Innovative technologies for safer
European coasts in a changing climate

THESEUS

A GIS-BASED DECISION SUPPORT SYSTEM FOR MULTICRITERIA COASTAL RISK ASSESSMENT AND MANAGEMENT: THE THESUES APPROACH

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THESEUS at a glance

- Title: Innovative coastal technologies for safer European coasts in a changing climate
- Instrument: Large Integrated Project - FP7
- Total Cost: 8.519.726 €, EC Contribution: 6.530.000 €
- Duration: 48 months, Start Date: 01/12/2009
- Consortium: 31 partners from 18 countries
- Project Coordinator: Barbara Zanuttigh, Alma Mater Studiorum Università di Bologna (Italy)
- Project Web Site: http://www.theseusproject.eu
- Key Words: coast, flood, erosion, risk, technology, mitigation, adaptation, climate change

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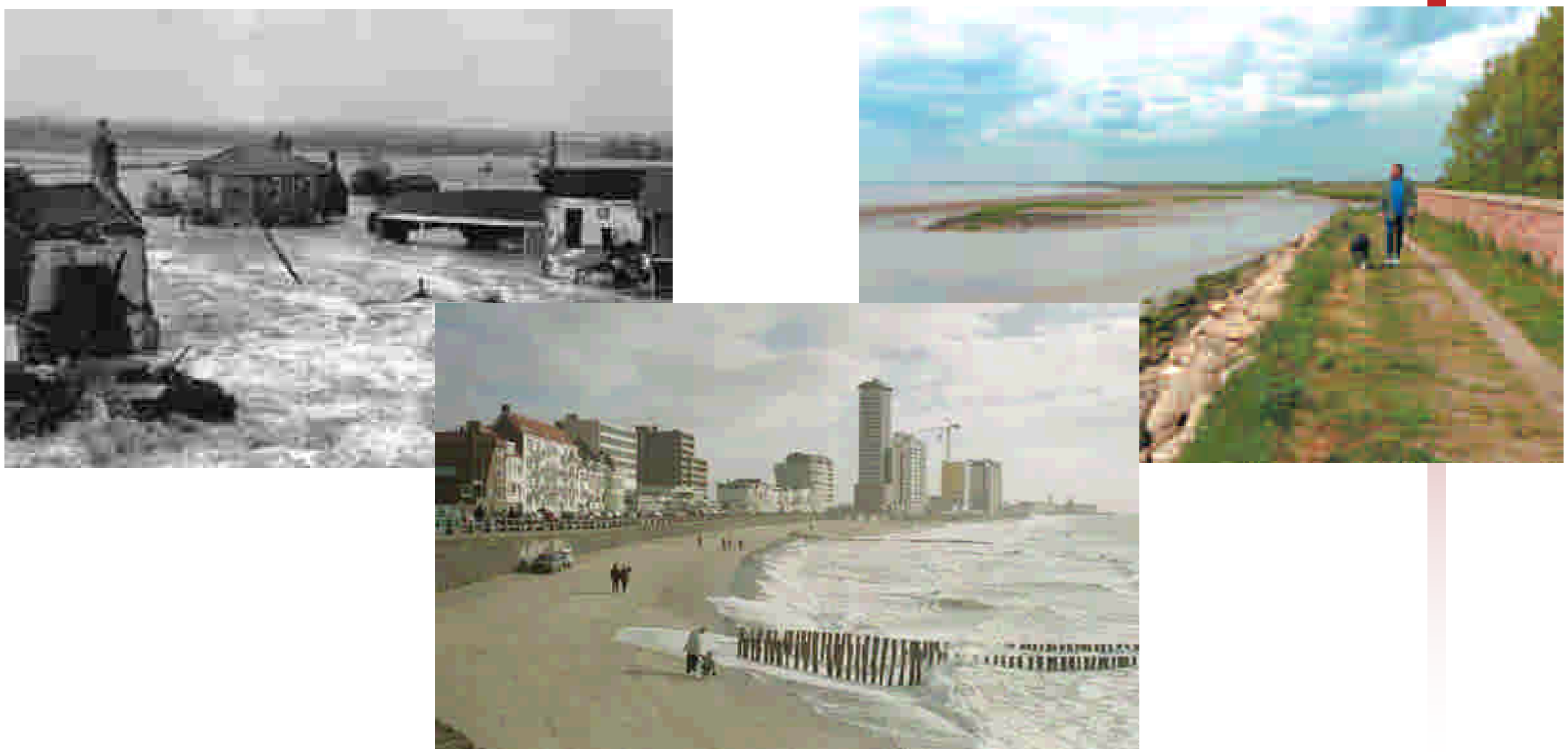
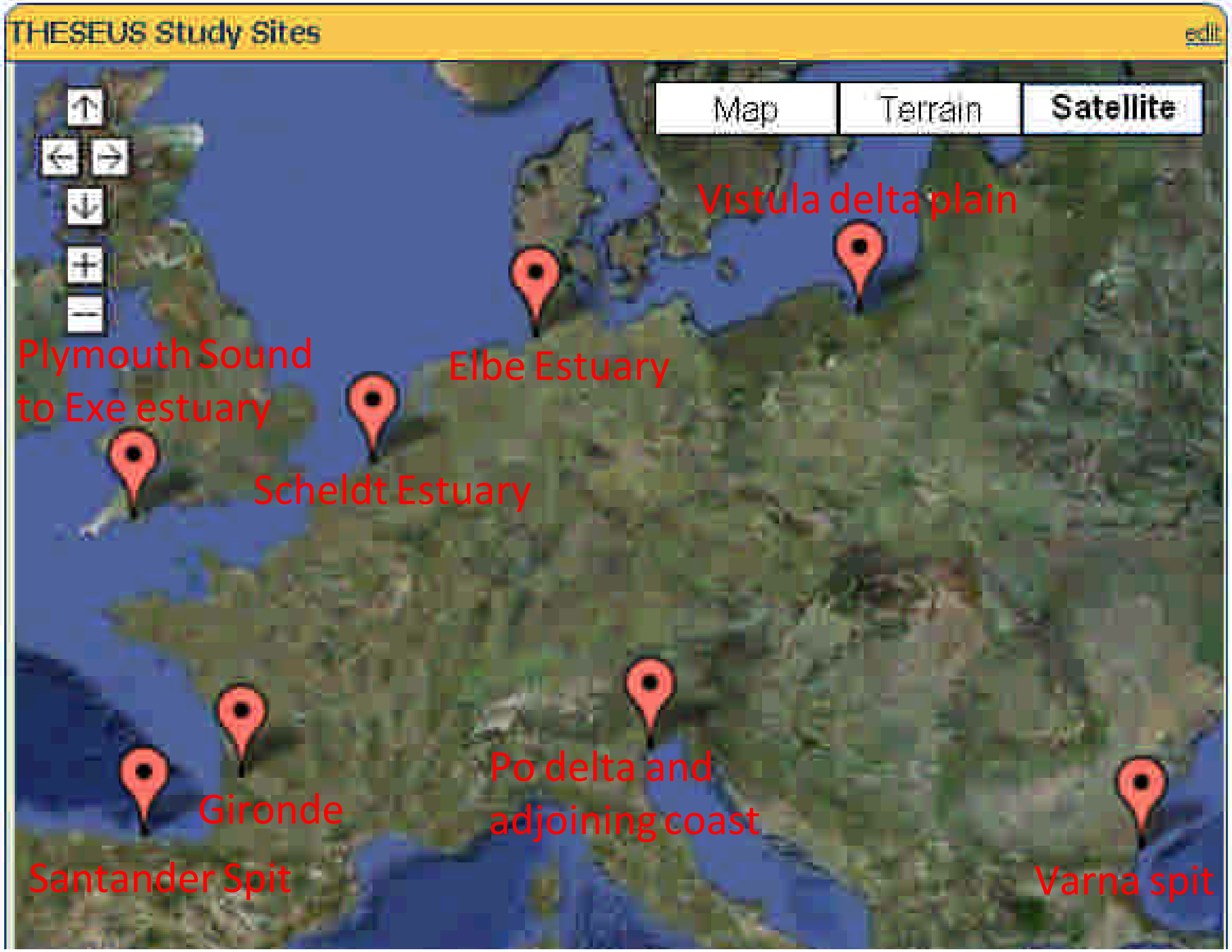
THESEUS Aim

- deliver a safe (or low-risk) coast for human use/development and healthy coastal habitats as sea levels rise and climate changes and the European economy continues to grow.



THESEUS study sites



Focus on the sites

Cesenatico (FC)

Boundaries

- Northern, Tagliata Channel
- Southern, Valverde
- Western, railway track

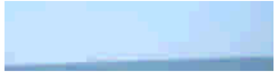
WP5 Theseus DSS: Concepts





- Decision Support System (DSS) is a computer based information system that supports decision making activities – typically consisting of underlying databases and mathematical models with a graphical user interface for editing, generating and viewing results.
- Prerequisites:
  - The target DSS users are “coastal managers” - Intermediate level. Stakeholders are administrators with technical skills Scientifically sound and innovate in particular aspects
  - Coherent with EU policies and vision
  - Trying to integrate and make useful most of Theseus findings.
- Core functionality:
  - Evaluate potential risks due to climate change in three distinct dimensions: economic, life losses and environmental.
  - Analyze and compare sets of mitigation measures, both structural and non-structural, to reduce risks.

DSS Flowchart



1) General Requirements:
- Scope
- Target User
- Flexibility
- IT and Technological

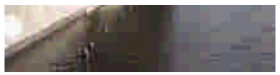
2) Flood Vulnerability/Damage Model
- Environmental, Socio –Economical Model
- GIS Based approach: Map Calculation
- Definition of Damage Function
- Identification of key flood parameters for damage/vulnerability evaluation
  - Water depth
  - Velocity
  - Turbolence
  - Duration

3) Mitigation Options and Scenario drivers
- List of mitigation option to be evaluated and modelled by the DSS
  - Costal engineerging measures
  - Evironmental mitigations
  - Socio economical actions

4) Coastal Mathematical Models
- Storm surge flood: GIS flood model
- Erosion
- Wave overtopping
- Evaluation of coastal mitigation options
- Models must be compliant with IT requirements defined previously

5) Multicriteria Risk Assessment
- Spatial GIS based MCA
  - Overall Risk Map (environment+socio+economic)
- Economic evaluation

6) Technological Design of DSS
- Web or Desktop
- GIS software
- Programming languages



THESEUS DSS Characteristics

- Target User: Coastal Managers
- Risk Scenarios -
  - Climate Change
  - Subsidence
  - Mitigation Measures
- Hazard: Flooding and Erosion
  - Storm Surge Flooding
  - Wave Overtopping
  - Coastline Erosion
- OUTPUT - Quali-Quantitative coastal risk assessment
  - Map of single coastal risk criteria (enviro, socio, economic)
    - Qualitative ranking (High, Medium, Low)
    - Quantitative ($, loss of life, loss of species)
  - Map of Multicriteria risk (MAUT MAC - Cost-Benefit $$)
- Support in mitigation measure selection
  - Where and Which are the best mitigation measures in order to minimize single and multi criteria coastal risk
- User friendly GUI
  - **Desktop** of Web-based
  - Open Source

THESEUS DSS Ingredients

- Relational Databases
  - Climate and wave data
  - Mitigation Measures
  - Damage Curve
- Geo-Databases
  - GIS Layers
    - Receptor
- Mathematical Models– Linked and embedded
  - Sea Level and wave propagation
  - Storm Surge Flooding
  - Wave Overtopping
  - Coastline Erosion
- Geoprocessing and Map algebra script
  - OGR/GDAL Libraries
  - Damage Function and MCA
- GIS Mapping GIS
  - Desktop GIS
  - Open Source

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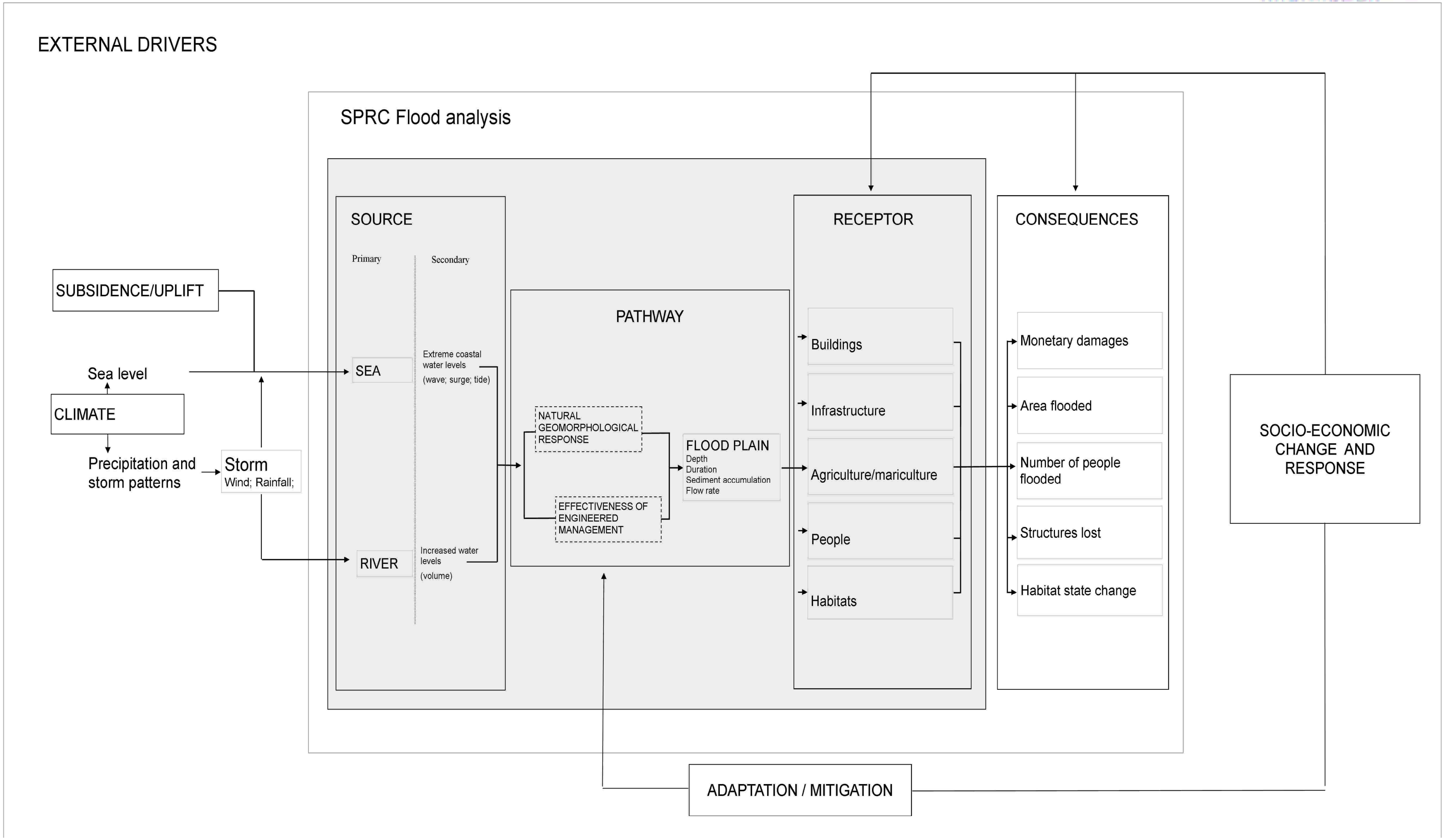
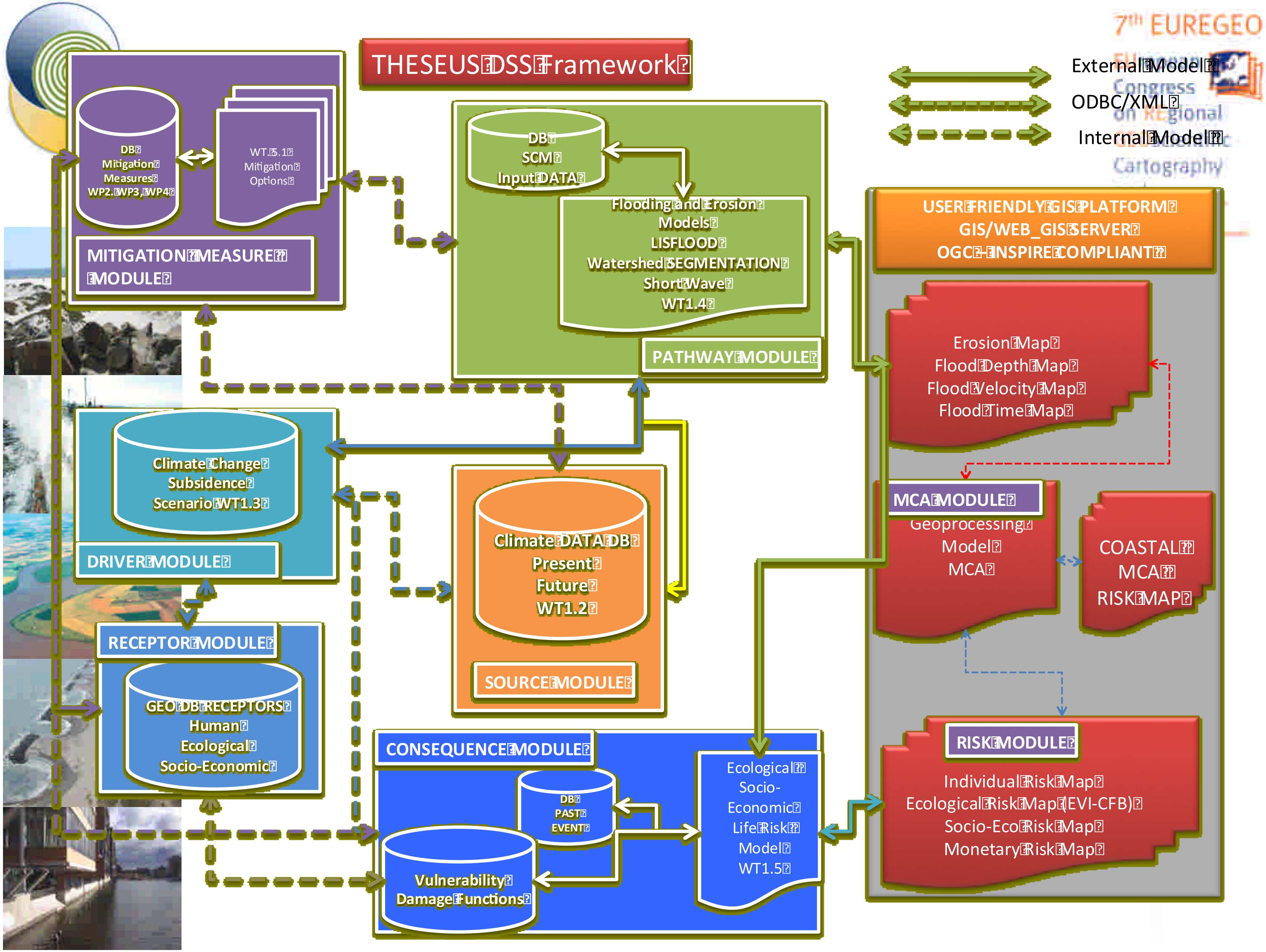
The SPRC Risk Assessment method





THESEUS DSS Framework
External Model
ODBC/XML
Internal Model
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DB
Mitigation
Measures
WP2, WP3, WP4
WT 5.1
Mitigation
Options
MITIGATION MEASURE
MODULE
DB
SCM
Input DATA
Flooding and Erosion
Models
LISFLOOD
Watershed SEGMENTATION
Short Wave
WT1.4
PATHWAY MODULE
USER FRIENDLY GIS PLATFORM
GIS/WEB_GIS SERVER
OGC - INSPIRE COMPLIANT
Erosion Map
Flood Depth Map
Flood Velocity Map
Flood Time Map
Climate Change
Subsidence
Scenario WT1.3
DRIVER MODULE
Climate DATA DB
Present
Future
WT1.2
SOURCE MODULE
MCA MODULE
Geoprocessing
Model
MCA
COASTAL
MCA
RISK MAP
RECEPTOR MODULE
GEO DB RECEPTORS
Human
Ecological
Socio-Economic
CONSEQUENCE MODULE
DB
PAST
EVENT
Vulnerability
Damage Functions
Ecological
Socio-
Economic
Life Risk
Model
WT1.5
RISK MODULE
Individual Risk Map
Ecological Risk Map (EVI-CFB)
Socio-Eco Risk Map
Monetary Risk Map

RECEPTOR MODULE

- GEO DB with Layer map useful for receptor identification by the DSS users
  - DTM, SRTM
  - Landuse
  - Urban classification
  - Population and Census data
  - Socio economic data
  - Vegetation map
  - Habitat map
- GEO DB (ESRI or POSTGis DB) with metadata
- GUI: The data are uploaded in the DSS, the user can interact in a mapping framework with the layers
- The user can define and add new receptor layers for risk assessment

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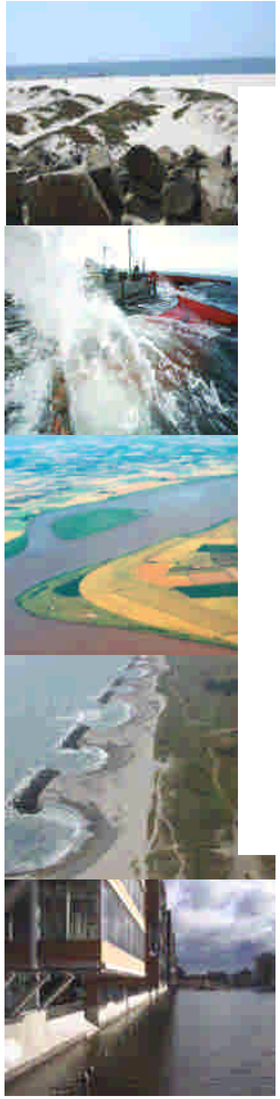
Receptors



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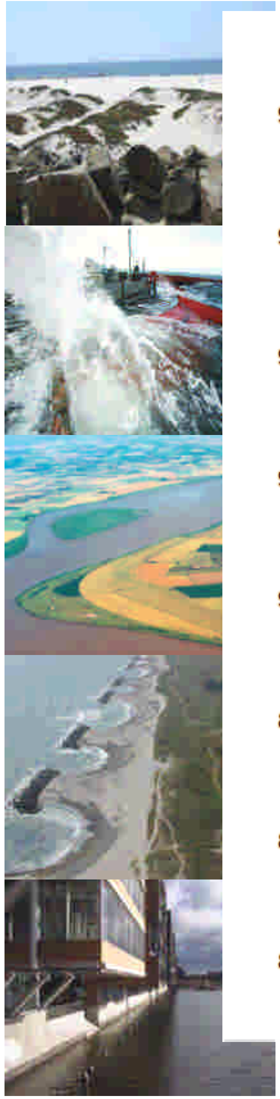
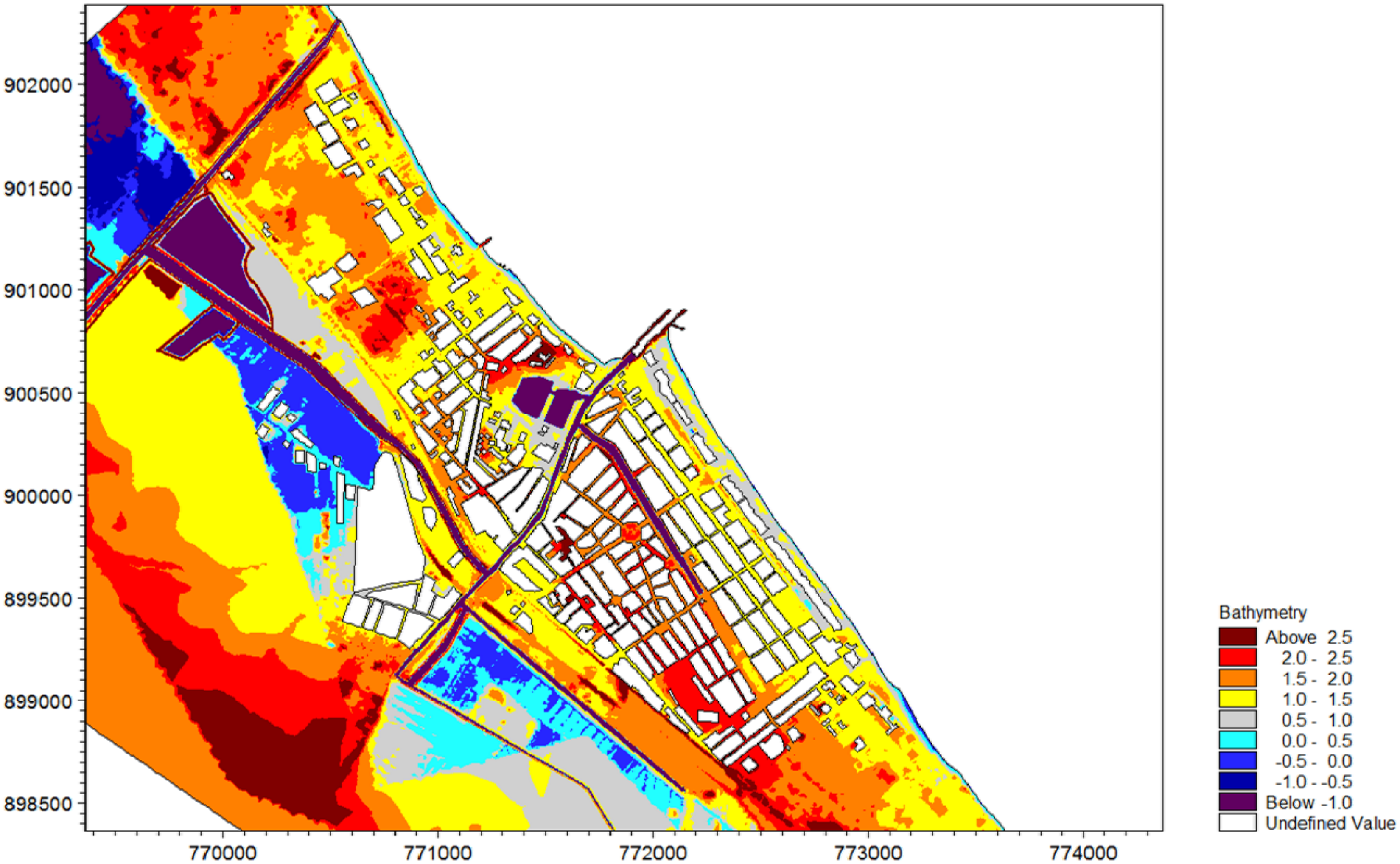
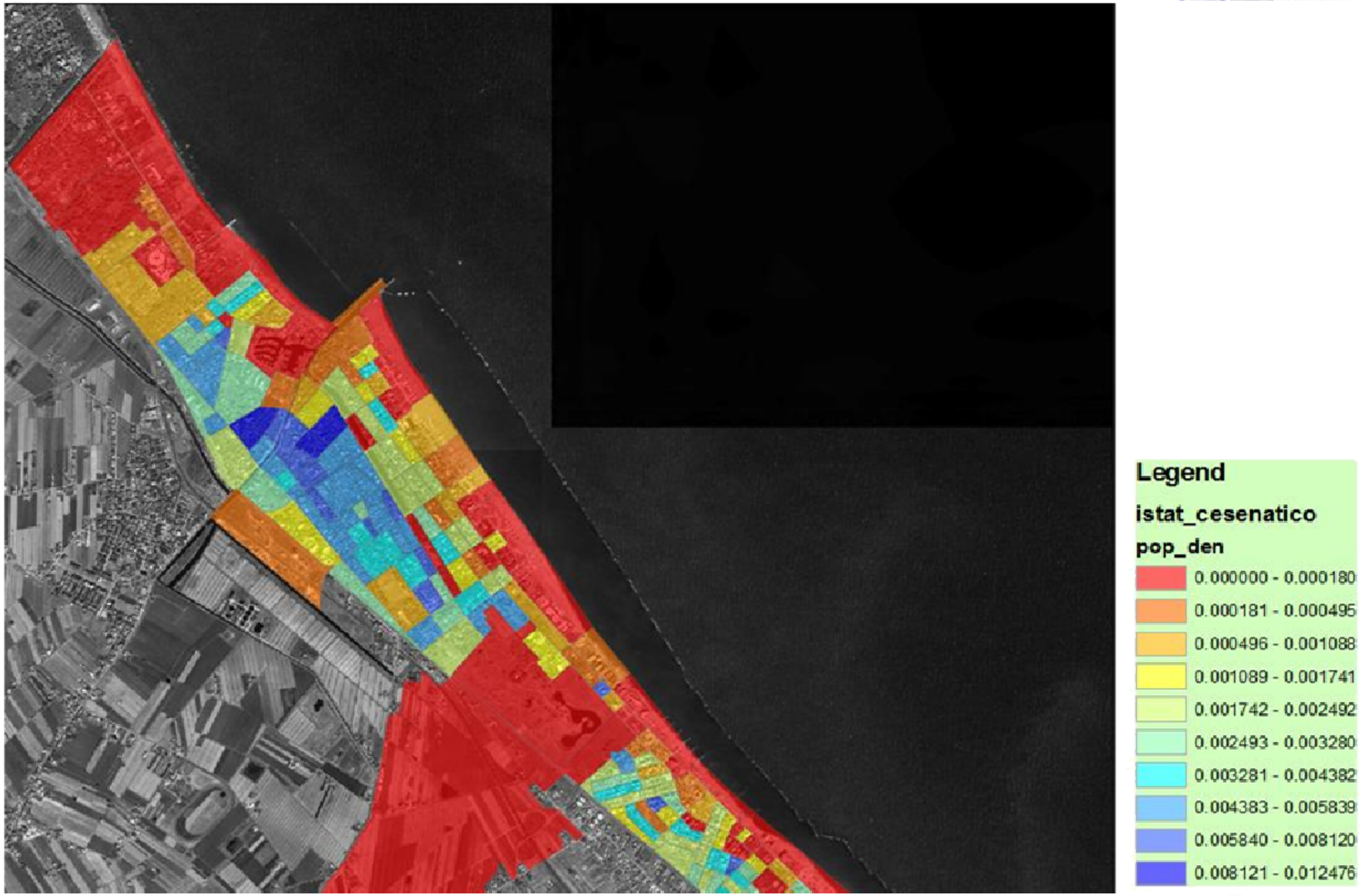
Bottom elevation





Population density



Sensitive Population Density

Cesenatico
Sensible Pop. Density
14>Age> 60

Legend

pop_sens_mq

- 0 - 0.0000001
- 0.000000101 - 0.001235269
- 0.001235269 - 0.001852904
- 0.001852904 - 0.002470538
- 0.002470538 - 0.003088173
- 0.003088173 - 0.003705808
- 0.003705808 - 0.004323442
- 0.004323442 - 0.004941077
- 0.004941077 - 0.005558711

0 195390 780 1,170 1,560
Meters

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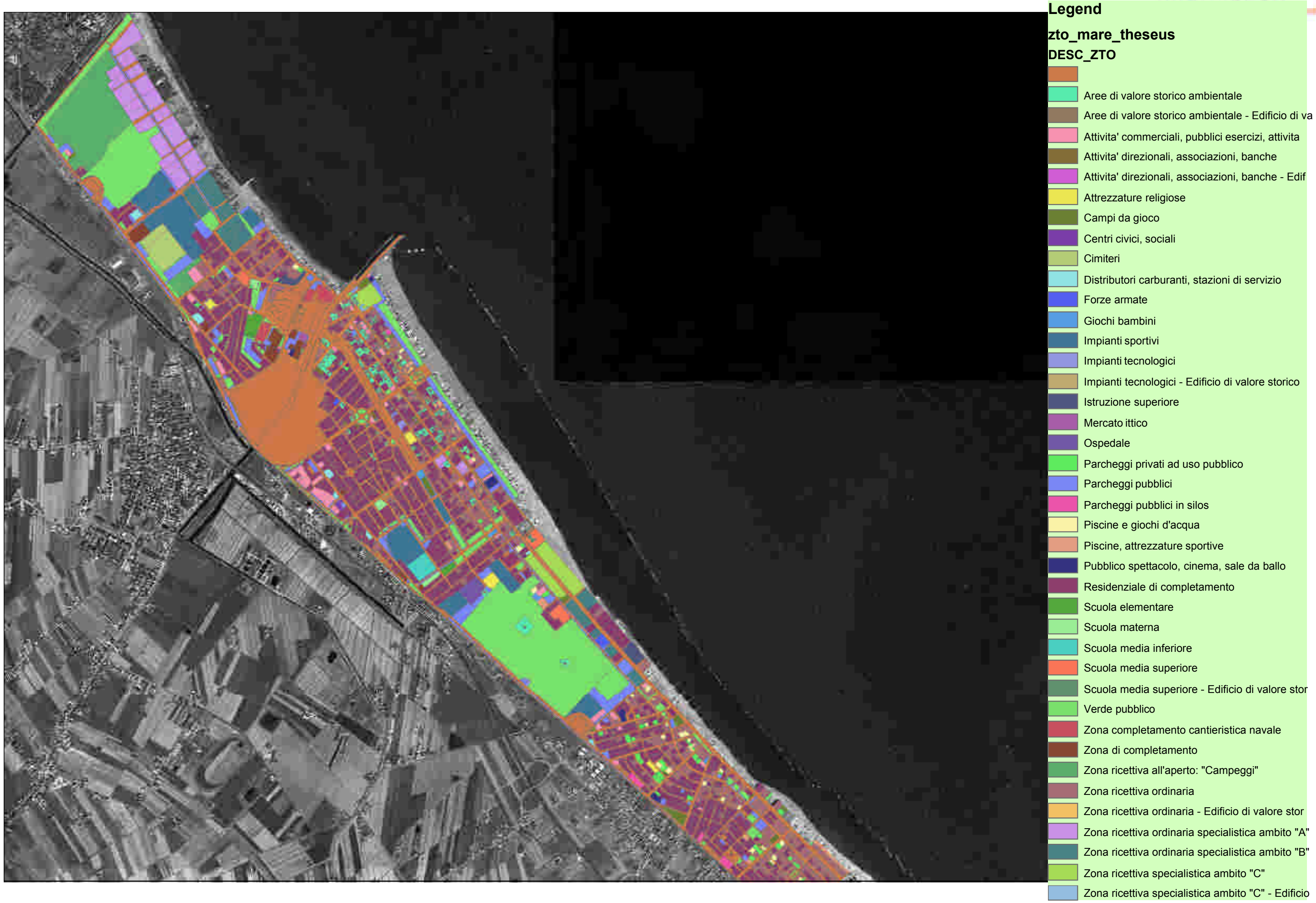
Land use



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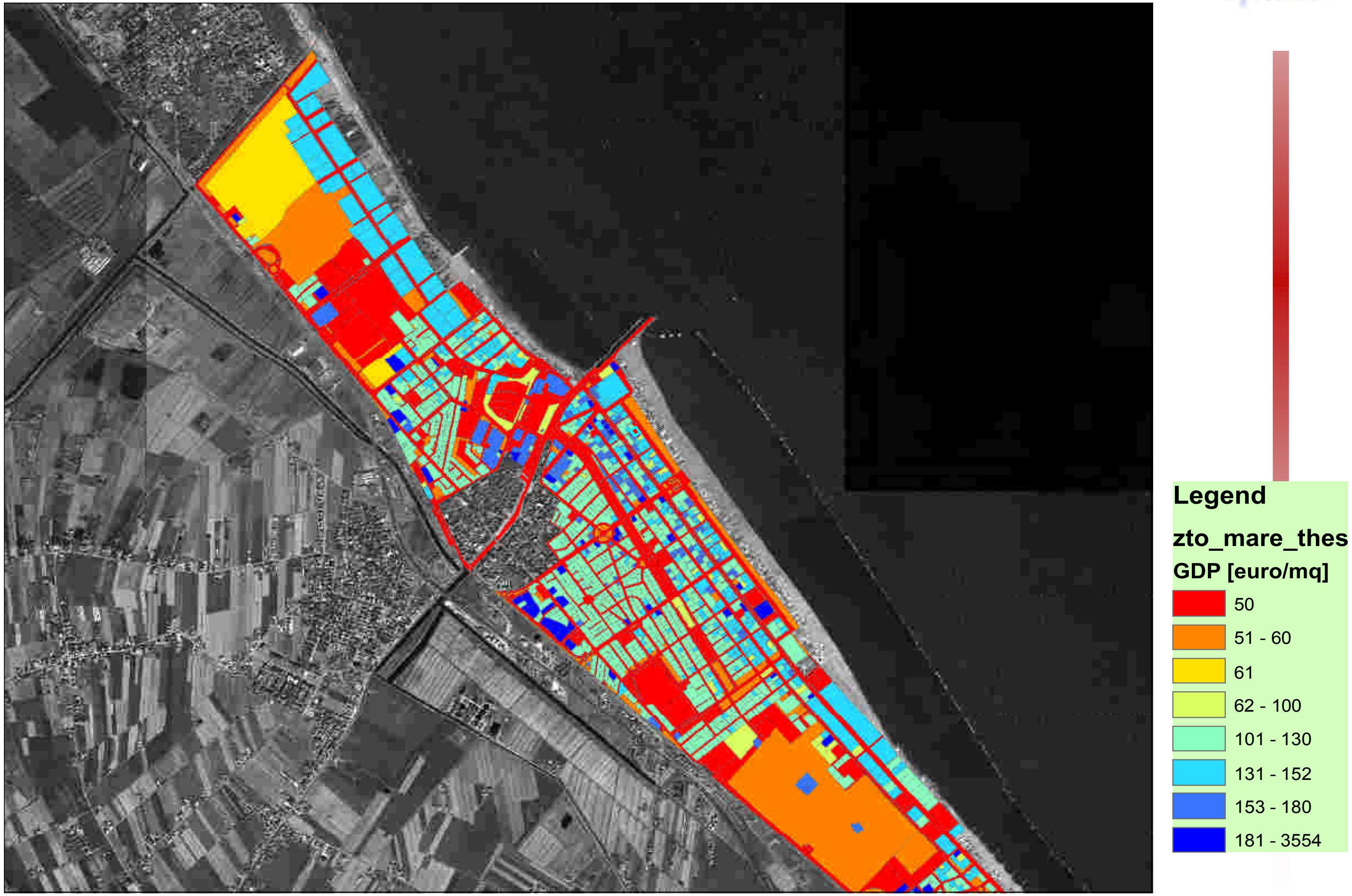
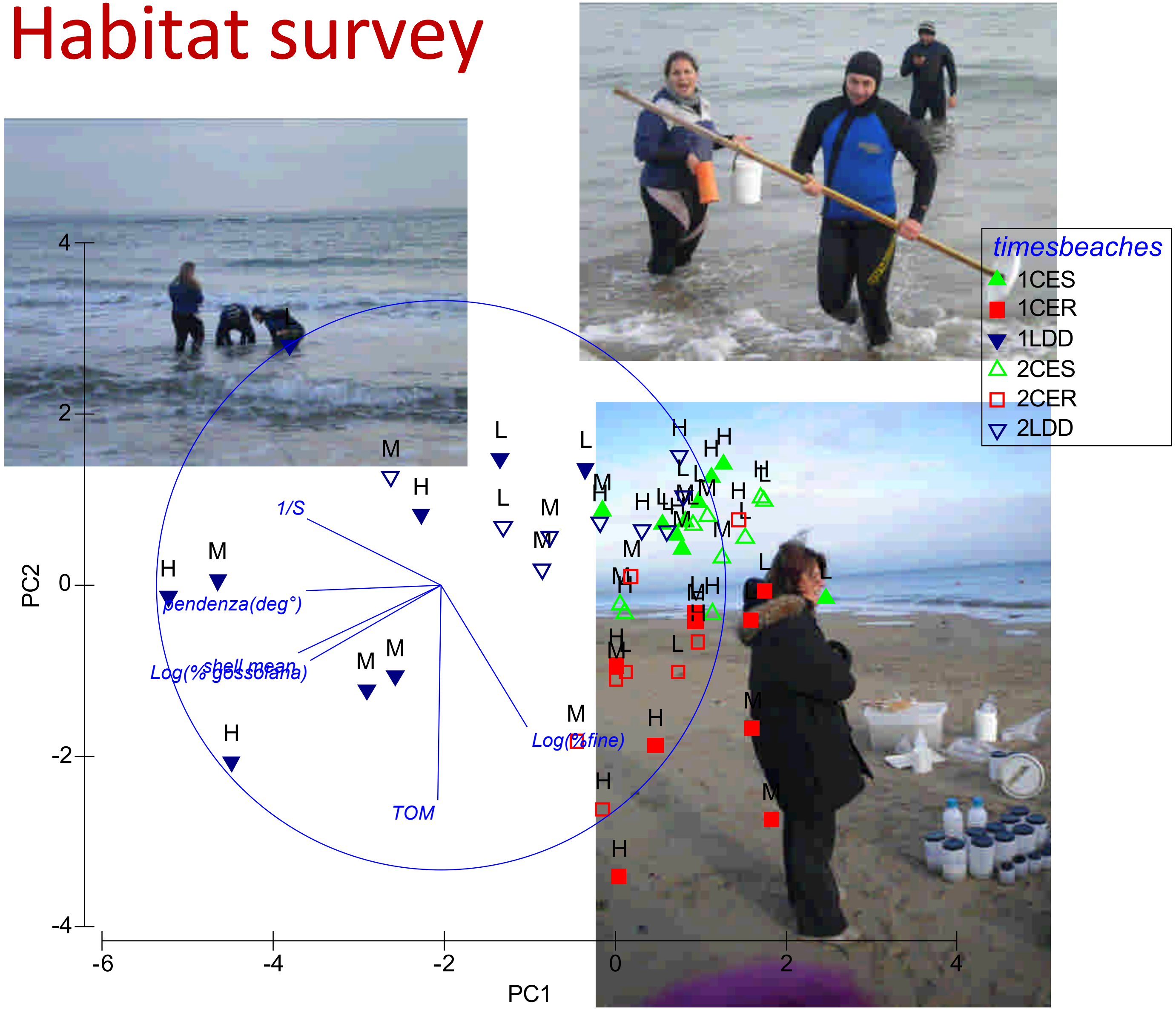
Spatial distribution of GDP



Habitat survey

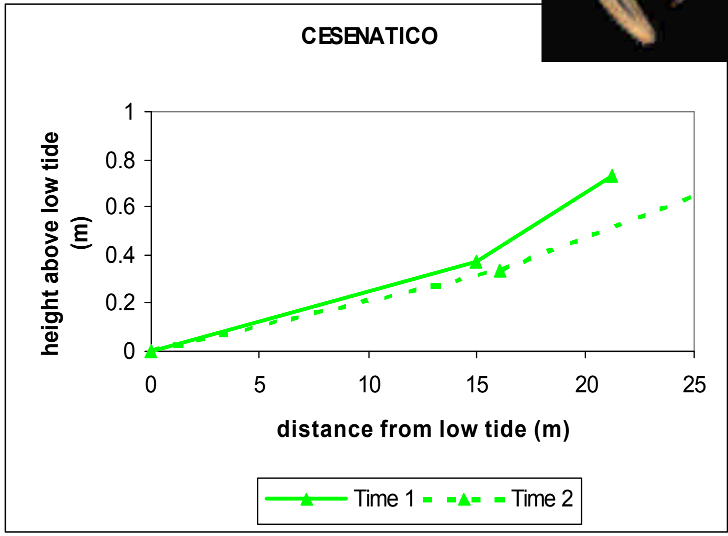




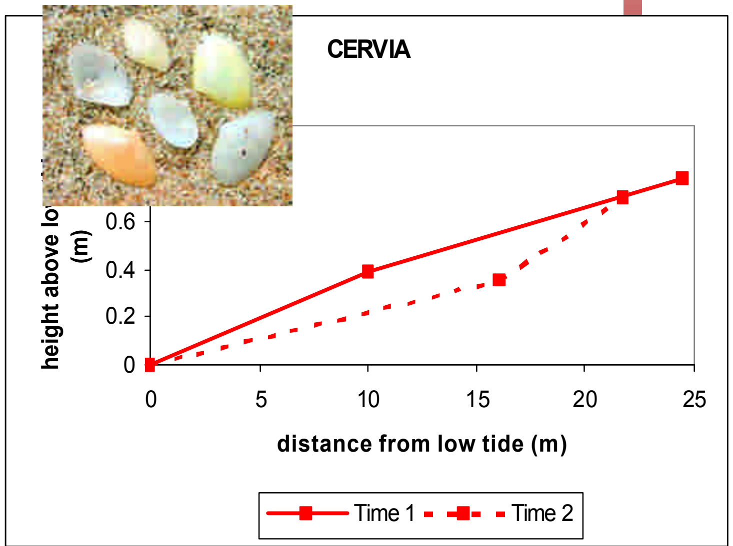


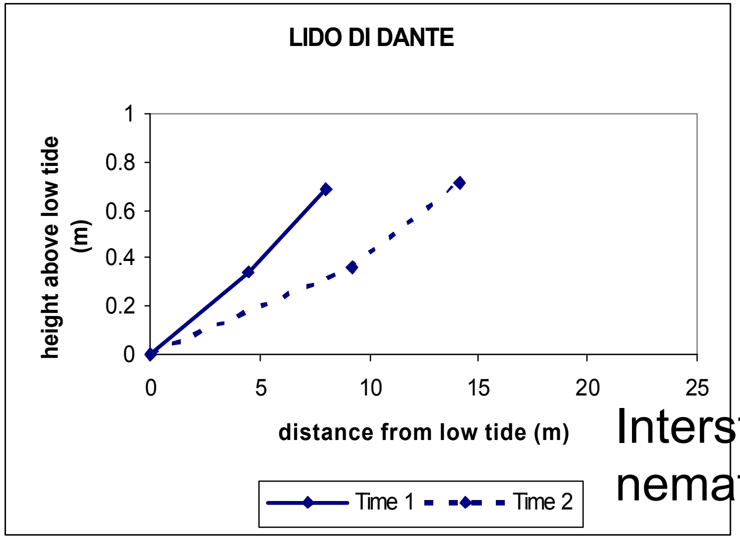
Habitat survey

Scolelepis squamata



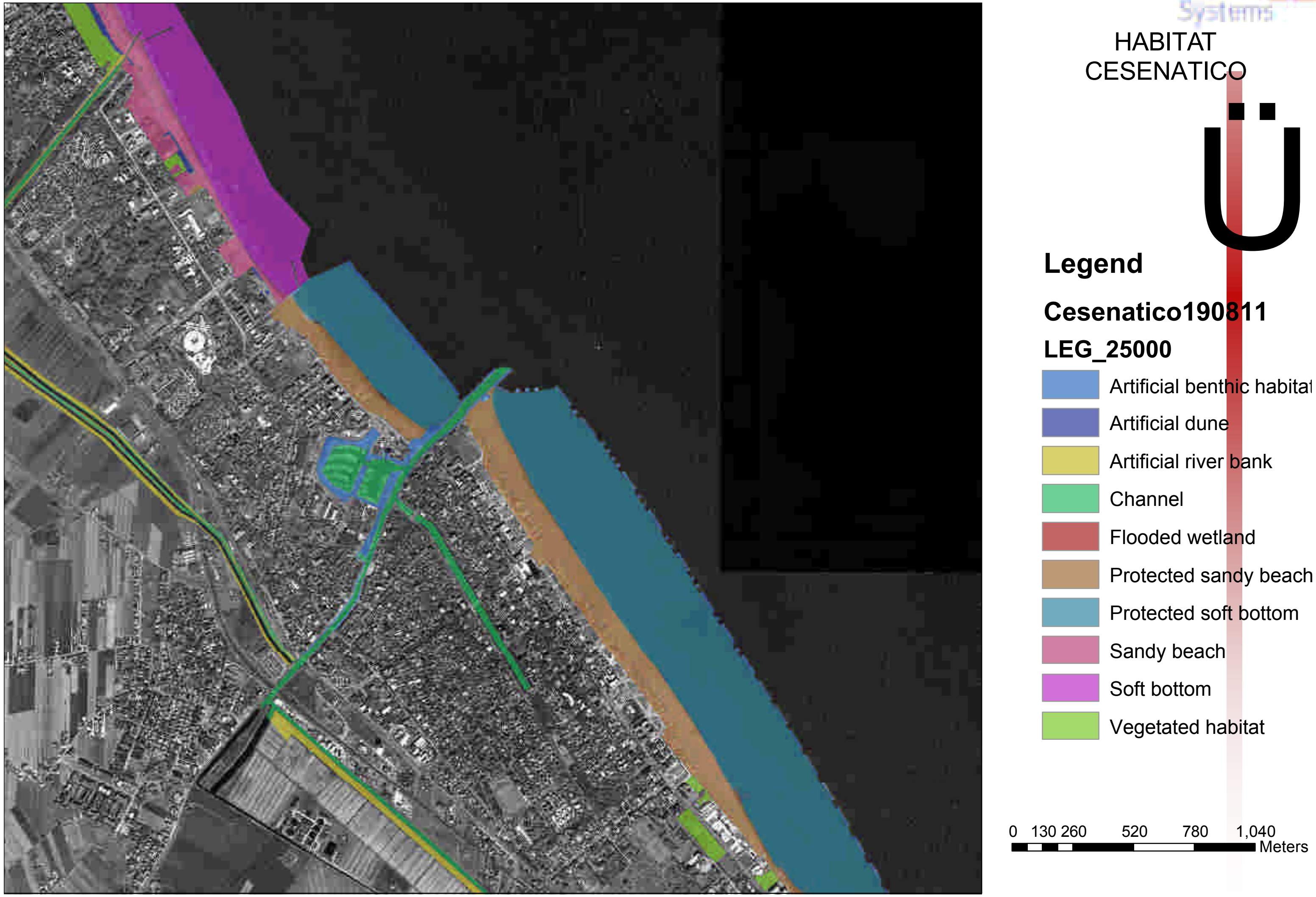
Huge abundance of *Lentidium mediterraneum*



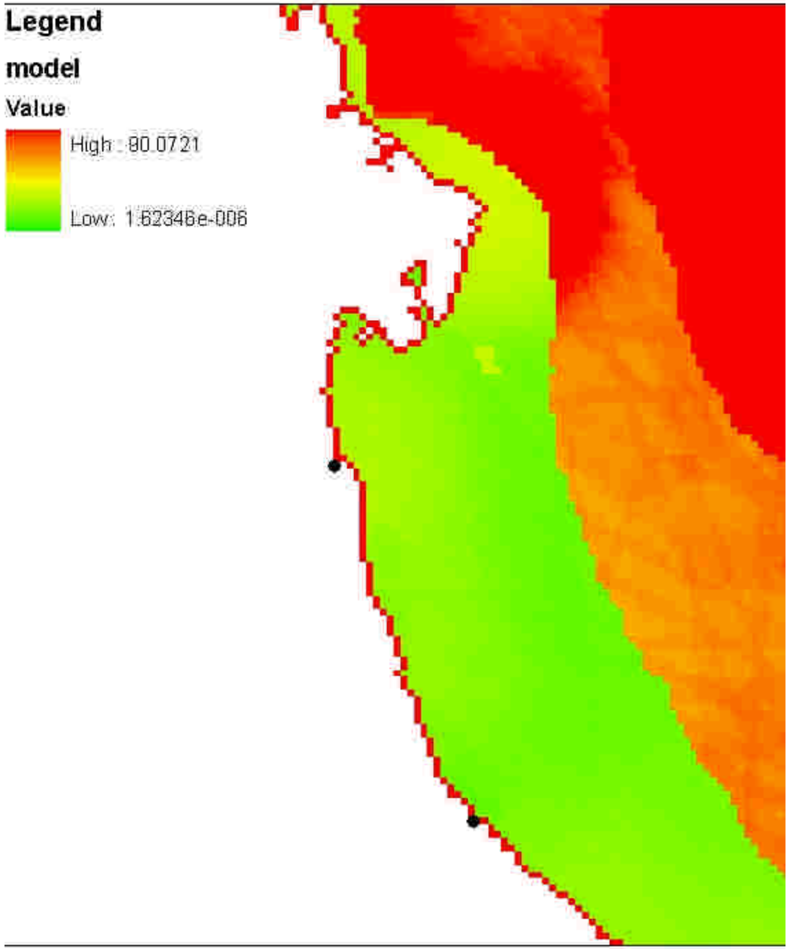


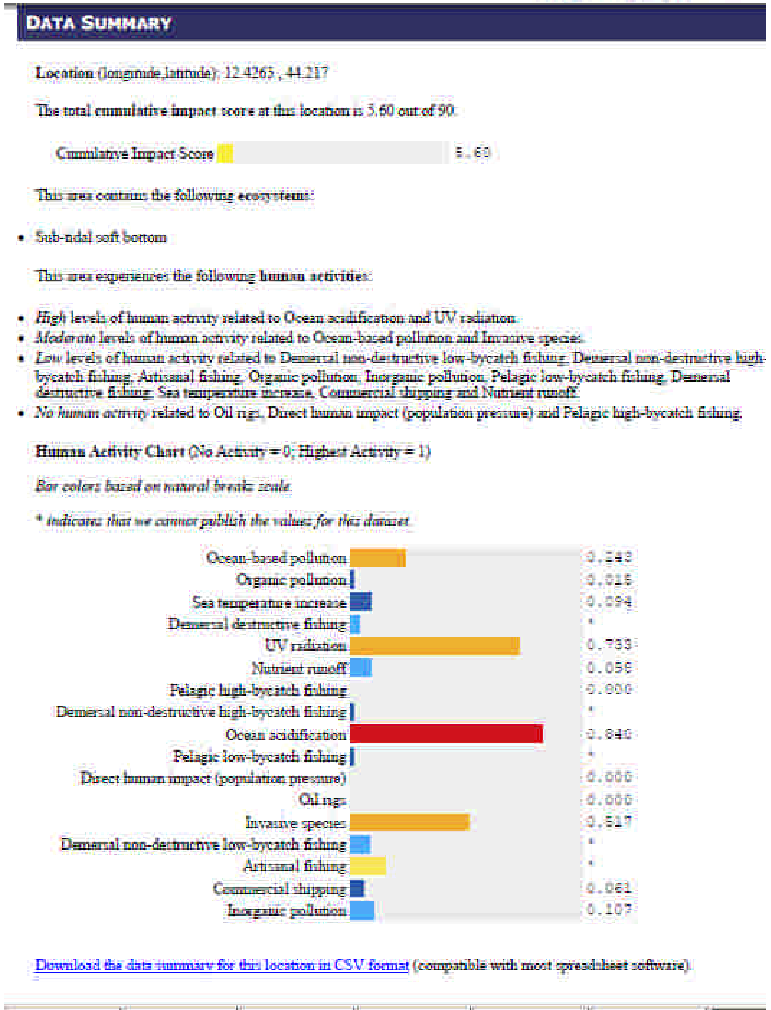
Interstitial organisms: big nematodes and turbellaria

Habitats


HABITAT
CESENATICO
Legend
Cesenatico190811
LEG_25000
Artificial benthic habitat
Artificial dune
Artificial river bank
Channel
Flooded wetland
Protected sandy beach
Protected soft bottom
Sandy beach
Soft bottom
Vegetated habitat
0 130 260 520 780 1,040
Meters

ArcGis map of other potentially relevant stressors





DATA SUMMARY

Location (longitude,latitude): 12.4263 , 44.217

The total **cumulative impact** score at this location is 5.60 out of 90.

Cumulative Impact Score 5.60

This area contains the following **ecosystems**:

- Sub-tidal soft bottom

This area experiences the following **human activities**:

- *High* levels of human activity related to Ocean acidification and UV radiation.
- *Moderate* levels of human activity related to Ocean-based pollution and Invasive species.
- *Low* levels of human activity related to Demersal non-destructive low-bycatch fishing, Demersal non-destructive high-bycatch fishing, Artisanal fishing, Organic pollution, Inorganic pollution, Pelagic low-bycatch fishing, Demersal destructive fishing, Sea temperature increase, Commercial shipping and Nutrient runoff.
- *No human activity* related to Oil rigs, Direct human impact (population pressure) and Pelagic high-bycatch fishing.

Human Activity Chart (No Activity = 0; Highest Activity = 1)

Bar colors based on natural breaks scale.

* *indicates that we cannot publish the values for this dataset.*

Ocean-based pollution	0.243
Organic pollution	0.015
Sea temperature increase	0.094
Demersal destructive fishing	*
UV radiation	0.733
Nutrient runoff	0.056
Pelagic high-bycatch fishing	0.000
Demersal non-destructive high-bycatch fishing	*
Ocean acidification	0.840
Pelagic low-bycatch fishing	*
Direct human impact (population pressure)	0.000
Oil rigs	0.000
Invasive species	0.517
Demersal non-destructive low-bycatch fishing	*
Artisanal fishing	*
Commercial shipping	0.061
Inorganic pollution	0.107

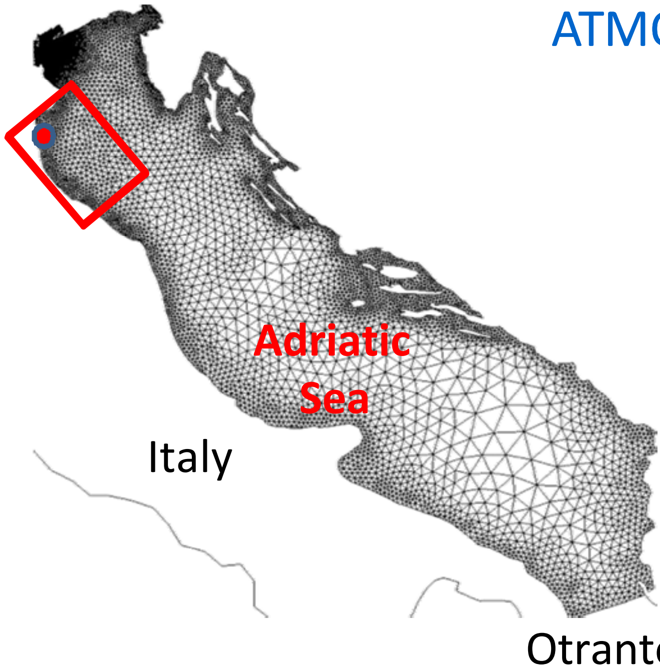
Download the data summary for this location in CSV format (compatible with most spreadsheet software).

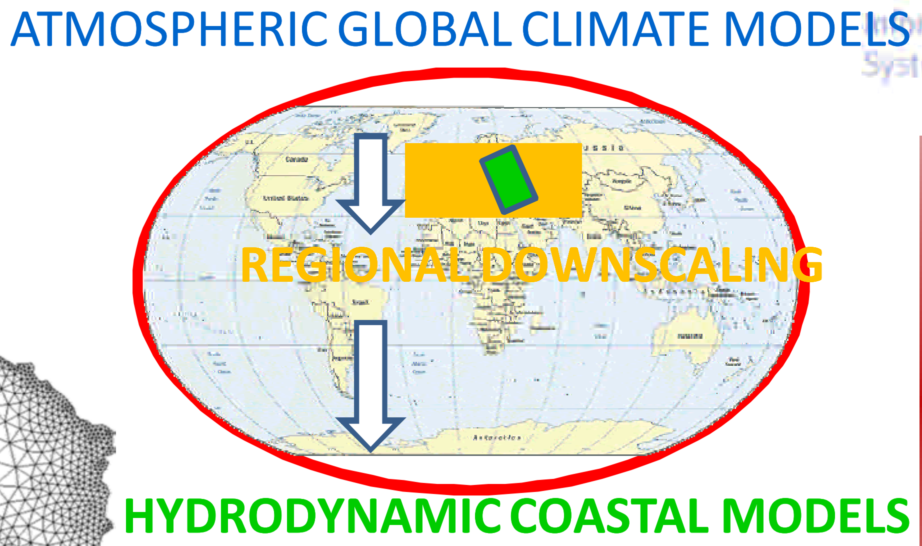
http://globalmarine.nceas.ucsb.edu

SOURCE MODULE

- Database of pre-cooked climate scenarios
  - for flooding purposes: pdf functions
    - Storm Surge including tide
    - Waves statistics
  - For erosion scenarios:
    - Representative typical annual wave climate
    - Time series
- User can interact with Flooding scenario by selecting the time horizon
- GUI: the user play with a time slider defining the time scenario and extracting climate/wave parameters
- The data selected in this module are used as input for Flooding and Erosion model

Sources: storm surge, waves

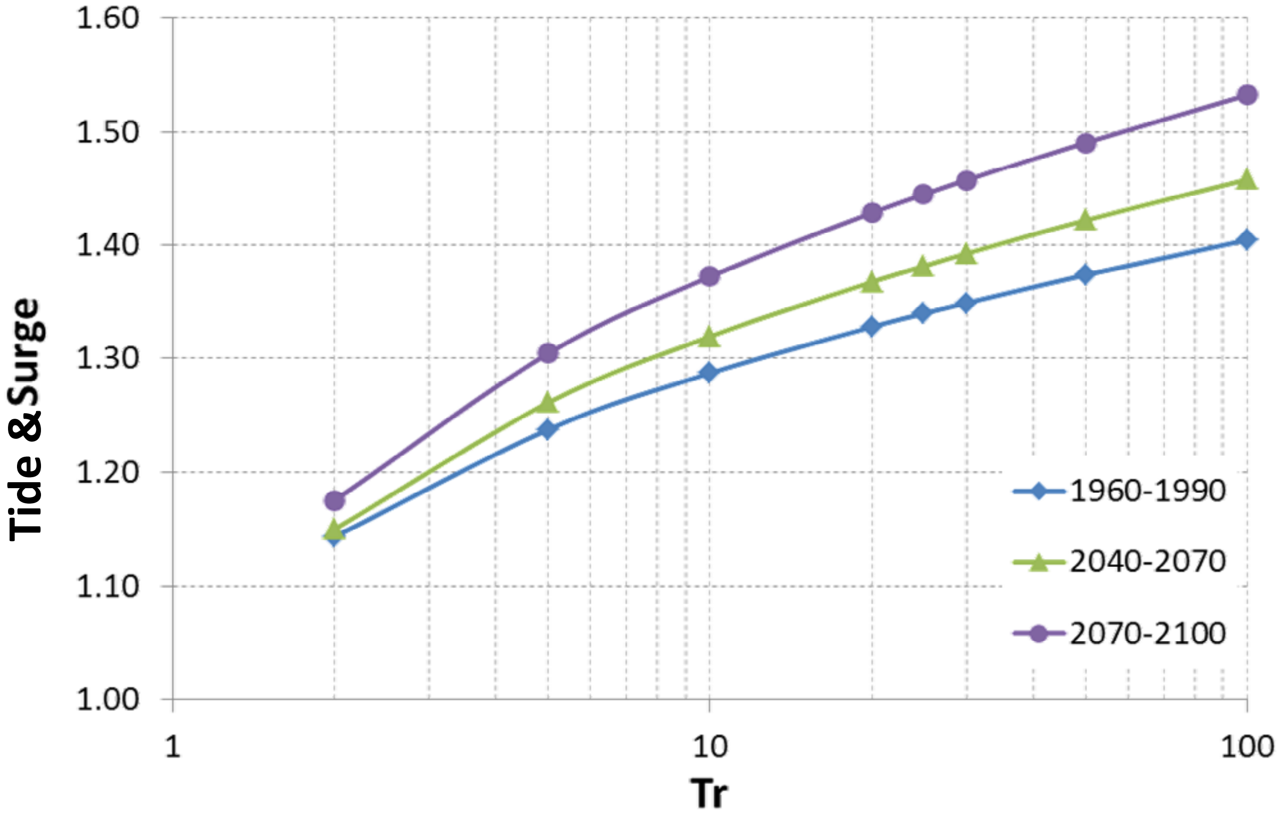




- 3D model SHYFEM coupled with spectral wave model WWM
- Climate model downscaling S18E5 is introduced.
- Regional downscaling atmospheric dataset, produced by DWD, provided by HZG
- Control period 1960-1990 and tA1B IPCC scenario (2010-2100).

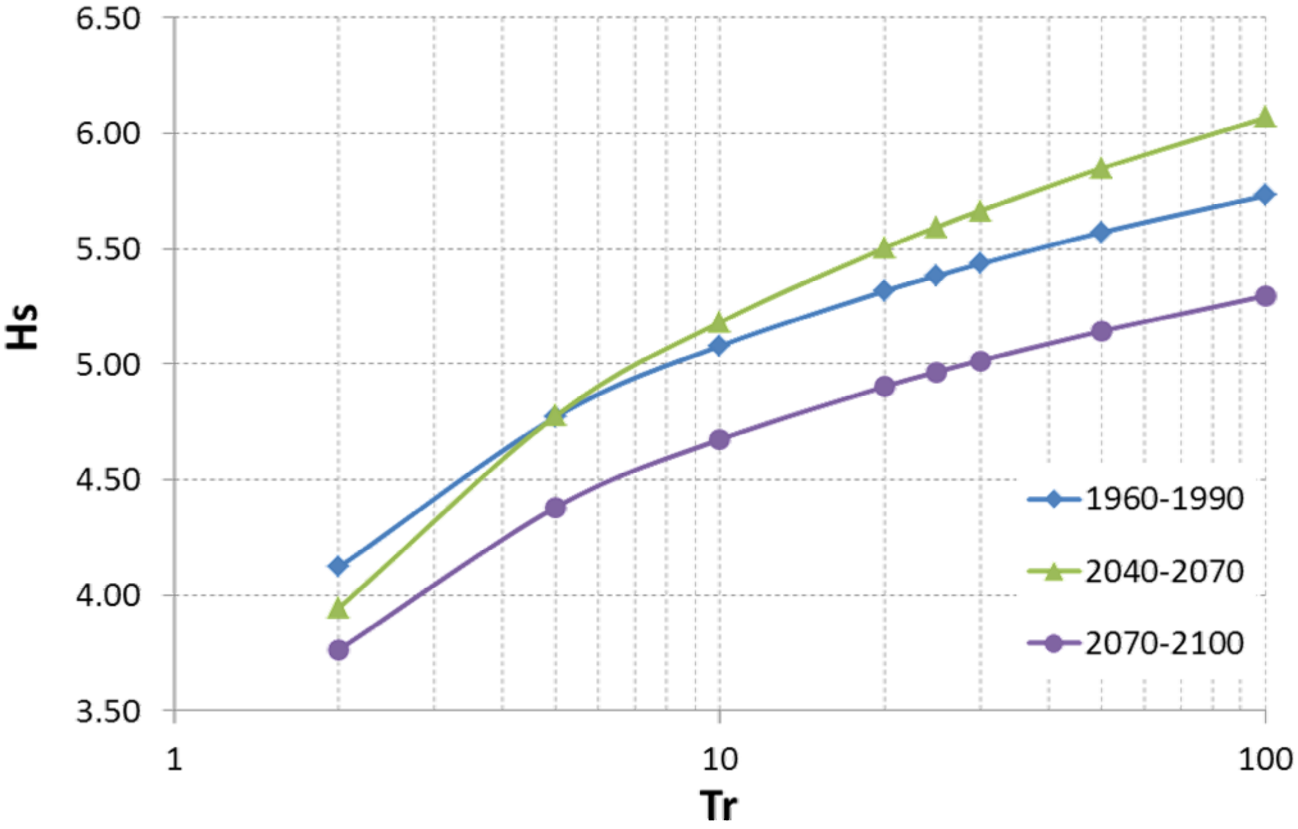
Sources: storm surge, waves

- Flooding scenarios

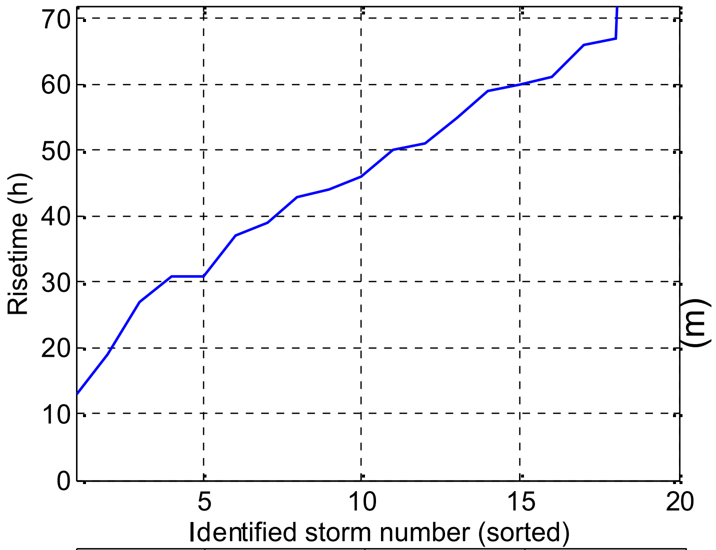


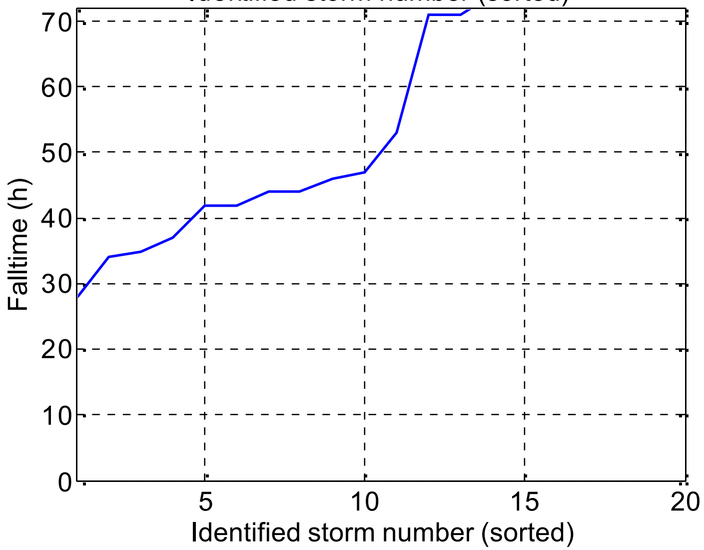
Sources: storm surge, waves

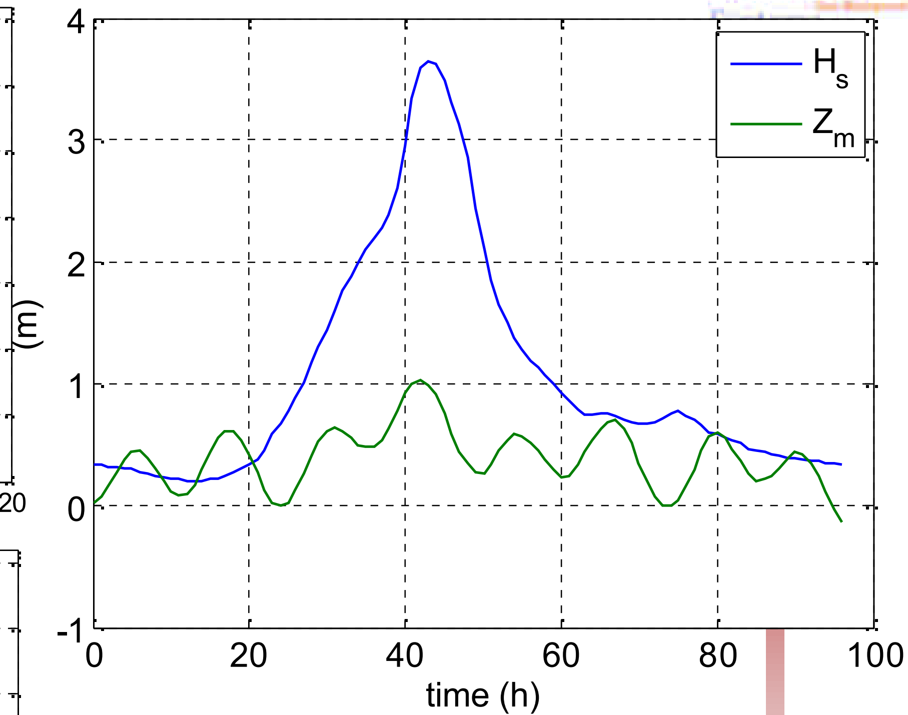
- Flooding scenarios



Flooding scenarios







- Peak storm duration: 12 hours

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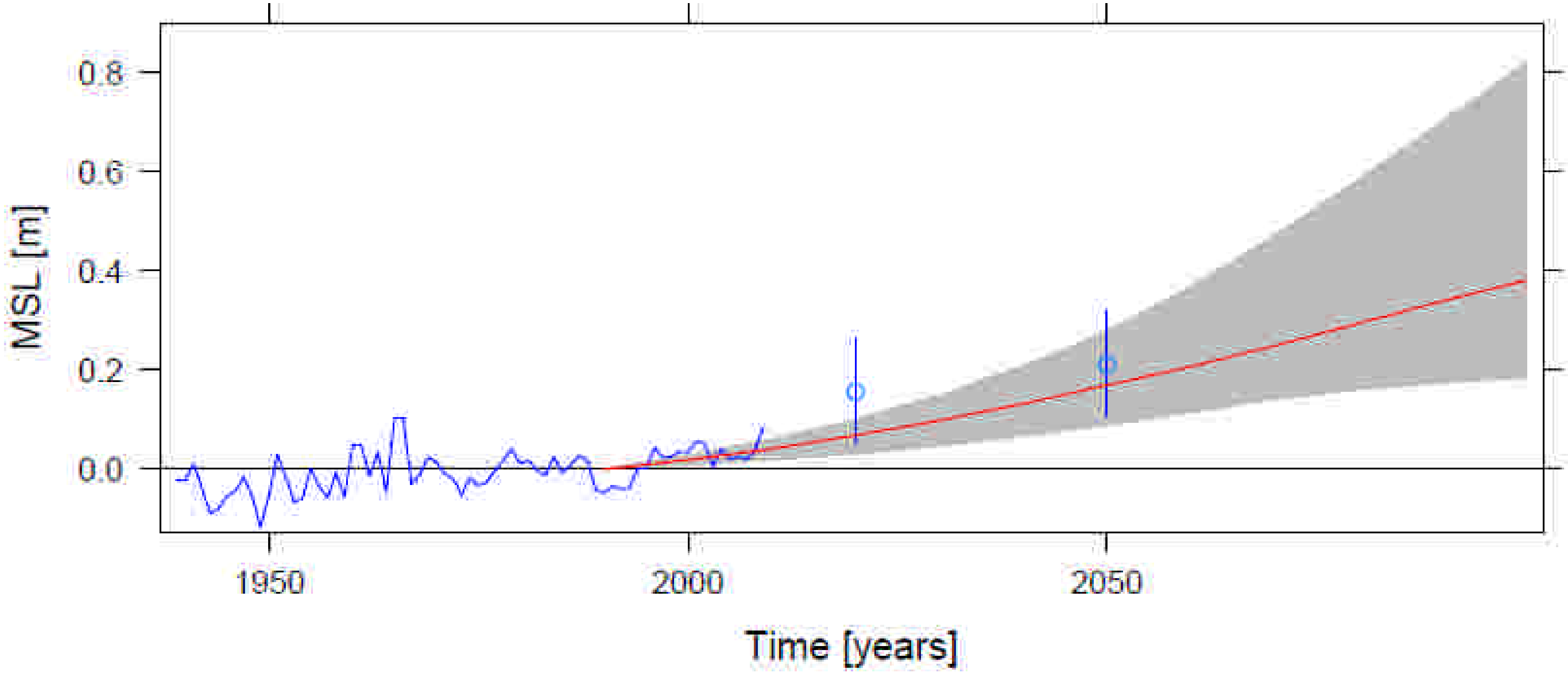
Climate change and MSL



DRIVERS MODULE - DSS GUI

- DataBase with subsidence and climate change trend
- The user can define a specific DRIVER scenario interacting through a GUI and selecting the climate change and subsidence characteristics
- The user can modify the pre-loaded climate change and subsidence trend
- GUI: a window with a curve tool (time vs subsidence/climate change)
- Raster GIS based procedure to obtain the new DTM considering the subsidence trend

Subsidence

Model for subsidence
Inclusion of this model to update the dtm

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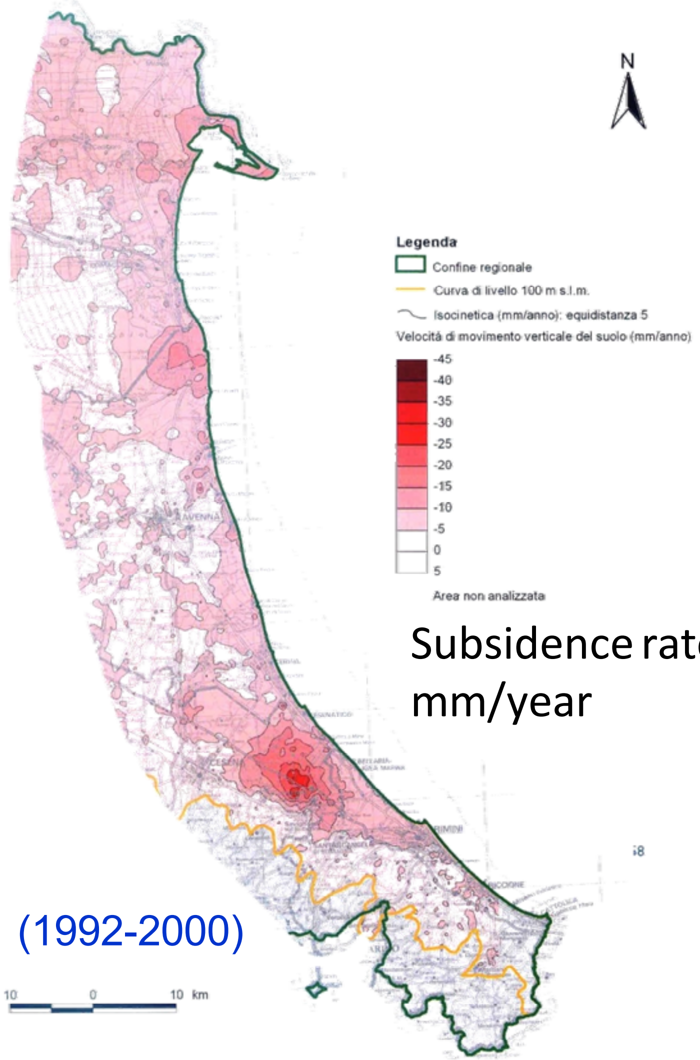
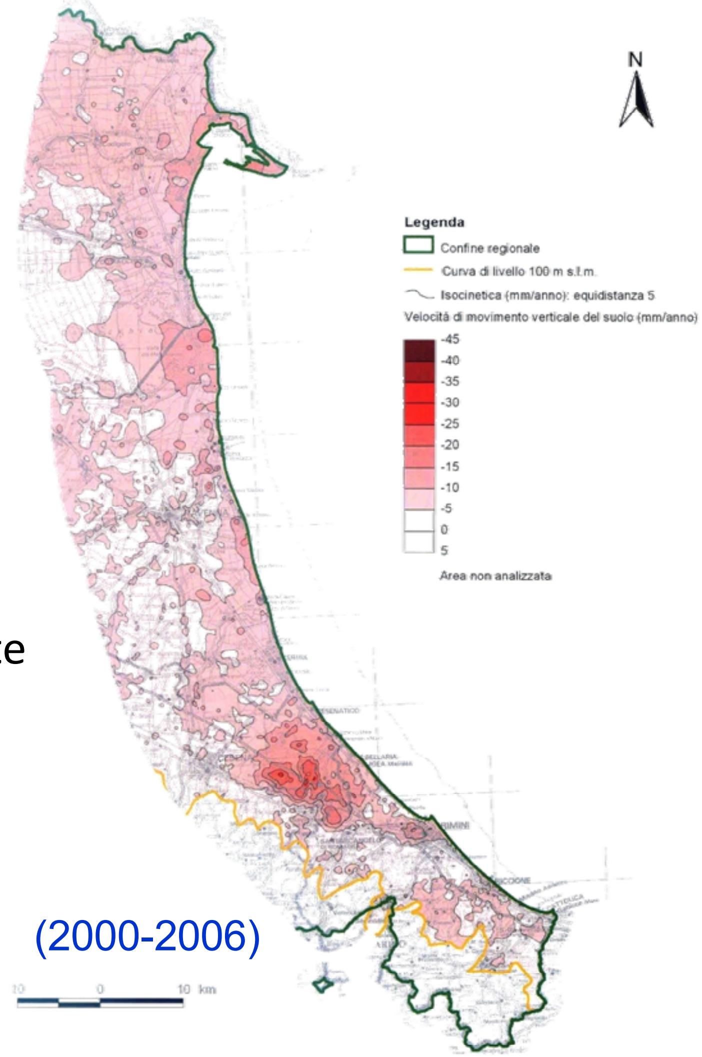


(1992-2000)

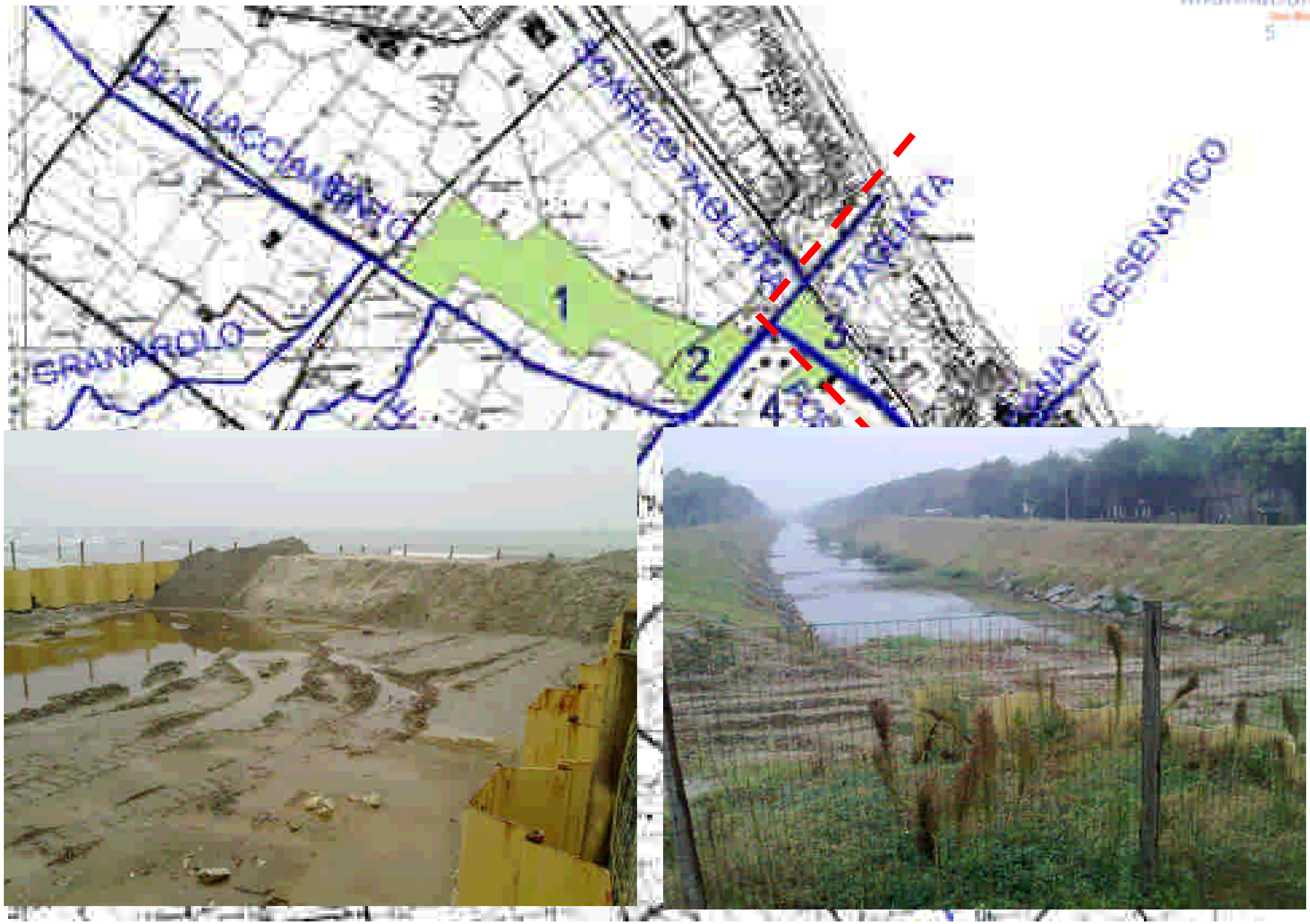
Subsidence rate mm/year



(2000-2006)

Existing management

Existing management



Pathway Module

- Sea Level and Wave Wave Propagation Models
  - Wave transmission – Matlab/Python Script
- Overtopping Models
  - Artificial Neural Model for overtopping (Verhaeghe 2008)
- Storm Surge Flooding Models
  - Pre-cooked run of numerical model
    - MIKE 21
  - GIS Based Mathematical models
    - LISFLOOD
    - Watershed segmentation flooding
- Erosion model
  - CERC Formula GIS Python Script
- **OUTPUT: Map of flooded area, water depth, velocities and duration**

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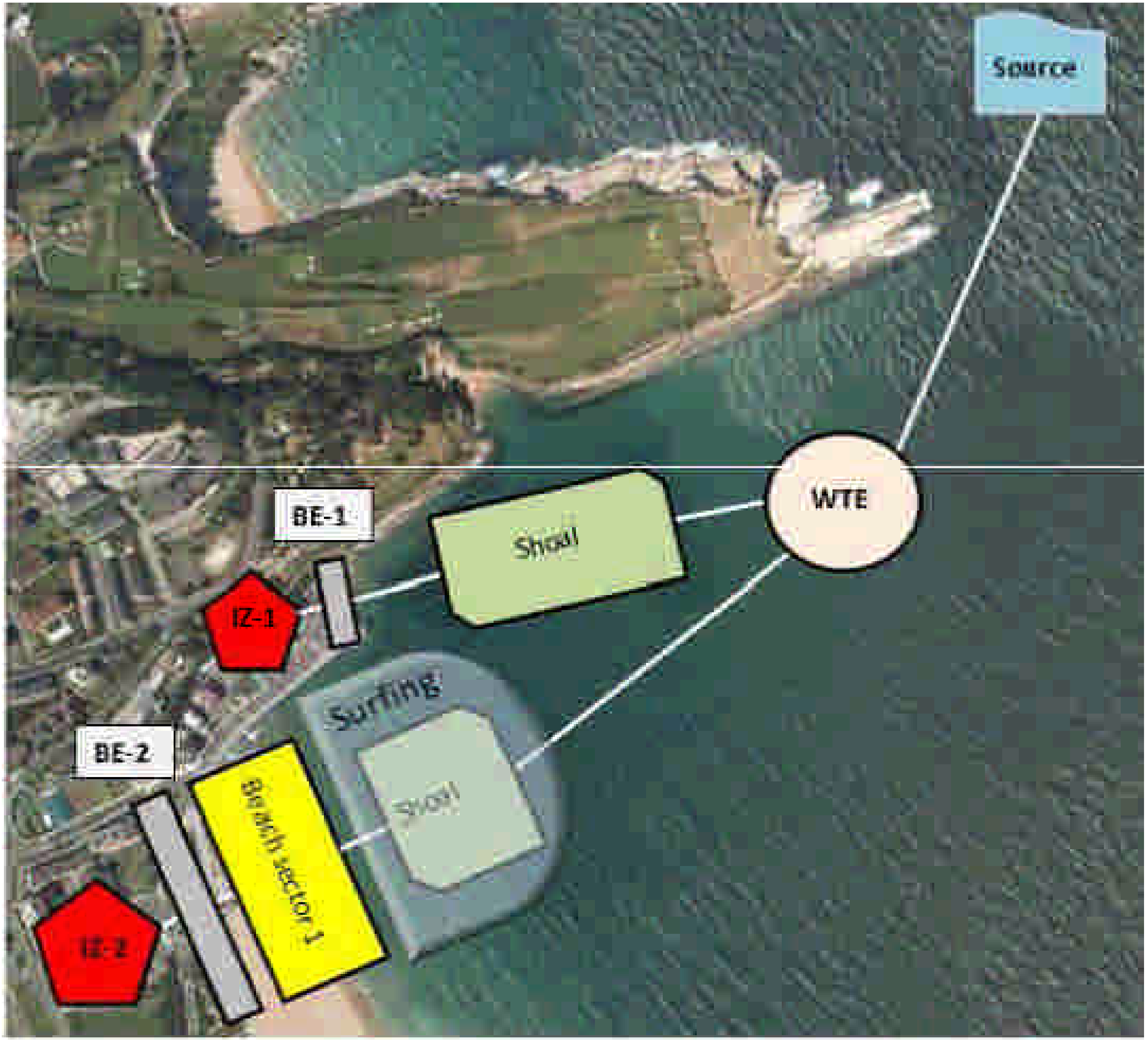
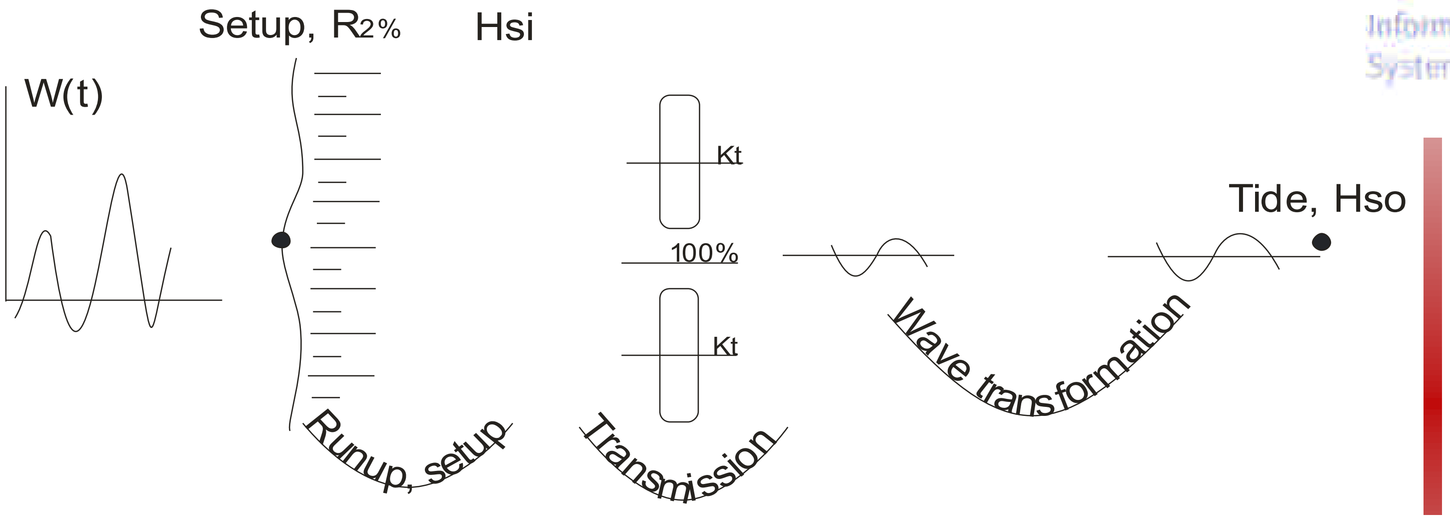
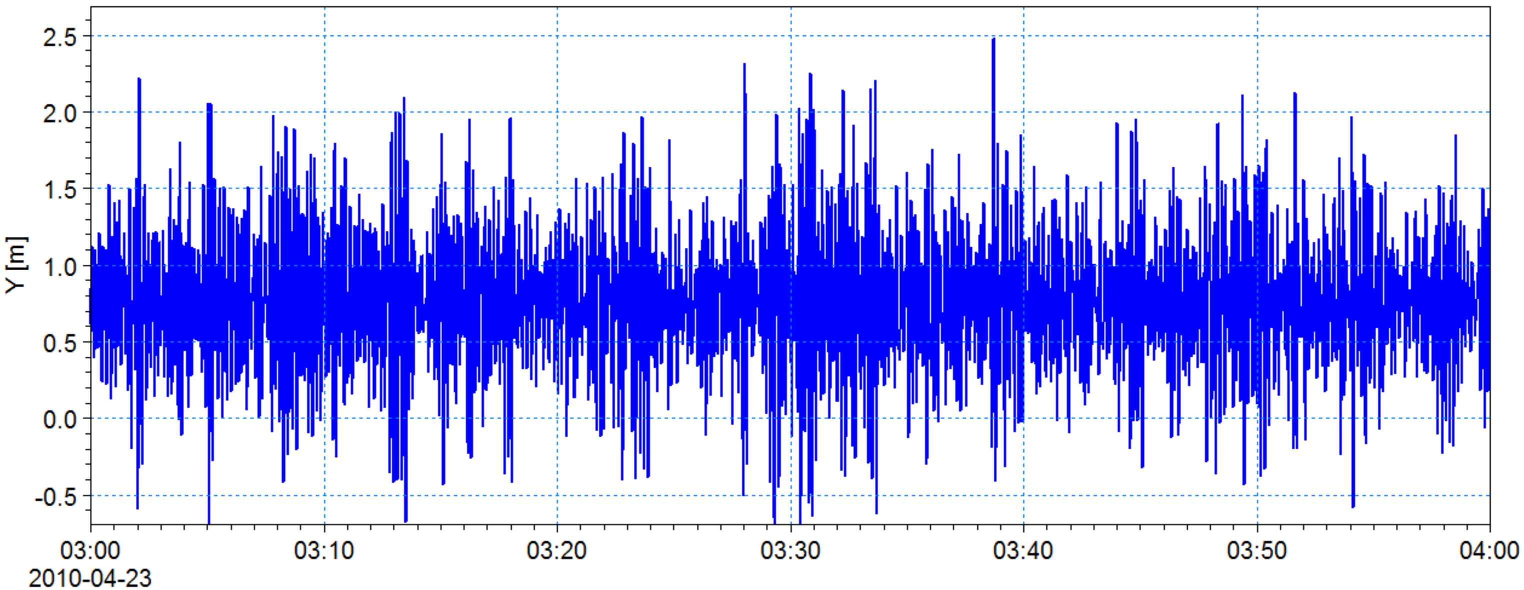
Sea Level and Wave Propagation



Shoreline boundary condition





GIS based Equilibrium Flood Mapping

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- Equilibrium flood mapping is based on a comparison of the maximum total water height and ground elevation; land lower than the maximum total water height is assumed to flood
  - Poulter, B., Halpin, P.N., 2008. Raster modelling of coastal flooding from sea-level rise. International Journal of Geographical Information Science 22 (2), 167–182.
  - I. Brown / Environmental Modelling & Software 21 (2006) 1479e1490
  - Bates, P.D., de Roo, A.P.J., 2000. A simple aster-based model for floodplain inundation. Journal of Hydrology 236, 54e77.
  - Impact of grid size in GIS based flood extent mapping using a 1D flow model M. G. F. Werner

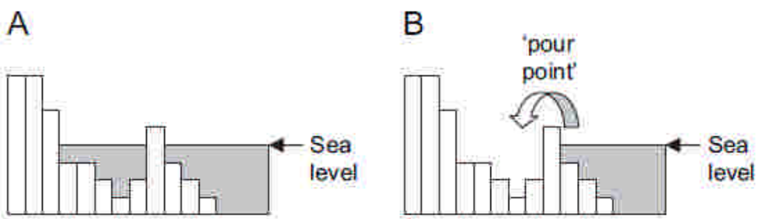
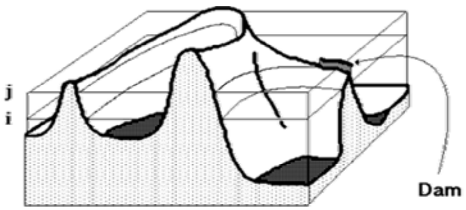
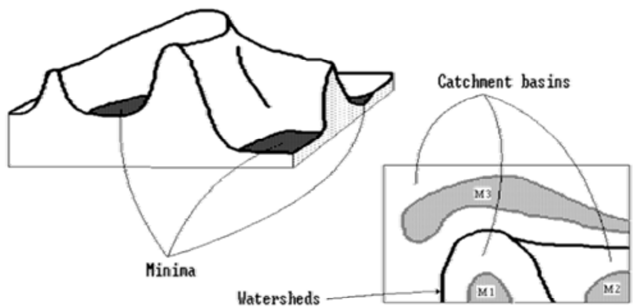


Fig. 2. GIS methods for estimating floodplain areas: (A) a simple contour-based method results in some low-lying coastal basins flooding despite the presence of an intervening barrier; (B) a more accurate hydrological method which recognises that these 'sink' features will only flood when the 'pour point' is reached.

Watershed Segmentation GIS model

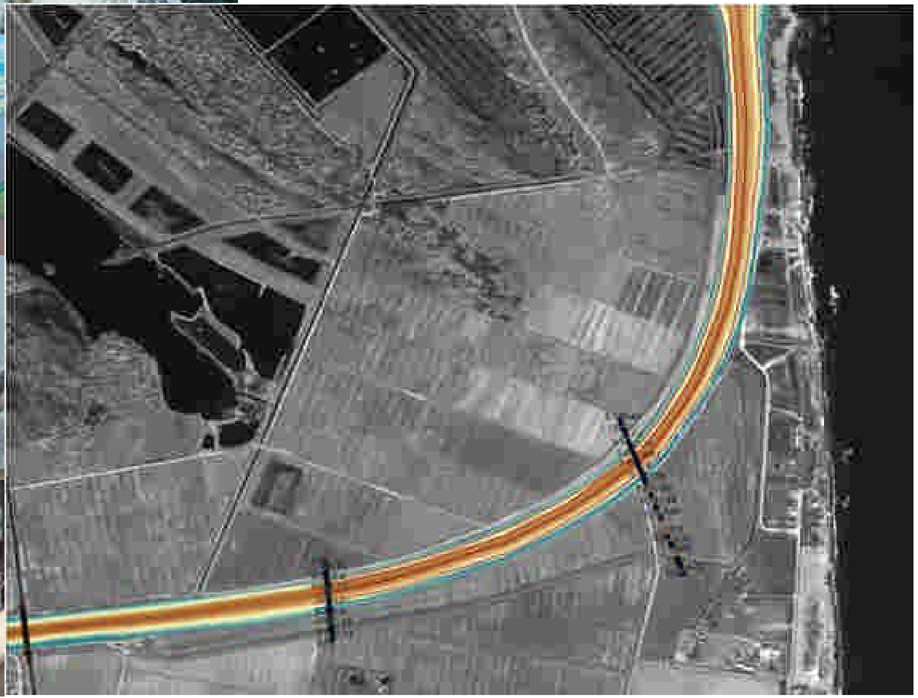
- marker controlled watershed segmentation algorithm operator (Meyer and Beucher, 1990; Soille and Ansoult, 1990)
  - CREDITS Nicolas BEUCHER (nicolas.beucher@ensta.org)
- The terrain model represented by a floating image is flooded preserving the hydraulic connectivity from a specific seed or source (usually the minima) defining a specific water level (storm surge)

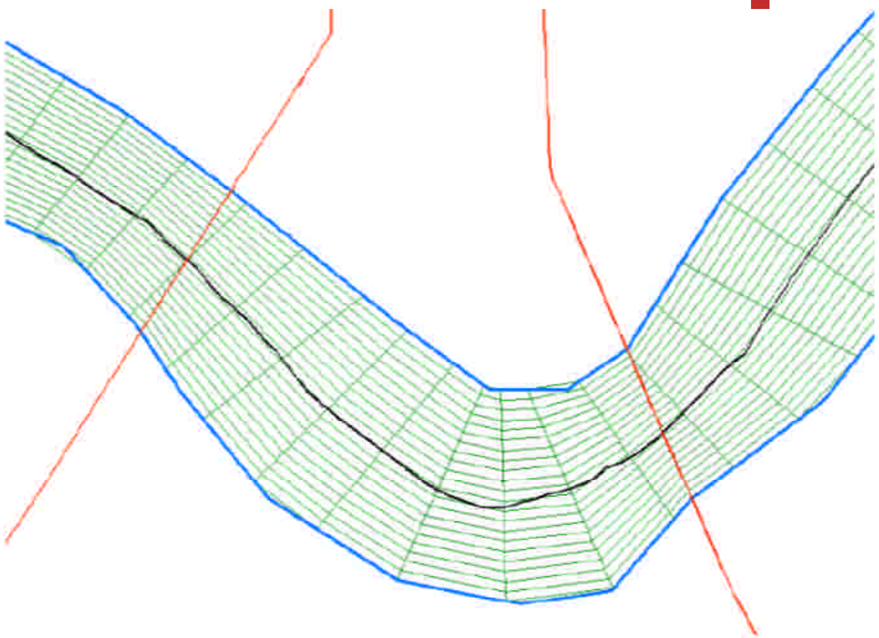




DTM pre-processing

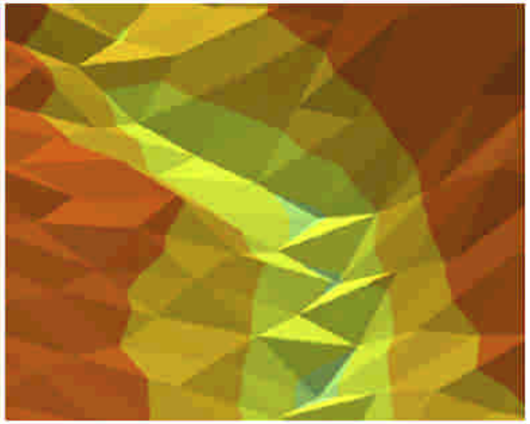
- Linear interpolation of river cross section and river bathymetry definition
- LIDAR no data in river bed
- Bank delineation





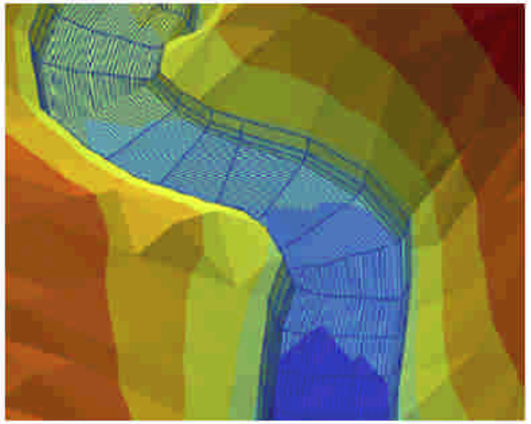
DTM pre-processing

a



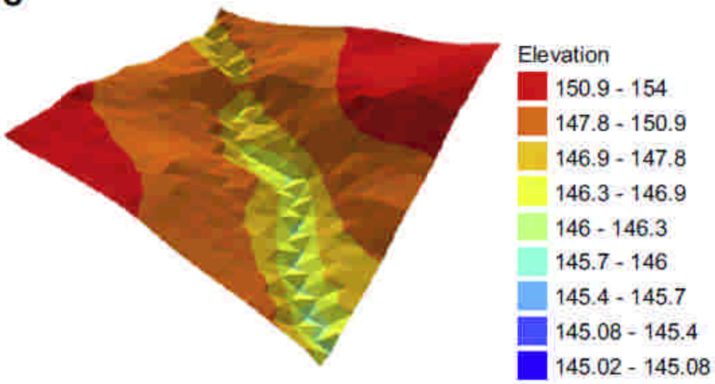
TIN created from LIDAR points results in artificial dams

b



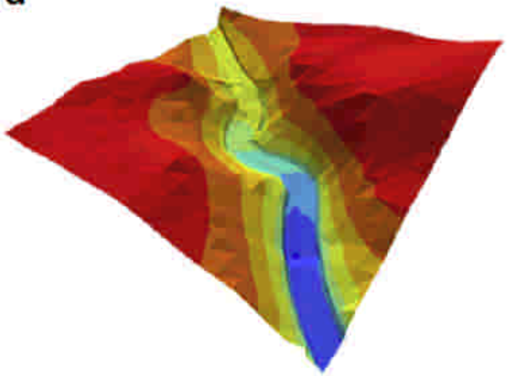
Integrated terrain (TIN) with mesh and LIDAR points

c

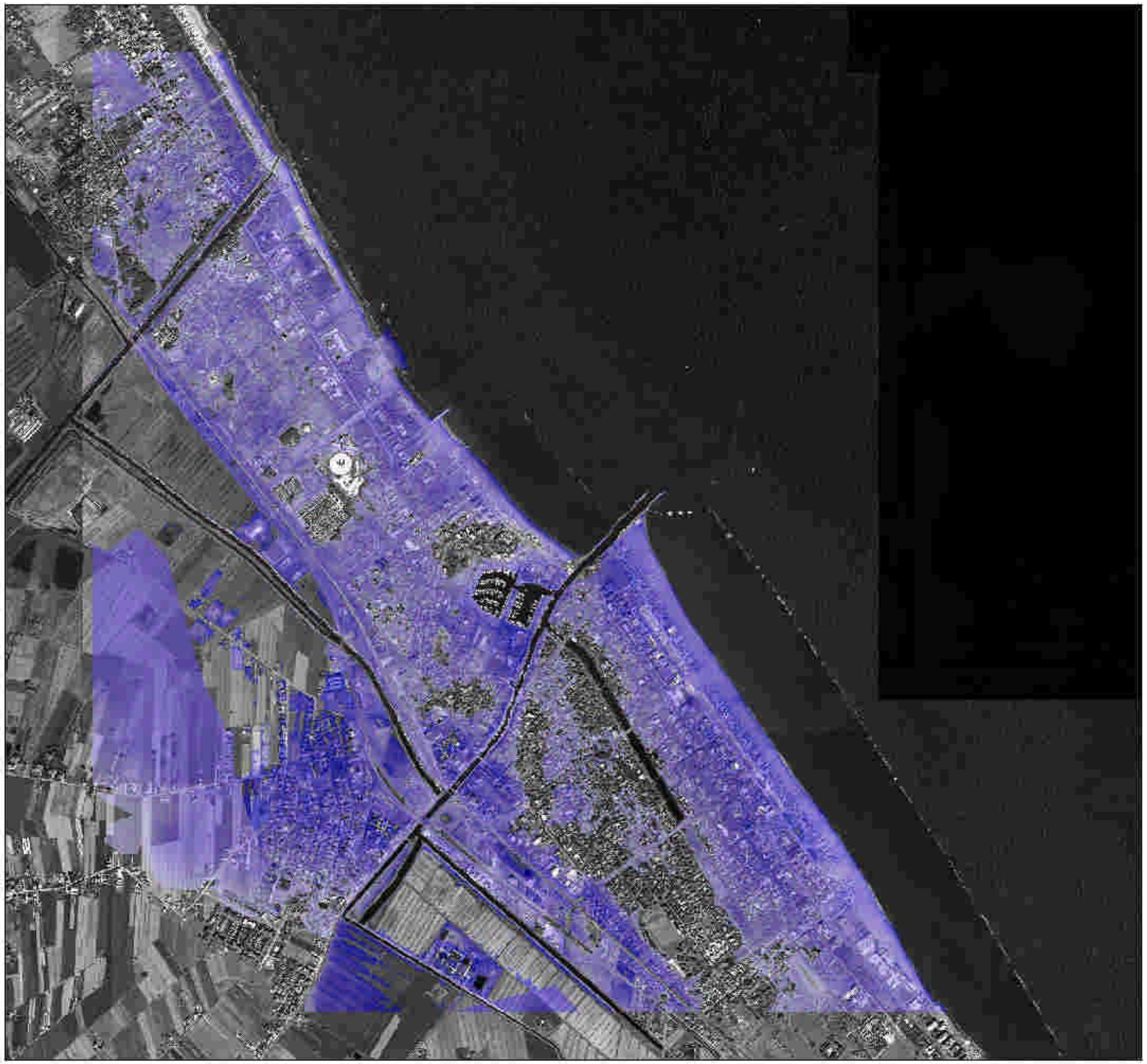


TIN created from LIDAR points

d



Integrated terrain (TIN) with mesh and LIDAR point



THESEUS WP1
Storm Surge Flooding
Return Time 50 Years
Year Scenario 2050
Cesenatico Study Site

Legend

Y_2050TR_50WLdtm4ws_cessub50.tif

Water Depth cm

- 0
- 1 - 10
- 11 - 20
- 21 - 30
- 31 - 40
- 41 - 50
- 51 - 60
- 61 - 70
- 71 - 80
- 81 - 90
- 91 - 100
- 101 - 110
- 111 - 120
- 121 - 130
- 131 - 160

N

0 187.5375 750 Kilometers

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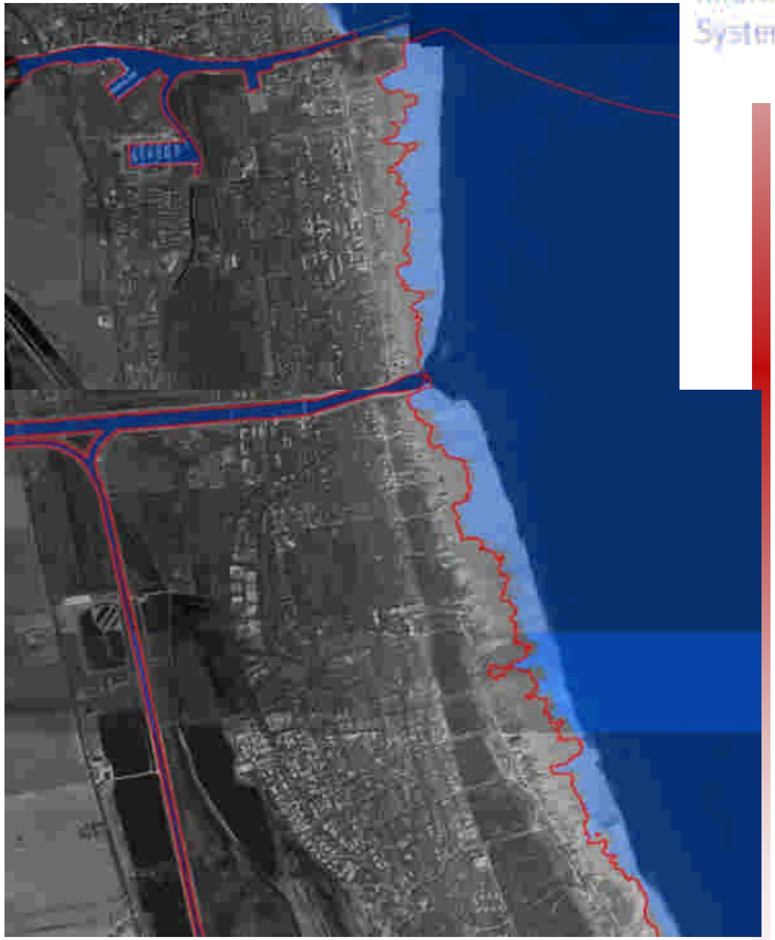
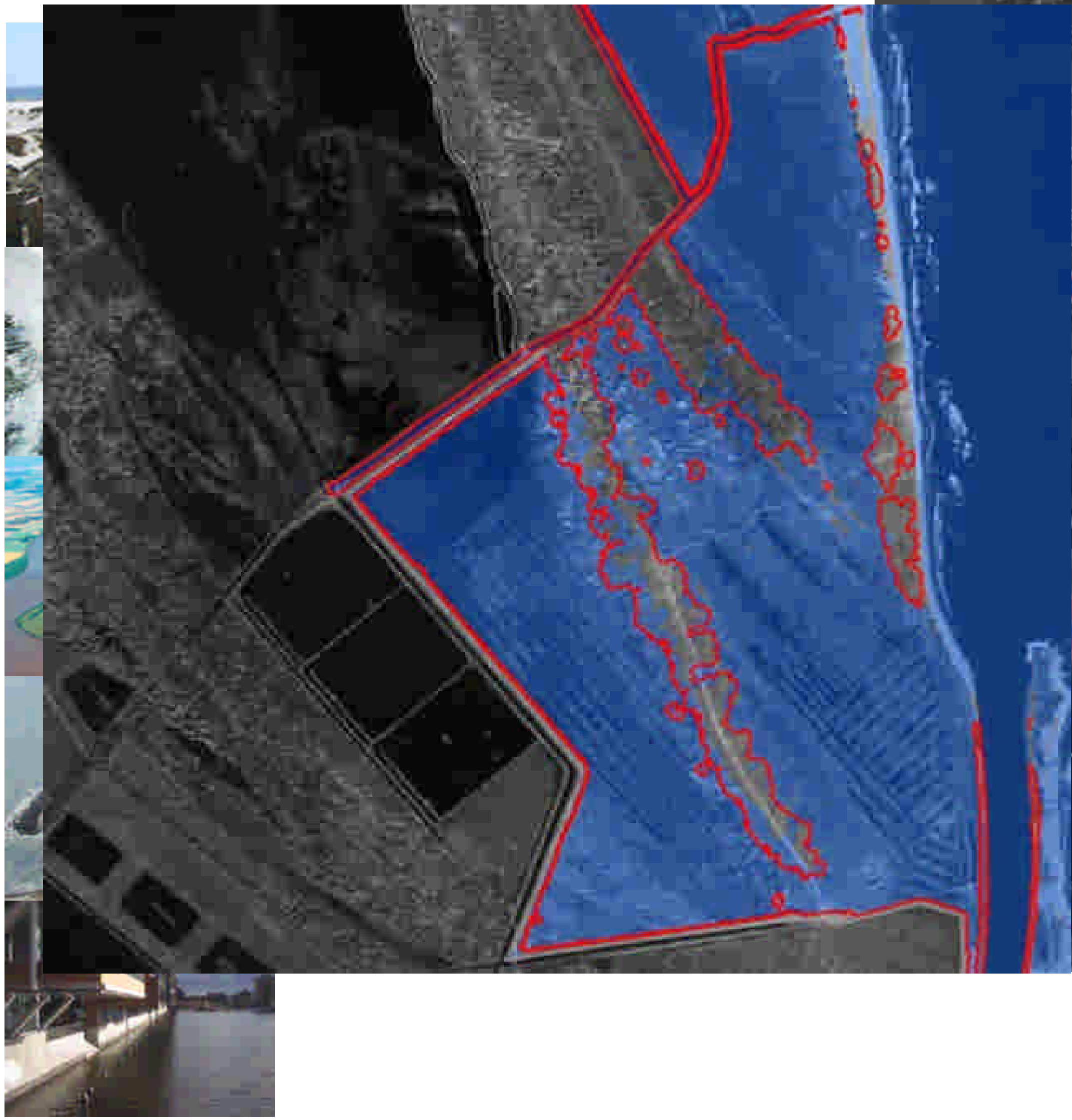
MIKE 21 Vs WS GIS based model

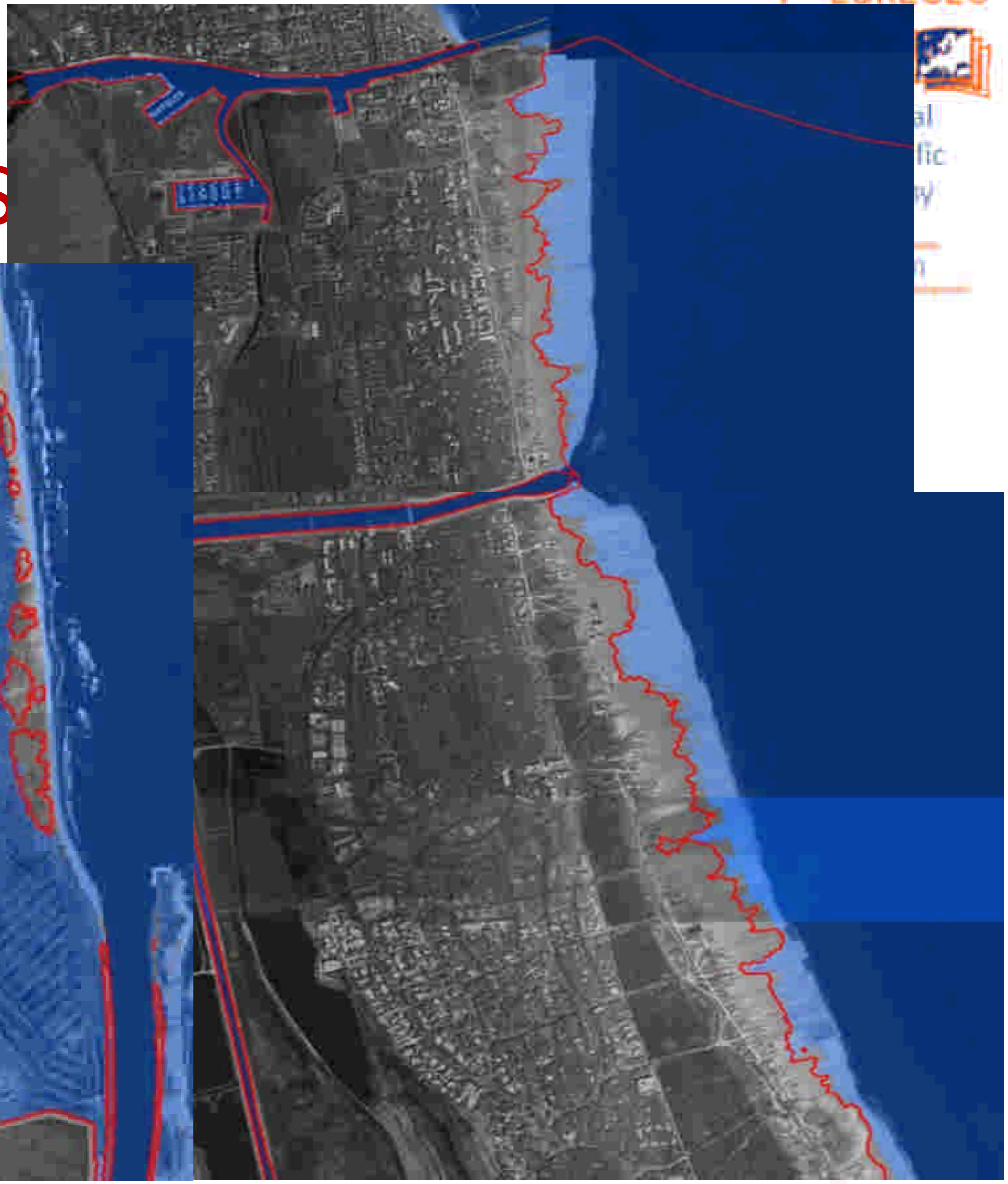
- Maximum flood extension simulated with MIKE 21 and the GIS model



Tr=100 years

MIKE 21 Vs WS

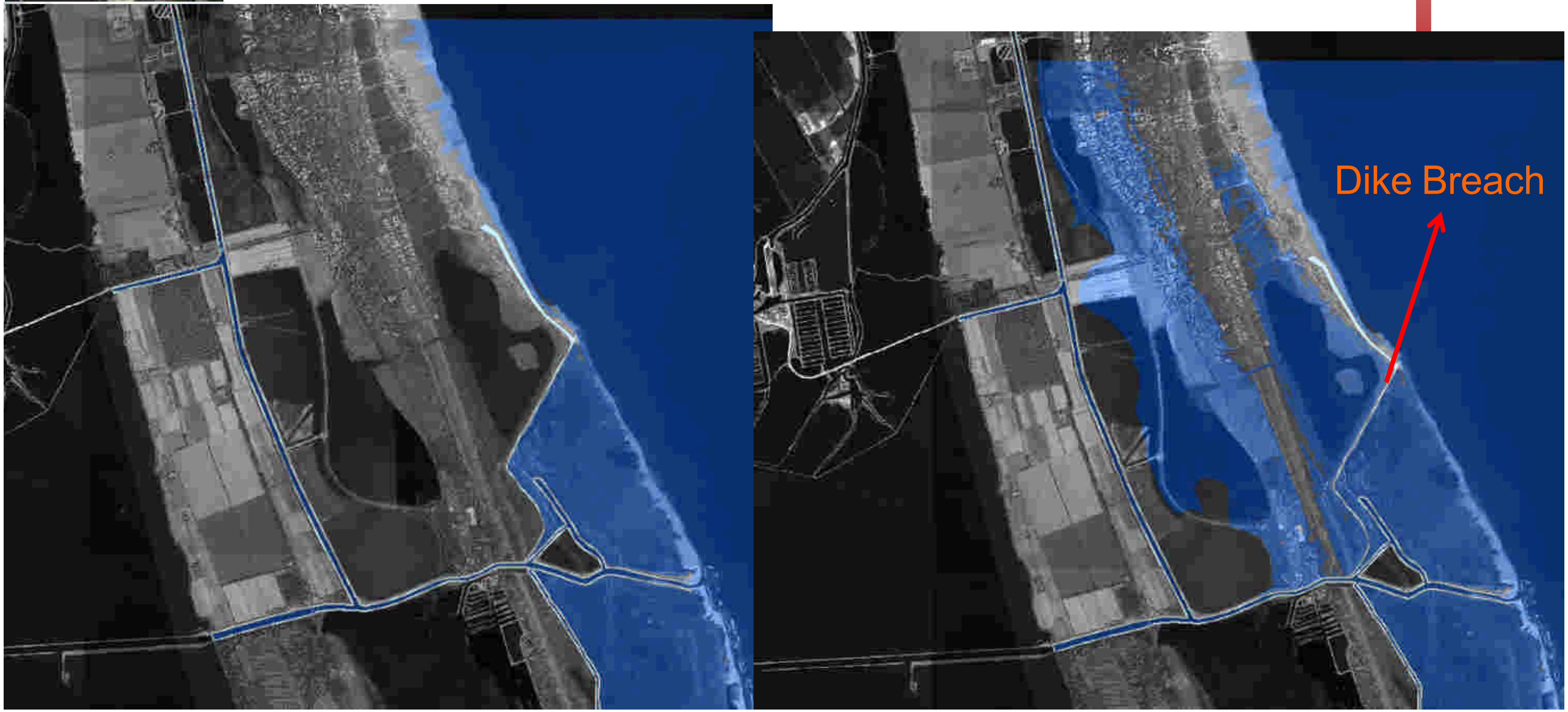




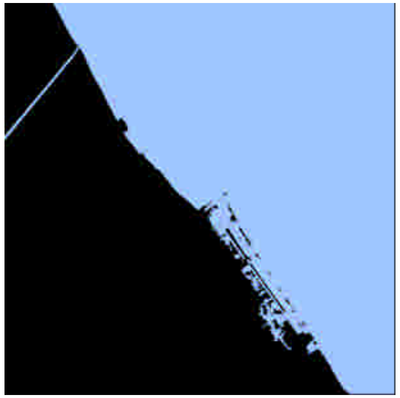
Tr=100 years

Watershed Segmentation GIS model Map of Flooded Area

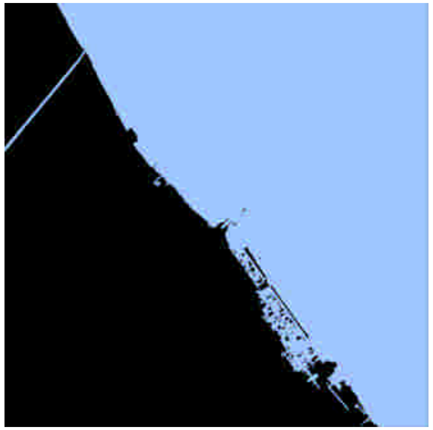
- Possibility to map flood extension and water level in presence of new defense systems (dikes,barriers, etc) or if they deleted or damaged/breached



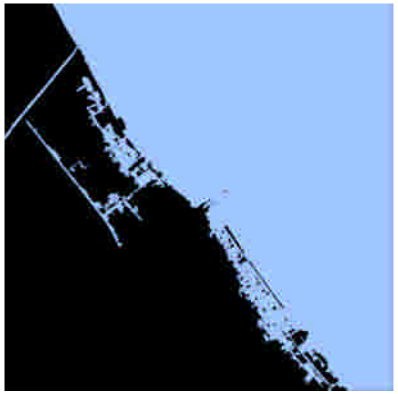
Watershed Segmentation Models: Finite Volume



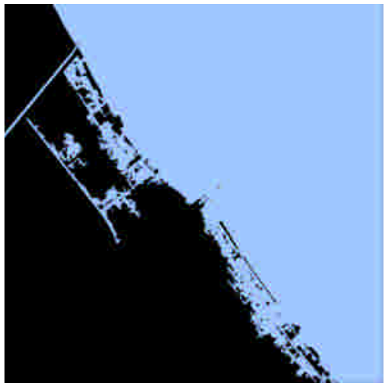
8 Mmc



15 Mmc



25 Mmc

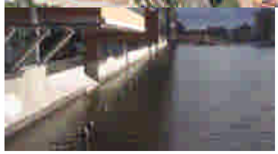


35 Mmc

Watershed Finite Volume Test

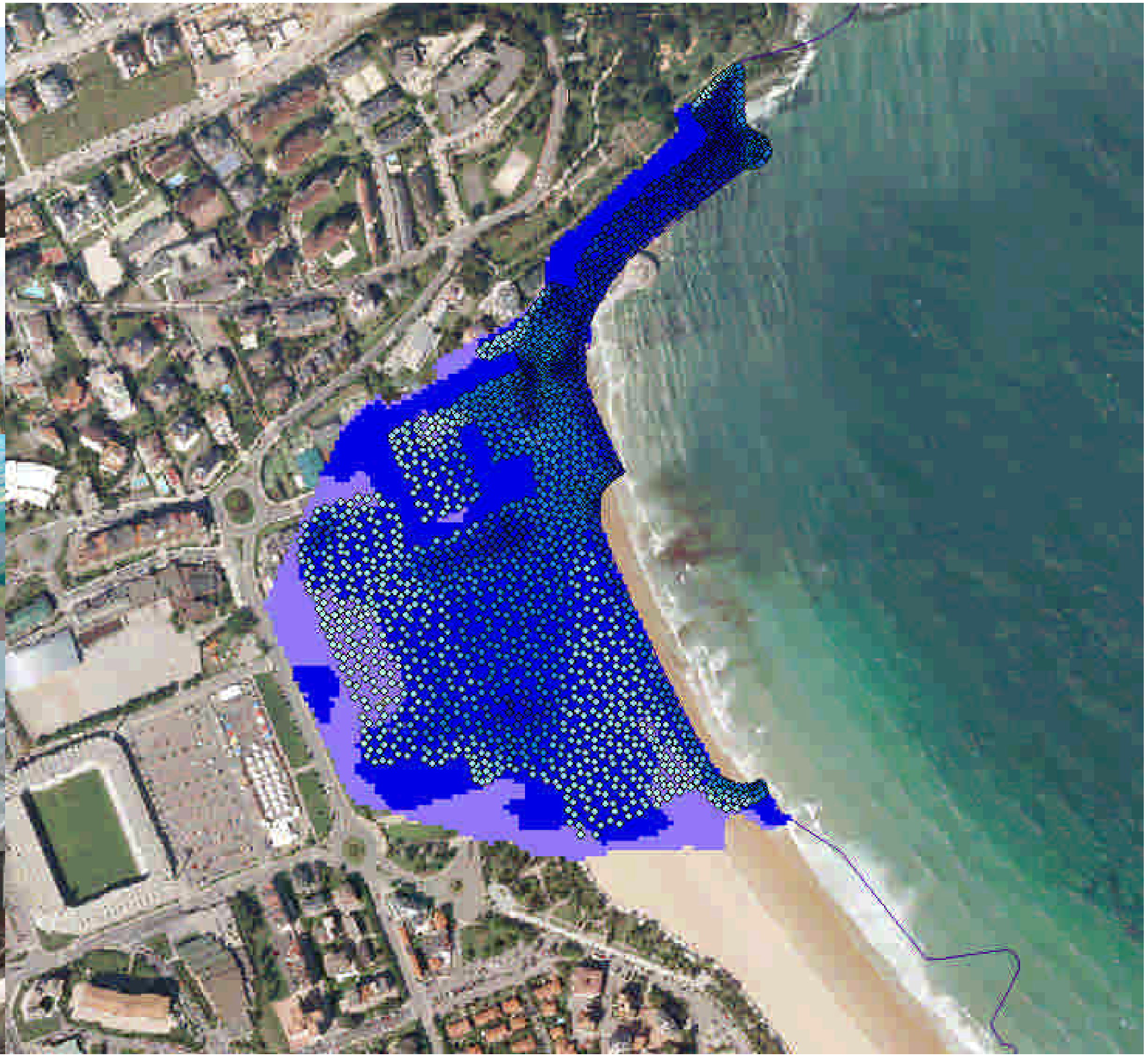
- Q=10000 mc

Watershed Finite Volume Test



- Q=100000 mc

Watershed Finite Volume Test



- Q=1000000 mc

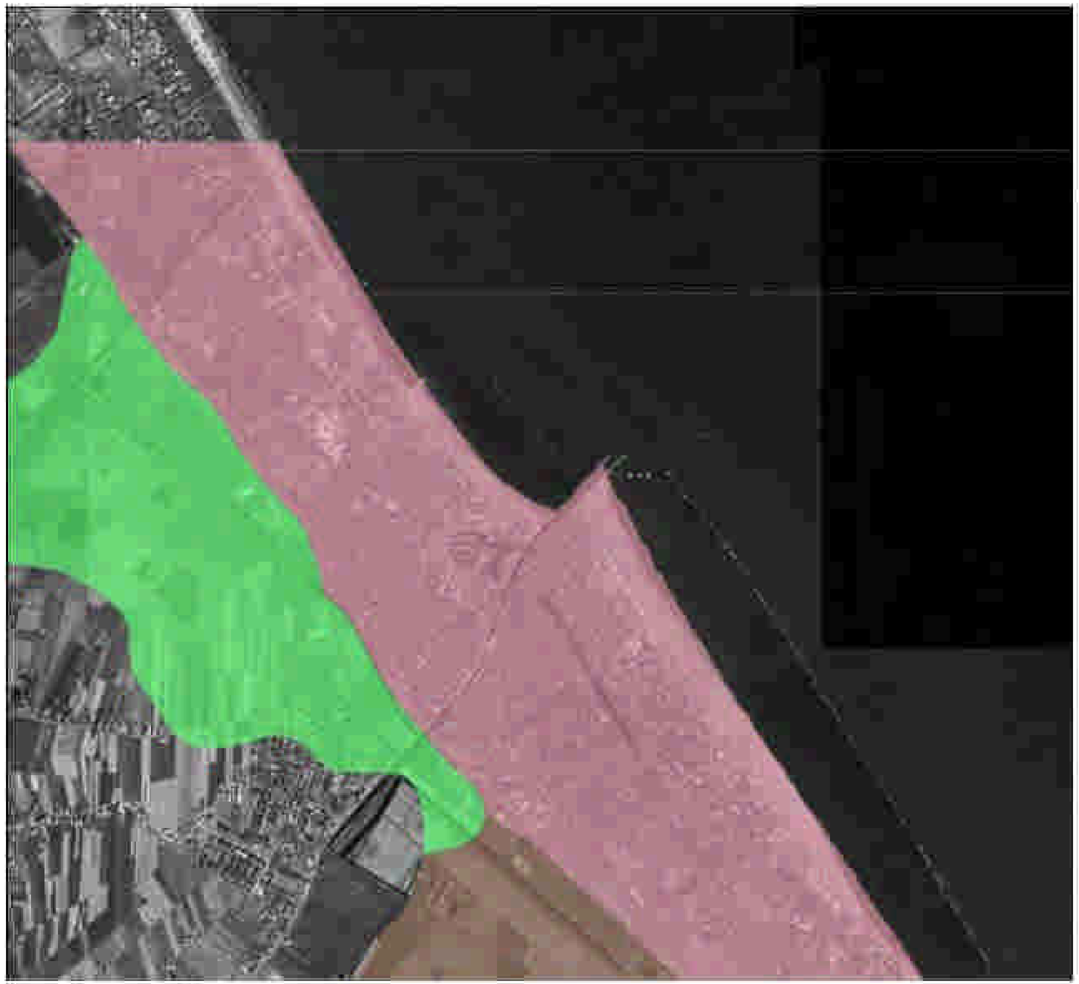
Flood Duration

$$\frac{dh}{dt} = -\frac{K}{n} * \frac{h - h0}{L} * h_0 * px * \frac{1}{px^2} = -a\left(hh_0 - h_0^2\right) =$$

where

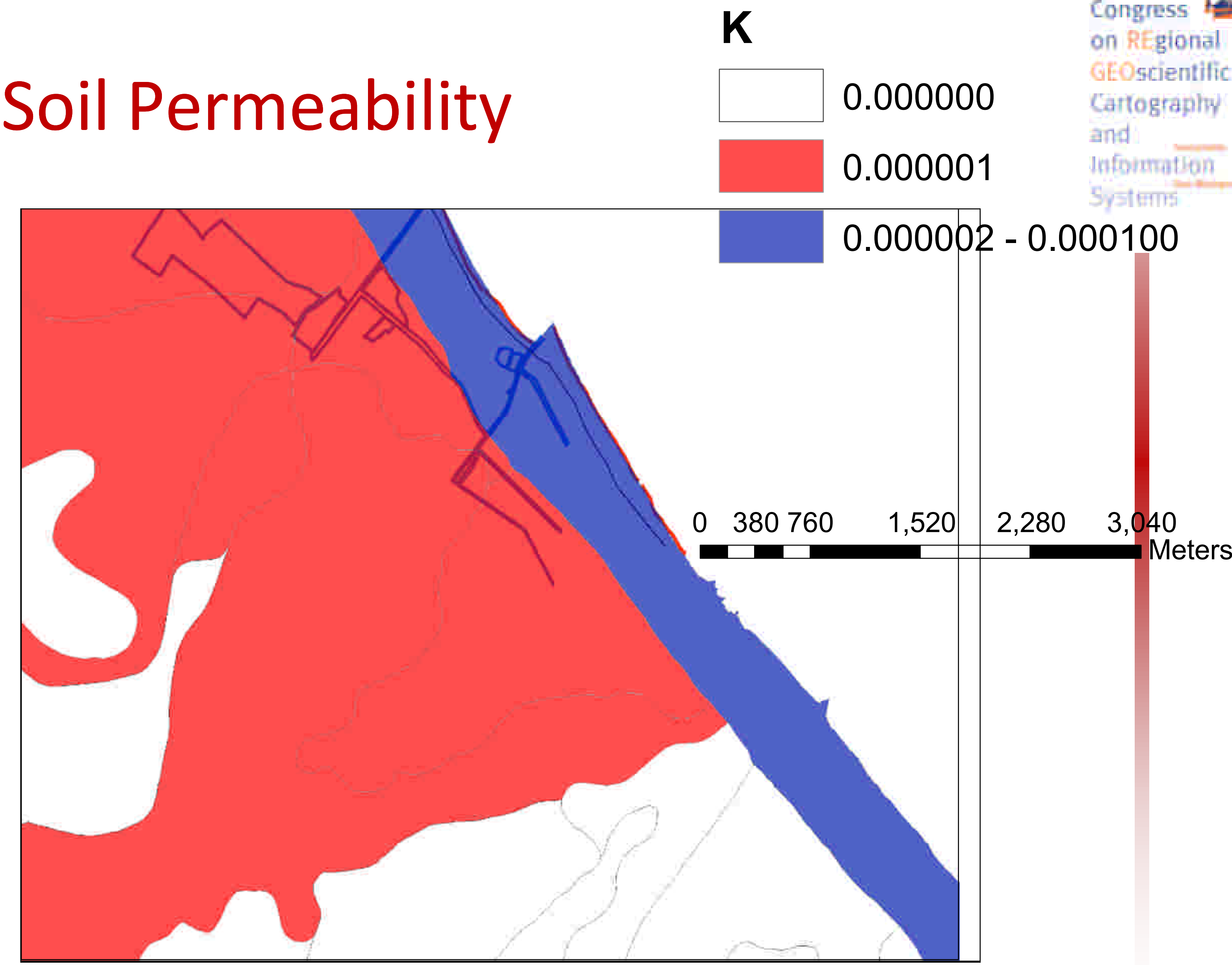
- A=soil surface flooded area= px*px (m2)
- n= porosity
- px= width of flow = pixel size (m)
- S= medium thickness of hydraulic head (m)
- K= permeability (m/s)
- i= hydraulic gradient (-)
- h=hydraulic head of flooded pixel
- h0= hydraulic head of the nearest drainage system (river, sea, channel)
- L= distance pixel I from the nearest drainage system (river, sea, channel)

Soil Type



(pink)	Sand
(green)	Silt and clay
(brown)	Silt and clay

Soil Permeability

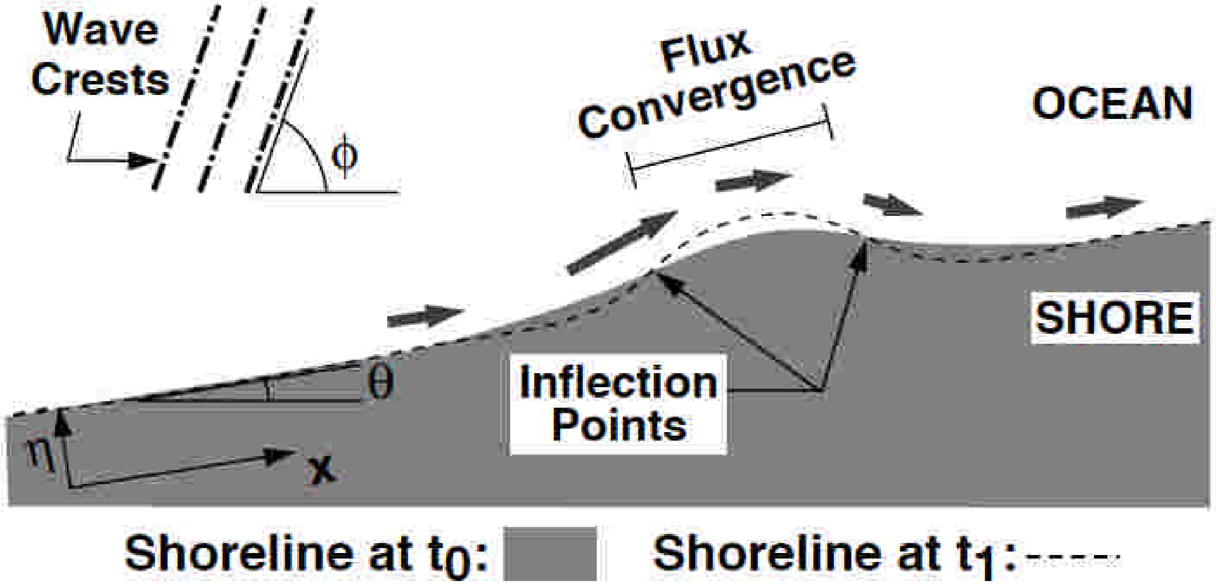


Erosion scenarios, GIS simplified model

- Required input:
  - Shoreline survey;
  - Sediment sampling;
  - Selection of the scenario
  - Typical annual wave climate;
  - Time horizon for the simulation.
- Assumptions:
  - average uniform sediment diameter in the area (d50=0.2 mm),
  - reconstruction of a Dean’s beach profile (A=0.09),
  - Triangular distribution of sediment transport (maximum at the breaking line).

EROSION

1 Line Model – Miller and Dean



Erosion scenarios, shoreline change

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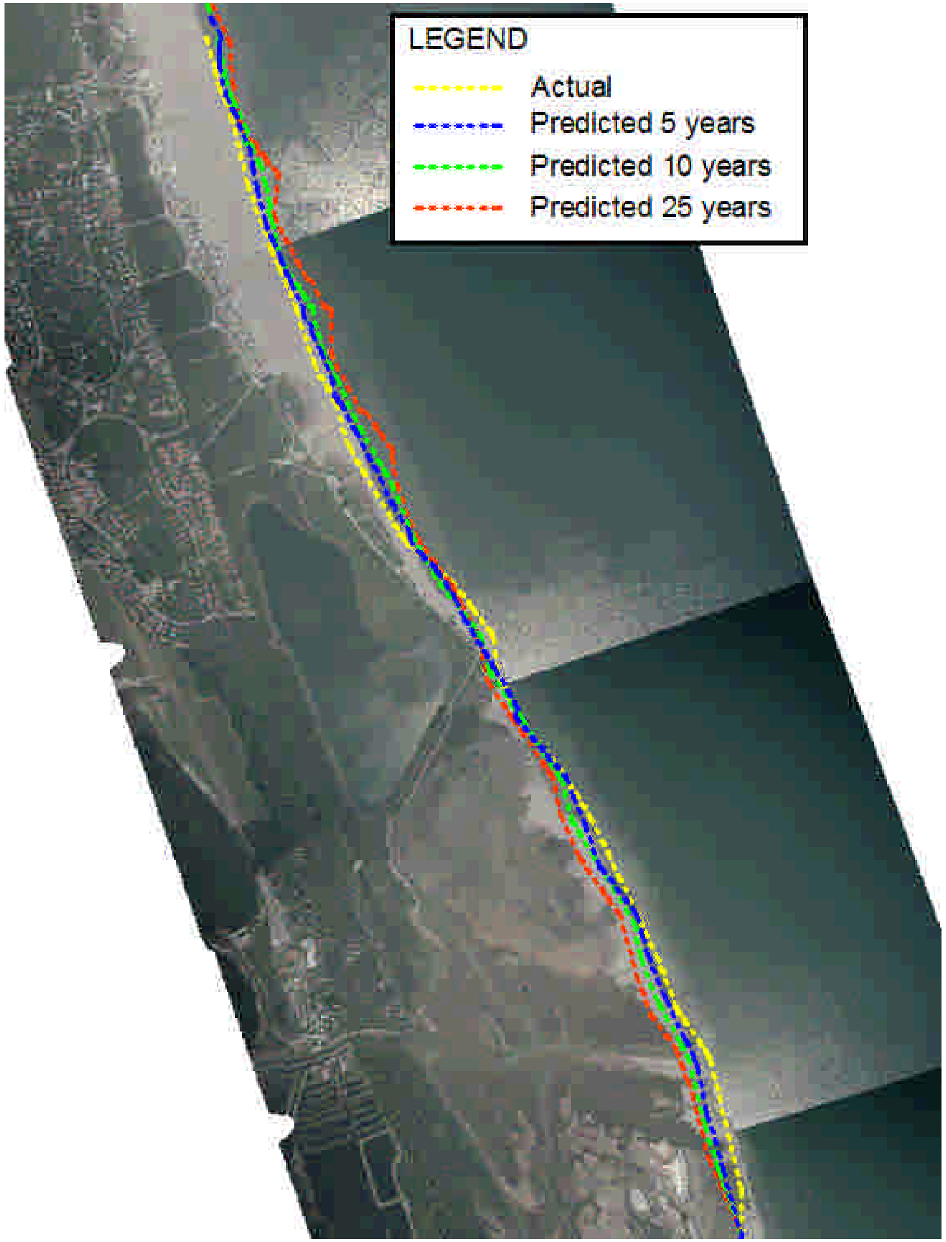
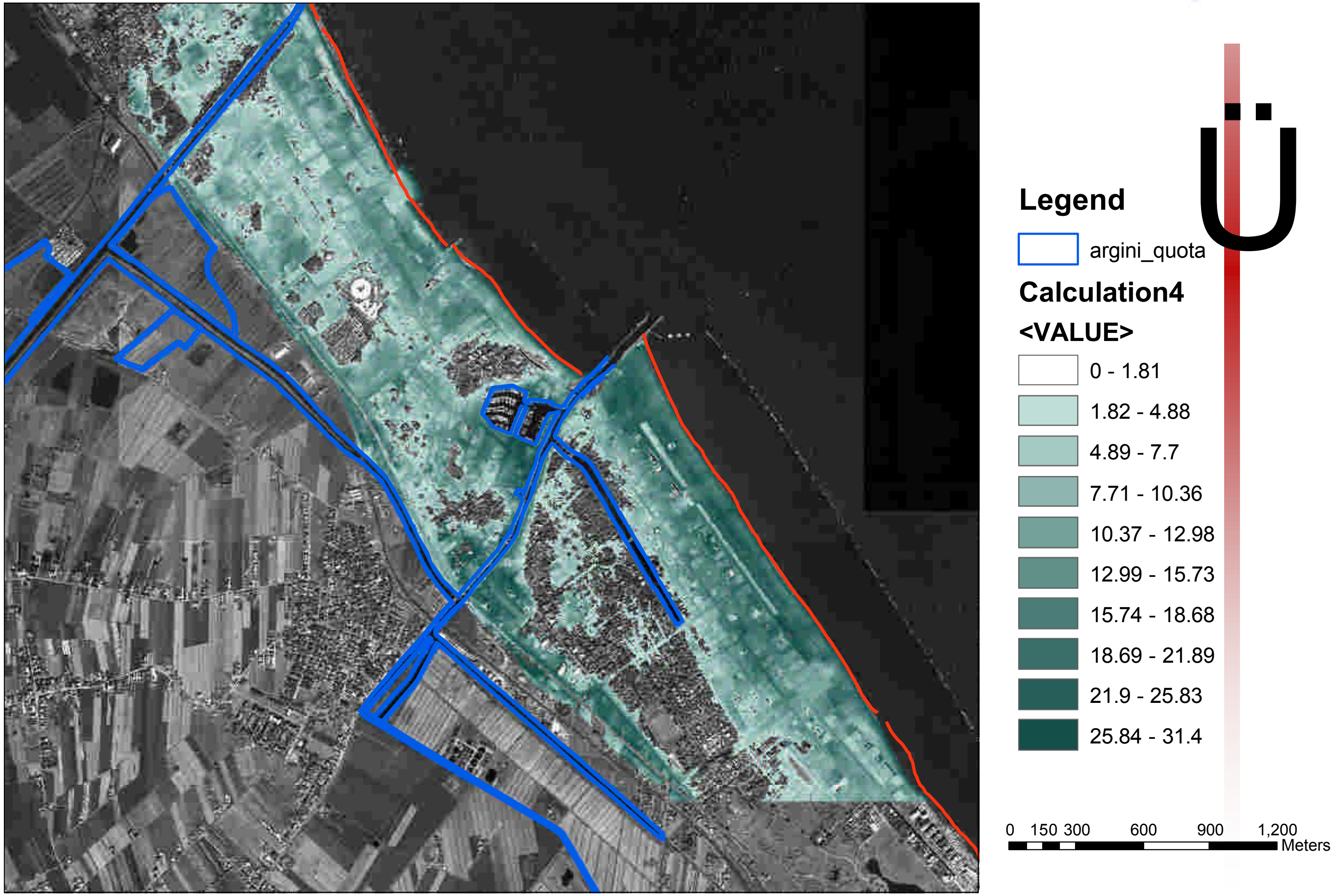
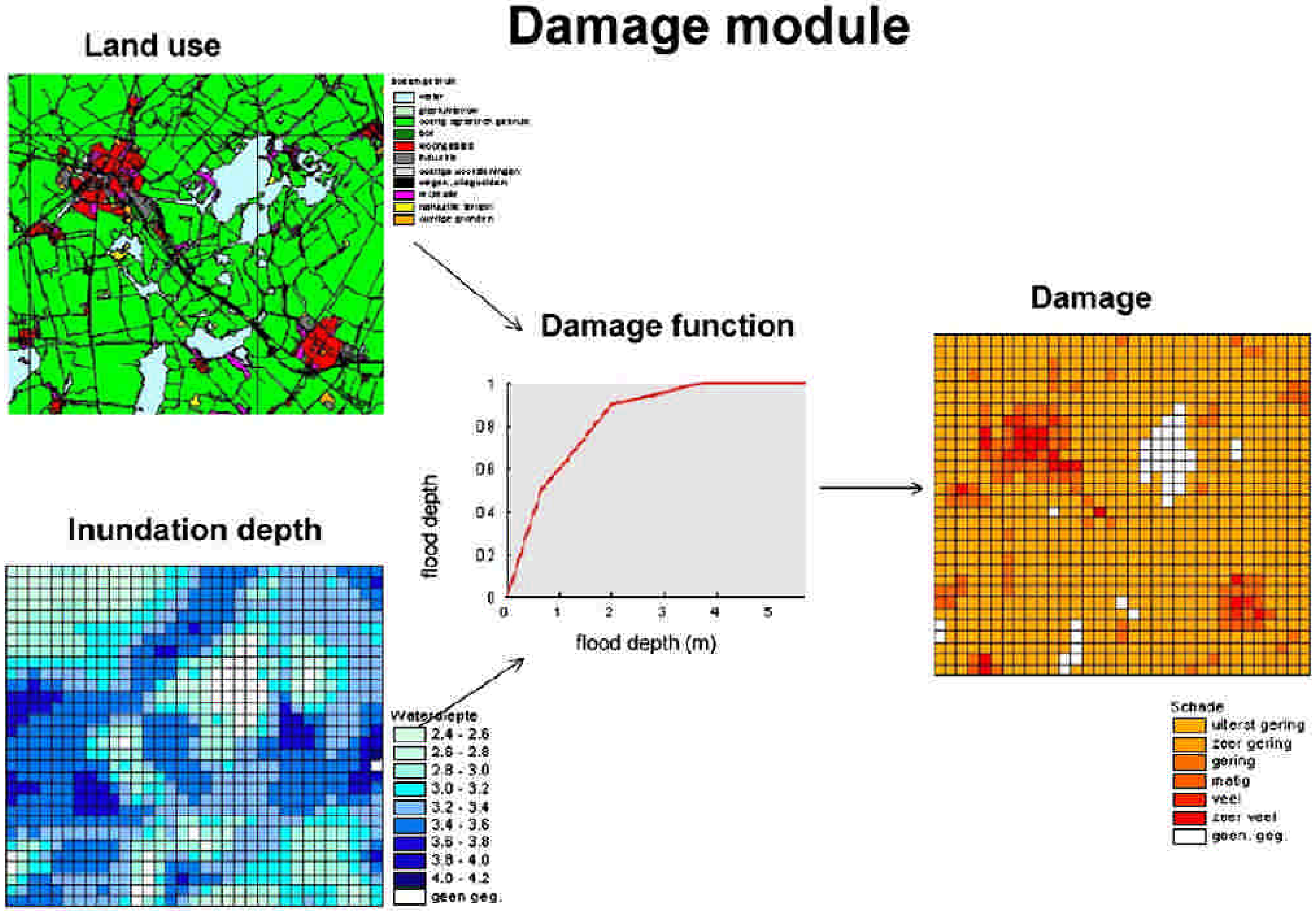


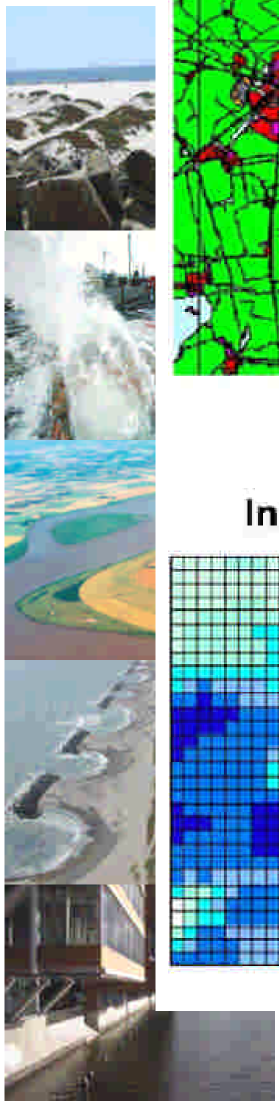
Flood Duration (h)



CONSEQUENCE/ IMPACT MODULE -

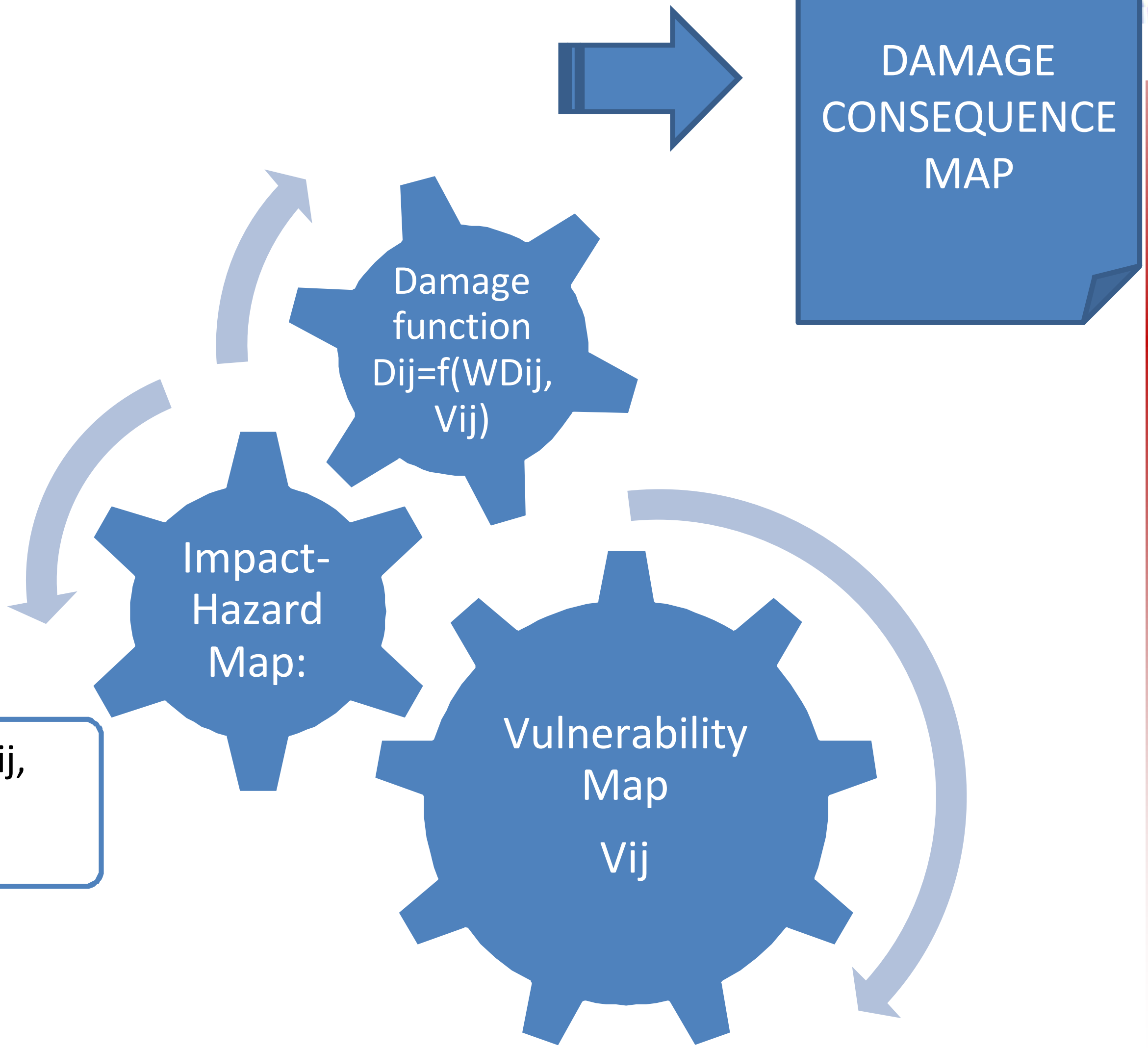
Vulnerability - Damage Function Approach





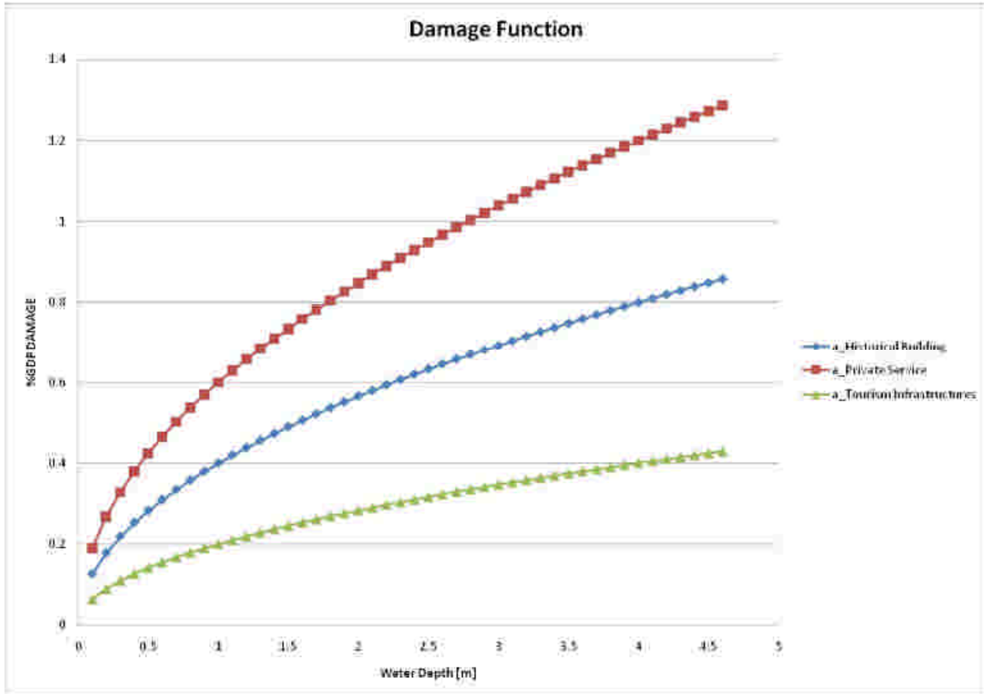
CONSEQUENCE/ IMPACT MODULE -
Vulnerability - Damage Function Approach

- Water Depth WDij,
- Velocity,
- Duration



CONSEQUENCE MODULE - IMPACT
Damage Function Approach

- Vulnerability Map Vij
- Hazard/stressor Map: Water Depth, Velocity, Duration
  - WDij
- Damage function Dij=f(Wdij, Vij)



Damage Function : Example

- Kok, 2001

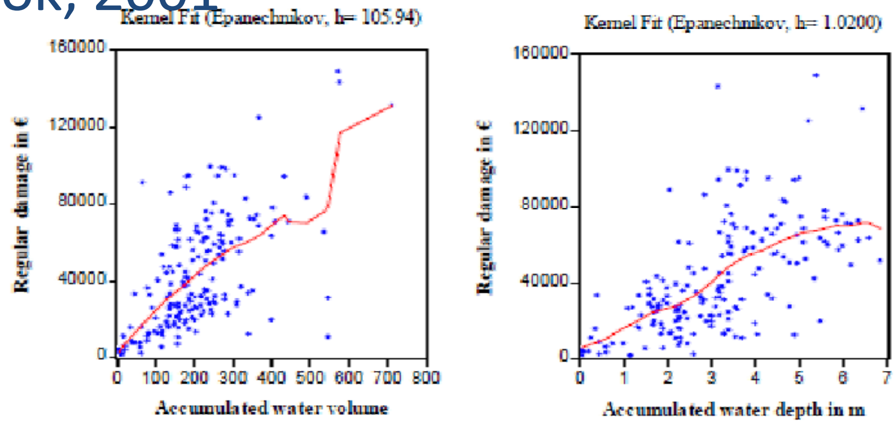


Fig. 4. Scatter plot with the water-volume- and water-depth-damage (Epanechnikov-kernel with bandwidth *h*) for regular damage. Data source: Amt der NÖ Landesregierung, Abteilung Landwirtschaftsförderungen (2006a).

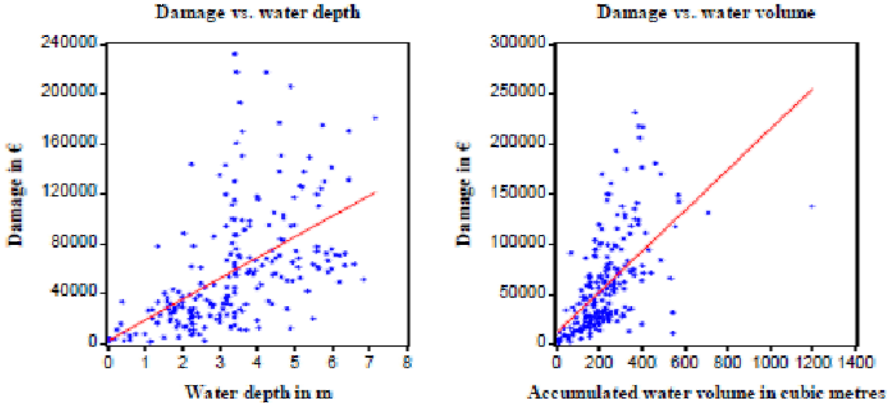


Fig. 5. Accumulated lin-lin-water-volume-damage curve and accumulated lin-lin-water-depth-damage curve (accumulated for all building types). Data source: Amt der NÖ Landesregierung, Abteilung Landwirtschaftsförderungen (2006a).

Depth (metres)	Damage factor
0	0
0.5	0.06
1	**0.08**
1.5	0.10
2	**0.44**
3	**0.62**
4	0.78
5	0.80
6	1

Consequence Module IMPACT

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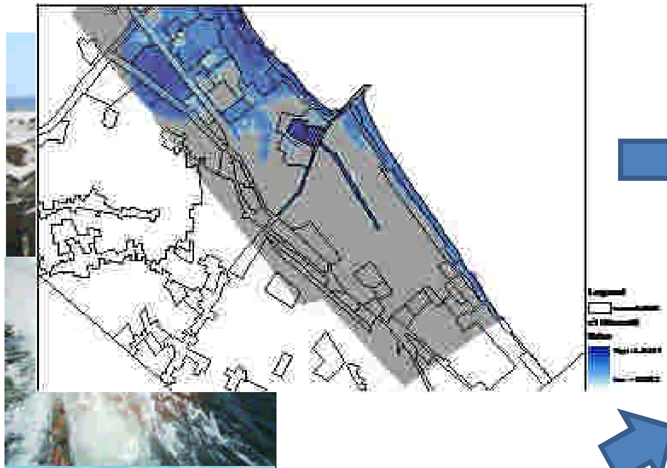
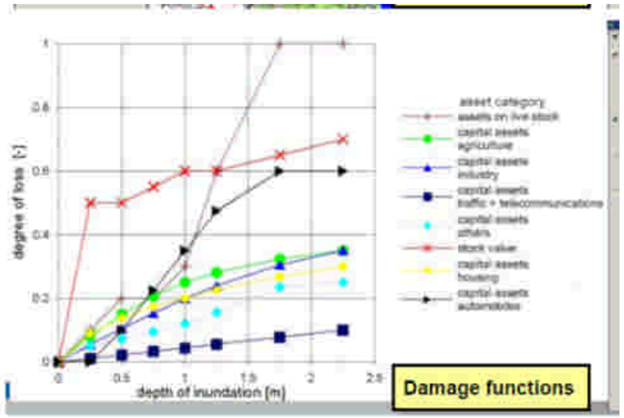
Height/Velocity Flood Map



DAMAGE Function

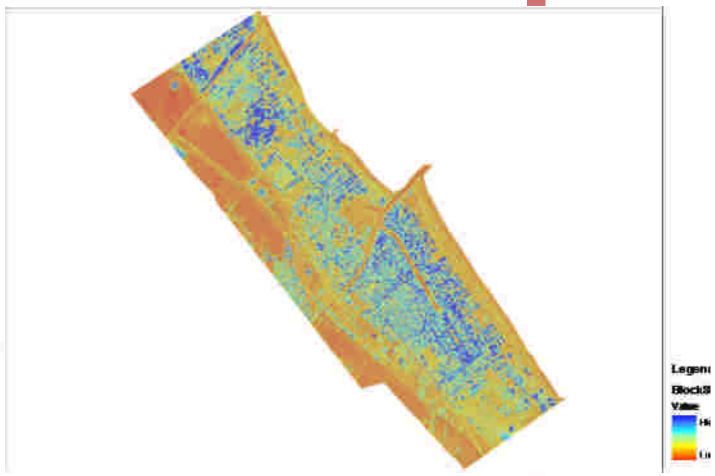


Economic DamageMap
Ecological DamageMap
Social DamageMap

Population Map

Landuse Map

Assets Map



Economic impact

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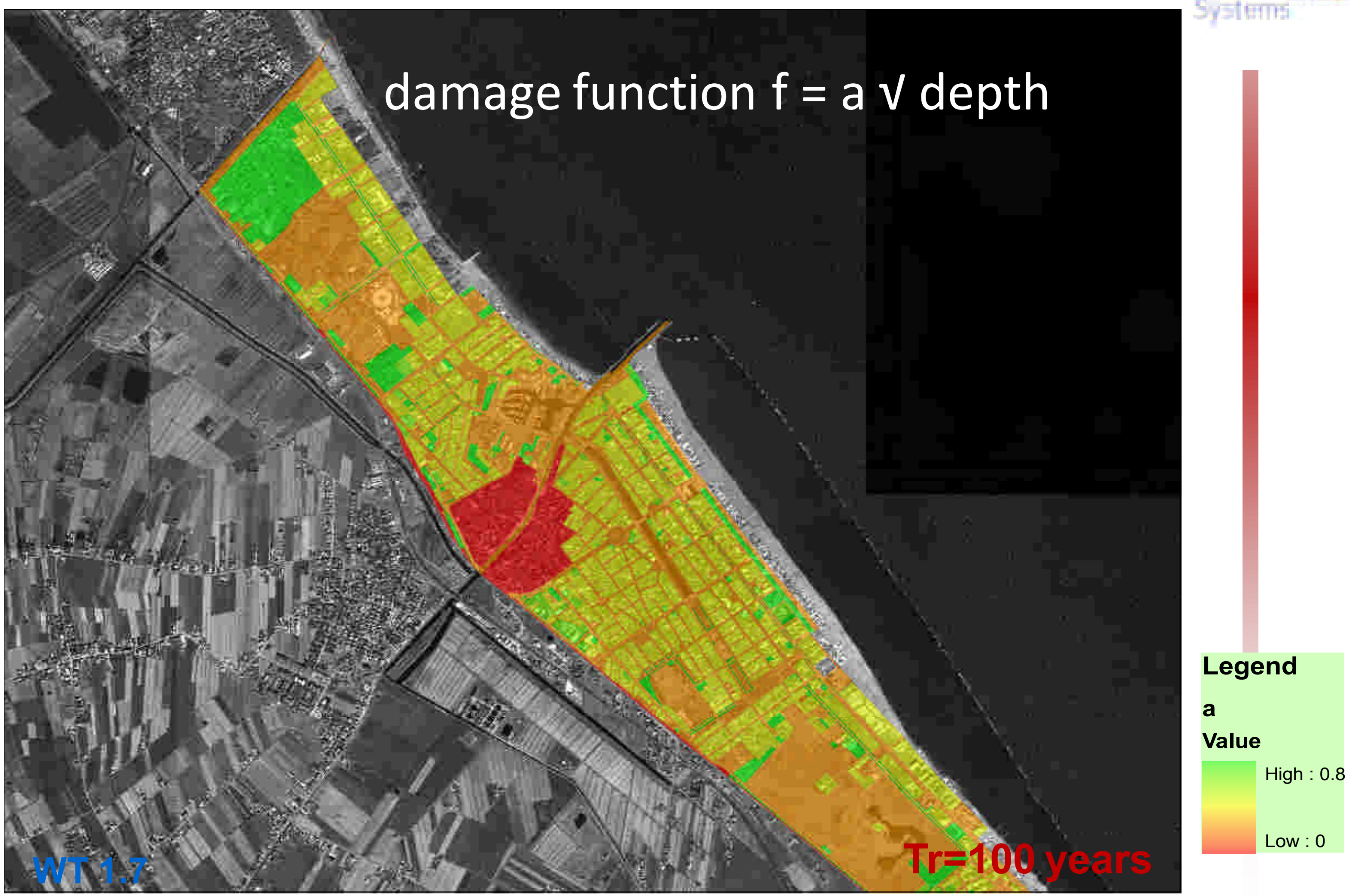

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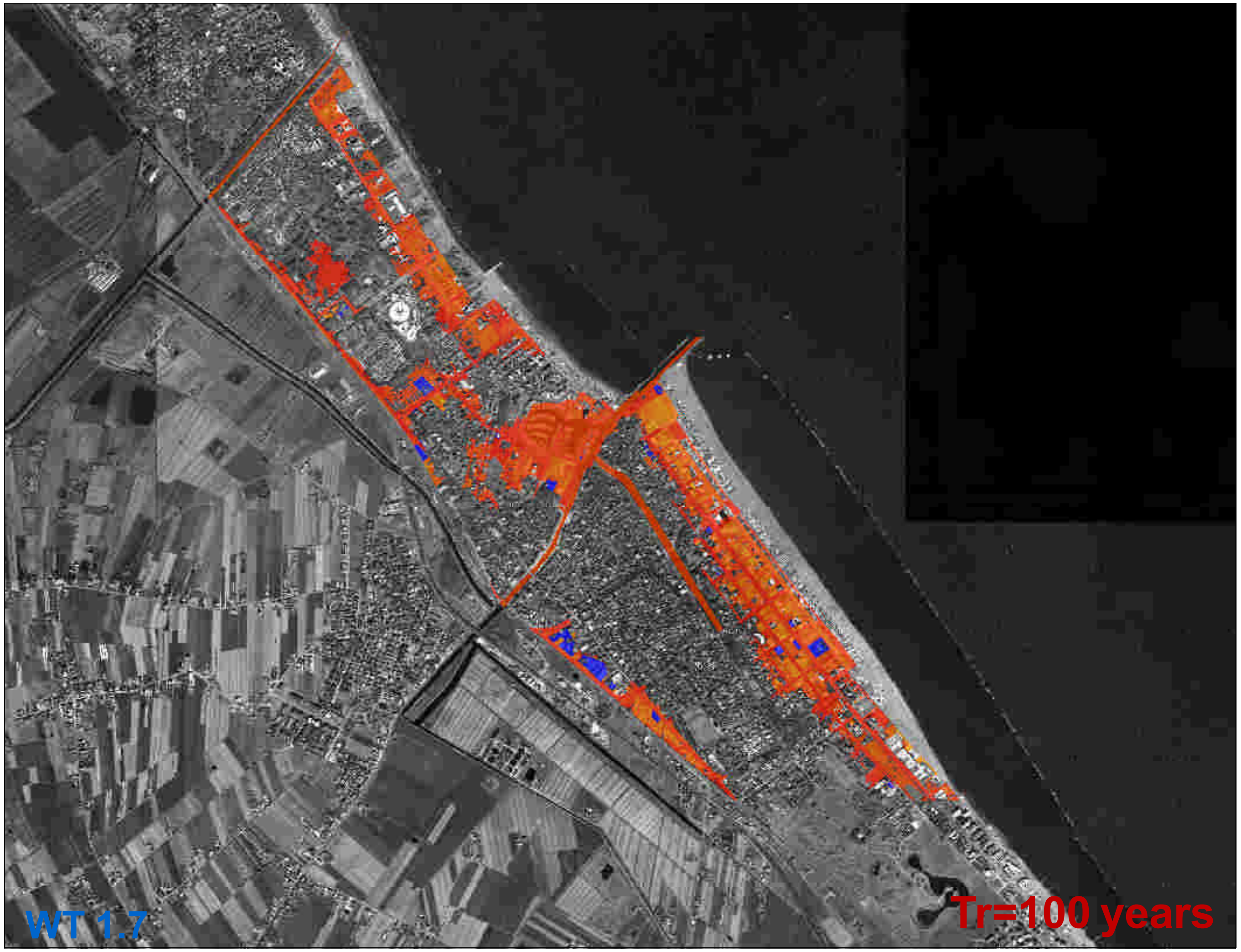
Distribution of economic damages



Legend

damage

GDP [euro/mq]

High : 3846.6

Low : 0

Environment vulnerability assessment

Sampling, Historical data

Temperature
Wind
Currents
Granulometry
Sediment transport
……

Biological variables

WT 1.5

FBEM learning algorithm

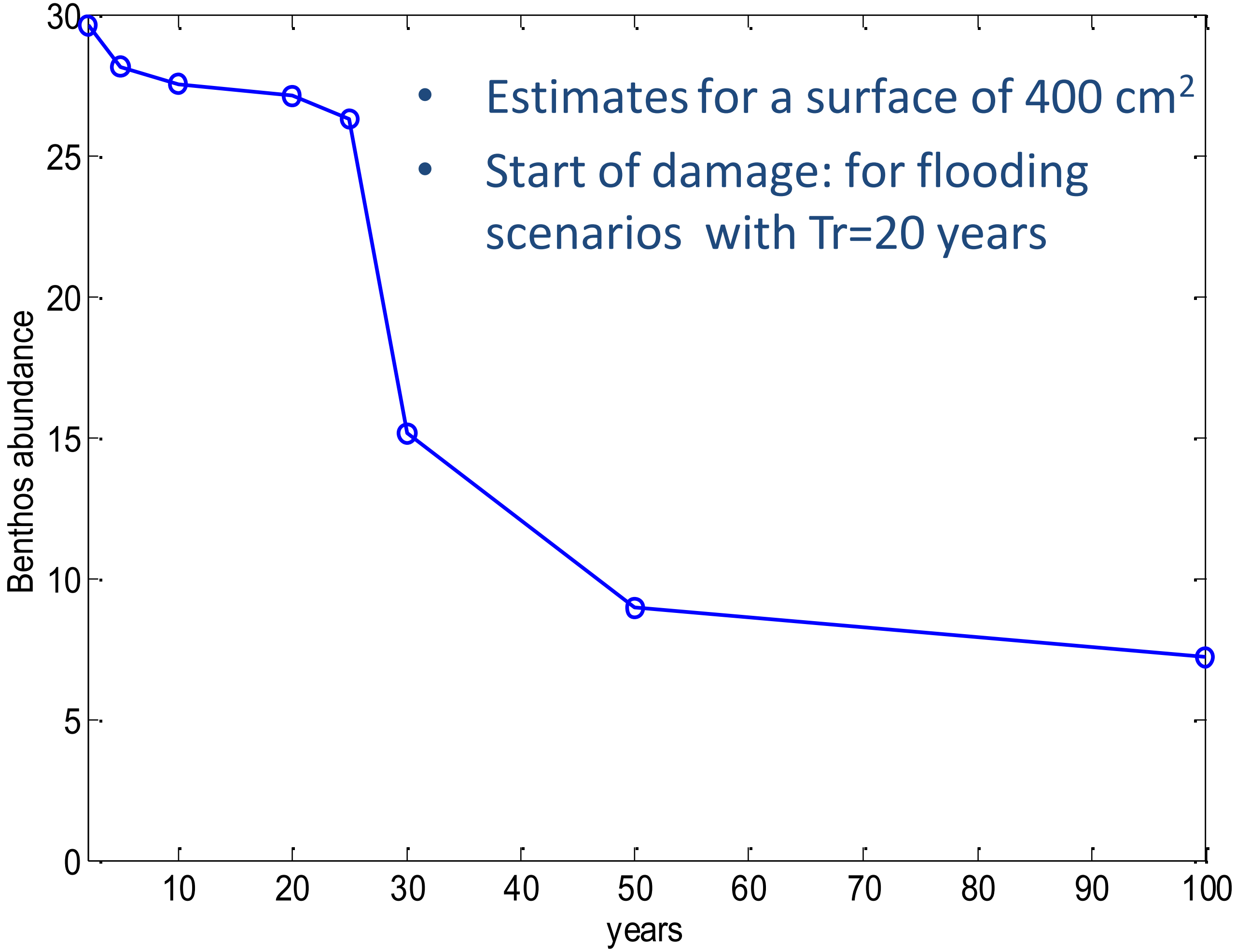
FBEM predictive algorithm

New sampling, Physical model, On line data

Δ Temperature
Δ wind
Δ currents
Δ granulometry
Δ sediment transport
……

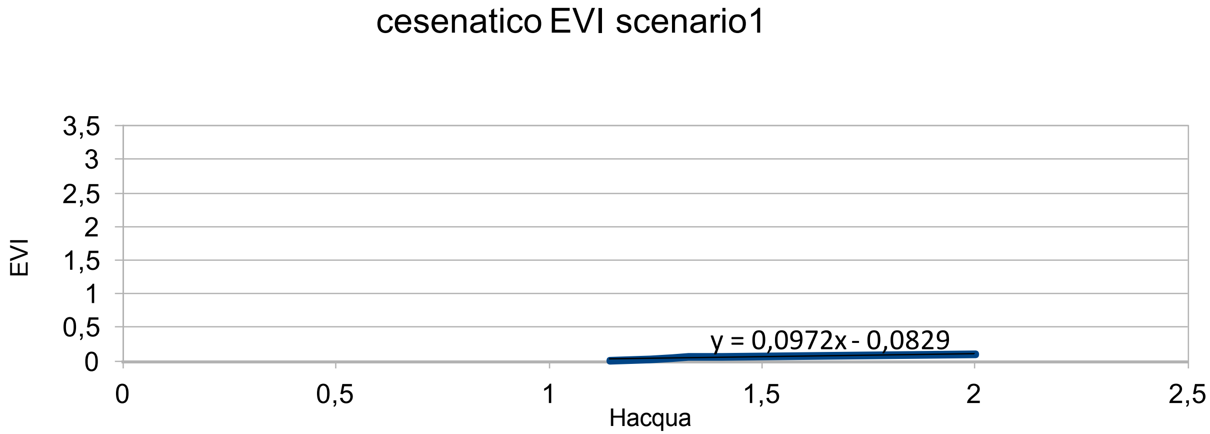
Δ biological variables + biological autocorrelation

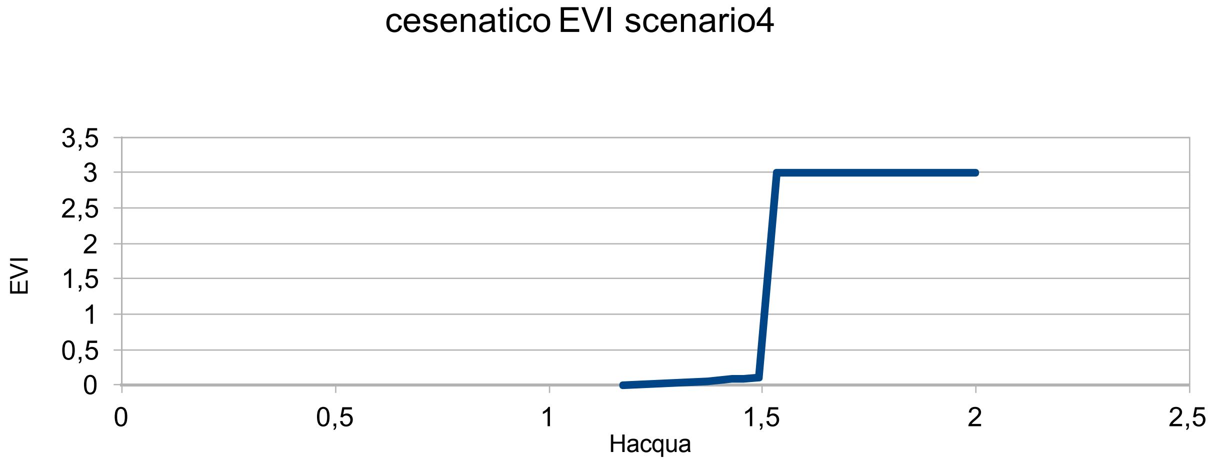
Vulnerability of benthic communities



- Estimates for a surface of 400 cm^2
- Start of damage: for flooding scenarios with Tr=20 years

EVI Benthos


cesenatico EVI scenario1
EVI
Hacqua
y = 0,0972x - 0,0829
0
0,5
1
1,5
2
2,5
3
3,5

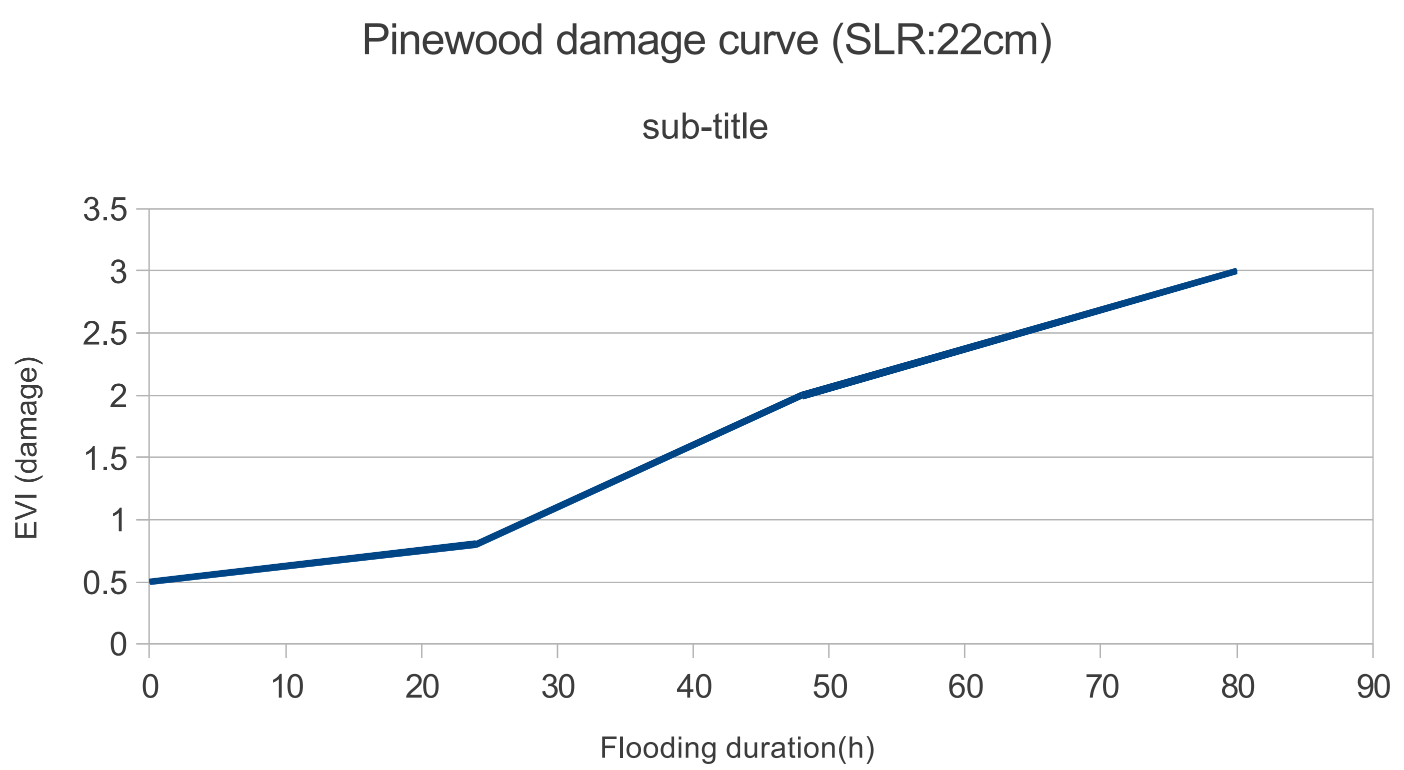

cesenatico EVI scenario4
EVI
Hacqua
0
0,5
1
1,5
2
2,5
3
3,5

PINEWOOD EVI matrix

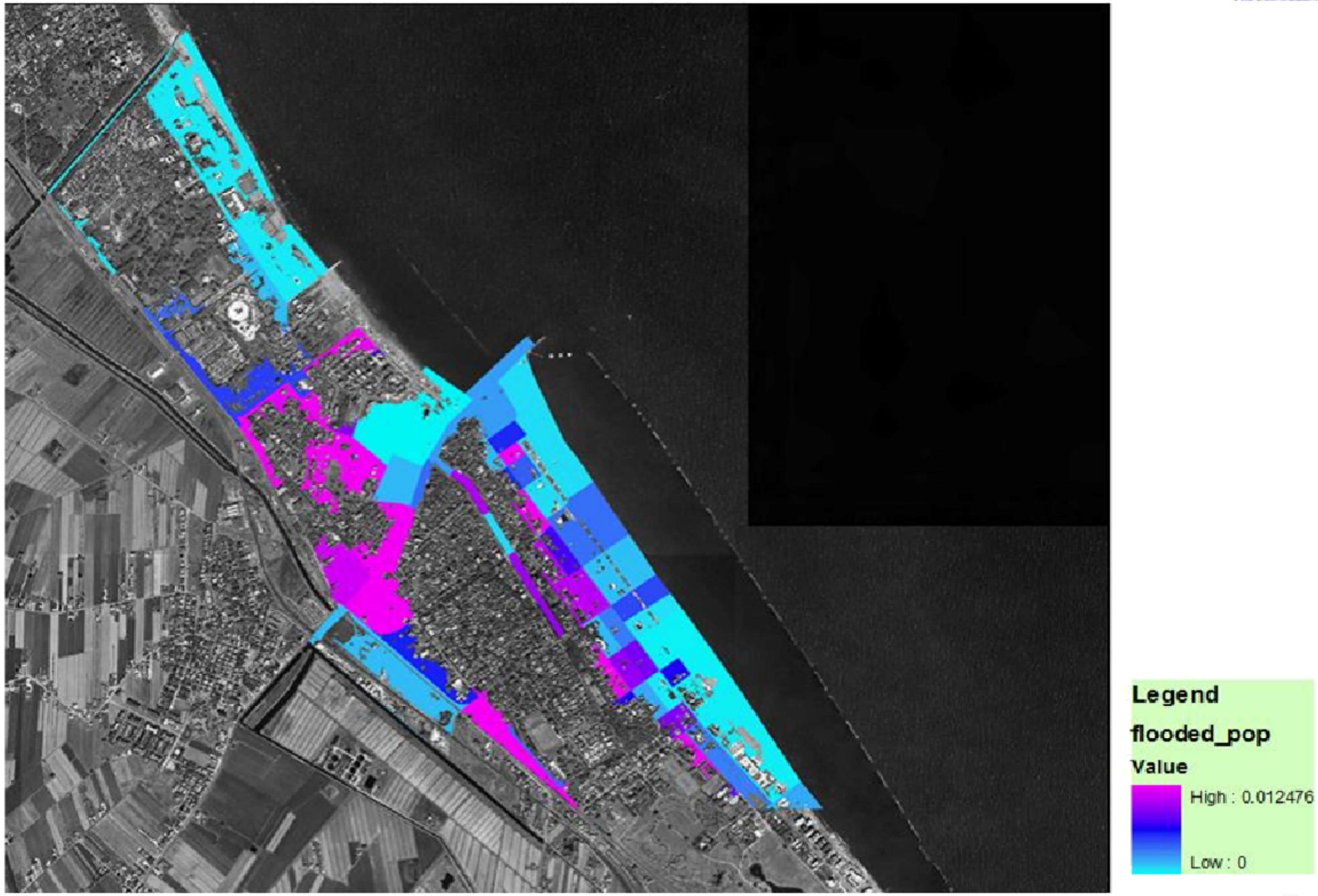
Drivers : sea level rise, elevation, flooding duration

elevation		0	0	0	0	1	1	1	1	2	2	2	2
Subsidence (cm)		0	30	50	70	0	30	50	70	0	30	50	70
Sea level rise (cm)	0	0	2	2	3	0	1	1	2	0	0	1	2
	13	1	3	3	3	1	2	2	3	0	1	2	2
	22	2	3	3	3	1	2	3	3	0	2	2	3

Pinewood damage curves



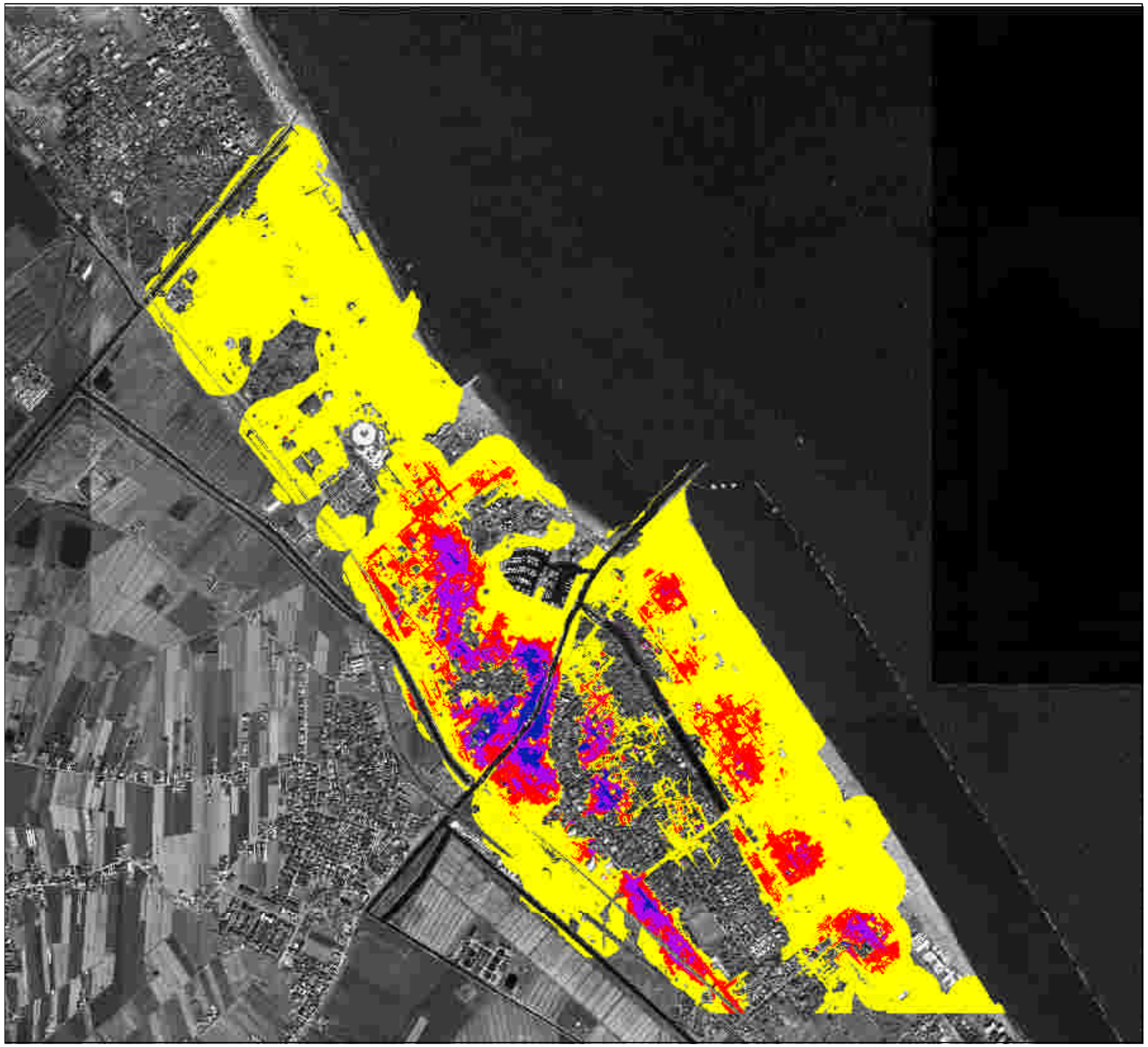
Social vulnerability: 'flooded' people



WT 1.7

Tr=100 years

Vulnerability of Sensitive Population (14>Age>60)



Social Risk to Life

Scenario 2050
TR 50

Legend

SocialRisk2PopSens

<VALUE>

- 0
- 1
- 2
- 3
- 4

0 120240 480 720 960
Meters

Risk for Population

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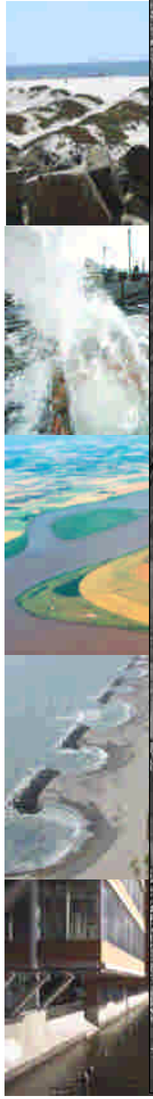
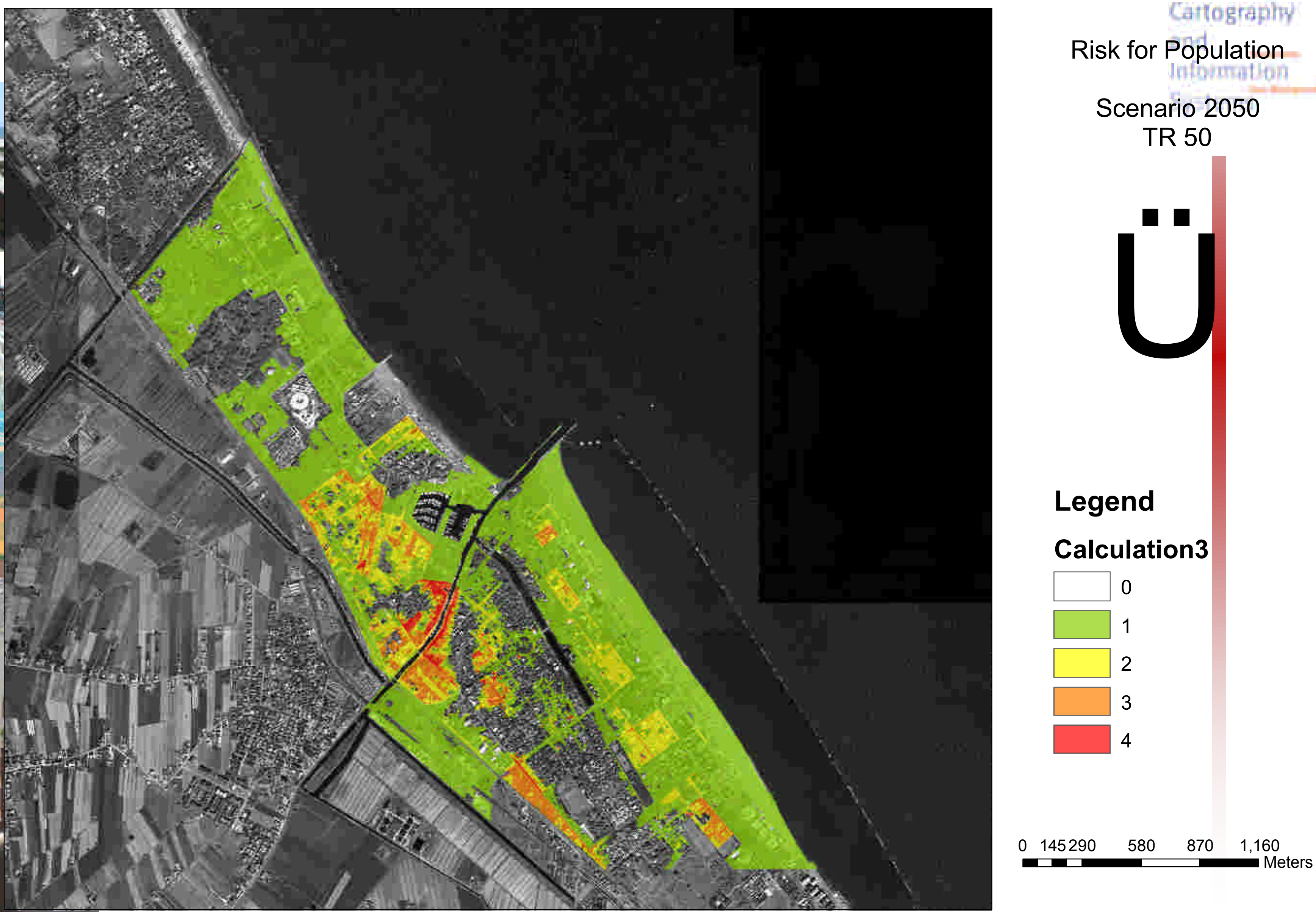
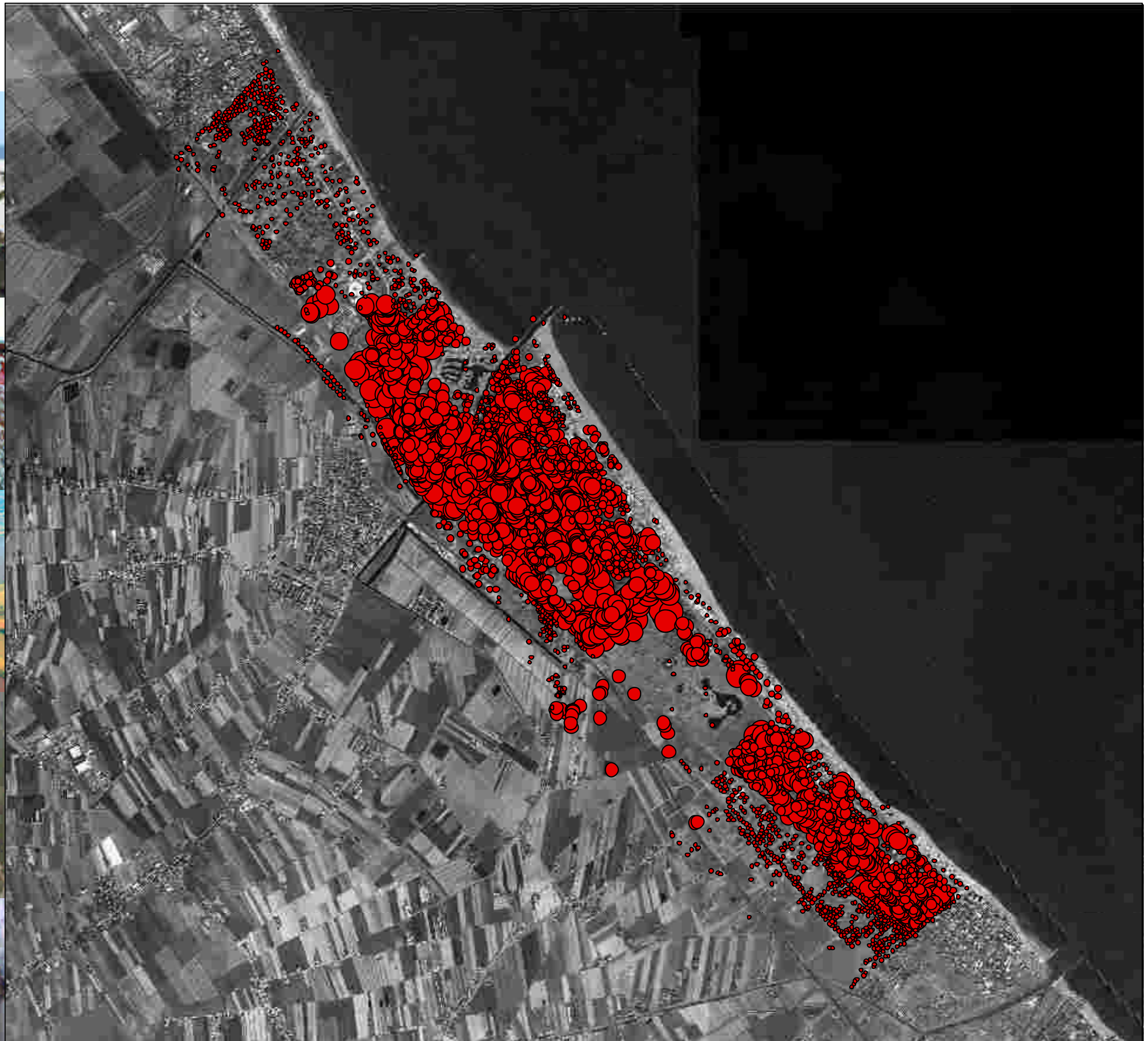




Vulnerability- Sensible Pop



Cesenatico
Sensible Pop.
14>Age> 60

Legend

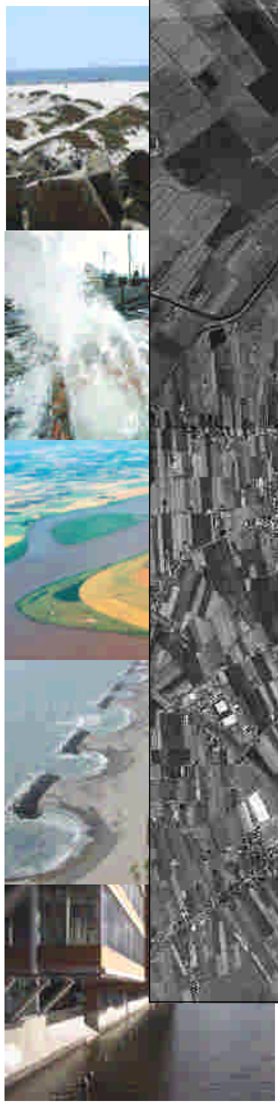
edifici_point_istat

popsens_po

- 0.000000 - 0.157895
- 0.157896 - 0.400000
- 0.400001 - 0.590909
- 0.590910 - 0.750000
- 0.750001 - 0.928571
- 0.928572 - 1.125000
- 1.125001 - 1.625000
- 1.625001 - 2.315789
- 2.315790 - 5.500000

0 195390 780 1,170 1,560
Meters

Vulnerability- Sensible Pop. Density



Cesenatico
Sensible Pop. Density
14>Age> 60

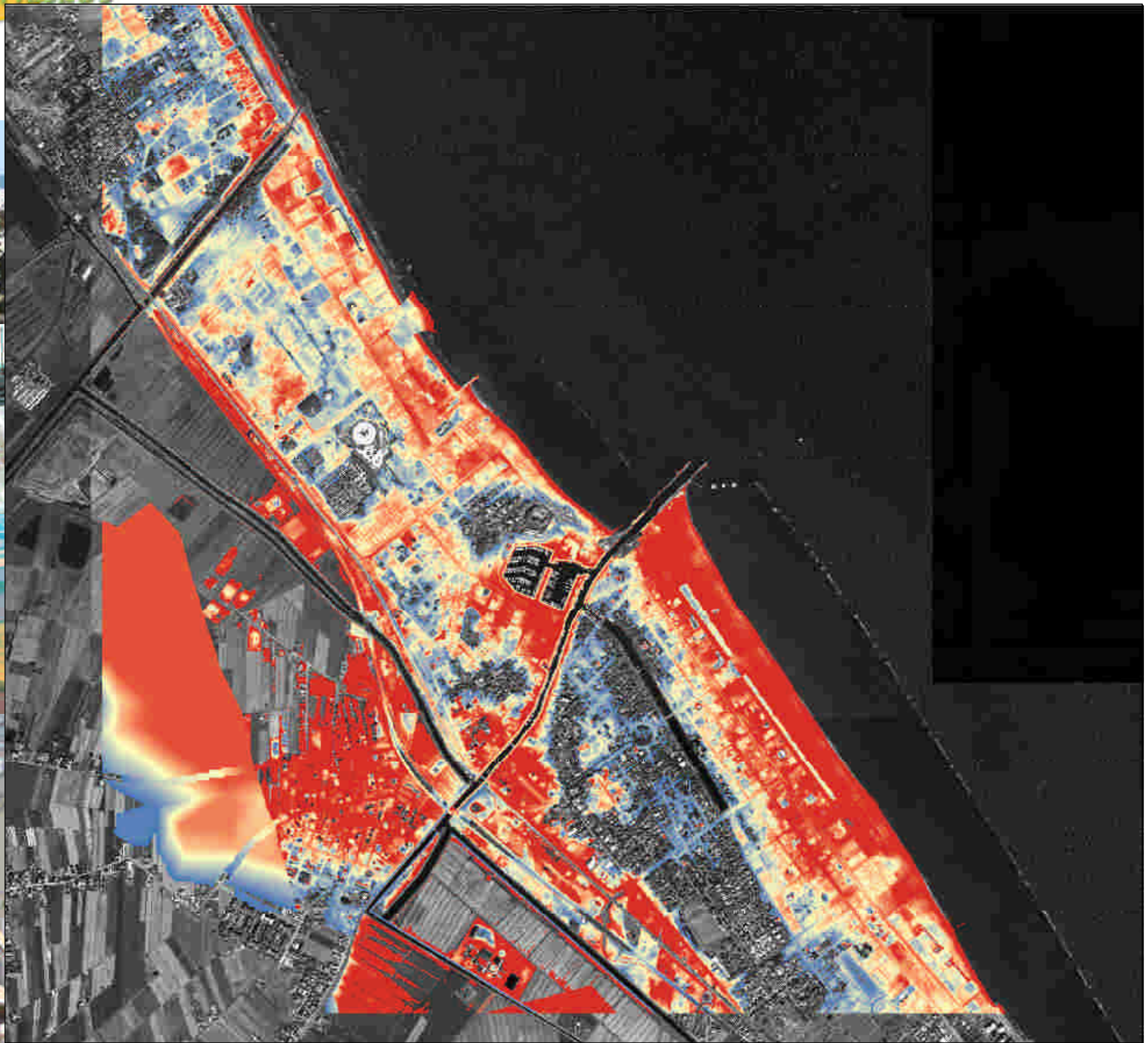
Legend

pop_sens_mq

- 0 - 0.0000001
- 0.000000101 - 0.001235269
- 0.001235269 - 0.001852904
- 0.001852904 - 0.002470538
- 0.002470538 - 0.003088173
- 0.003088173 - 0.003705808
- 0.003705808 - 0.004323442
- 0.004323442 - 0.004941077
- 0.004941077 - 0.005558711

0 195390 780 1,170 1,560 Meters

Hazard – Water Depth



Hazard
Water Depth
Scenario 2050
TR 50

Legend

Y_2020TR_50WLdtm4ws_cessub50.tif

Value

High : 155

Low : 0

0 120240 480 720 960
Meters

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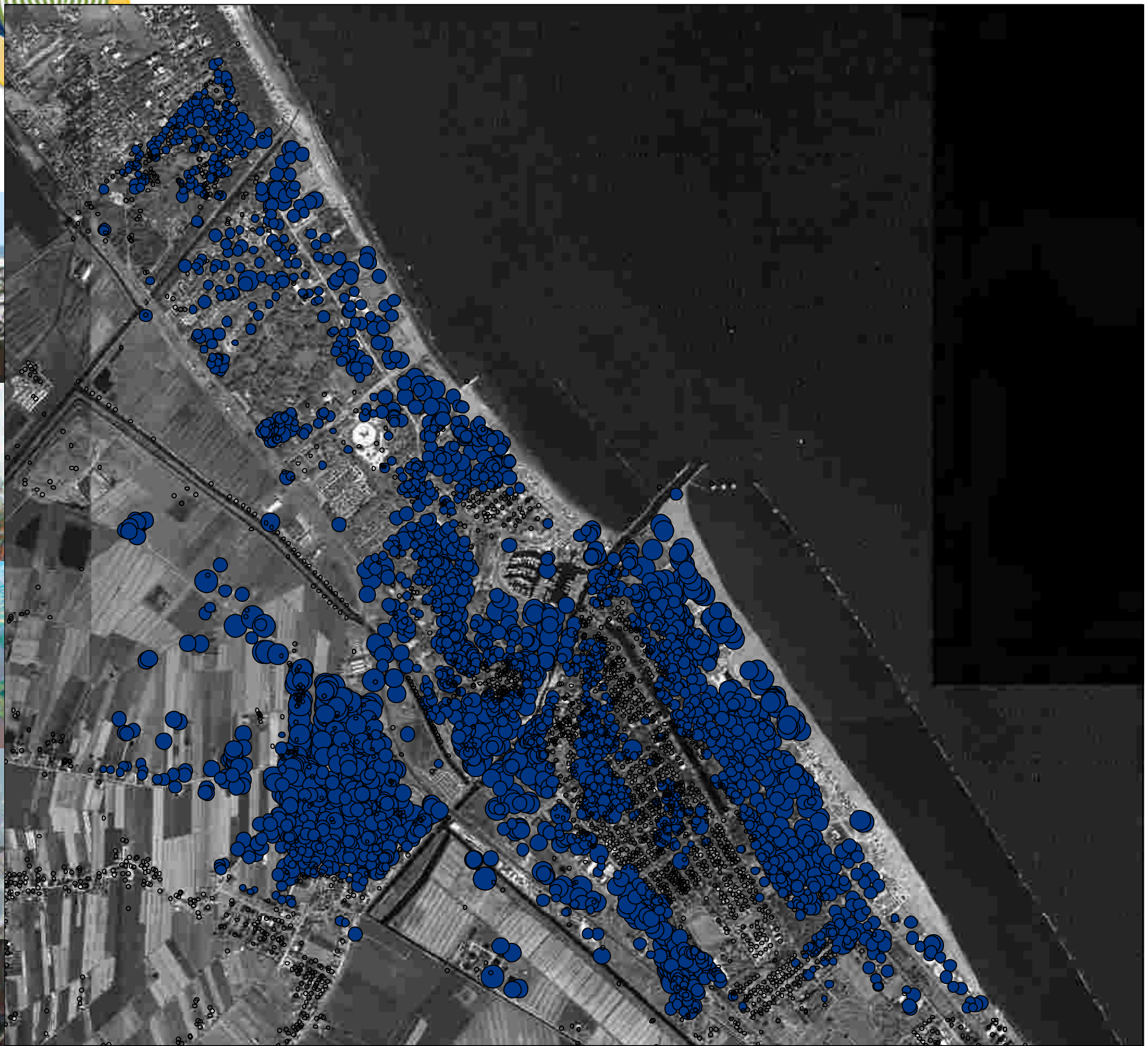
Hazard
Water Depth cm at Buildings

Scenario 2050
TR 50



Legend

edifici_Y_2020TR_50WL

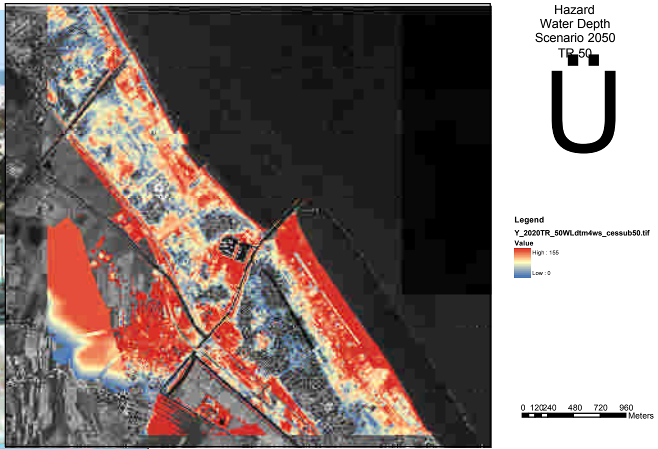
RASTERVALU

- -9999.000000 - 5.000000
- 5.000001 - 8.800003
- 8.800004 - 25.000000
- 25.000001 - 40.799995
- 40.799996 - 57.222504
- 57.222505 - 74.400002
- 74.400003 - 92.073227
- 92.073228 - 109.904976
- 109.904977 - 129.601944
- 129.601945 - 154.899994

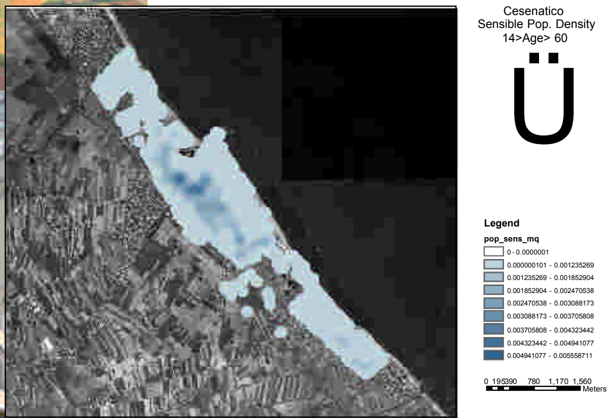
0 120240 480 720 960
Meters

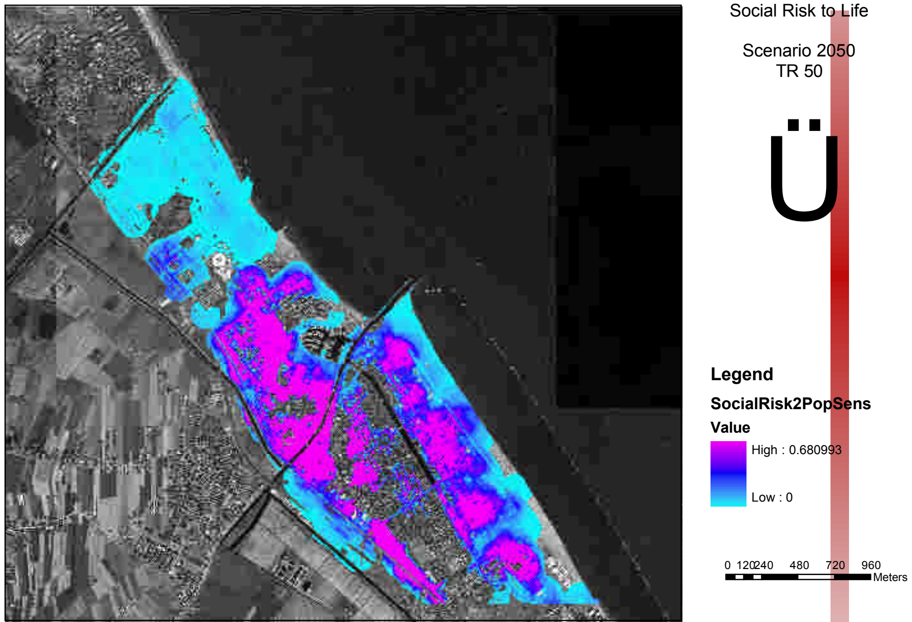
Social Risk for Sensible Pop= Hazard(WD)*Vulnerability

HAZARD



VULNERABILITY





Social Risk Index – Sensible Population (14>Age>60)

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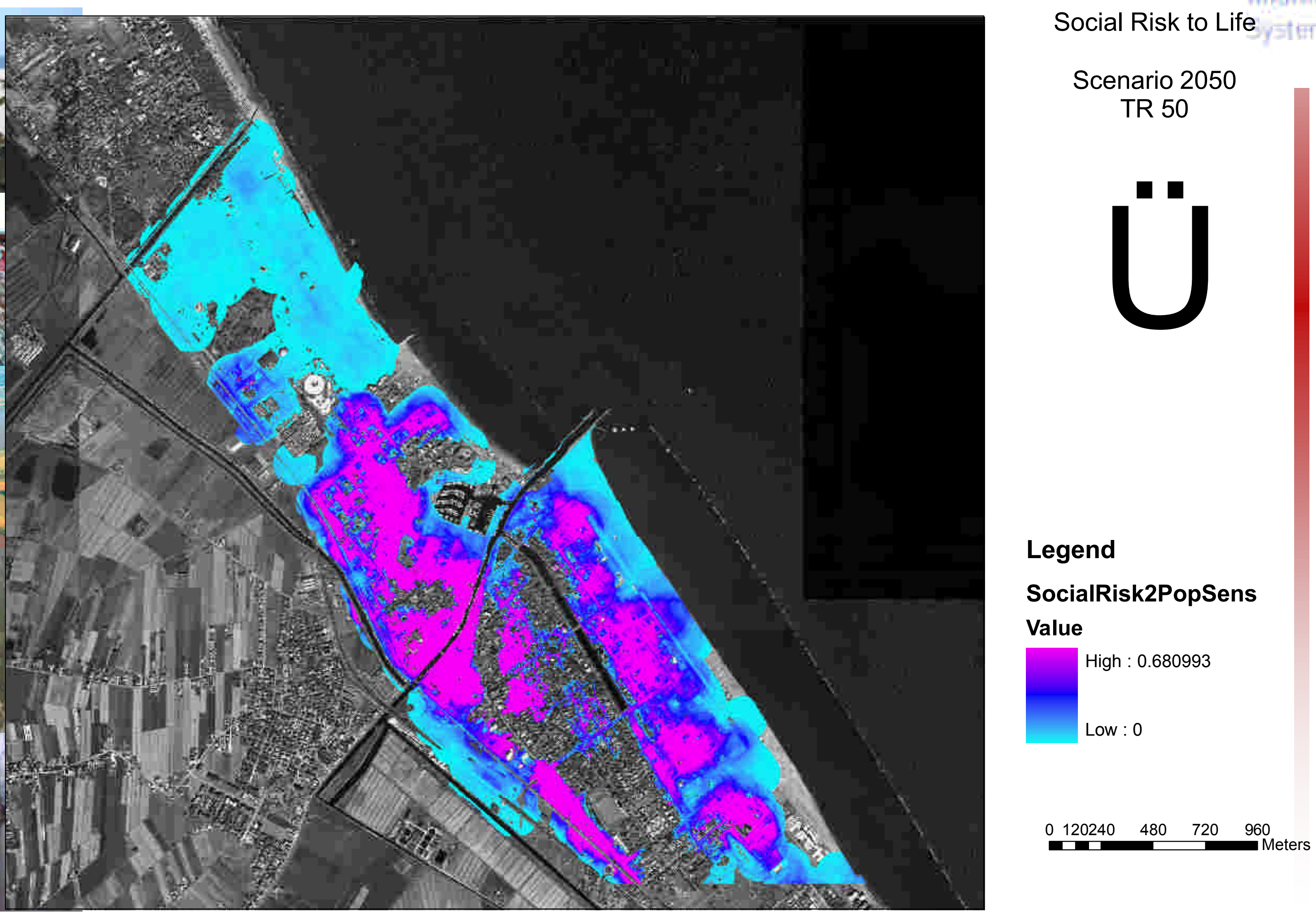
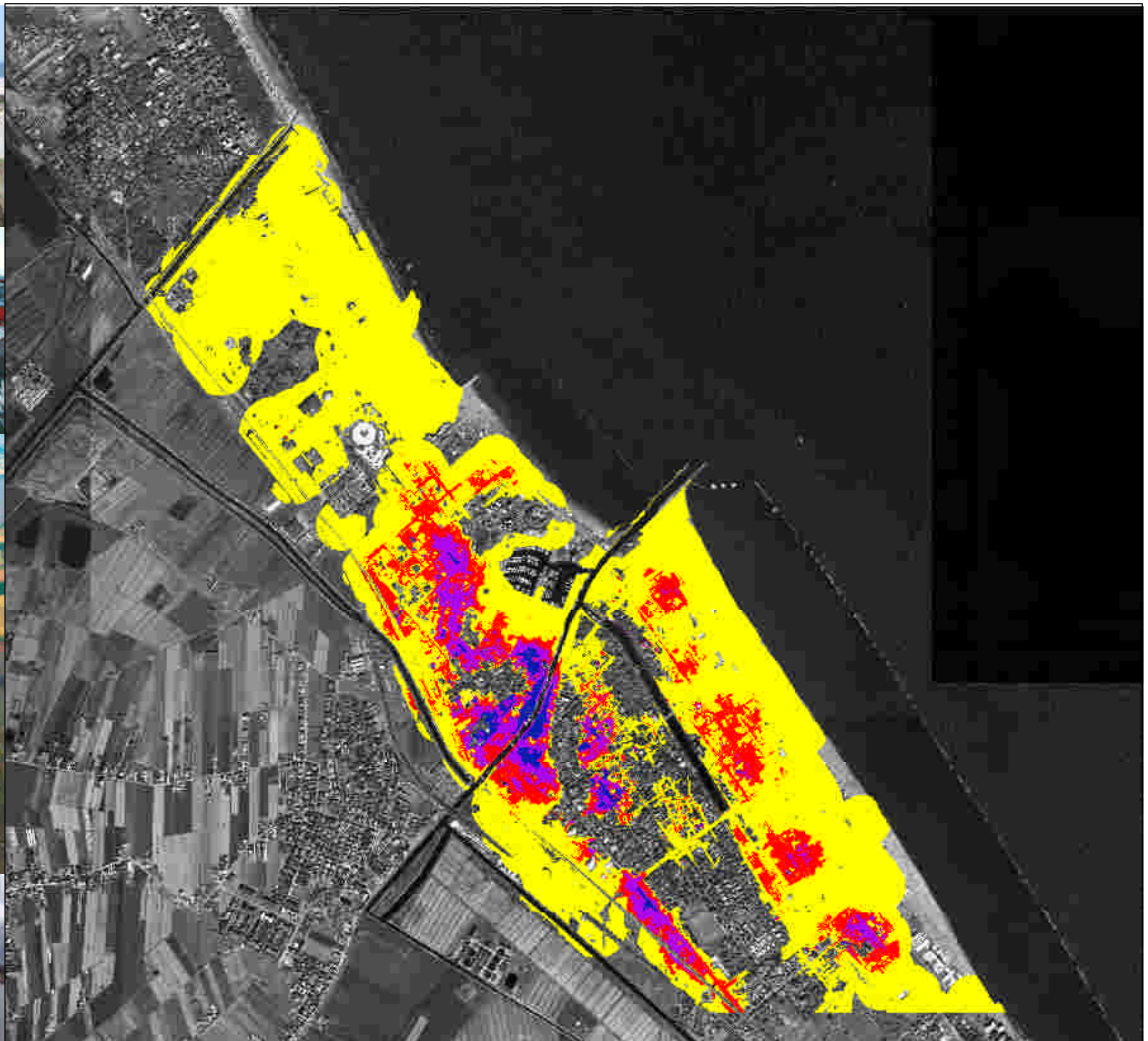


Social Risk Index – Sensible Population (14>Age>60)



Social Risk to Life

Scenario 2050
TR 50

Legend

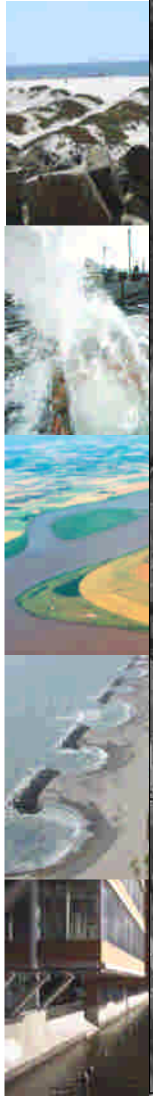
SocialRisk2PopSens

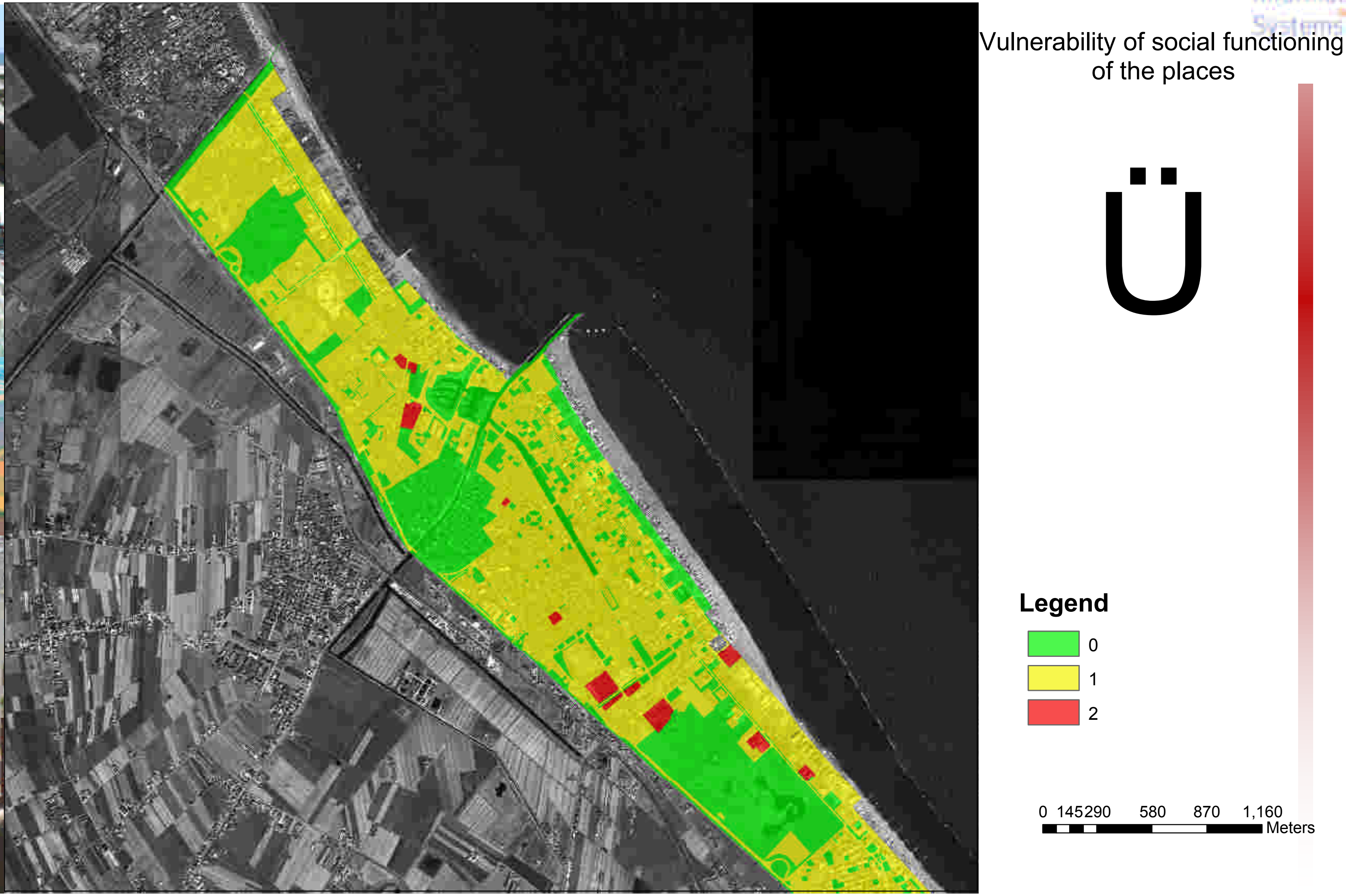
<VALUE>

- 0
- 1
- 2
- 3
- 4

0 120240 480 720 960
Meters

Vulnerability of social functioning of the places





Risk for social functioning of the places

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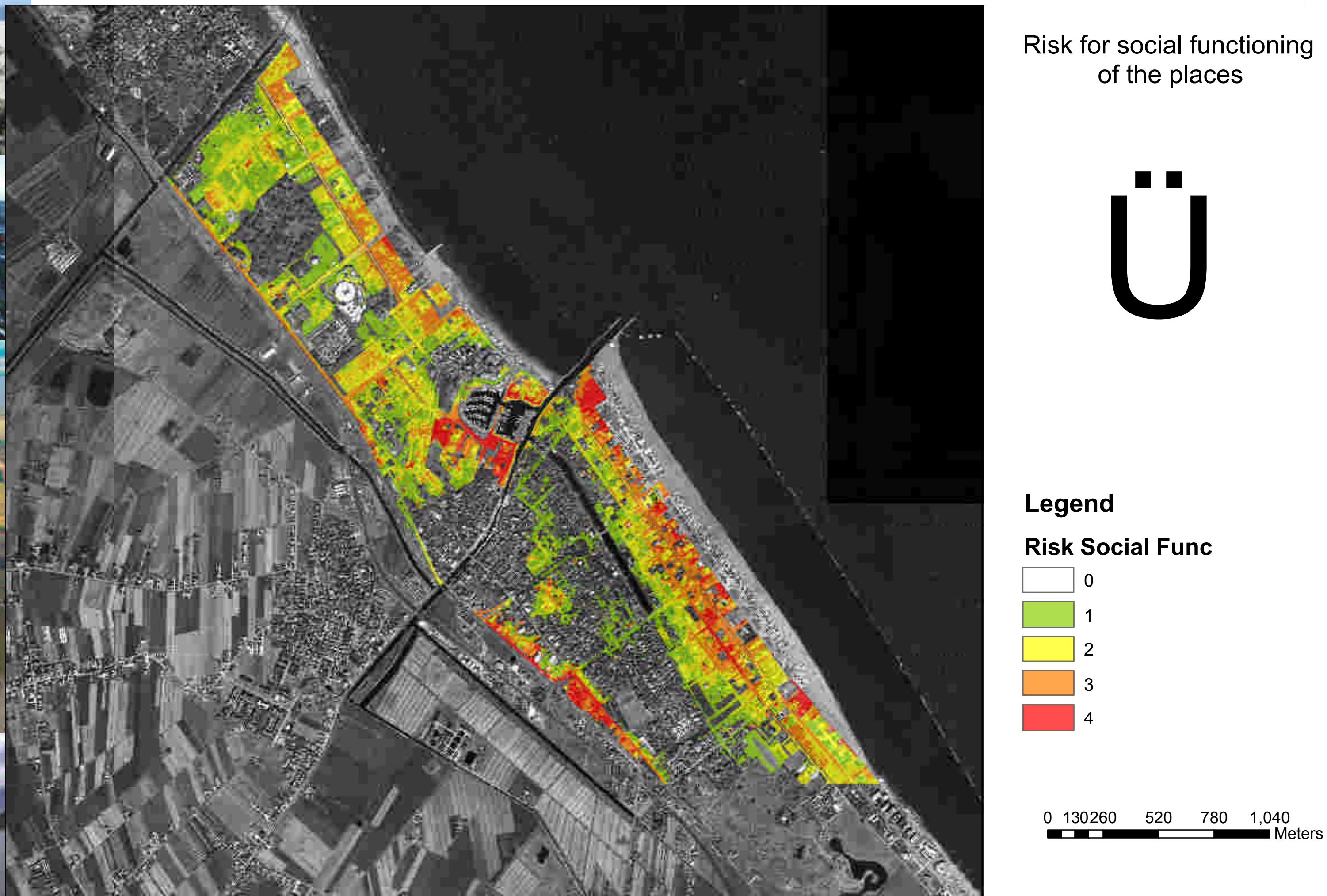
- Risk_SF= Vulnerability_SF*WD(cm)



Single and Multi Criteria Risk assessment

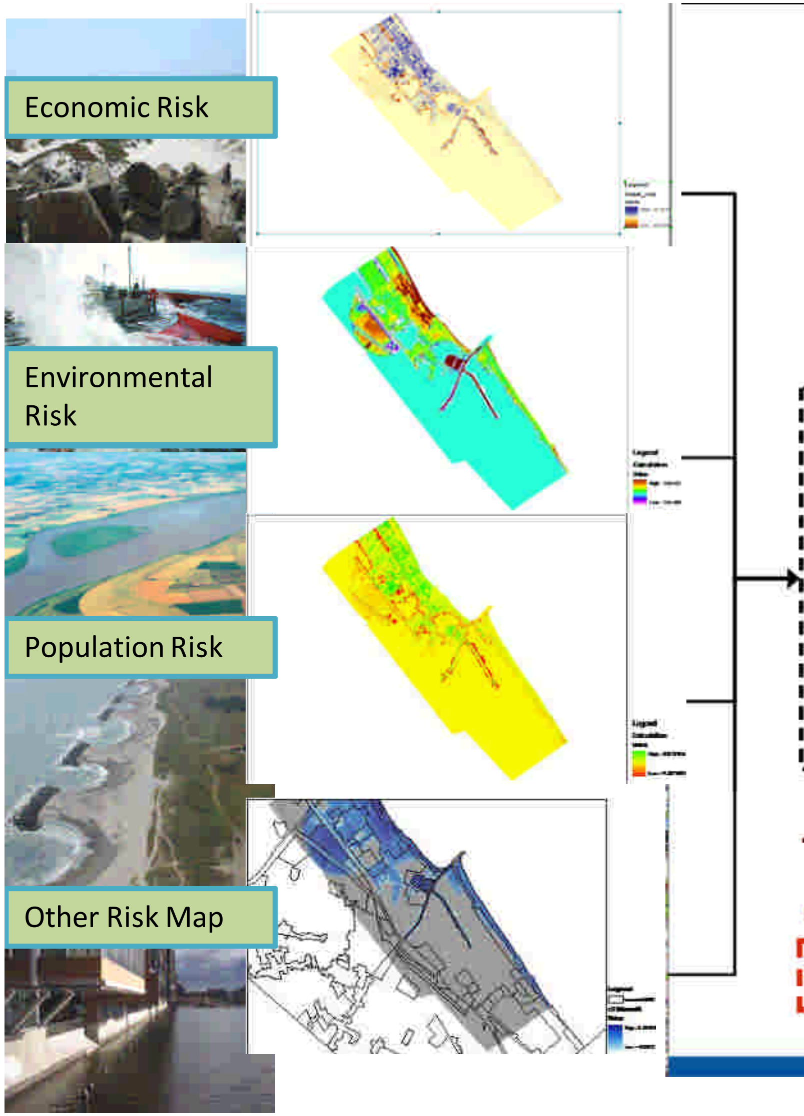
- What kind of method?
  - One-metric or
  - Multiple-metrics and multi-criteria analysis

- Criteria for integrated risk evaluation?
  - Selection of an homogeneous quantification for the impact
  - Risk evaluation in absolute terms so that risk in different study sites can be compared
  - Weights to be included in the final evaluation: selected by software user?

Single Risk Maps Indicator

- The user can define different flood risk map criteria
  - Economic risk
  - Environmental Risk
  - Social Risk
- The risk criteria can be converted in monetary value in order to obtain a single risk map or they can be analyzed in a spatial MCA tool

Multicriteria Risk Assessment



Multicriteria risk mapping: aggregation of the different criteria maps

Two different approaches used:

- Disjunctive approach
- Additive weighting approach

Multicriteria Approach: MAUT vs CB

- Problem Definition:
  - Set of risk mitigation measures (n alternatives)
    - Aj=A1….An
  - Set of risk criteria (environment, social, economic)
    - Ci=C1…….Cm
  - The score aij (raster map) describe the performance (costal risk indicator) of Alternative Aj respect the Criteria Ci
  - Wi(i=1…m) are the weight of importance for each Ci , assigned by stakeholders
- MAUT
  - Aggregation of different Ci risk criteria into a function, which has to be maximized
    - Economic risk
    - Environmental Risk
    - Social Risk
- CB Analysis
  - Evaluate the cost and benefit of each Aj in Monetary Base

Decision Support Module: MAUT MCA

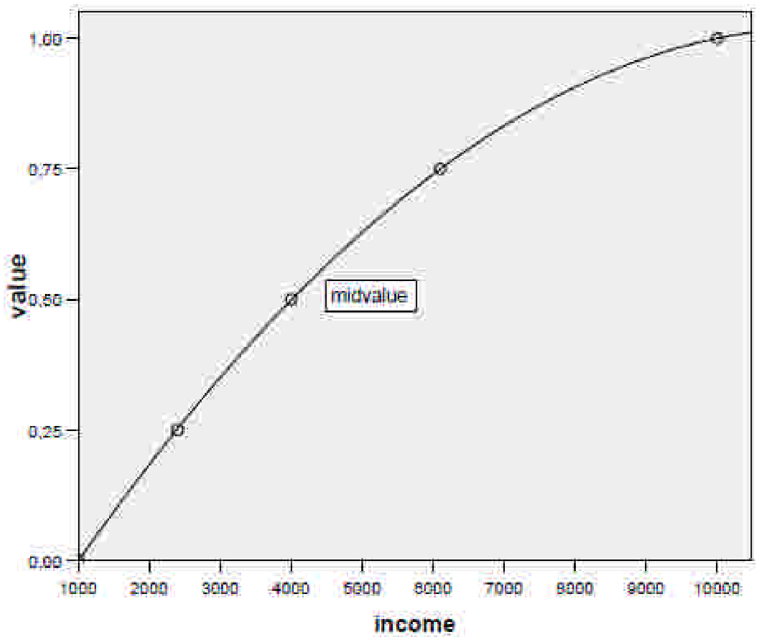
- The general concept of additive MAUT approaches is to generate a weighted average of the single criterion values for each alternative. Given a set of evaluation criteria (economic, environmental, social) and a set of alternatives (ex. Flood risk scenario, mitigation measures, etc) to be compared as well as scores for each alternative in each criteria and a set of weights for each criterion the procedure for this is the following:
  - Standardise the criteria scores to values (or utilities) between 0 and 1.
  - Calculate the weighted values for each criterion by multiplying the standardised value with its weight wi (pair-wise, ranking, ……)
  - Calculate the overall value (utility) for each alternative by summing the weighted values (utilities) of each criterion.
  - Rank the alternatives according to their aggregate value (utility).

$$x_j = \sum_{i=1}^{m} w_i a_{ij} / \sum_{i=1}^{m} w_i, \quad j = 1, \ldots, n.$$

  - where Xj is the overall value or utility of the alternative Aj, aij is the value or utility of the alternative j regarding criterion i and wi is the standardised weight for criterion

MCA Normalization

- MAUT :
- Normalization of aij score trought a normalization or utility function that transform the raw performance values of the alternatives against diverse criteria, both factual (objective, quantitative) and judgmental (subjective, qualitative), to a common, dimensionless scale (eg [0,1], [0,10], [H,M,L])
- Weight



MCA Weighting

- Rank Sum Method

$$w_j = \frac{n - r_j + 1}{\sum (n - r_k + 1)}$$

n = number of criteria ($k = 1, 2, \ldots, n$)
r_j = rank position of the criterion j

- Pairwise Comparison

Value	Definition
1	Equal importance
2	
3	Slightly more important
4	
5	Much more important
6	
7	Very much more important
8	
9	Absolutely dominating

Raster MCA

7th EUREGEO
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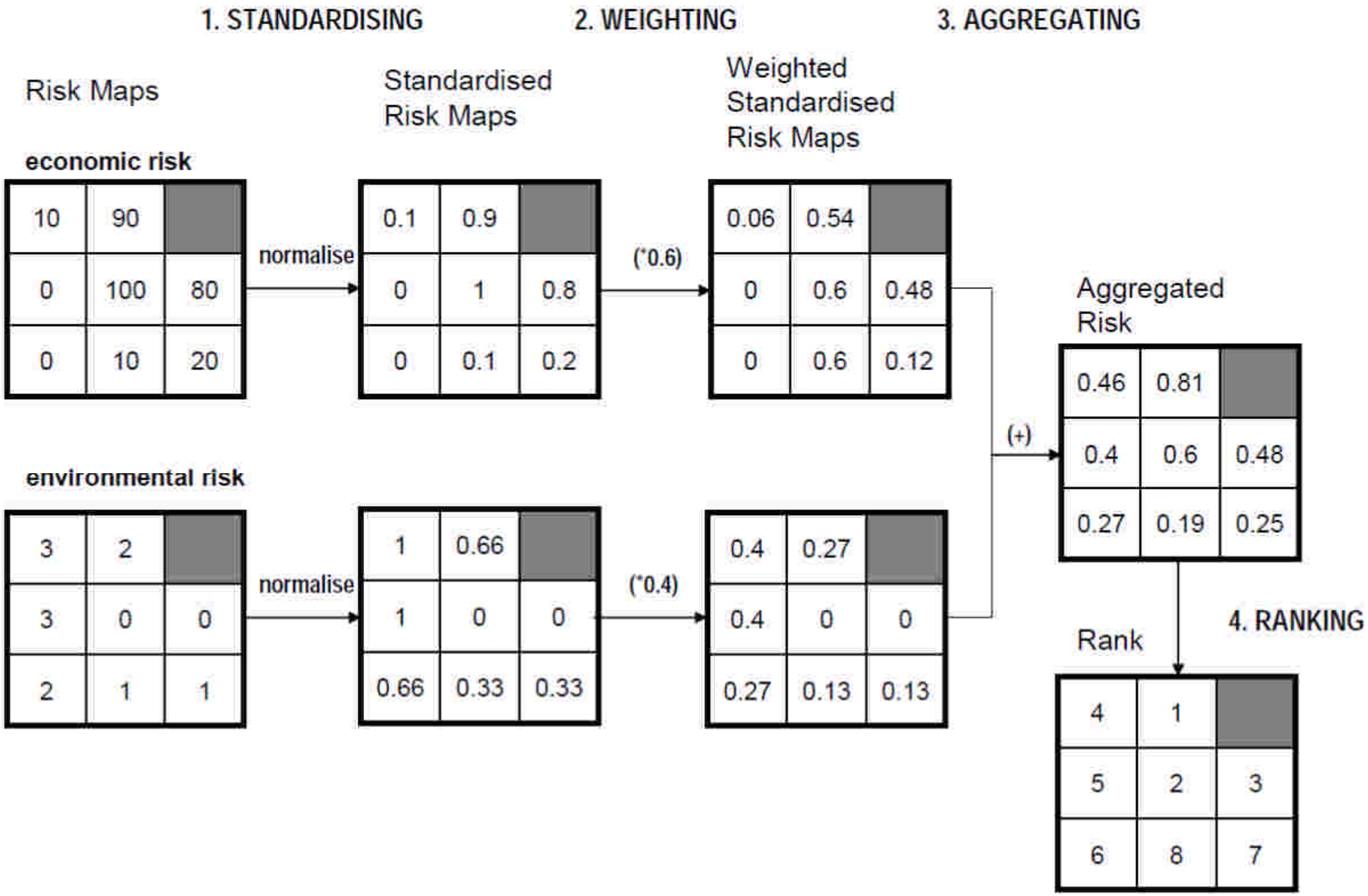

Based on Malczewski (1999), own example

MCA MAUT : Cesenatico Case Study

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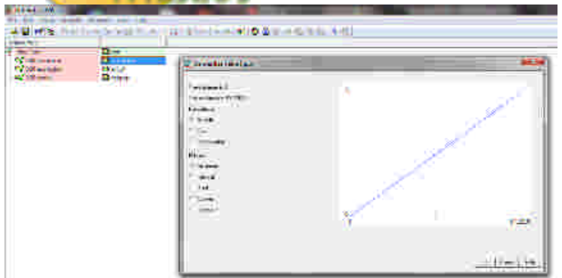

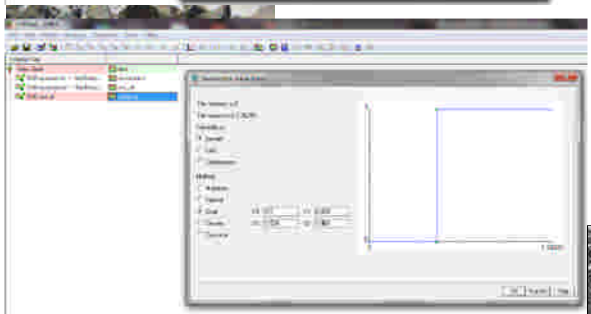

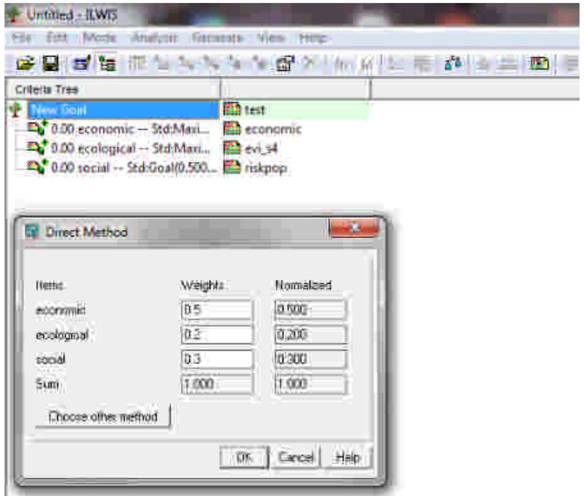

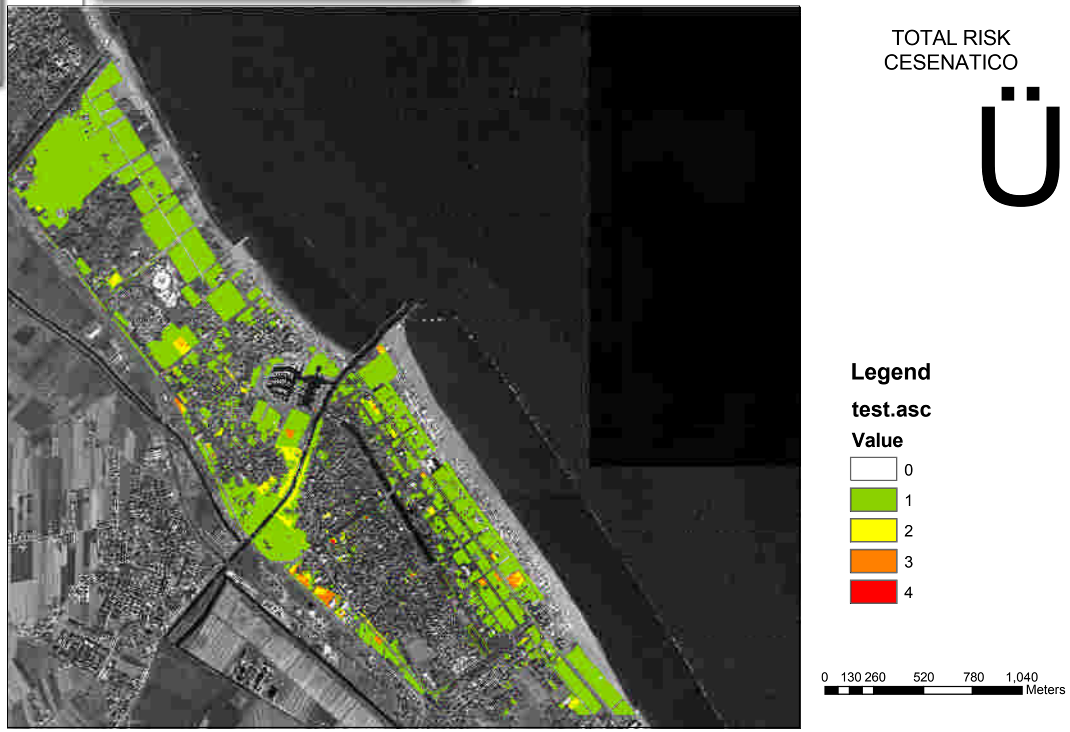

RISK & MCA MODULE GUI

- The single and multicriteria risk tools are developed using GIS map/raster algebra script (python GDAL).
- The GUI consist in a set of windows where the user can play with the different input for single and MCA (normalization, weighting, aggregation) risk assessment


Thank you for your kind attention