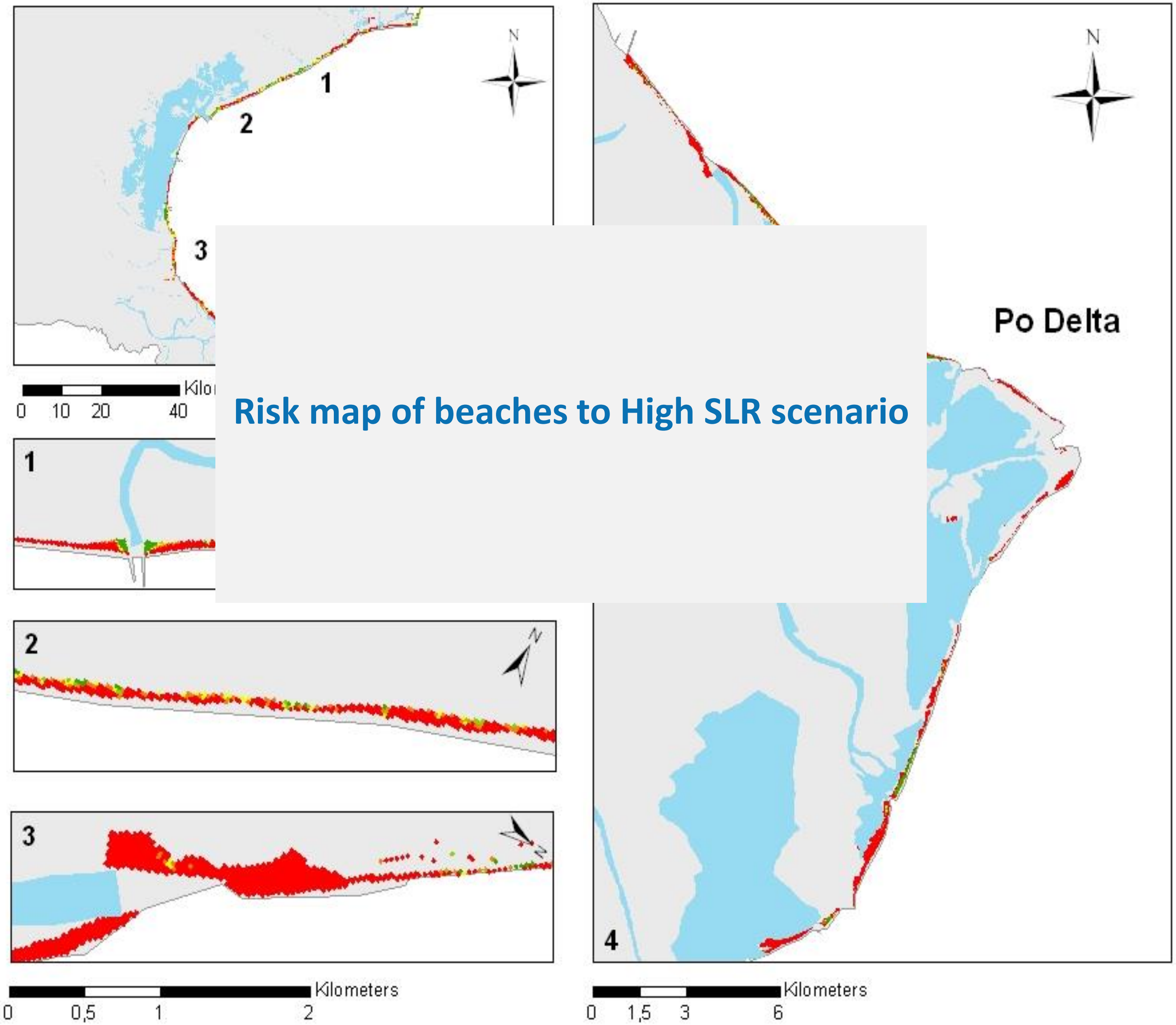
3) RISK ASSESSMENT FOR SLR



Data Source:
SHYFEM MODEL (emission scenario A1B for the year 2100).
Boundary condition: 45 cm SLR at Otranto.
High SLR scenario:
42 cm along the North Adriatic shoreline.

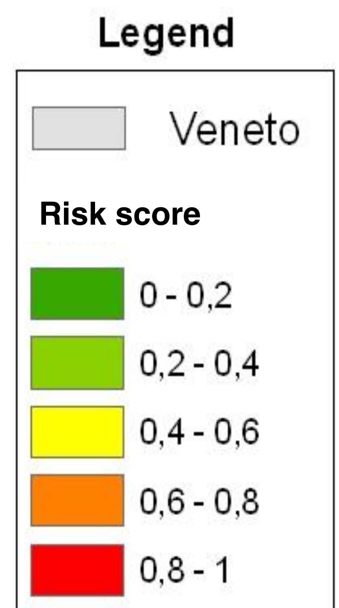


3) RISK ASSESSMENT FOR SLR



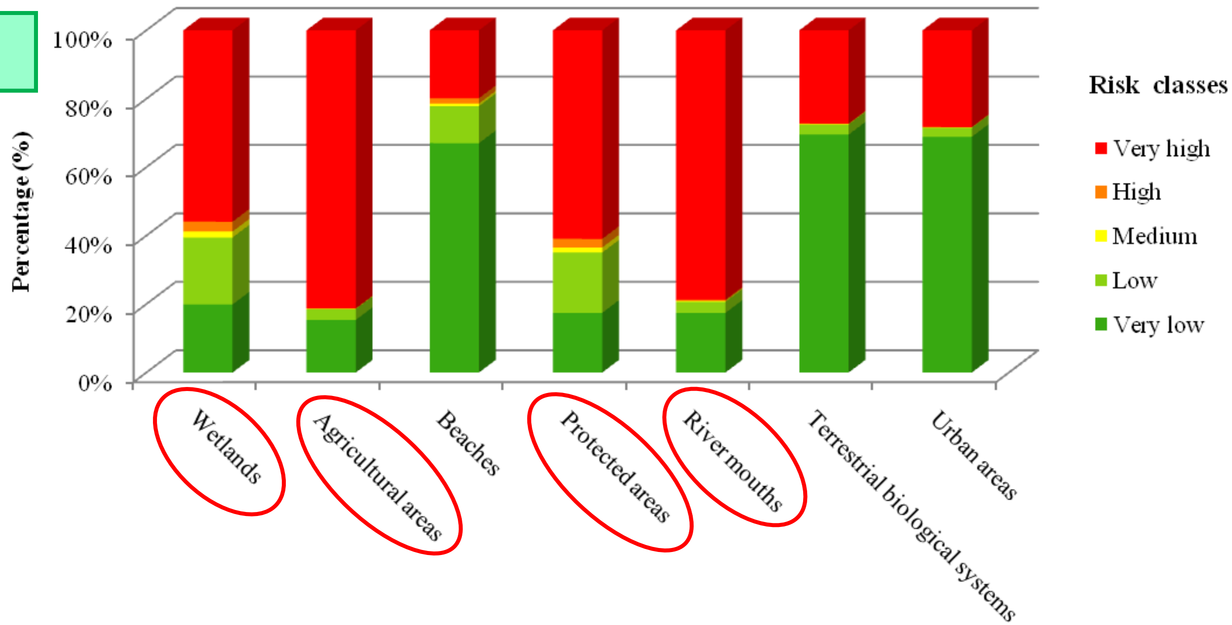
Risk map of beaches to High SLR scenario

Data Source:
SHYFEM MODEL (emission scenario A1B for the year 2100).
Boundary condition: 45 cm SLR at Otranto.
High SLR scenario:
42 cm along the North Adriatic shoreline.

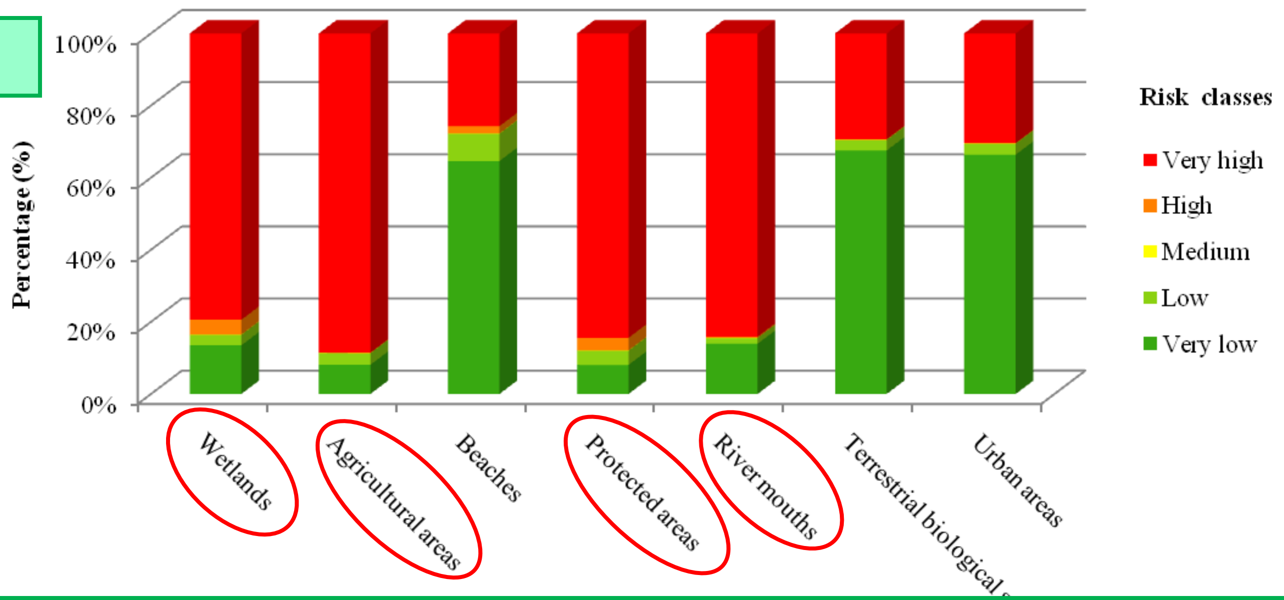


3) RISK ASSESSMENT FOR SLR

Low scenario



High scenario



Comparison between low and high SLR risk maps

4) DAMAGE ASSESSMENT FOR SLR

HAZARD METRICS
PATHWAY FACTORS
} Exposure maps

SUSCEPTIBILITY FACTORS → Susceptibility maps

Exposure maps + Susceptibility maps } Risk maps

VALUE FACTORS → Value maps

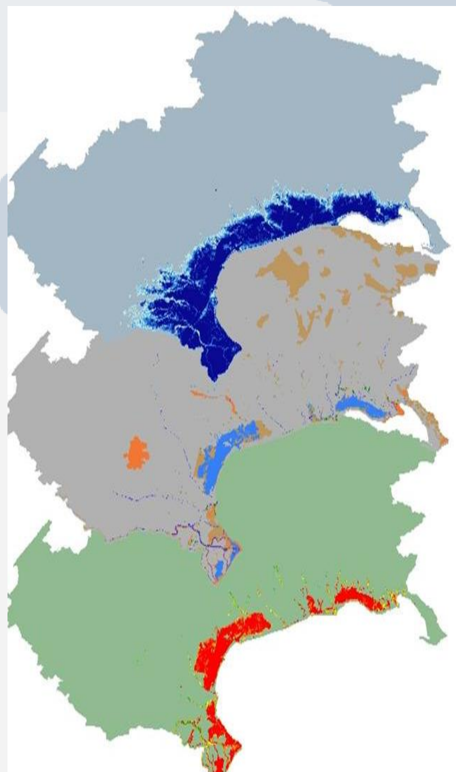
Risk maps + Value maps } Damage maps

Exposure map

Susceptibility map

Risk map

Damage map



decision support tools useful to guide the impact/risk management phase.

Adapted from:
http://www.adrc.or.jp/publications/Venten/HP/herath4.jpg

Value factors

Classification and normalization of value factors

Value factors are classified and normalized assigning a score from 0 to 1 following the linguistic evaluation in order to provide a relative estimation of the potential social, economic and environmental losses associated to targets and areas at risk in the case study area.

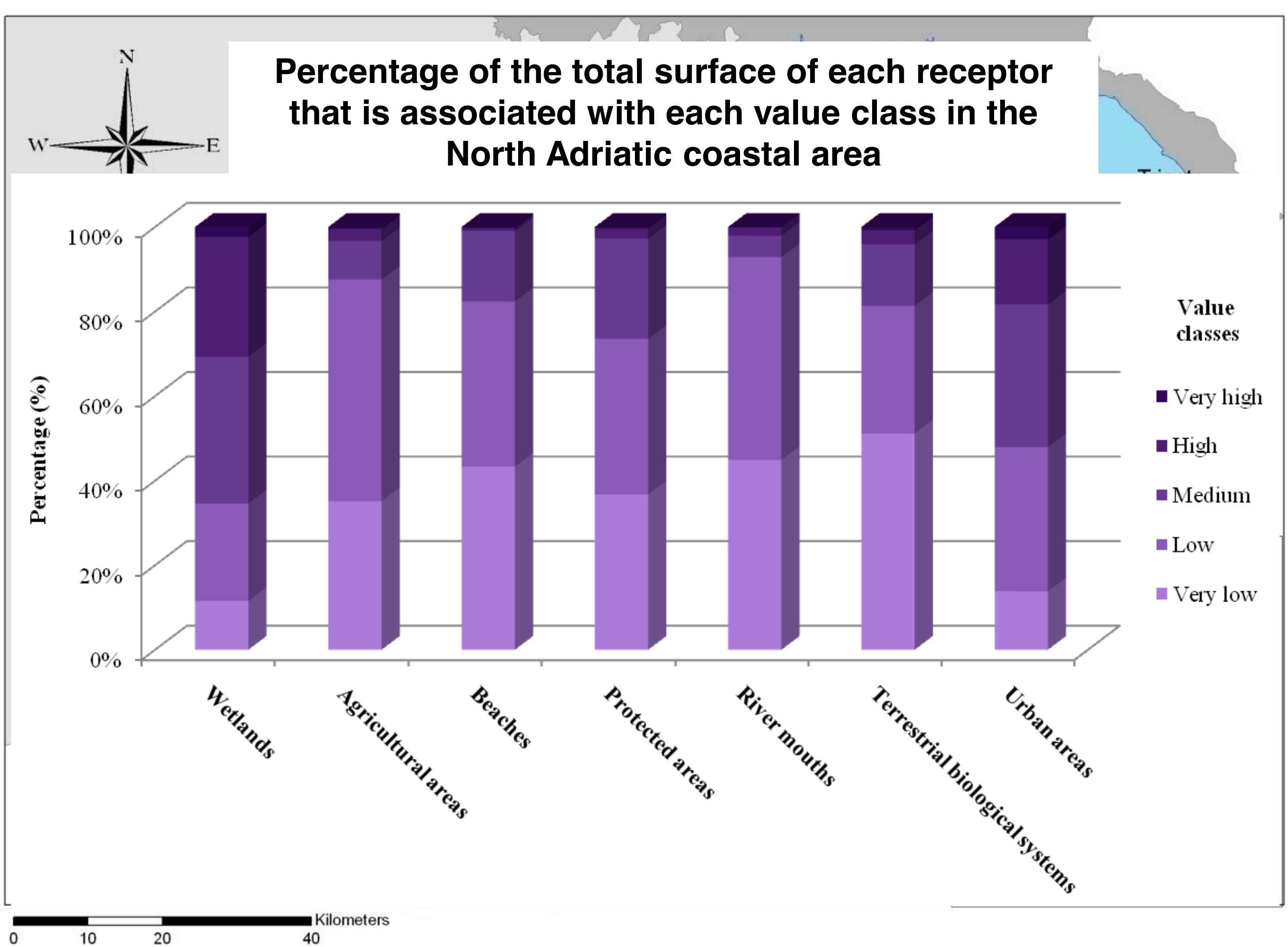
Linguistic Evaluation	Scores ($s_{i,n}$)
Most important class	1
Weakly less important class	0.8
Rather less important class	0.6
Strongly less important class	0.4
Less important class	0.2
No vulnerability/hazard	0

Stakeholders were involved in the identification, classification and normalization of value factors. Value scores were obtained by calculating the average of scores proposed by stakeholders for each value factor.

Value factors

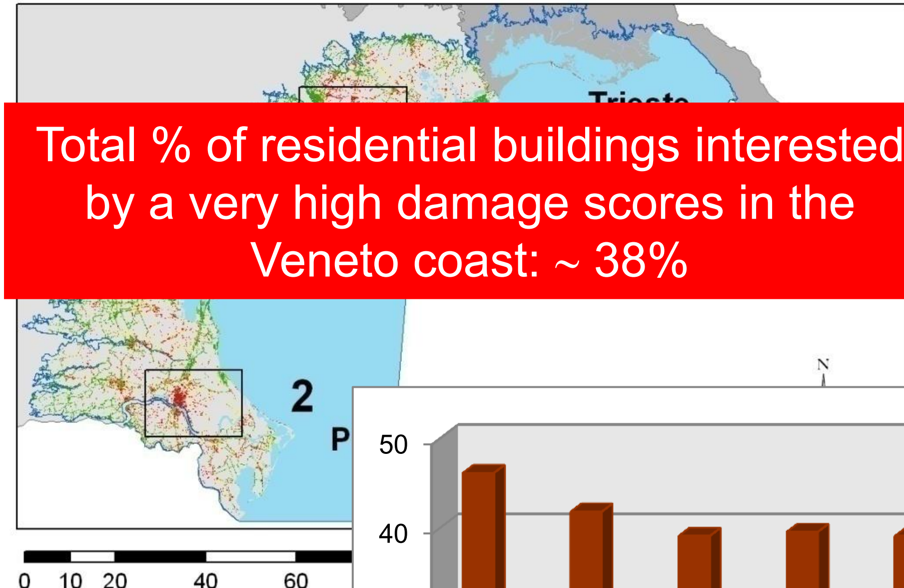
VALUE FACTOR	CLASS	SCORE
Protection level	National area	1
	Regional area	0.5
	Nature 2000 area	0
Urban typology	Residential building	1
	Commercial building	0.5
	Infrastructures	0
Agricultural typology	Permanent culture	1
	Stable meadow	0.5
	Arable	0
Wetland extension (Km^2)	0 – 19,9	0
	19,9 – 39,8	0.25
	39,8 – 59,8	0.5
	59,8 – 79,7	0.75
	79,7 – 99,6	1
Vegetation cover	Poor vegetation and meadow	0
	Vegetation with shrubbery	0.5
	Wood	1
Population density	< 100 inhabitants per region	0
	100-300 inhabitants per region	0.5
	> 300 inhabitants per region	1

VALUE MAPS

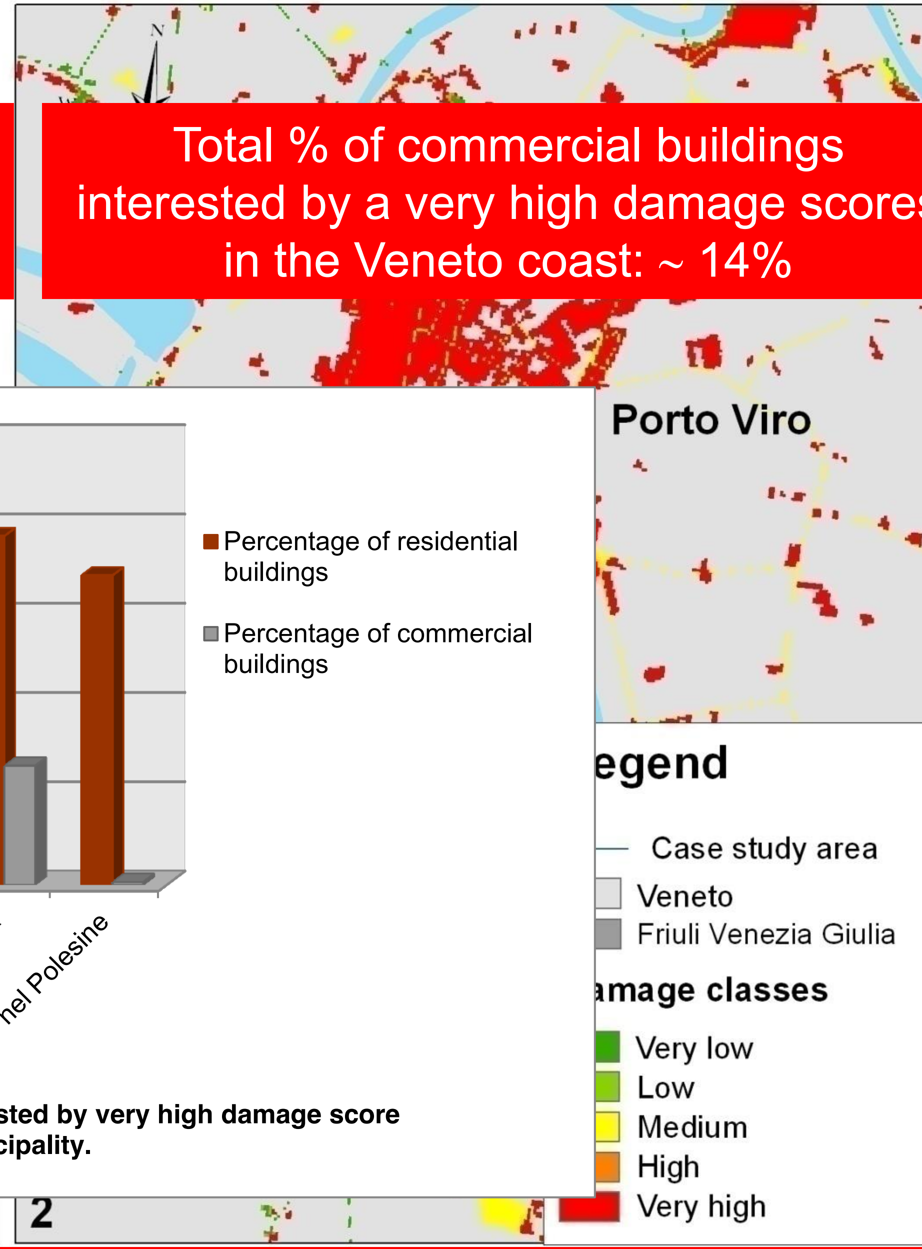


Value map for the agricultural areas.

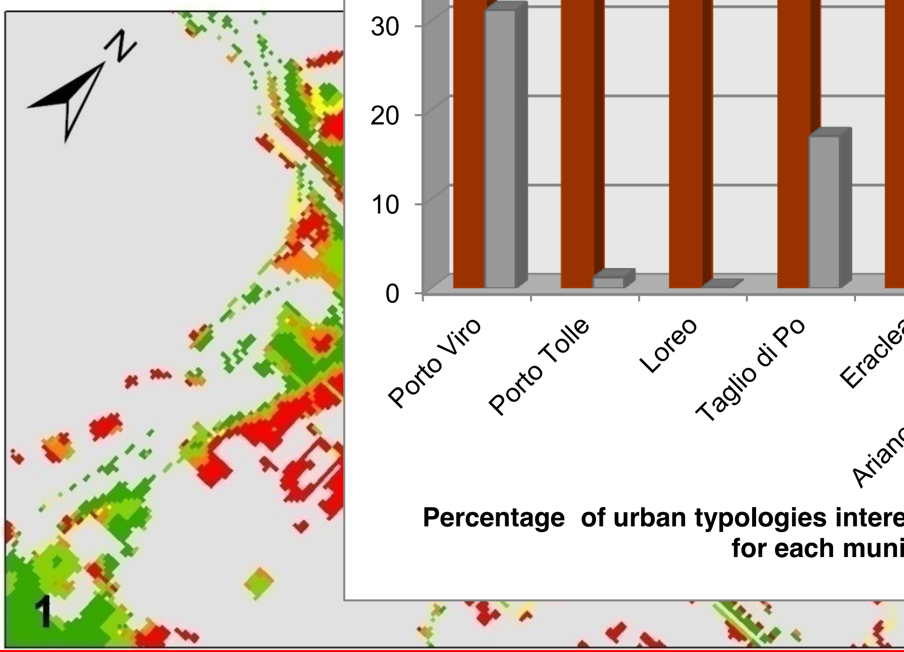
4) DAMAGE ASSESSMENT FOR SLR

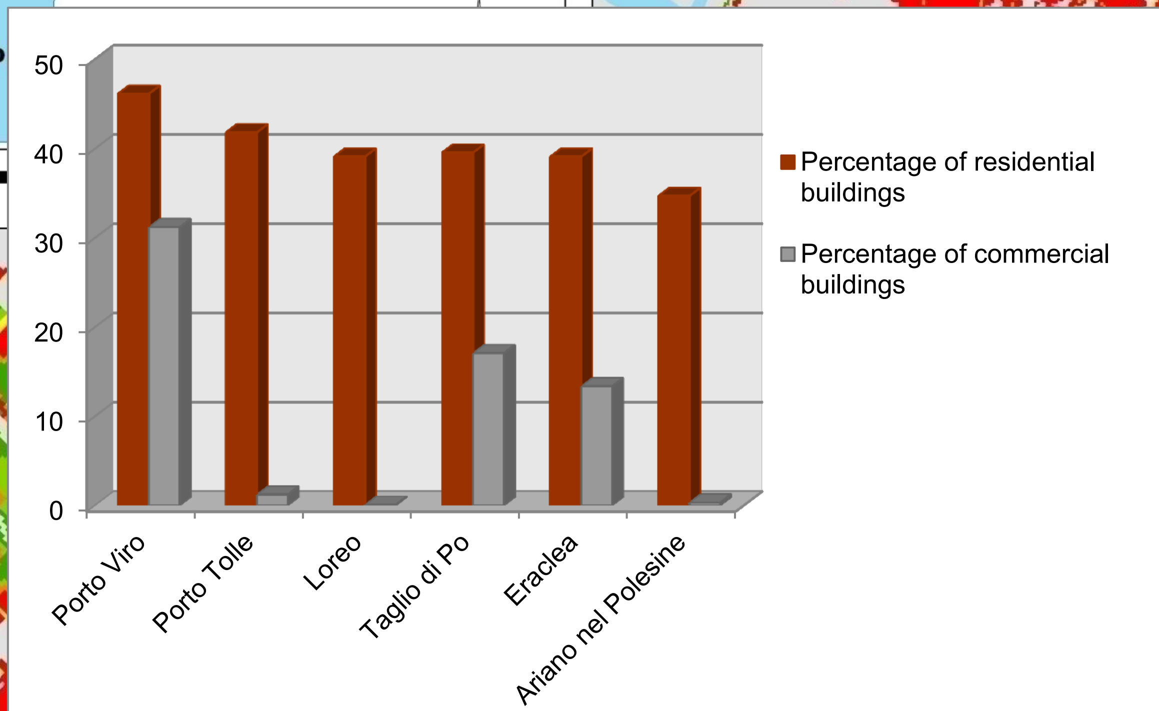


Total % of residential buildings interested by a very high damage scores in the Veneto coast: ~ 38%



Total % of commercial buildings interested by a very high damage scores in the Veneto coast: ~ 14%

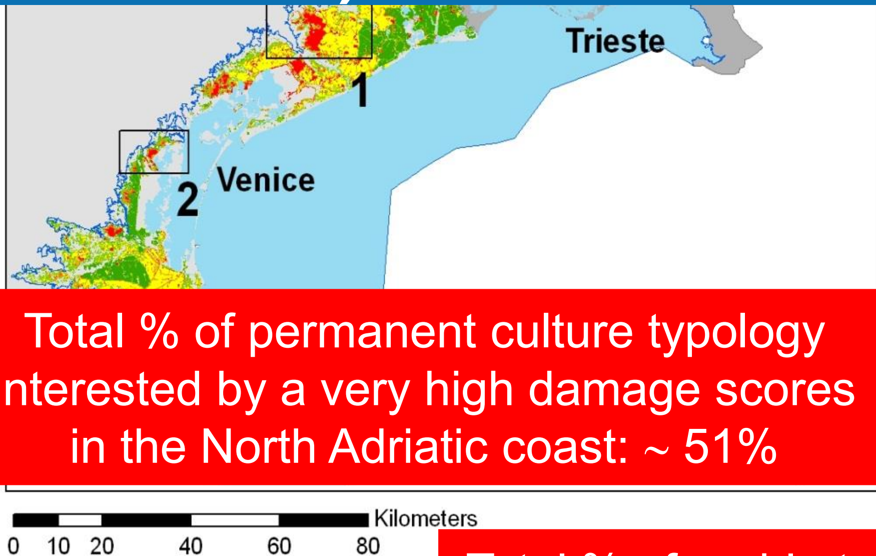




Percentage of urban typologies interested by very high damage score for each municipality.

Damage map of urban areas for the high SLR scenario (42 cm)

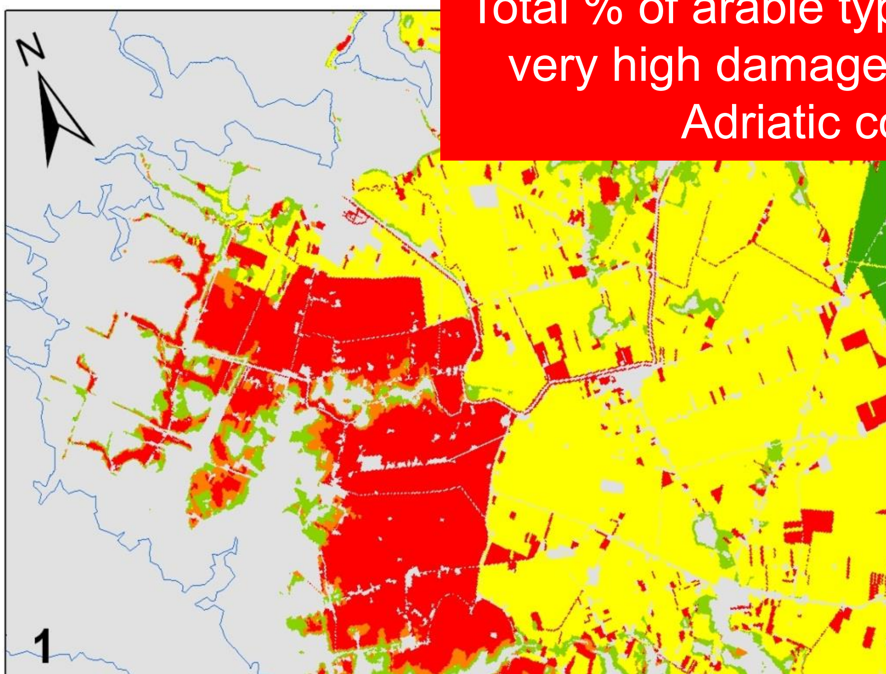
4) DAMAGE ASSESSMENT FOR SLR

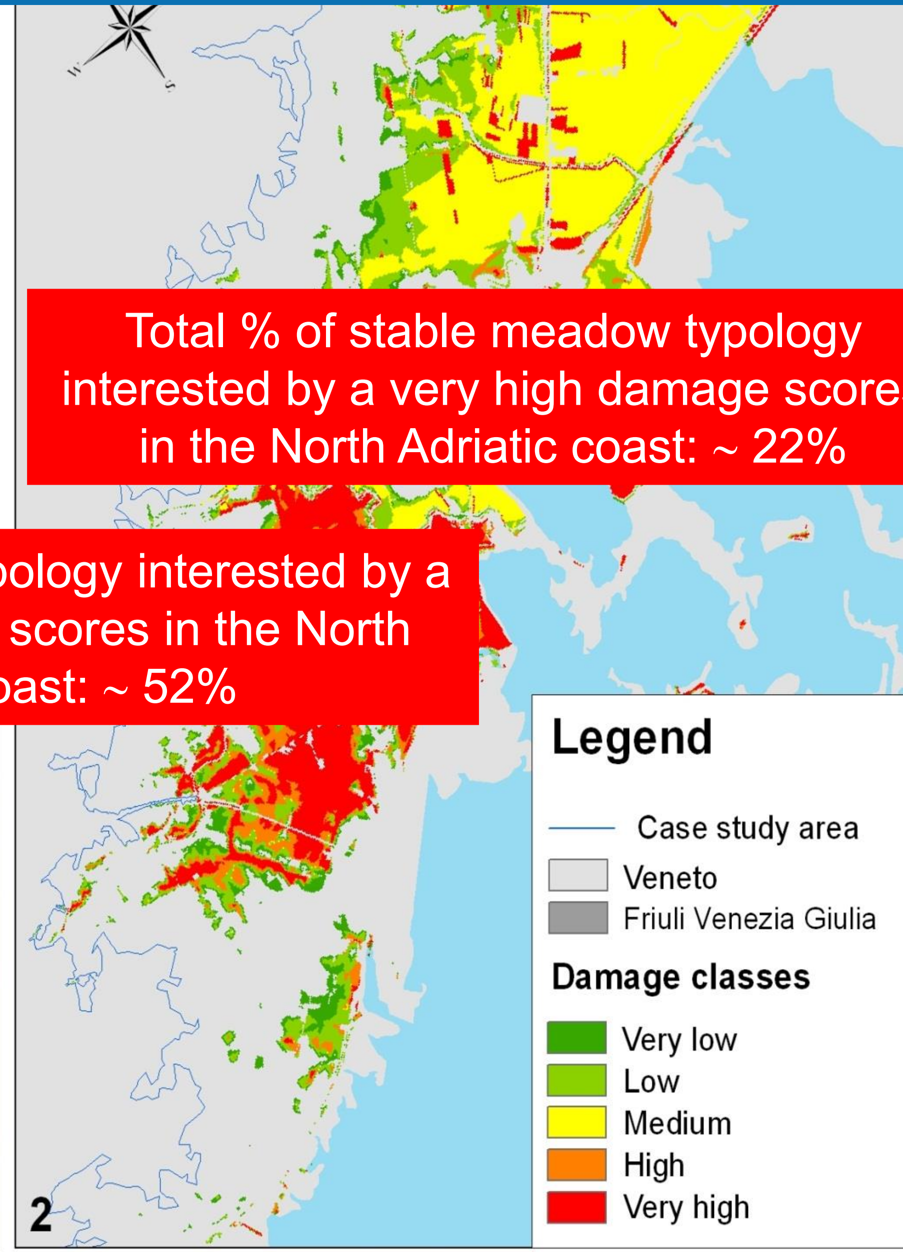


Total % of permanent culture typology interested by a very high damage scores in the North Adriatic coast: ~ 51%

Total % of stable meadow typology interested by a very high damage scores in the North Adriatic coast: ~ 22%

Total % of arable typology interested by a very high damage scores in the North Adriatic coast: ~ 52%





Damage map of agricultural areas for the low SLR scenario (17 cm)

NEXT INTERACTIVE SESSION

Session 2: Application of the DEcision support SYstem for COastal climate change impact assessment (DESYCO) for the development of climate risk products in the coastal zone of the north Adriatic Sea

- Division of the participants into groups and distribution of informative material (20 minutes);
- Discussion and definition of the input data (i.e. hazard scenario and vulnerability matrix) to use in the application for each group (60 minutes);
- Application of the RRA methodology to the North Adriatic case study area for the production of maps and statistics (90 minutes);
- Discussion and comparison between groups results (60 minutes)

Division of the participants into groups

Group	Surname Name
1	BAUDOUIN Jean Philippe
	ONWUEMELE Andrew
	GONDAL Irfan Ahmad
	PUTRA Agie Wandala
2	COSTA Alfredo Jorge
	SARKER Md. Motaleb Hossain
	GONZALEZ REVIRIEGO Nube
	REALE Marco
3	KOMKOUA MBIENDA Armand Joel
	STEFFEN Sophie
	IBRAHIM Muhammad
	ROUSSOS Anargyros
4	MENSAH Caleb
	YANSEN
	KAMAVISDAR Anand
	SALIFU Musah
5	NKRUMAH Francis
	YOUNAS Hassan
	KHATIWADA Medha
	SHAHID Imran

Group	Surname Name
6	QUAGRAINE Kwesi Akumenyi
	WAIMANN Cristian
	KUMAR Rajesh
	LEMESIOS Ioannis
7	RAMACHANDRAN Prasannavenkatesh
	HERNANDEZ GARCES Anel
	KWAWU Caroline Rosemyya
	PATEL Amitkumar Dilipbhai
8	SRNEC Lidija
	TORRALBA FERNANDEZ Veronica
	MAHMOUD Marwa Moatasim M.
	PARAJULI Kshitij
9	TESFAYE Yirgalem Negash
	MALL Rajesh Kumar
	CINDRIC Ksenija
	SINGH Narendra

DEFINITION OF INPUT DATA

Construction of Vulnerability matrix:

You are involved in the selection of vulnerability factors (i.e. pathway, attenuation, susceptibility and value factors) for the construction of vulnerability matrix

DEFINITION OF INPUT DATA

Pathway factors:
physical characteristics of the receptors which contribute in determining the possibility of contact with climate change hazards and therefore potential exposure areas.

- Elevation;
- Distance from coastline;


Attenuation factors: elements able to attenuate the intensity of the hazard associated to an impact.

- Current or planned adaptation options;
- Artificial or natural structures;
- Dunes;
- Seawalls


DEFINITION OF INPUT DATA

Susceptibility factors:

- They determine the degree to which receptors could be affected by a climate-related impact;
- They are mostly represented by **geo-physical** or **ecological** factors intrinsic of the territory.

- Slope;
- Geomorphology;
- River mouth typology (estuary, delta);
- Vegetation cover;
- Wetland extension.

DEFINITION OF INPUT DATA

Value factors:
identify relevant environmental and socio-economic values of the receptors that need to be preserved for the interest of the community.

- Protected level (e.g. Nature 2000, Site of Community Importance);
- Population density;
- Urban typology (e.g. residential, commercial, infrastructure);
- Agricultural typology (e.g. permanent cultures , stable meadows, arable);
- Wetland extension;
- Vegetation cover;.

PARTCIPATIVE PROCESS

VULNERABILITY MATRIX

- What are the pathway factors that you assigned to each receptor? Why?
- What are the attenuation factors that you assigned to each receptor? Why?
- What are the susceptibility factors that you assigned to each receptor? Why?
- What are the value factors that you assigned to each receptor? Why?

Impact	Wetlands	Urban areas	Agricultural areas
Sea Level Rise			

Pathway factors	Attenuation factors	Susceptilbity factors	Value factors

DEFINITION OF INPUT DATA

PARTCIPATIVE PROCESS

Classification and scoring of vulnerability factors:

You are asked to classify and score the selected susceptibility and value factors following the linguistic evaluation trough the assignation of a score from 0 to 1 to each susceptibility/value class in order to provide a relative estimation of the potential social, economic and environmental losses associated to targets and areas at risk in the case study area.

Linguistic Evaluation	Scores ($s_{i,n}$)
Most important class	1
Weakly less important class	0.8
Rather less important class	0.6
Strongly less important class	0.4
Less important class	0.2
No vulnerability/hazard	0

DEFINITION OF INPUT DATA

PARTCIPATIVE PROCESS

SUSCEPTIBILITY FACTORS

- **Do you think that susceptibility factors really determine the degree to which the receptors could be affected by a climate change impact based on site-specific territorial information?**
- **Do we really need to define a susceptibility score for the territory that will be permanently inundated by the sea?**

A SLR inundation event affect all the receptors in the same way, causing a **permanent loss of receptors' sub-areas** based only on the elevation of the cells.

Each **cell of the territory is** considered to have the same **maximum susceptibility** to SLR impacts.

Susceptibility score equal to 1→ homogeneous susceptibility map for the investigated area.

PARTCIPATIVE PROCESS

VALUE FACTORS

➢ **How did you assign the value scores to each value class? Why?**

Value Factor	Classes	Score (0-1)

➢ **Do you think that value factors really determine relevant environmental and socio-economic values of the receptors that need to be preserved for the interest of the community?**

Lunch break!

See you at 1:30

DEFINITION OF INPUT DATA

CLIMATE INFORMATION

Definition of hazard scenario:

You are involved in the selection of the hazard scenario to applied for the study of sea level rise on north Adriatic coast

CLIMATE INFORMATION

SEA LEVEL RISE SCENARIOS

Different forcing to considered in sea level change projections:

- Thermosteric effect: thermal expansion at Mediterranean basin-scale.
- Halosteric effect: changes in salinity.
- Mass addition: it's due to changes in mass budget of the Mediterranean Sea (almost compensated by halosteric effect).
- Dynamical effect: due to local changes in oceanic circulation.
- Change of near-Atlantic sea level due to all the processes including ice melting (glaciers or ice sheets).
- Changes in sea floor.
- Storm surges (local and snapshot effect).
- Tides (periodic effect).[u1]

DEFINITION OF INPUT DATA

CLIMATE INFORMATION

EMISSION SCENARIOS :

Different emission scenario families:

A1: a future world of very rapid economic growth and rapid introduction of new and more efficient technologies;

A2: a very heterogeneous world with continuously increasing global population and regionally oriented economic growth;

B1: a convergent world with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies;

B2: a world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population and intermediate economic development.

(IPCC, 2007)

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EMISSION SCENARIOS :

Different emission scenario families:

RCP 8.5 : characterized by increasing greenhouse gas emissions over time, representative of scenarios in the literature that lead to high greenhouse gas concentration levels (Riahi et al. 2007).

RCP6 : a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshoot, by the application of a range of technologies and strategies for reducing greenhouse gas emissions (Fujino et al. 2006; Hijioka et al. 2008).

RCP 4.5 : a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshooting the long-run radiative forcing target level (Clarke et al. 2007).

RCP 2.6 : a “peak-and-decline” scenario; its radiative forcing level first reaches a value of around 3.1 W/m2 by mid-century, and returns to 2.6 W/m2 by 2100. In order to reach such radiative forcing levels, greenhouse gas emissions (are reduced substantially, over time (Van Vuuren et al. 2007a).

DEFINITION OF INPUT DATA

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Great variability in sea level rise value projections

Climate change hazard	Data source	Category	Domain	Spatial resolution	Sea level forcing	Emission senario	Time Scenario	Sea level rise value (cm)	
Sea level rise scenarios	**IPCC, 2007**	Ocean and sea Circulation models	Global		Sea temperature (thermal expansion)	B1	2081-2100	LOW:	17
					Oceanic circulation	A1F1		HIGH:	60
	IPCC, 2013	Ocean and sea Circulation models	Global		Sea temperature (thermal expansion)	RCP2.6	2081-2100	LOW:	25
					Oceanic circulation	RCP8.5		HIGH:	80
	CNR-ISMAR	Ocean and sea Circulation models	North Adriatic sea	2.5 km-50 metres	Sea temperature (thermal expansion)	A1B	2070-2100	LOW:	17
					Oceanic circulation			HIGH:	42
	ENEA	Ocean and sea Circulation models	Mediterranean sea	50 km	Sea temperature (thermal expansion)	A1B	2041-2050	LOW:	4
								MEDIUM:	15
					Oceanic circulation			HIGH:	27
	Vermeer and Rahmstorf, 2009	Ocean and sea Circulation models	Global			B1	2100	LOW:	80
						A1F		HIGH:	160

DEFINITION OF INPUT DATA

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➢ Which scenario did you chose? Why?

Group	SLR Scenario	Motivation
1		
2		
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