



MOVIDA

On the update of flood hazard and risk maps in the Po River District: results obtained for flood damage modelling

F. Ballio et al.

Context of the MOVIDA project

According to the Floods Directive, River Districts must update Preliminary Risk Analyses, Flood Hazard and Risk Maps, and Flood Risk Management Plans every 6 years

Activities implemented by the Po River District (21 universities/research centres involved)



State of art hydrological analysis (considering climate change effects) to update design precipitation and discharge data



Implementation of state of art modelling tools for the definition of flooded areas and the spatial distribution of water depth and velocity (i.e. hazard maps)



Implementation of state of art modelling tools for the definition of the spatial distribution of expected damage (i.e. damage/risk maps)

Objective of the MOVIDA project

To reach an analytical evaluation of expected damage, to support the updating of the Floods Directive in the Po District, especially regarding the CBA of mitigation measures

Focus of the analysis

- Five macro-categories of exposed elements as identified by the Floods Directive: people, infrastructures, economic activities, cultural and environmental heritage, factories at major accident risk.
- Identification of **specific, physically-based models for each category** (and sub-categories)

Requirements of the methodological approach

- To guarantee consistency and applicability of results, at the level of each category and at the district scale
- To adopt **models calibrated/validated for the Italian context**, easy to be implemented by non-expert users

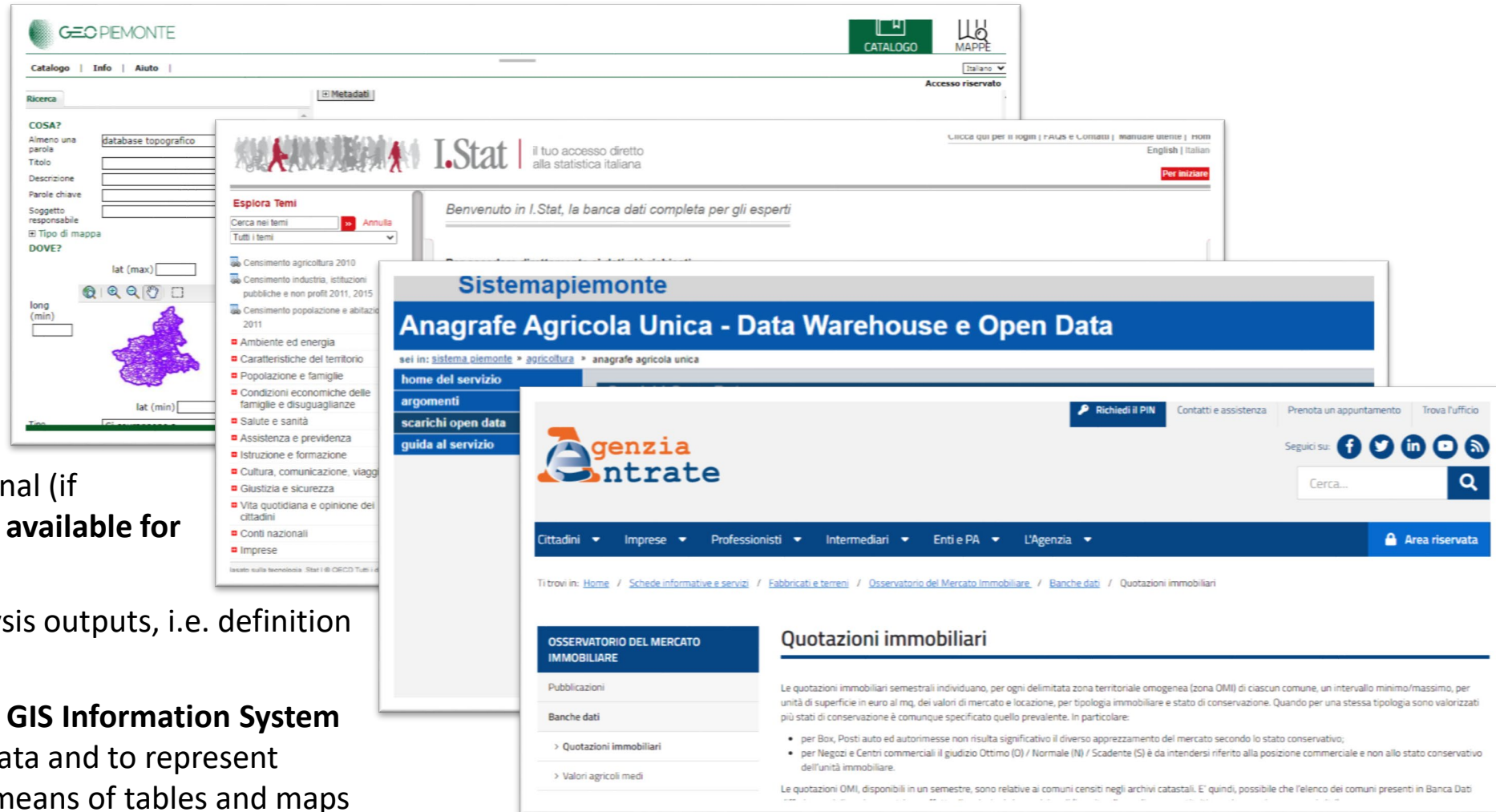


Objective of the MOVIDA project

To reach an analytical evaluation of expected damage, to support the updating of the Floods Directive in the Po District, especially regarding the CBA of mitigation measures

Sub-objectives

- To identify institutional (if possible) **input data available for the whole District.**
- To standardise analysis outputs, i.e. definition of output maps
- To develop an **Open GIS Information System** to elaborate input data and to represent analysis output, by means of tables and maps



The collage displays four web interfaces relevant to the project:

- GEOPIEMONTE:** A GIS application with a search bar, filters (COSA?, DOVE?), and a map of Piedmont.
- I.Stat:** The official ISTAT website for accessing Italian statistical data.
- Sistemapiemonte:** A portal for agricultural data, featuring an 'Anagrafe Agricola Unica' and 'Data Warehouse e Open Data'.
- agenzia entrate:** The official website of the Italian Revenue Agency, showing 'Quotazioni immobiliari' (real estate quotations).



Working group



Autorità di Bacino
Distrettuale del Fiume Po

Tommaso Simonelli



Università
degli Studi
di Ferrara

*Paolo Ciavola
Enrico Duo*



UNIVERSITÀ DEGLI STUDI DI TORINO

*Enrico Borgogno
Barbara Drusi
Velia Bigi
Federica Ghilardi*



Consiglio Nazionale delle Ricerche

*Simone Sterlacchini
Marco Zazzeri
Fabio Luino
Laura Turconi*



ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

*Alessio Domeneghetti
Francesca Carisi
Natasha Petruccelli*



UNIVERSITÀ
DEGLI STUDI
DI BRESCIA

*Marco Pilotti
Luca Milanese
Gabriele Farina*



IUSS
Scuola Universitaria Superiore Pavia

*Mario Martina
Clara Armaroli
Riccardo Giusti
Marcello Arosio
Beatrice Monteleone*



UNIVERSITÀ
DEGLI STUDI
FIRENZE

*Fabio Castelli
Chiara Arrighi*



UNIVERSITÀ DEGLI STUDI DELL'AQUILA

Anna Rita Scorzini

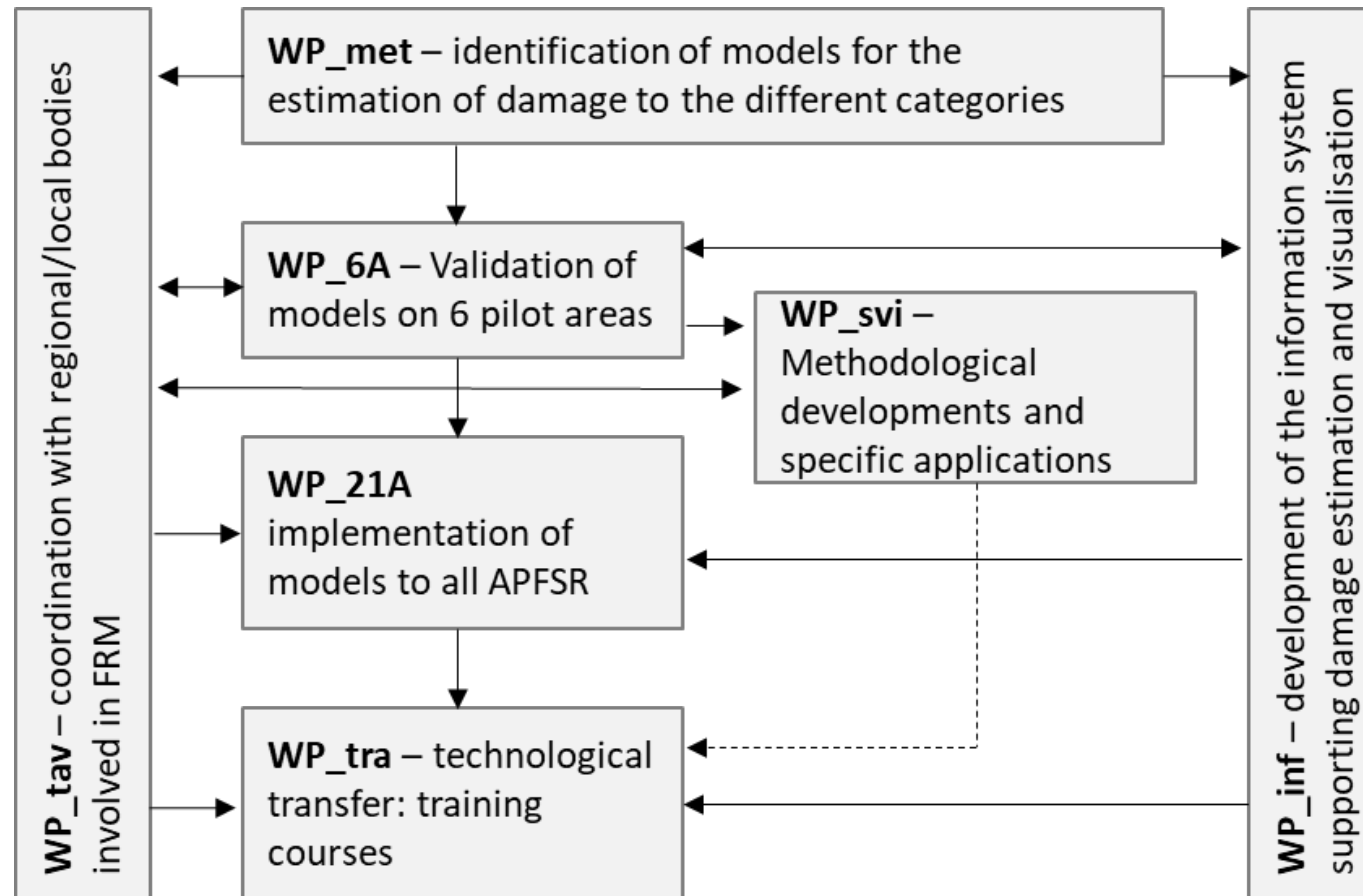


POLITECNICO
MILANO 1863

*Francesco Ballio
Daniela Molinari
Alice Gallazzi*

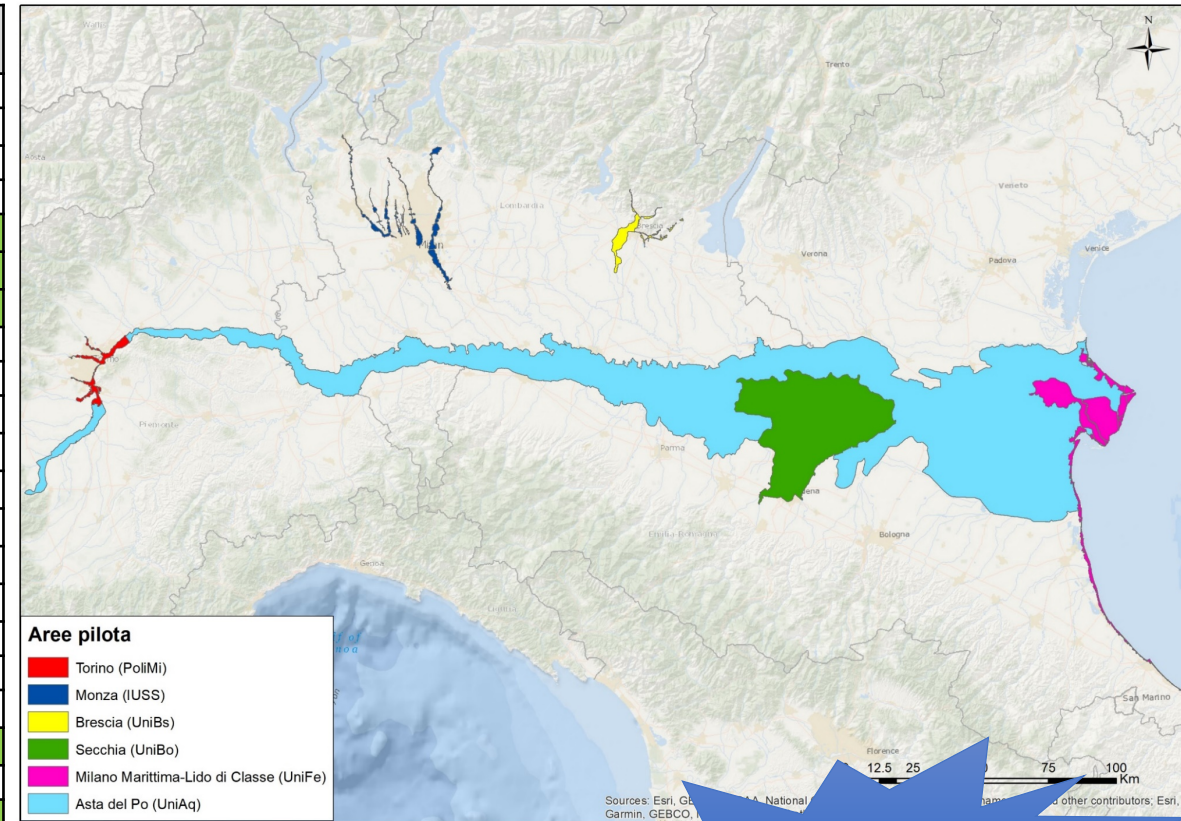
Structure of the project

- 3 methodological steps (WP_met, WP_6A, WP_21A)
- 3 supporting activities (WP_inf, WP_tav, WP_tra)
- Methodological developments and specific applications (WP_svi)



State of art: development and implementation of the methodology on six pilot areas

Exposed element	Level 1 (quantitative)	Level 2 (qualitative)	Level 3 (descriptive)
People			
Strategic infrastructures			
Roads and railways			
Other networks			
Strategic buildings			
Economic activities			
Residential buildings (structure)			
Residential buildings (contents)			
Industrial and commercial activities (structure)			
Industrial and commercial activities (equipment)			
Agricultural activities (certain crops)			
Agricultural activities (other crops, livestock)			
Cultural and environmental heritage			
Cultural heritage			
Environmental heritage			
Factories at major accident risk			



Meso-scale



People

Level 1: quantitative evaluation of potential damage (i.e. exposure)

METHODOLOGY

Modelling approach: evaluation of the total resident population and vulnerable groups, i.e. children and the elderly

Map scale: ISTAT census block (meso-scale)

Scale of analysis: meso-scale (ISTAT census block)

Hazard data: FRMPs hazard maps

Physical exposure data: ISTAT – Population and household census 2011

Vulnerability data: ISTAT – Population and household census 2011

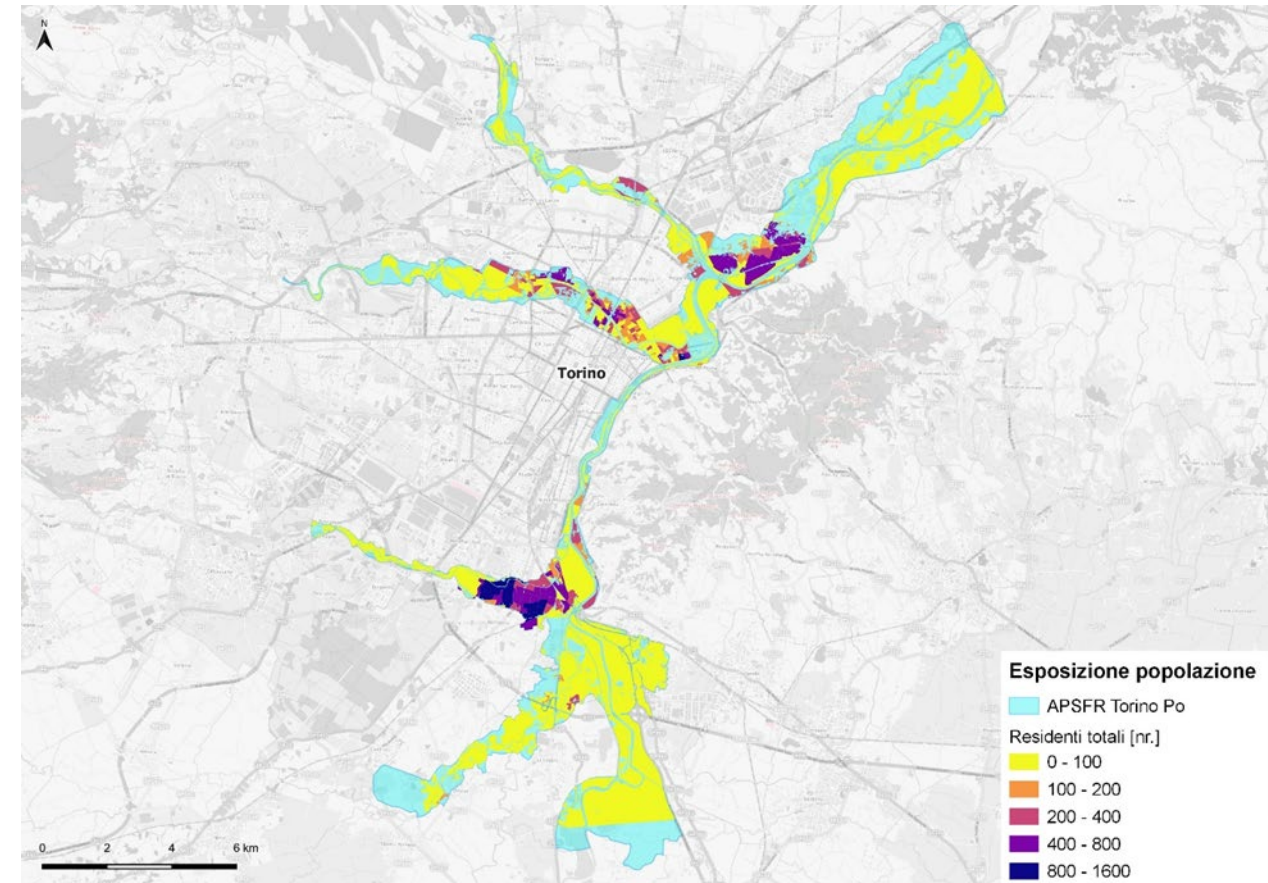
Potential damage indicators:

- Number of residents
- Number of residents over 65
- Number of residents under 10

People

Level 1: quantitative evaluation of potential damage (i.e. exposure)

Exposed resident population [n.]	Low probability scenario (TR=500 y)
Residents in the flooded area	81 092
Residents over 65 in the flooded area	17 745
Residents under 10 in the flooded area	7 795

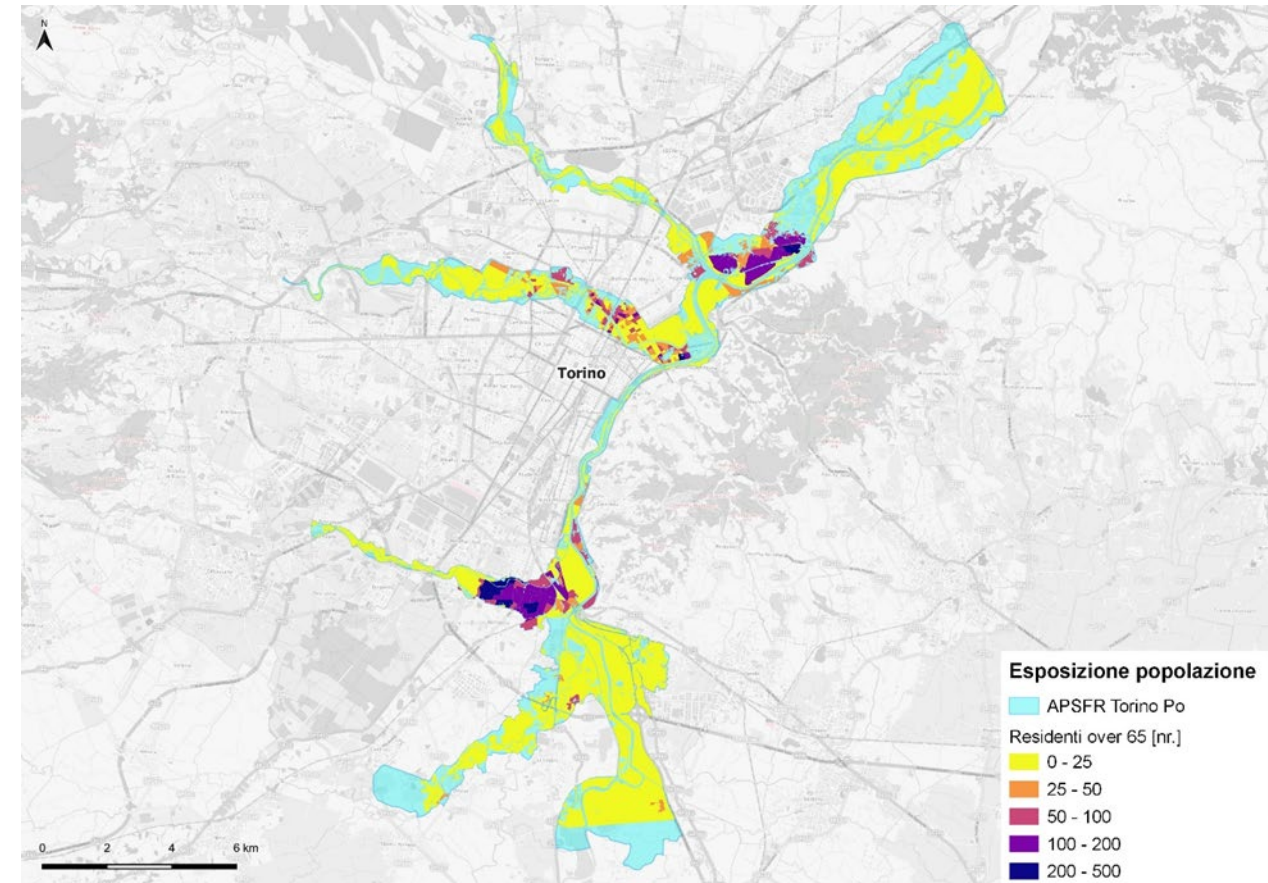


Total resident population per census block

People

Level 1: quantitative evaluation of potential damage (i.e. exposure)

Exposed resident population [n.]	Low probability scenario (TR=500 y)
Residents in the flooded area	81 092
Residents over 65 in the flooded area	17 745
Residents under 10 in the flooded area	7 795

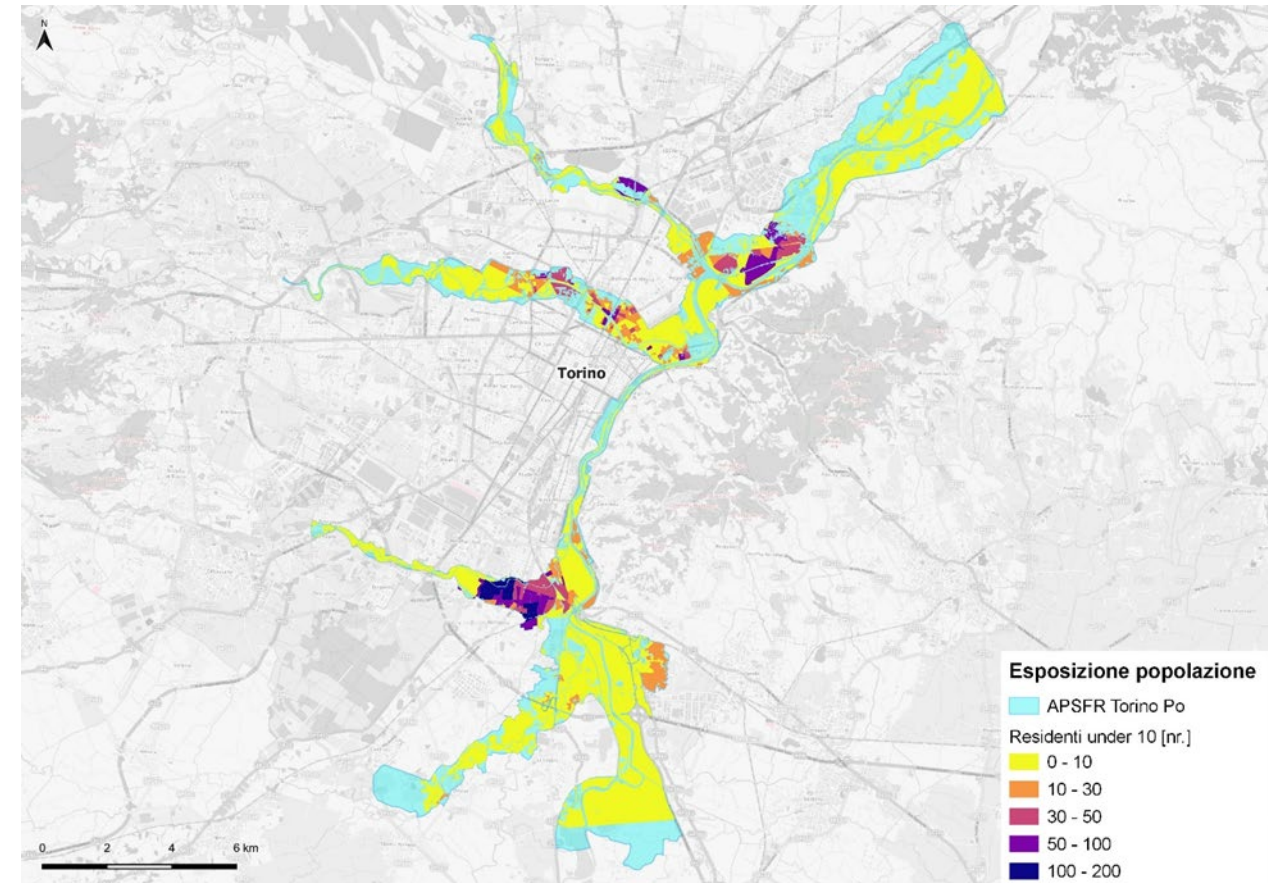


Resident population over 65 per census block

People

Level 1: quantitative evaluation of potential damage (i.e. exposure)

Exposed resident population [n.]	Low probability scenario (TR=500 y)
Residents in the flooded area	81 092
Residents over 65 in the flooded area	17 745
Residents under 10 in the flooded area	7 795



Resident population under 10 per census block



Roads & railways

Level 2: qualitative evaluation of expected damage

METHODOLOGY

Modelling approach: qualitative evaluation of functional damage by means of a new, ad-hoc method + collection of anecdotal data regarding the physical damage

Map scale: individual tract

Scale of analysis: individual tract

Hazard data : FRMPs hazard maps

Physical exposure and vulnerability data: Open Street Map, National and Regional Data

Anecdotal data: National Research Council Archive

Qualitative damage indicators:

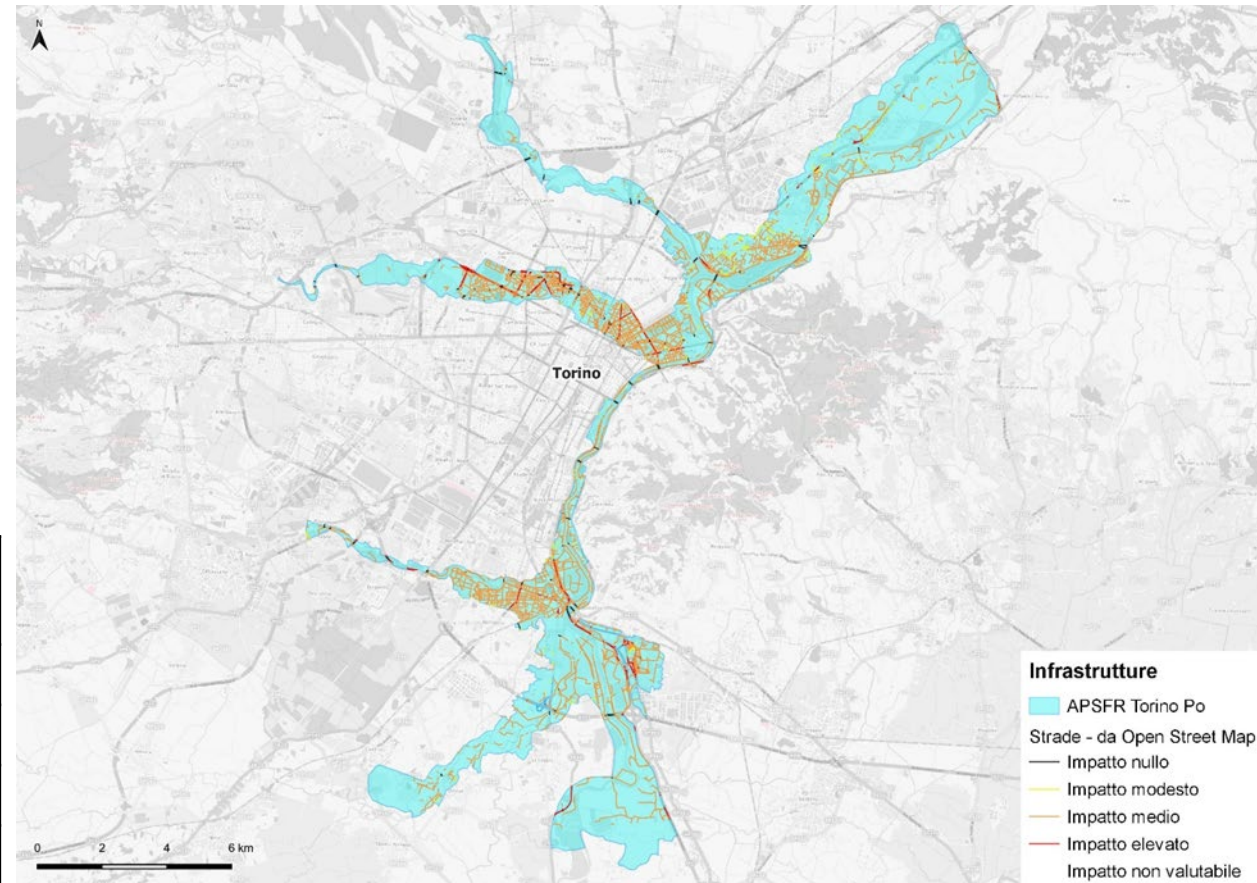
- Length of tracts with low impact (km)
- Length of tracts with medium impact (km)
- Length of tracts with high impact (km)

Roads & railways

Level 2: qualitative evaluation of expected damage

Length of exposed tracts, by road typology [km]	Low probability scenario (TR=500 y)
Highways	4.0
Main roads	34.1
Secondary roads	167.2
Country/minor roads	123.6
Other (e.g. pedestrian, cycling)	106.3
Tunnels	1.9
Bridges	18.0

Length of exposed tracts, by impact class [km]	Low probability scenario (TR=500 y)
No impact	18.0
Low impact	9.9
Medium impact	388.8
High impact	38.4
Not evaluable	0.0



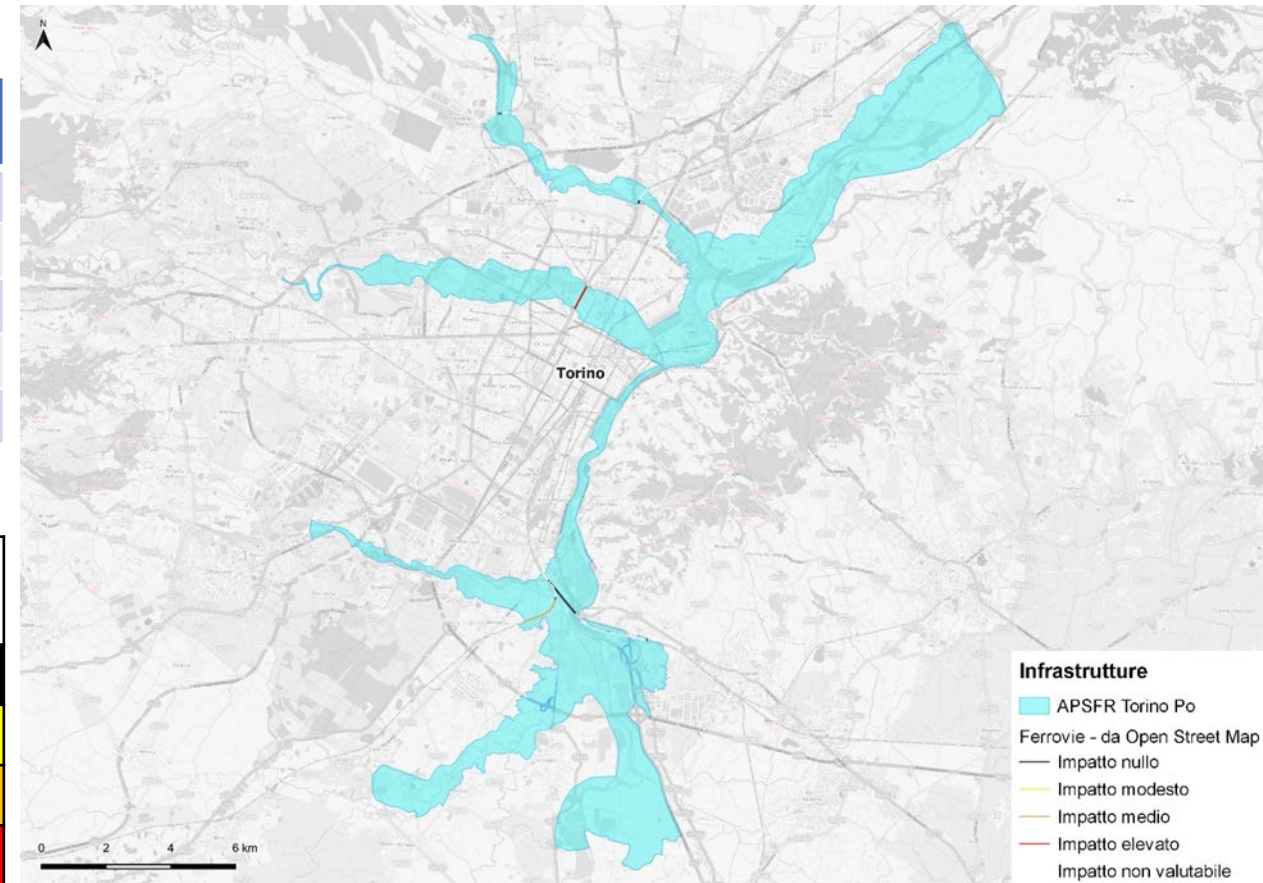
Impact on the road network

Roads & railways

Level 2: qualitative evaluation of expected damage

Length of exposed tracts, by railway line typology [km]	Low probability scenario (TR=500 y)
Single-track railway line	2.3
Multiple-track railway line	0.0
High-speed railway line	0.0
Tunnels	3.2
Bridges	5.5

Length of exposed tracts, by impact class [km]	Low probability scenario (TR=500 y)
No impact	5.5
Low impact	0.0
Medium impact	2.3
High impact	3.2
Not evaluable	9.3



Impact on the railways



Other networks

Level 2: qualitative evaluation (yes/no) of potential damage (i.e. exposure)

METHODOLOGY

Modelling approach: identification of ports and airports (potential damage) + collection of anecdotal data for other networks such as electricity grid, telecommunications network, water supply network and drainage system

Map scale: individual infrastructure

Scale of analysis: individual infrastructure

Hazard data : FRMPs hazard maps

Physical exposure and vulnerability data: Open Street Map

Potential damage indicator:

- **Number of exposed infrastructures**



Strategic buildings

Level 2: qualitative evaluation (yes/no) of potential damage (i.e. exposure)

METHODOLOGY

Modelling approach: identification of strategic buildings (potential damage) + collection of anecdotal data

Map scale: being defined

Scale of analysis: individual building

Hazard data : FRMPs hazard maps

Physical exposure and vulnerability data: being defined

Anecdotal data: National Research Council Archive

Potential damage indicator:

- Number of exposed strategic buildings



Residential buildings

Level 1: quantitative evaluation of expected damage

METHODOLOGY

Modelling approach: evaluation of the economic damage to building structures by a set of models: simple-INSYDE (PoliMi), Carisi et al. (UniBo), Arrighi et al. (UniFi)

Map scale: ISTAT census block (meso-scale)

Scale of analysis: micro-scale (individual building); meso-scale (ISTAT census block) where micro-scale data are not available (i.e. Regional Topographic Database - DBTR)

Hazard data: FRMPs hazard maps

Physical exposure data: DBTR; where DBTR is not available, ISTAT – Population and household census 2011

Economic exposure data: CRESME – Italian Research Centre for the building sector

Vulnerability data: ISTAT – Population and household census 2011, Real Estate property database – 2019

Damage indicator:

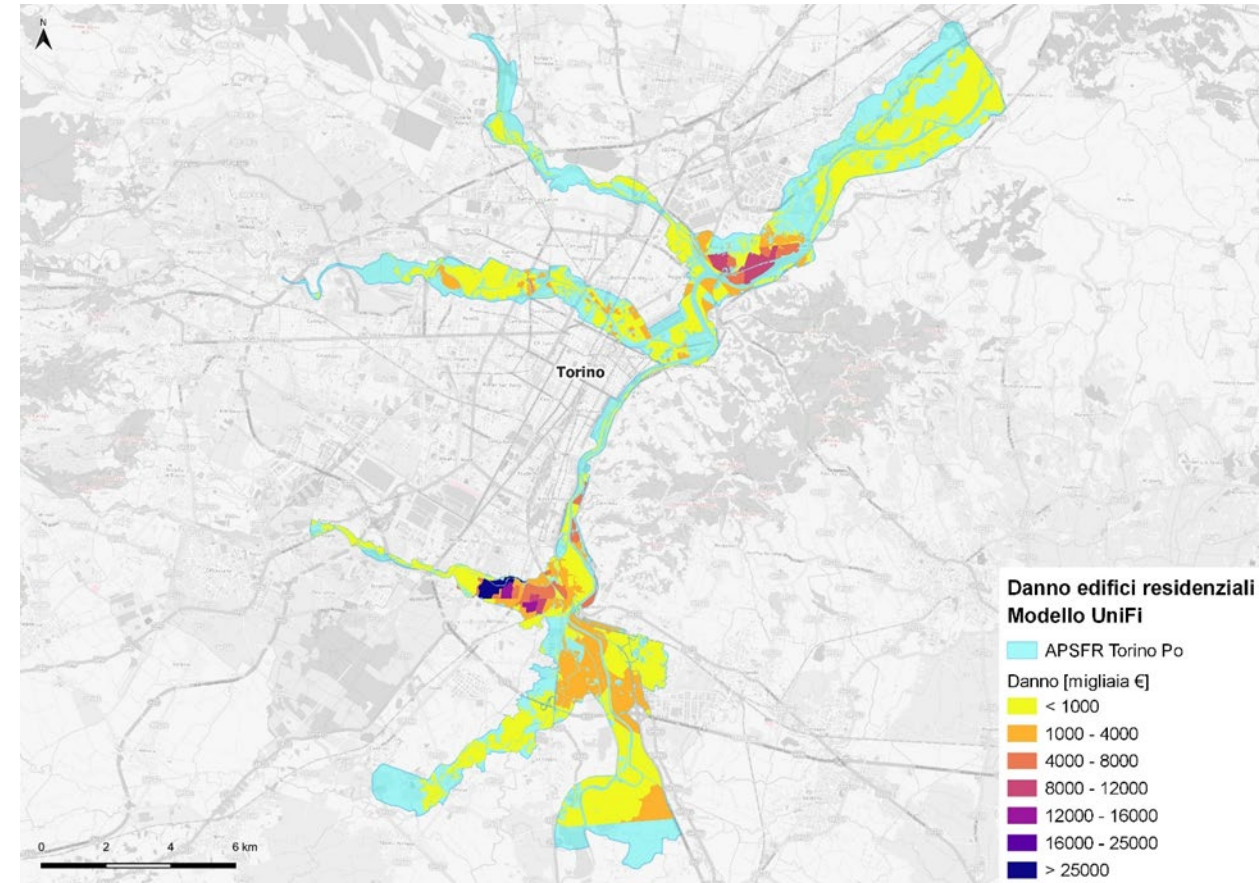
- Economic damage to building structure (€)

Residential buildings

Level 1: quantitative evaluation of expected damage

Exposed residential buildings	Low probability scenario (TR=500 y)
Buildings in the flooded area [n.]	6 096
Surface of buildings in the flooded area [m ²]	1 099 775
Economic value of exposed buildings [M€]	1 675
Average economic value per building [€]	274 728

Economic damage to the structure of exposed buildings	Low probability scenario (TR=500 y)
Total damage Arrighi et al. (UniFi) [M€]	447
Total damage Carisi et al. (UniBo) [M€]	243
Total damage Simple-INSYDE (PoliMi) [M€]	133
Average damage per building Arrighi et al. (UniFi) [€]	73 270
Average damage per building Carisi et al. (UniBo) [€]	39 833
Average damage per building Simple-INSYDE (PoliMi) [€]	21 823



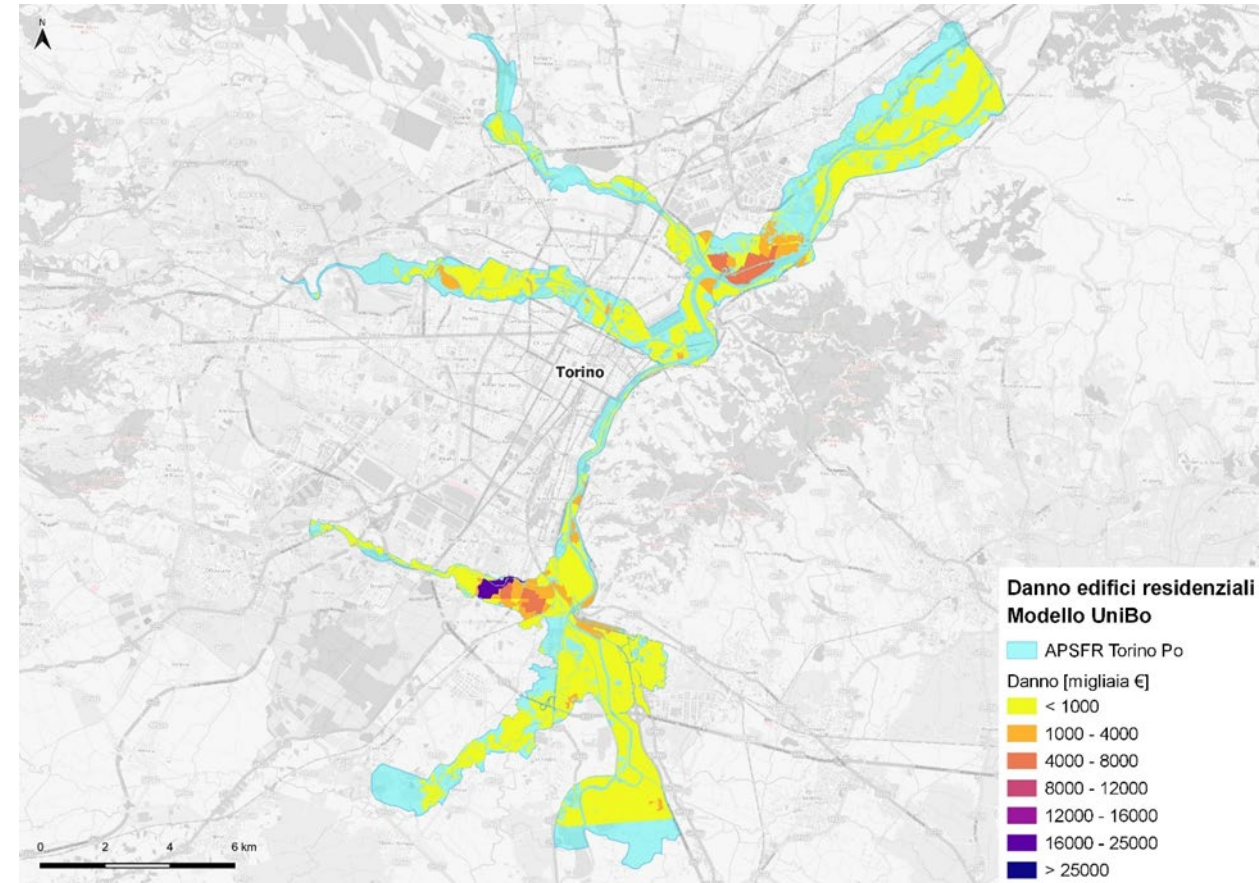
Damage to residential buildings per census block – model by Arrighi et al.

Residential buildings

Level 1: quantitative evaluation of expected damage

Exposed residential buildings	Low probability scenario (TR=500 y)
Buildings in the flooded area [n.]	6 096
Surface of buildings in the flooded area [m ²]	1 099 775
Economic value of exposed buildings [M€]	1 675
Average economic value per building [€]	274 728

Economic damage to the structure of exposed buildings	Low probability scenario (TR=500 y)
Total damage Arrighi et al. (UniFi) [M€]	447
Total damage Carisi et al. (UniBo) [M€]	243
Total damage Simple-INSYDE (PoliMi) [M€]	133
Average damage per building Arrighi et al. (UniFi) [€]	73 270
Average damage per building Carisi et al. (UniBo) [€]	39 833
Average damage per building Simple-INSYDE (PoliMi) [€]	21 823



Damage to residential buildings per census block – model by Carisi et al.

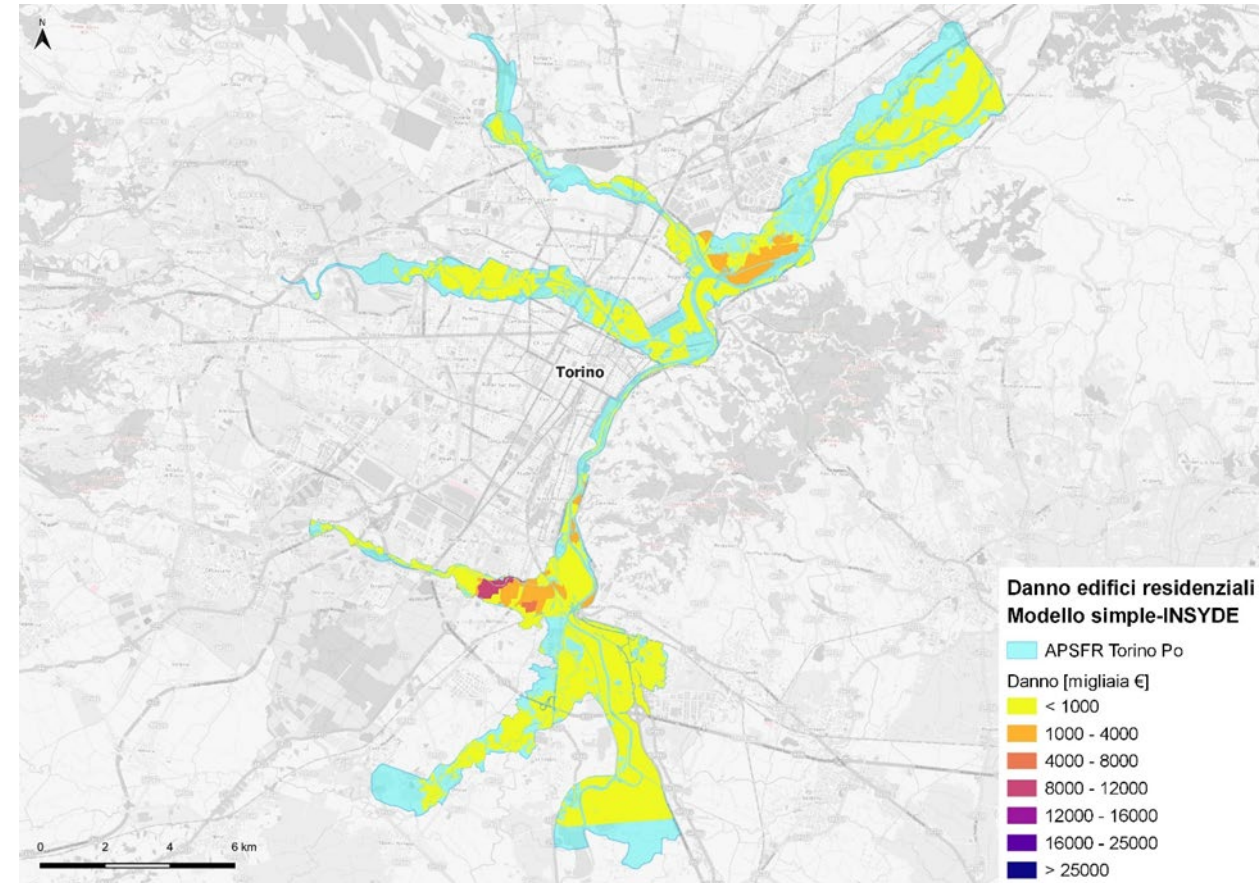


Residential buildings

Level 1: quantitative evaluation of expected damage

Exposed residential buildings	Low probability scenario (TR=500 y)
Buildings in the flooded area [n.]	6 096
Surface of buildings in the flooded area [m ²]	1 099 775
Economic value of exposed buildings [M€]	1 675
Average economic value per building [€]	274 728

Economic damage to the structure of exposed buildings	Low probability scenario (TR=500 y)
Total damage Arrighi et al. (UniFi) [M€]	447
Total damage Carisi et al. (UniBo) [M€]	243
Total damage Simple-INSYDE (PoliMi) [M€]	133
Average damage per building Arrighi et al. (UniFi) [€]	73 270
Average damage per building Carisi et al. (UniBo) [€]	39 833
Average damage per building Simple-INSYDE (PoliMi) [€]	21 823



Damage to residential buildings per census block – Simple-INSYDE model



Economic activities (industrial & commercial)

Level 1: quantitative evaluation of potential damage (i.e. exposure)

METHODOLOGY

Modelling approach: evaluation of the economic value of building structures and equipment by means of the Flood-IMPAT procedure

Map scale: ISTAT census block (meso-scale)

Scale of analysis: meso-scale (ISTAT census block)

Hazard data : FRMPs hazard maps

Physical exposure data : ISTAT – Industry census 2011, ISTAT – ASIA (2018)

Economic exposure data : ISTAT – National data on economic activities (2018)

Vulnerability data: ISTAT – Industry census 2011, ISTAT – ASIA (2018)

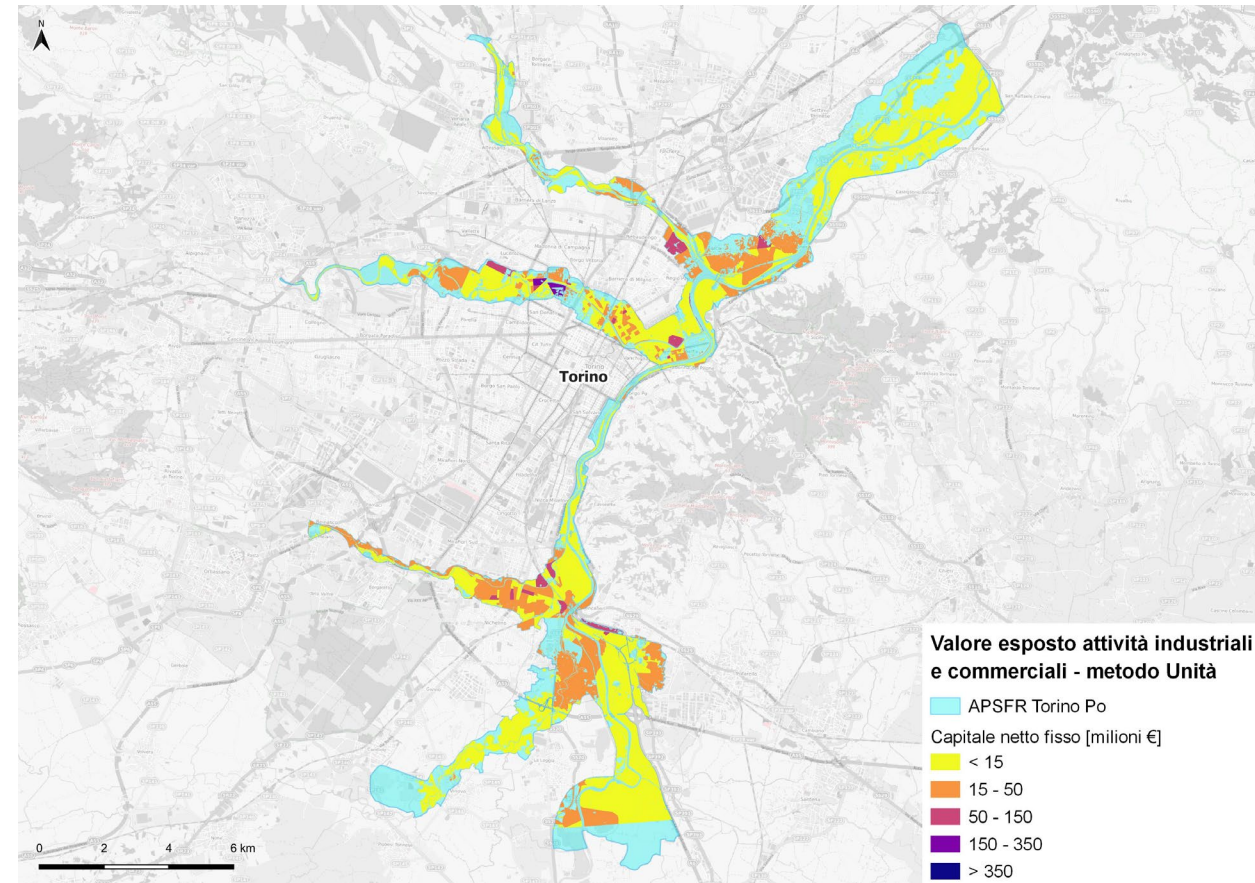
Potential damage indicators:

- Net capital stock of structure per NACE code (€)
- Net capital stock of equipment per NACE code (€)

Economic activities (industrial & commercial)

Level 1: quantitative evaluation of potential damage (i.e. exposure)

Exposed economic activities	Low probability scenario (TR=500 y)
Activities in the flooded area [n.]	6 173
Employees in the flooded area [n.]	31 726
Net capital stock – structure [M€]	7 495
Net capital stock – equipment [M€]	1 213

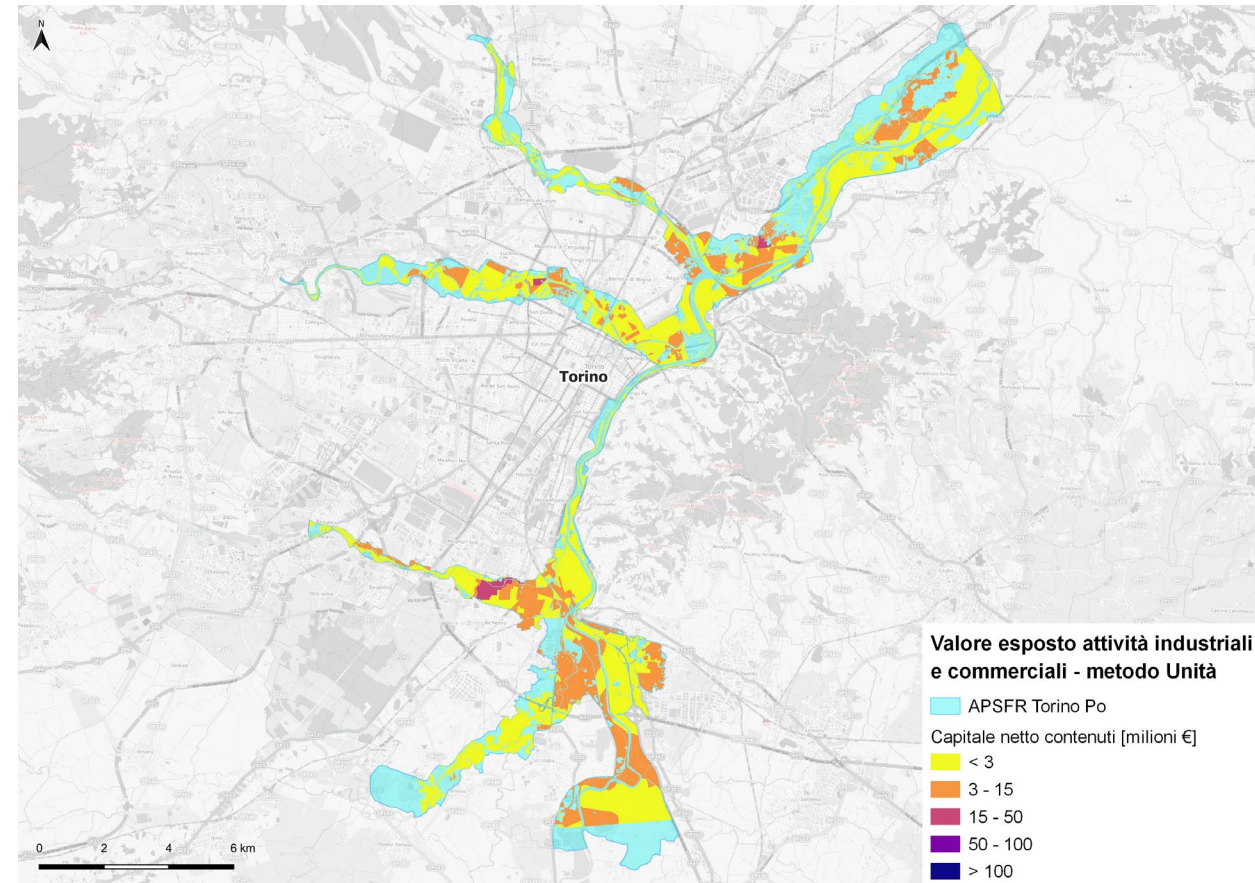


Economic value of economic activities structure, per census block

Economic activities (industrial & commercial)

Level 1: quantitative evaluation of potential damage (i.e. exposure)

Exposed economic activities	Low probability scenario (TR=500 y)
Activities in the flooded area [n.]	6 173
Employees in the flooded area [n.]	31 726
Net capital stock – structure [M€]	7 495
Net capital stock – equipment [M€]	1 213



Economic value of equipment of economic activities, per census block



Agricultural activities

Level 1: quantitative evaluation of expected or potential damage

METHODOLOGY

Modelling approach: evaluation of the economic damage (i.e. loss of gross profit) by means of AGRIDE-c model for maize, wheat, barley, rice and grassland; evaluation of the economic exposure (i.e. gross output) for all the crops; evaluation of the physical exposure (i.e. species and number of animals) for the livestock

Map scale: cadastral parcel (meso-scale)

Scale of analysis: cadastral parcel, by assuming that the main cultivated crop covers the entire parcel surface (meso-scale); individual livestock

Hazard data: FRMPs hazard maps + data on past flood events to identify the typical duration and time of occurrence of the floods in the area

Physical exposure and vulnerability data: cadastre, farmers applications for CAP payments; national database of the livestock register

Economic exposure data: SIAN crop yields, ISMEA prices, EU contributions from Regional Rural Development Programmes, regional price lists for agricultural operations by contractors

Expected and potential damage indicators:

- Economic damage to maize, wheat, barley, rice, grassland (€)
- Gross output for all the crops (€)
- Number of livestock units per species

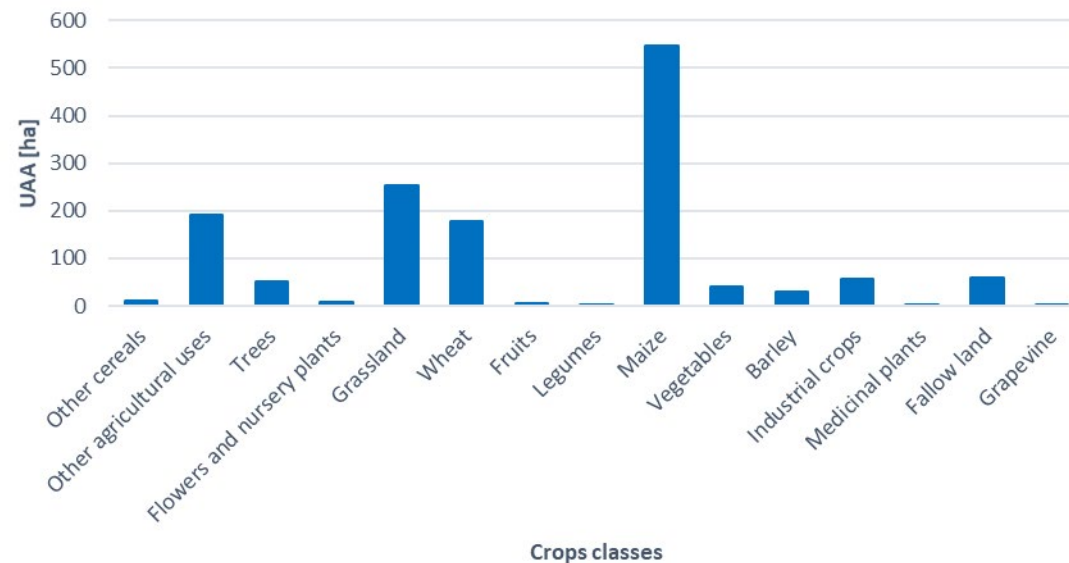


Agricultural activities

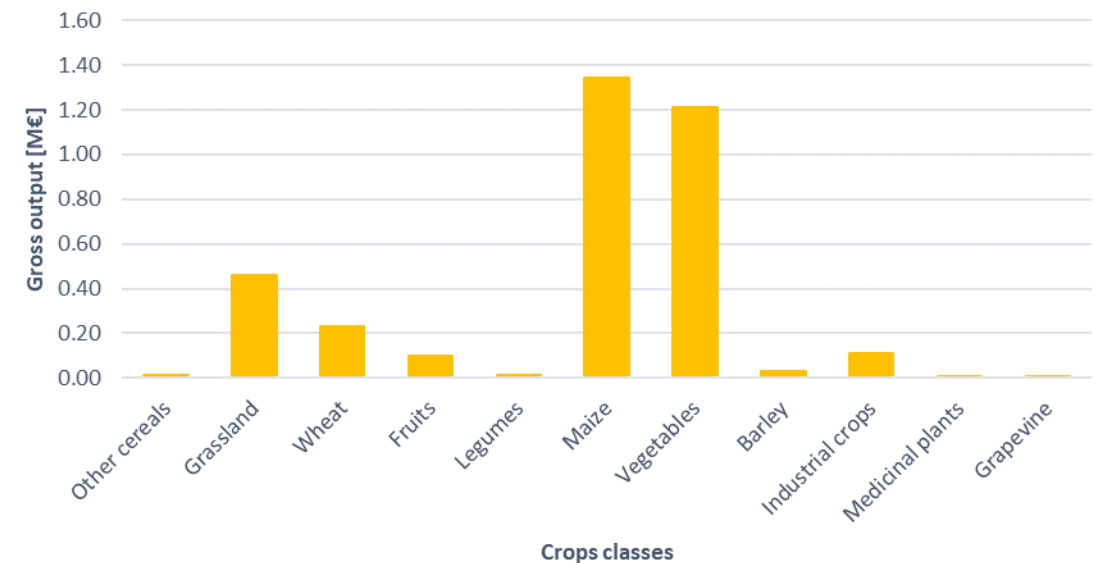
Level 1: quantitative evaluation of expected or potential damage

Exposed crops	Low probability scenario (TR=500 y)
Utilised agricultural area (UAA) in the flooded area [ha]	1 435
Economic value of exposed crops [M€]	3.52

Utilised agricultural area



Economic value of exposed crops



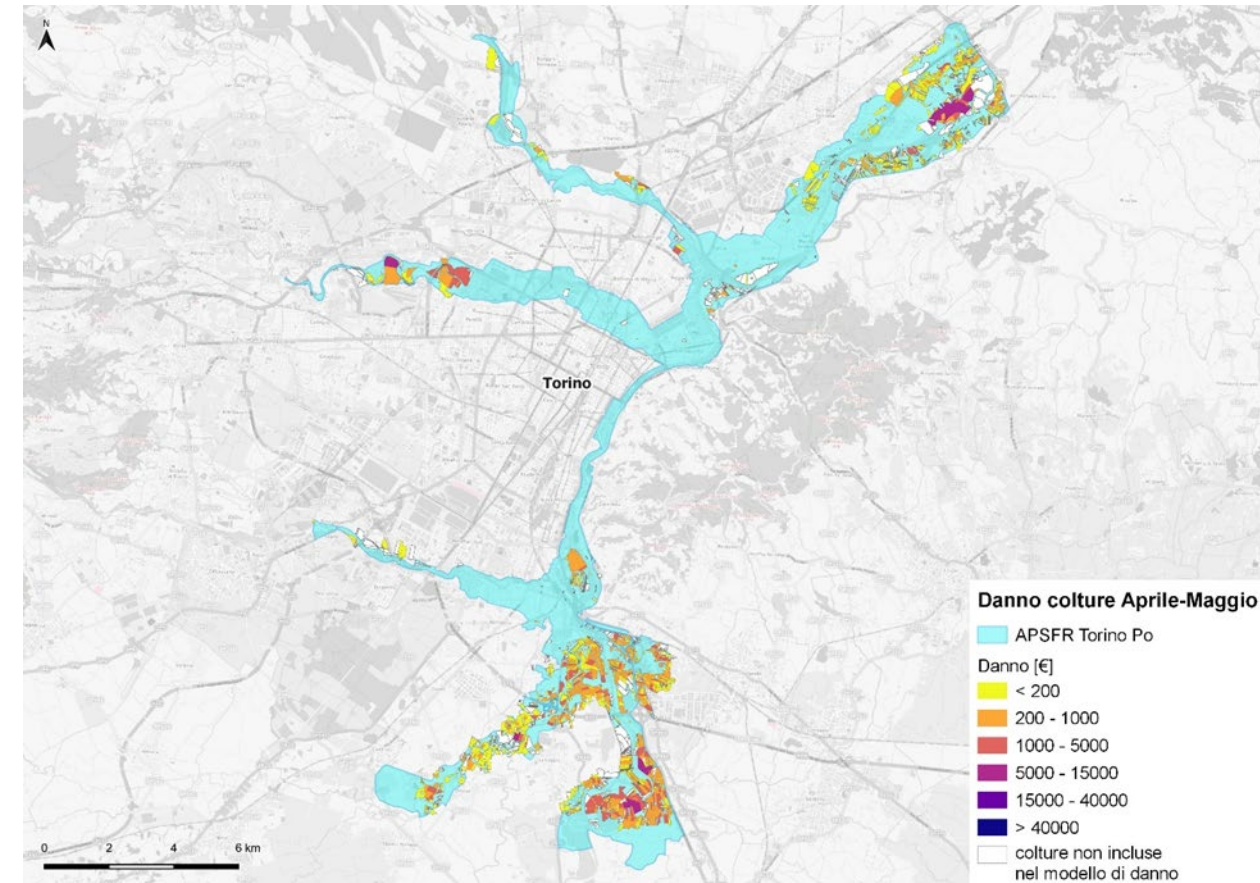
Agricultural activities

Level 1: quantitative evaluation of expected or potential damage

Economic damage to maize, wheat, barley, rice, grassland in the flooded area [M€]	Low probability scenario (TR=500 y)
Maximum expected damage – April/May	0.73
Minimum expected damage – October	0.38

These crops account for:

- 70% of the UAA
- 59% of the Gross output

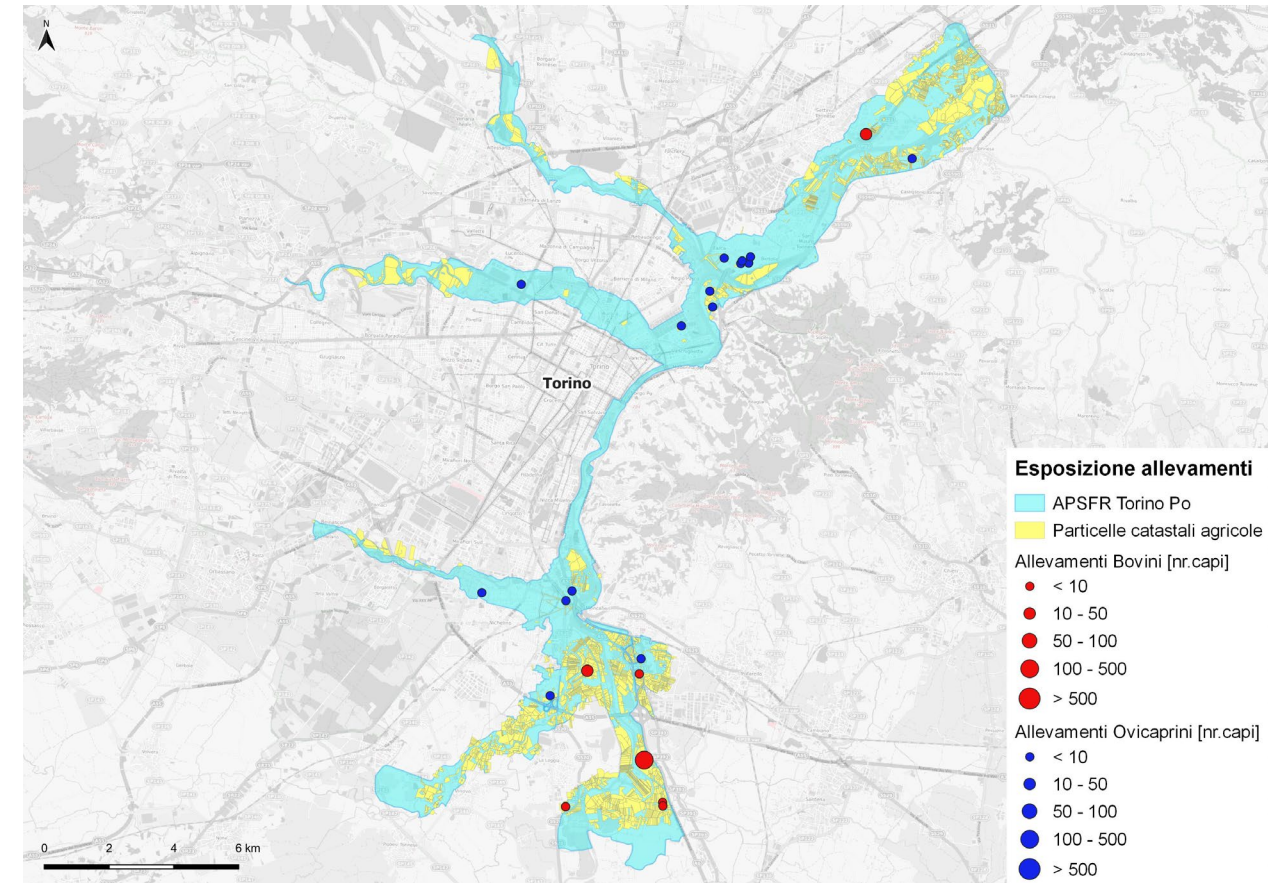


Maximum expected damage to maize, wheat, barley, rice and grassland, per cadastral parcel (months of flood occurrence: April-May)

Agricultural activities

Level 1: quantitative evaluation of expected or potential damage

Exposed livestock units per species [n. heads]	Low probability scenario (TR=500 y)
Cattle	306
Sheep and goats	45
Pigs	-
Poultry	-



Species and number of animals of livestock farming



Cultural heritage

Level 2: qualitative evaluation of potential damage (i.e. exposure)

METHODOLOGY

Modelling approach: qualitative evaluation of damage to cultural heritage by means of a new, ad-hoc method

Map scale: being defined

Scale of analysis: individual asset

Hazard data : FRMPs hazard maps

Physical exposure and vulnerability data: a single database of cultural assets for the whole District developed by combining and homogenising different regional data

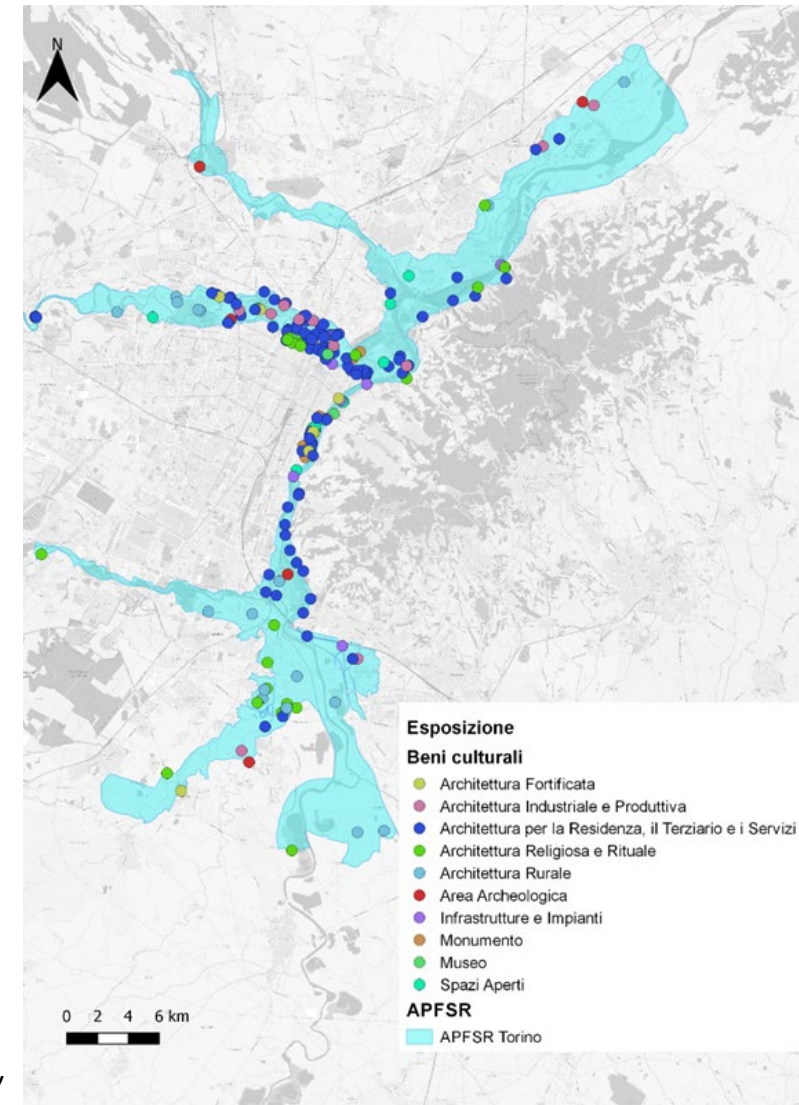
Potential damage indicator:

- **Number of cultural assets by typology**

Cultural heritage

Level 2: qualitative evaluation of potential damage (i.e. exposure)

Exposed cultural heritage, by typology [n.]	Low probability scenario (TR=500 y)
Military architecture	8
Industrial architecture	13
Residential and tertiary sector architecture	105
Religious architecture	25
Rural architecture	18
Archaeological sites	5
Infrastructures and structures	9
Monuments	8
Museums	5
Open-air sites	11



Exposed cultural heritage, by typology



Environmental heritage and factories at major accident risk Level 2: qualitative evaluation of potential damage (i.e. exposure)

METHODOLOGY

Modelling approach: identification (and classification) of environmental assets and potential contamination sources (hotspots) by means of a new, ad-hoc method + collection of anecdotal data

Map scale: being defined

Scale of analysis: being defined

Hazard data : FRMPs hazard maps

Physical exposure and vulnerability data: a single database of environmental assets and hotspots for the whole District developed by combining and homogenising different regional data

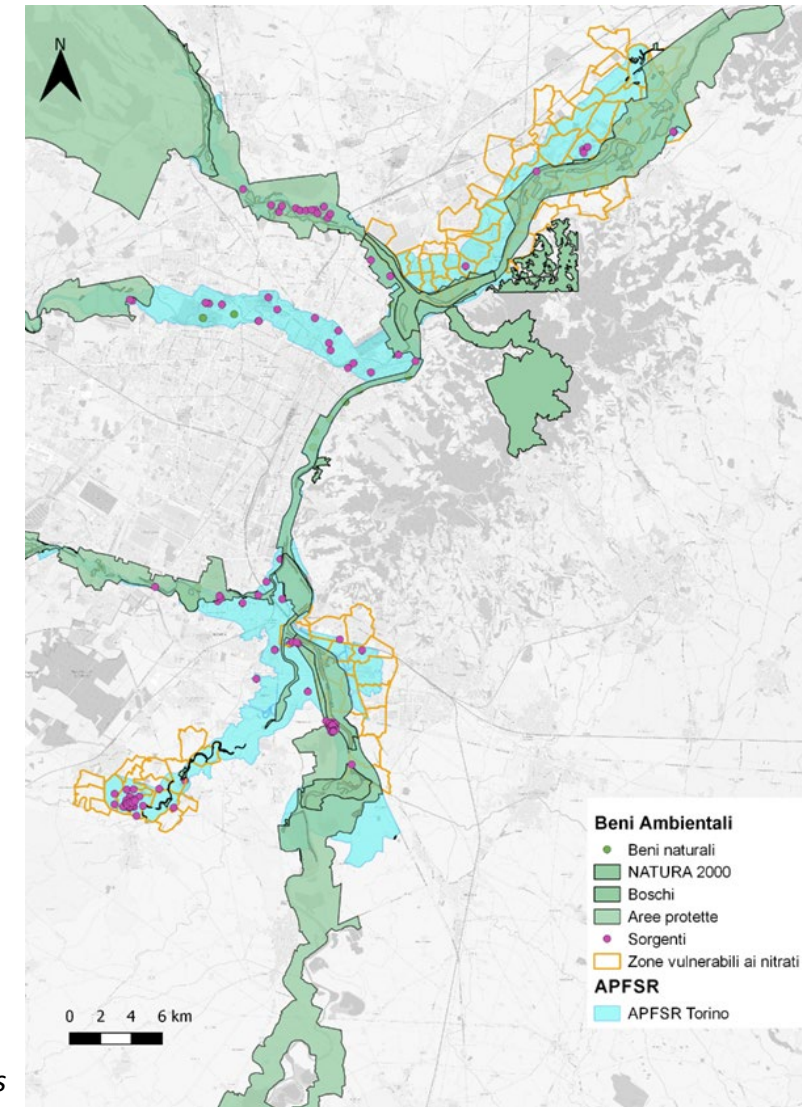
Potential damage indicators:

- Number of environmental assets
- Number of potential contamination sources (hotspots)

Environmental heritage and factories at major accident risk Level 2: qualitative evaluation of potential damage (i.e. exposure)

Exposed hotspots and environmental heritage, by typology [n.]	Low probability scenario (TR=500 y)
Natural assets (points)	11
Protected areas	14
Woods	115
EUAP	2
Natura2000 protected areas	3
Nitrate vulnerable zones	89
Hotspots (e.g. wastewater treatment plants, waste facilities, contaminated sites)	189

(provisional evaluation)



Exposed environmental heritage and hotspots

Damage indicators for each category of exposed elements

	Damage indicators
People	number of residents
	number of residents over 65
	number of residents under 10
Roads and railways	length of tracts with low impact (km)
	length of tracts with medium impact (km)
	length of tracts with high impact (km)
Other networks	number of infrastructures
Strategic buildings	number of strategic buildings
Residential buildings (structure)	economic damage to building structure (€)
Industrial and commercial activities (structure and equipment)	net capital stock of structure per NACE code (€)
	net capital stock of equipment per NACE code (€)
Agricultural activities (crops, livestock)	economic damage to maize, wheat, barley, rice, grassland (€)
	gross output for all the crops (€)
	number of livestock units per species
Cultural heritage	number of cultural assets, by typology
Environmental heritage	number of environmental assets
Factories at major accident risk	number of potential contamination sources (hotspots)



ISYDE: open source GIS Information SYstem for Damage Estimation

- Development of a PostgreSQL database, with PostGIS extension, for the management/sharing of input and output data by project partners (i.e. project repository).
- **Implementation in «ISYDE» of developed models for the categories: residential buildings, roads & railways, population**

The screenshot shows the 'Modello_db_piemonte' interface for estimating flood damage to residential buildings. The window has a title bar with a close button. Below the title bar, there are two tabs: 'Parametri' (selected) and 'Log'. The main area contains several input fields, each with a dropdown arrow and a three-dot menu icon. The fields are: 'Mappa tirante idraulico', 'Edifici poligoni', 'Fascia pericolosità', 'Sezioni censuarie', 'Unità volumetrica', and 'Zone OMI'. Below these, there are two sections for output: 'output_micro' and 'output_meso'. Each section has a text input field with the placeholder '[Crea layer temporaneo]' and a three-dot menu icon. Below each text input field is a checkbox labeled 'Apri il risultato dopo l'esecuzione dell'algoritmo', which is checked in both cases. At the bottom of the window, there is a progress bar showing '0%' and an 'Annulla' button. Below the progress bar, there is a button labeled 'Esegui come Processo in Serie...' and two buttons labeled 'Esegui' and 'Chiudi'.

Modello_db_piemonte

Interface for the estimation of flood damage to residential buildings

Parametri Log

Mappa tirante idraulico

Edifici poligoni

Fascia pericolosità

Sezioni censuarie

Unità volumetrica

Zone OMI

output_micro

[Crea layer temporaneo]

☒ Apri il risultato dopo l'esecuzione dell'algoritmo

output_meso

[Crea layer temporaneo]

☒ Apri il risultato dopo l'esecuzione dell'algoritmo

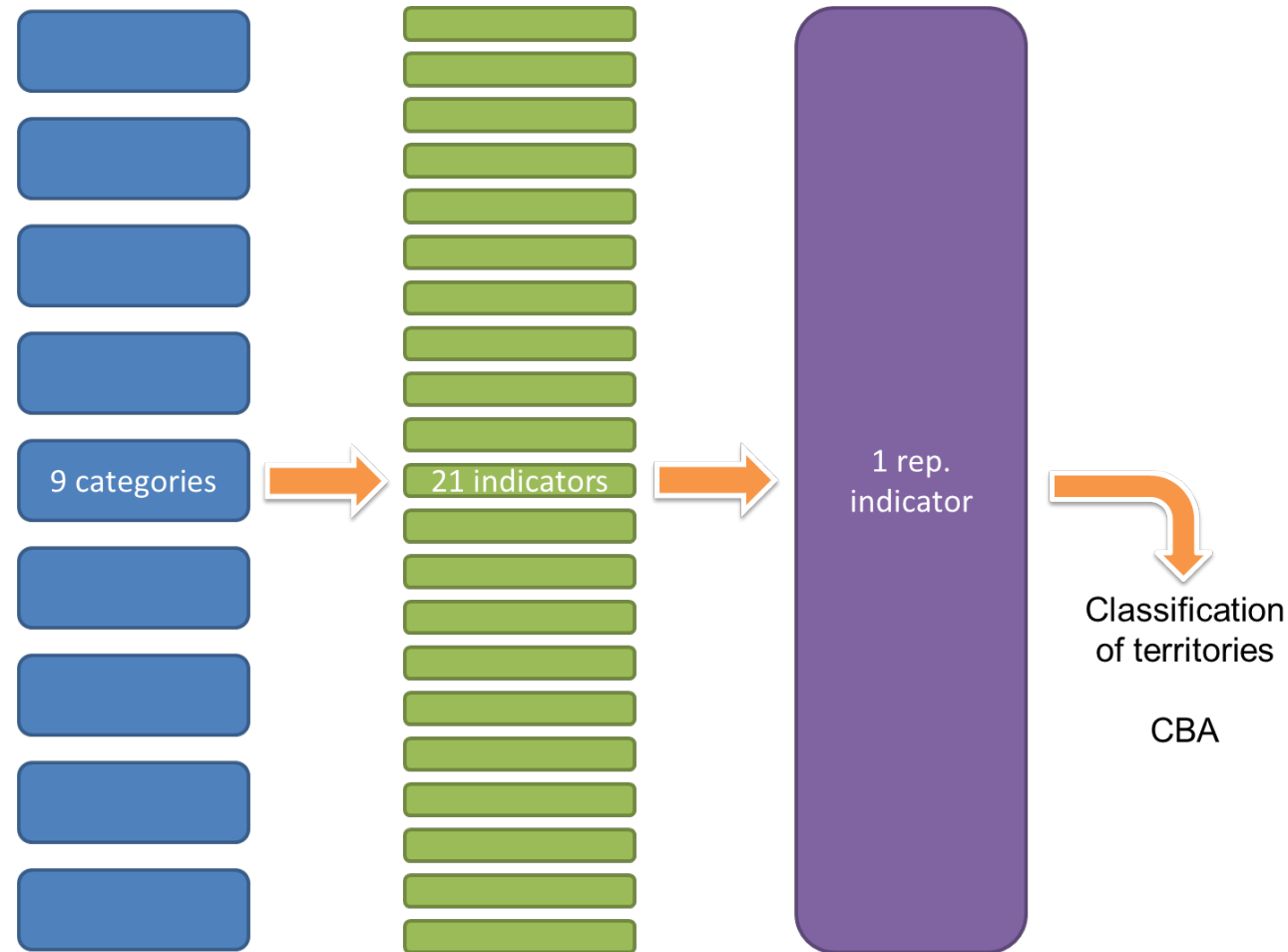
0%

Annulla

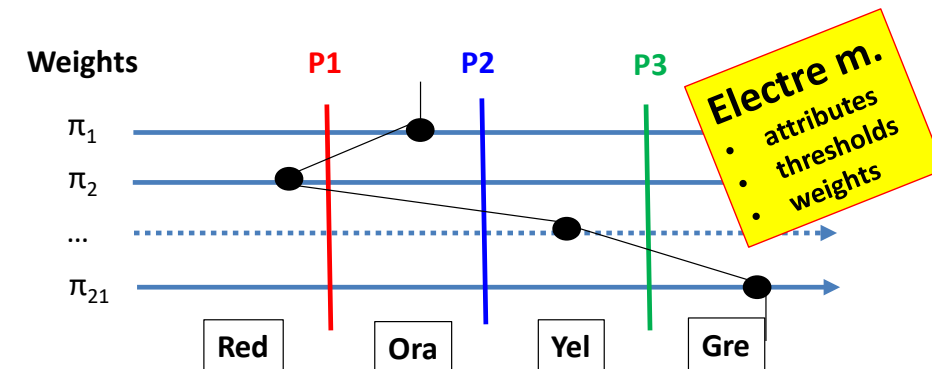
Esegui come Processo in Serie...

Esegui Chiudi

Next steps: Development of a damage representative index

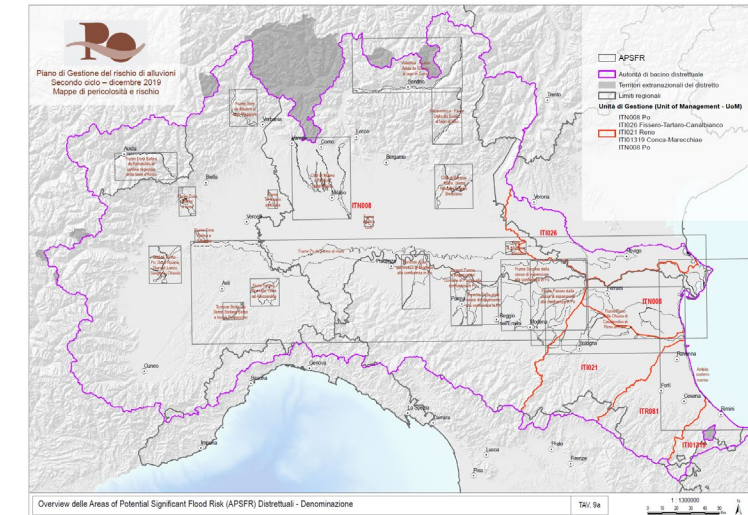
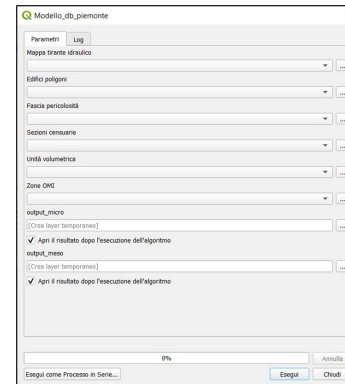
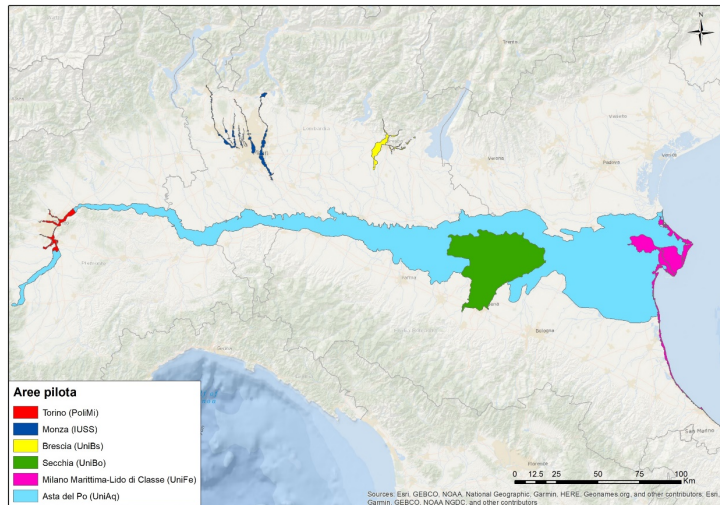


Multicriteria rating model





Next steps: Damage evaluation to all APFSRs/ technological transfer to Regional Authorities



Next steps: WP_svi

Population:

- *Evaluation of commuters*
- *Identification of hotspot*
- *Evaluation of the probability for people to be damaged on the bases of hazard intensity*
- *Development of a model for the estimation of physical damage (i.e. death)*
- *Development of a model for the estimation of indirect damage*
- *Development of a model for the estimation of emergency costs linked to people*

Roads and Railways

- *Development of a model for the estimation of functional damage to subways*
- *Development of a model for the estimation of indirect damage linked to traffic disruption, on the basis of data on traffic flows*

Residential buildings

- *Development of a model for the estimation of damage in coastal areas*
- *Identification of a representative model among the three actually implemented*



Next steps: WP_svi

Economic activities (industrial and commercial)

- *Development of a new methodology to estimate the economic value of activities, on the basis of micro-data on business economic balance*
- *Evaluation of indirect damage to business (i.e. lack of income) for a pilot area*

Agricultural activities

- *Use of satellite data to define cultural types*
- *Extension of the implemented model to the coastal area, including the effect of salinity*

Cultural heritage

- *Evaluation of indirect damage, in terms of loss of visitors/tourists, for a pilot area (e.g. in an art city)*

Historical analysis

- *Development of complementary damage maps on the basis of historical damage data*

