# KULTURISK METHODOLOGY: PHYSICAL/ENVIRONMENTAL REGIONAL RISK ASSESSMENT.

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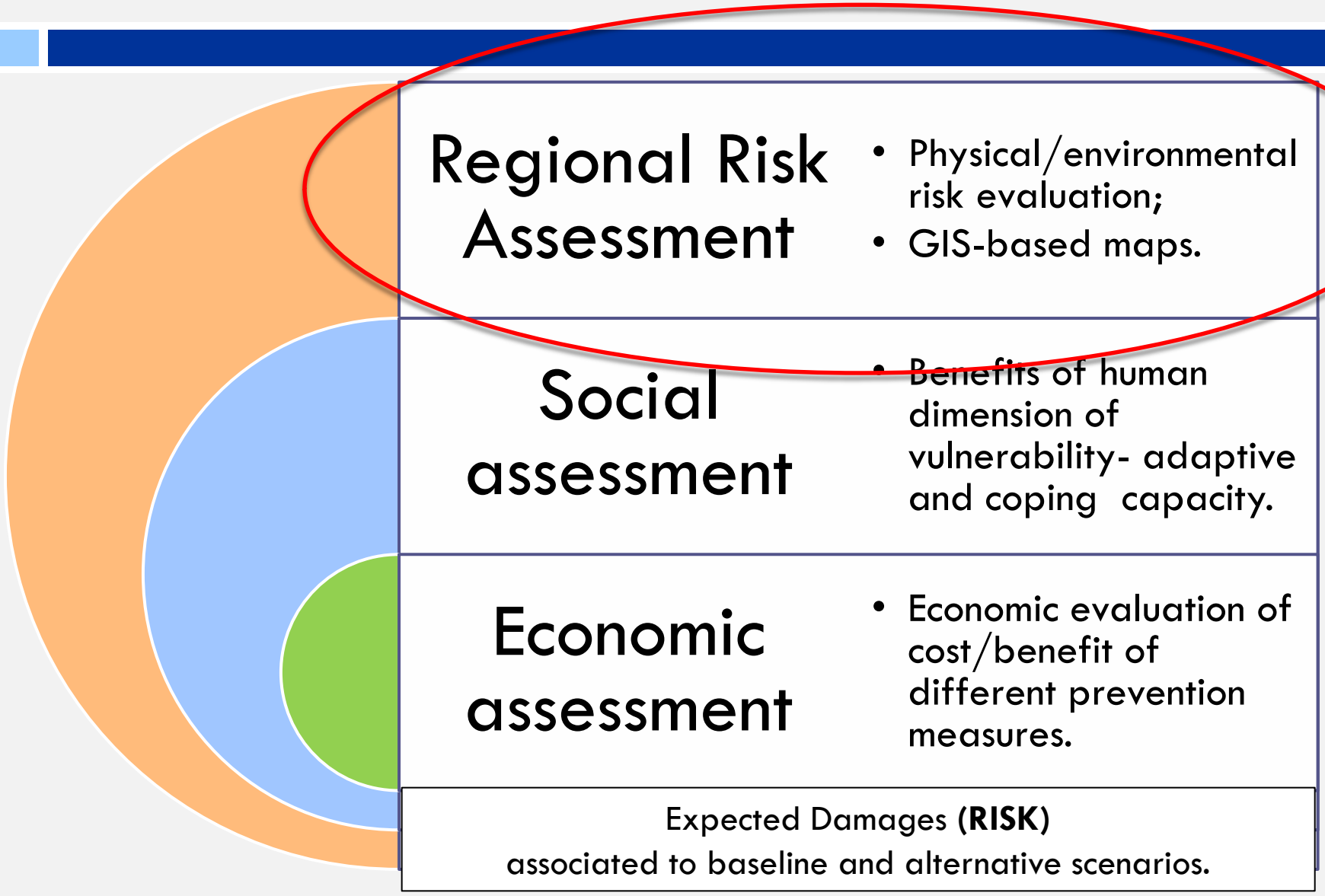
# THE KULTURisk METHODOLOGY TO ESTIMATE RISK LEVELS



# REGIONAL RISK ASSESSMENT approach (Landis, 2005)

**Regional Risk Assessment (RRA):** a risk assessment that deals with problems affecting large geographic areas where **multiple habitats, sources, stressors** and **endpoints** are present and their spatial relationships need to be evaluated at the **regional scale** (Landis, 2005).

- **Identification** of the different **sources, habitats** and possible **impacts** and their locations in the region.
- **Ranking** the importance of the **different components** of the risk assessment (sources, habitats and impacts).
- **Spatial visualisation** of the different components of the risk assessment to verify if they overlap.
- Division of the region in **sub-regions.**
- Relative **risk model**: based on a system of numerical **ranks** and **weights** factors developed in order to combine and assess different kinds of risks.

**Maps** of the prioritized **risk regions** and of the spatial distribution of the analyzed **stressors** and **targets**.

# RRA-KULTURisk methodology

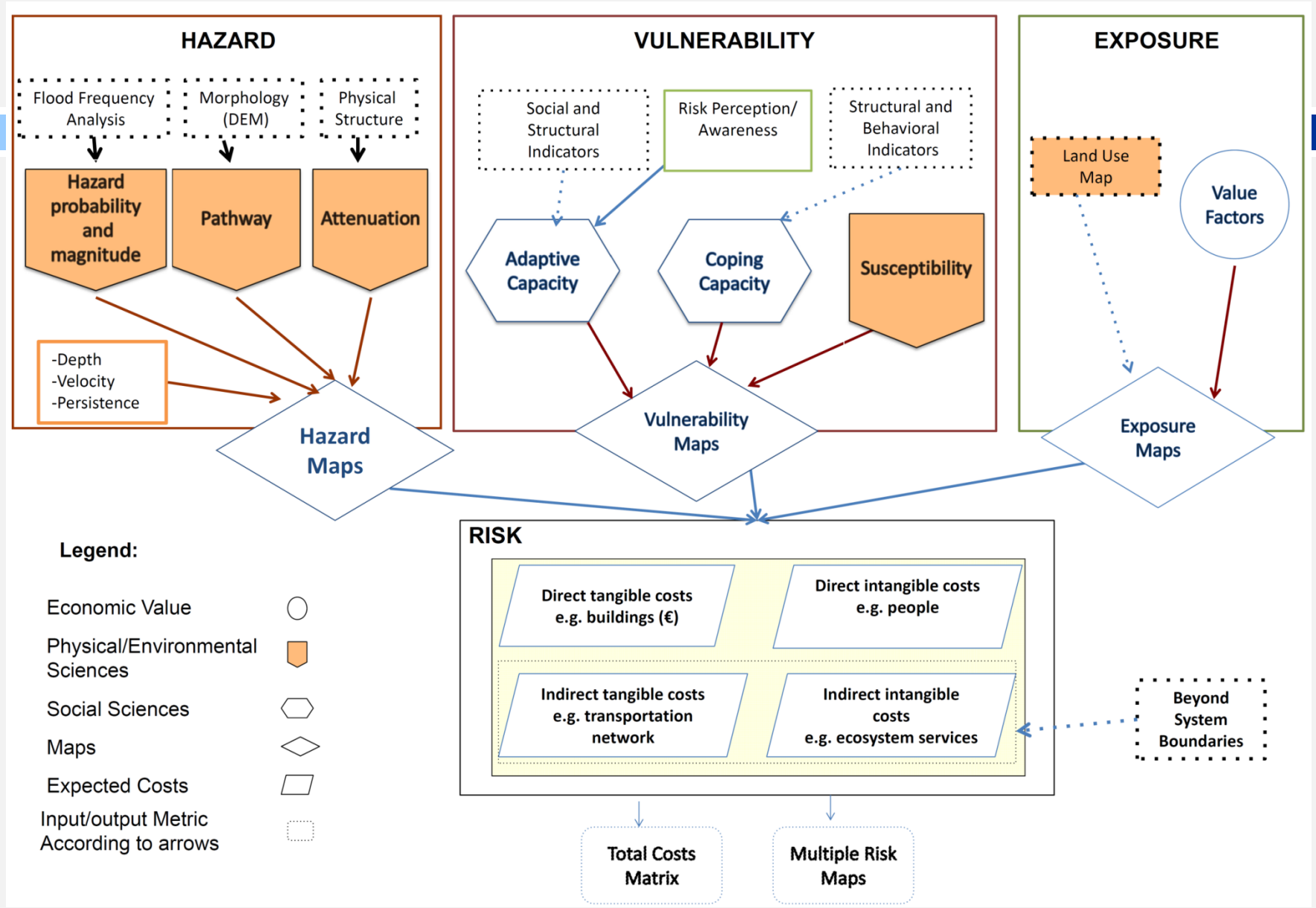
**General objectives:**

- Provide a general methodology for the **integrated assessment** of risks levels associated to flood hazards on **multiple receptors/elements at risk** (i.e. population, economic activities, natural and semi-natural systems, cultural heritage);
- Provide a methodology that allows to **identify** and **prioritize areas** and **targets** at risk in the considered region and to evaluate the benefits of different prevention scenarios;
- Provide a methodology that could be applied in **different problem contexts, case studies** and **spatial scales** representing a benchmark for the implementation of the Floods Directive at the European level.

**Specific objectives:**

- Provide a set of **indicators** for the different **physical/environmental components** of the KULTURisk framework;
- Provide a set of **equations to normalize** and **aggregate** these indicators in a (spatially resolved) integrated Risk Index.

# THE KULTURisk CONCEPTUAL FRAMEWORK




Balbi et al., 2012; Giupponi et al., 2012

# Operational steps for the implementation of the KULTURisk RRA methodology

**Step 1. Hazard assessment:** aimed at identifying hazard metrics (e.g. flood velocity, water depth, flood extension) coming from numerical models (e.g. hydrodynamic deterministic or probabilistic models) and the scenarios to be investigated (e.g. baseline or alternative).

**Step 2. Exposure assessment:** aimed at identifying and selecting the receptors (i.e. elements at risk) to be considered in the case study, based on the objectives of the analysis.

**Step 3. Susceptibility assessment:** aimed at evaluating the degree to which the receptors could be affected by a flood hazard based on physical/environmental site-specific information (e.g. % of people over 75 years, vegetation cover, tolerance to the submersion).

**Step 4. Physical/environmental risk assessment:** aimed at defining a relative risk that allows to identify and classify areas and hotspots at risk in each case study.

# List of the selected receptors

- According to the 4 macro-categories proposed in the Floods Directive (2007/60 CE);
- Considering the CORINE Land Cover classes (Büttner et al., 2006) as main dataset for the identification of receptors and spatial unit of analysis at the meso-scale.

- PEOPLE;
- BUILDINGS;
- INFRASTRUCTURES;
- AGRICULTURE;

} ECONOMIC ACTIVITIES

- NATURAL & SEMI-NATURAL SYSTEMS;
- CULTURAL HERITAGE.


# Physical/environmental risk to people

Number of people (in residential areas) potentially injured or dead by a flood event (without considering adaptive/coping capacity).

| Indicator | Data source |
|---|---|
| **Hazard metrics** | |
| Water depth | Flood/hydraulic map |
| Flood velocity | Flood/hydraulic map |
| Debris factor | Land cover map |
| **Exposure** | |
| People | Census data, Land cover/Land use map |
| **Susceptibility factors** | |
| % of people over 75 years | Census data |
| % of people infirm/disable/long term sick | Census data |

- it focuses on **residential areas** identifying them as major hotspots where people live;
- All the people are present in their homes at the **low ground** (no safe areas);
- **No** considerations about **adaptive** and **coping capacity**.

UK Department for Environment Food and Rural Affairs (DEFRA, 2006)

# Physical/environmental risk to buildings

Surface ($km^2$) and percentage of flooded buildings belonging to different uses (residential, commercial-industrial) in each risk class (e.g. inundated, partially damaged, destructed).

| Indicator | Data source |
|---|---|
| **Hazard metrics** | |
| Water depth (d) | Flood/hydraulic map |
| Flood velocity (v) | Flood/hydraulic map |
| **Exposure** | |
| Buildings | Land cover/Land use map |

- It is assumed that all the **buildings** are basically dominated by **masonry structures** (i.e. the same building type: **susceptibility** = k);
- The CORINE Land Cover **polygons** considered for this receptor are **all covered by buildings.**
- 3 risk classes are defined based on **thresholds** determined by *v* and *dv* values.

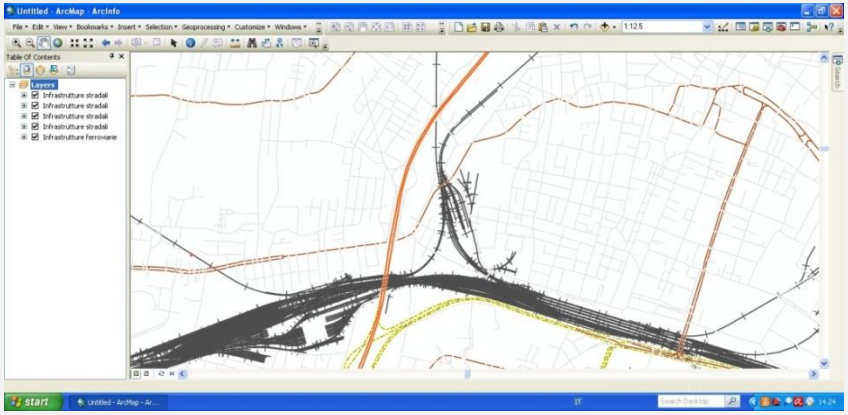
At the **micro-scale** the **physical susceptibility** can be defined considering the material construction and its quality, the building level, the state of conservation in order to have a more detailed analysis of the physical/environmental risk.

# Physical/environmental risk to infrastructures

Length (km) and percentage of roads and railways inundated by a flood event.

Risk for infrastructures: loss of service (e.g. not practicable roads and connections, no power supply) due to a flooding scenario. No direct damages are considered.

| Indicator | Data source |
|---|---|
| **Hazard metrics** | |
| Flood extension | Flood/hydraulic map |
| **Exposure** | |
| Infrastructures | Road and railway atlas |



At the **micro-scale** the **physical susceptibility** can be defined considering the material construction, the dimension and the slope of the considered infrastructure in order to have a more detailed analysis of the physical/environmental risk.

# Physical/environmental risk to agriculture

Surface ($km^2$) and percentage of the flooded agricultural typologies (e.g. arable land, vineyards) in which the harvest is lost.

The aim of the risk-based methodology at the meso-scale for agriculture is to define the percentage of the harvest loss due to a flood event (without any consideration about the damage to agricultural buildings).

| Indicator | Data source |
|---|---|
| **Hazard metrics** | |
| Water depth (d) | Flood/hydraulic map |
| Flood velocity (v) | Flood/hydraulic map |
| **Exposure** | |
| Agricultural typologies | Land cover/Land use map |

Thresholds for the hazard metrics are provided by Citeau (2003) for different agricultural typologies (e.g. vegetables, vineyards, fruit trees) in the **spring, summer** and **autumn** seasons.
In the **winter** period there are no agricultural cultivations that can be destroyed.

# Physical/environmental risk to natural & semi-natural systems

Surface ($km^2$) and percentage of flooded natural and semi-natural systems potentially affected by loss of ecosystem services in the case study area.

| Indicator | Data source |
|---|---|
| **Hazard metrics** | |
| Flood extension | Flood/hydraulic map |
| **Exposure** | |
| Natural & semi-natural systems | Land cover/Land use map |
| **Susceptibility factors** | |
| Vegetation cover | Land cover/Land use map |
| Slope | Digital Elevation Model (DEM) |
| Soil type | Geomorphologic/soil map |
| Wetland extension | Land cover/Land use map |

Hazard, exposure and susceptibility are aggregated to estimate the **relative risks** (e.g. low, medium, high) in order to **identify** and **prioritize** natural and semi-natural systems affected by flood-related impacts in the case study area.

Aggregated with a MCDA function in order to evaluate the degree to which the receptors could be affected by a flood scenario.

Torresan et al., 2012

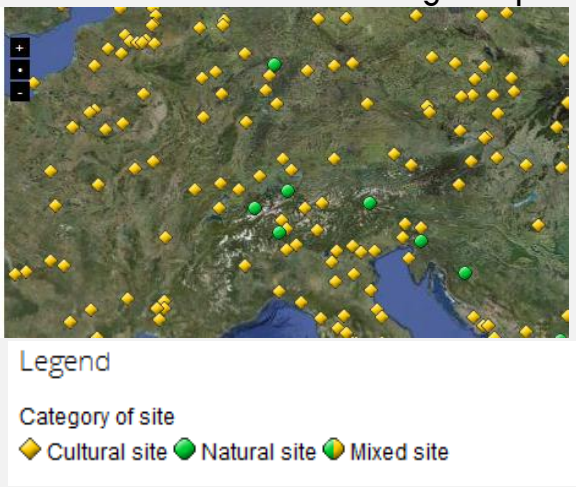
# Physical/environmental risk to cultural heritage

Number of monuments, surface ($km^2$) and percentage of historical buildings and archeological/anthropological sites.

The aim of the risk-based methodology at the meso-scale for cultural heritage is to define the cultural heritage (i.e. monuments, historical buildings, archeological/anthropological sites) inundated by a flood event.

| Indicator | Data source |
|---|---|
| **Hazard metrics** | |
| Flood extension | Flood/hydraulic map |
| **Exposure** | |
| Cultural heritage | Regional technical map, UNESCO cultural heritage map |

UNESCO cultural heritage map.




At the **micro-scale** the **physical susceptibility** can be defined considering the material construction, the state of conservation and the dimension of the cultural heritage in order to have a more detailed analysis of the physical/environmental risk.

# Total risk

- Receptors can be related to more than one land use classes => it is necessary to calculate a **total risk** by aggregating different receptor-related risks for the same geographical unit

| **Land use** / **Receptor** | Urban areas | Commercial and industrial areas | Agricultural areas | Natural and semi-natural areas |
|---|---|---|---|---|
| Population | | | | |
| Buildings | | | | |
| Infrastructures | | | | |
| Agriculture | | | | |
| Natural and semi-natural areas | | | | |
| Cultural heritage | | | | |

- **NORMALIZATION OF RECEPTORS-RELATED RISK:**
  - Definition of classes (categorical or numerical).
  - Assignation of relative scores and weights to each class (0-1), based on site-specific knowledge, literature data and expert judgement.

- **TOTAL RISK**
  - Is calculated by **aggregating** normalized receptor-related risks by means of **Multi Criteria Decision Analysis methods.** This allows to identify and classify areas and hotspots at risk in each case study.

# Total risk: weighted average

- Assumption: receptor overlapping is considered linearly additive : weighted average of partial risks :

$$R_{tot} = \frac{\sum_{\forall r} w_r R'_r}{\sum_{\forall r} w_r} \quad w_i \in [0,1] \forall r$$

Where:

$R_{tot}$ = total risk;

$w_r$ = weight associated with the *r* receptor-based risk ;

$R'_r$ = normalized risk associated to the r receptor.

- The **Total Risk** allows to identify, classify and map homogeneous **flood risk areas** in the analyzed territory.
- Total risk map provide a basis for **land use planning** and can be used to localize **hotspots** at risk (e.g. hospitals, schools, airports, harbours, railway stations, protected areas, potential installations causing pollution, etc.).

# Physical/environmental Regional Risk Assessment outputs: GIS-based maps and statistics

**People**

Number and percentage of people injured/death by a flood event.

**Natural & semi-natural systems**

Surface ($km^2$) and percentage of the flooded areas in each risk class (e.g. low, medium, high).

**Cultural heritage**

Number of monuments, surface ($km^2$) and percentage of flooded historical buildings and archeological sites.

**Buildings**

Surface ($km^2$) and percentage of flooded buildings (residential, commercial, industrial) in each risk class (e.g. inundated, partially damaged, destructed).

**Infrastructures**

Length (km) and percentage of roads and railways inundated by a flood event.

**Agriculture**

Surface ($km^2$) and percentage of the flooded agricultural typologies (e.g. arable land, vineyards) in which the harvest is lost.

**TOTAL RISK.**

Relative risk is calculated by aggregating different receptor-related risks by means of Multi Criteria Decision Analysis methods. This allows to identify and classify areas and hotspots at risk in each case study.

# Conclusions

- The RRA methodology is flexible and can be adapted to different case studies (i.e. large rivers, alpine/mountain catchments, urban areas and coastal areas) and spatial scales (i.e. from the large river to the urban scale);

- The RRA methodology allows to compare different flood scenarios considering the future planning of structural and/or non-structural measures;

- The RRA methodology will be applicable with basic GIS functions and tools, without requiring a software implementation of complex algorithms

- The RRA methodology provides GIS-based maps and statistics of the physical/environmental risk of a flood event.

- The results obtained by RRA can be integrated with adaptive and coping capacity and can be used as input for the economic evaluation of damages (e.g. tangible costs, intangible costs).

Thanks for your attention

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# Data needs

| **Data sources** |
| --- |
| Corine Land Cover 2006 |
| Census data |
| Road atlas |
| Regional technical map |
| UNESCO cultural heritage map |
| Digital Elevation model (DEM) |
| Geomorphologic/soil map |
| Protected area maps |

CORINE Land Cover nomenclature 2006.

| Level 1 | Level 2 | Level 3 |
|---|---|---|
| 1 Artificial surfaces | 11 Urban fabric | 111 Continuous urban fabric |
| | | 112 Discontinuous urban fabric |
| | 12 Industrial, commercial and transport units | 121 Industrial or commercial units |
| | | 122 Road and rail networks and associated land |
| | | 123 Port areas |
| | | 124 Airports |
| | 13 Mine, dump and construction sites | 131 Mineral extraction sites |
| | | 132 Dump sites |
| | | 133 Construction sites |
| | 14 Artificial, non-agricultural vegetated areas | 141 Green urban areas |
| | | 142 Sport and leisure facilities |
| 2 Agricultural areas | 21 Arable land | 211 Non-irrigated arable land |
| | | 212 Permanently irrigated land |
| | | 213 Rice fields |
| | 22 Permanent crops | 221 Vineyards |
| | | 222 Fruit trees and berry plantations |
| | | 223 Olive groves |
| | 23 Pastures | 231 Pastures |
| | 24 Heterogeneous agricultural areas | 241 Annual crops associated with permanent crops |
| | | 242 Complex cultivation patterns |
| | | 243 Land principally occupied by agriculture, with significant areas of natural vegetation |
| | | 244 Agro-forestry areas |
| 3 Forest and semi natural areas | 31 Forests | 311 Broad-leaved forest |
| | | 312 Coniferous forest |
| | | 313 Mixed forest |
| | 32 Scrub and/or herbaceous vegetation associations | 321 Natural grasslands |
| | | 322 Moors and heathland |
| | | 323 Sclerophyllous vegetation |
| | | 324 Transitional woodland-shrub |
| | 33 Open spaces with little or no vegetation | 331 Beaches, dunes, sands |
| | | 332 Bare rocks |
| | | 333 Sparsely vegetated areas |
| | | 334 Burnt areas |
| | | 335 Glaciers and perpetual snow |
| 4 Wetlands | 41 Inland wetlands | 411 Inland marshes |
| | | 412 Peat bogs |
| | 42 Maritime wetlands | 421 Salt marshes |
| | | 422 Salines |
| | | 423 Intertidal flats |

Caetano et al., 2009