DELIVERABLE D.T1.1.2

Report including an inventory of existing tools for risk evaluation

Version 1
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With contribution of all partners

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1. INTRODUCTION

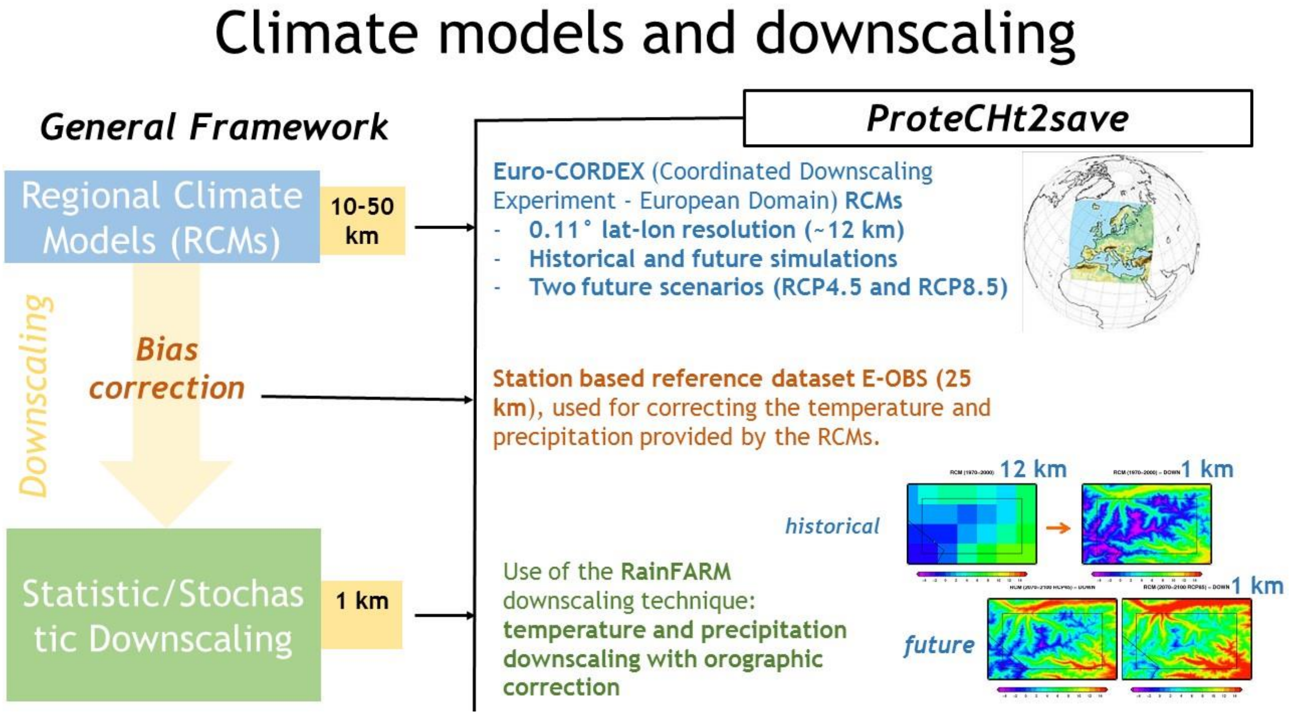
WP T1 *Identification of risk areas and priorities* focuses on the analysis of procedures, tools and database to identify the most important hot-spots where different categories of cultural heritage are exposed to individual extreme events due to climate change (heavy precipitation, flood, drought periods). Activity A.T1.1 *Analysis of existing state-of-the-art approaches, methods and models to identify risk areas* is the first step of WP T1 and deliverable D.T1.1.2 *Report including an inventory of existing tools for risk evaluation* aims at highlighting the suitable and pertinent tools for the risk prone areas assessment in Central Europe to extreme events. Section 2 of the present deliverable summarizes the climate models, downscaling approaches and tools of data analysis that will be utilized in ProteCHt2save on the basis of the work done also within D.T1.1.1. *Identification of appropriate procedures for the assessment of climate impact on cultural heritage*. Section 3 Illustrates selected projects, which results are of possible capitalization and integration in ProteCHt2save, in addition to significant international databases and national plans for adaptation to climate change. Finally, section 4 presents the elaboration of the data collected in D.T1.1.1 at different territorial levels (local/regional/national/international) for each Country/Region involved in ProteCHt2save.

2. CLIMATE MODEL DATA, DOWNSCALING AND ANALYSIS TOOLS

The climate model data, downscaling and analysis tools selected for the assessment of risk prone areas in Central Europe to extreme events have been detailed and described in Deliverable D.T1.1.1 *Identification of appropriate procedures for assessment of climate change impact on cultural heritage*.

The tools and methodology that will be utilized in ProteCHt2sae are here summarized (Figs.1,2):

- Selection of **Euro-CORDEX simulations** at 0.11 degrees and ~12 km resolution (http://euro-cordex.net/imperia/md/content/csc/cordex/20161219-eurocordex-simulations.pdf).
- Analysis of Regional Climate Models (**RCMs) historical and projection simulations.**
- Selection two future scenarios (**RCP4.5 and RCP8.5**).
- Use of also **historical and scenario simulation** with the state-of-the-art high resolution global climate model **EC-Earth.**
- Model bias correction using **state-of-the-art station-based reference datasets (E-OBS** http://www.ecad.eu/download/ensembles/ensembles.php).
- Downscaling (resolution grids 1kmX1km) for precipitation (using **RainFARM method**) and temperature (based on orographic correction.
- Analysis of changes in climate extremes by exploitation of software tools which are being developed in the framework of the **Copernicus C3S project MAGIC** (C3S 34a lot2) by ISAC-CNR (http://portal.c3s-magic.eu/).



Euro-CORDEX (Coordinated Downscaling Experiment - European Domain) **RCMs**
- 0.11° lat-lon resolution (~12 km)
- Historical and future simulations
- Two future scenarios (RCP4.5 and RCP8.5)

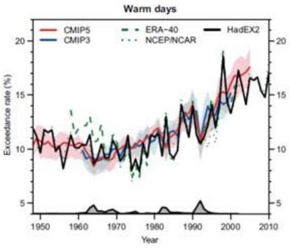
Station based reference dataset E-OBS (25 km), used for correcting the temperature and precipitation provided by the RCMs.

Use of the **RainFARM** downscaling technique: **temperature and precipitation downscaling with orographic correction**

Figure 1. Tools and methodology selected for the assessment of risk prone areas in Central Europe to extreme events

Climate extremes and metrics

The analysis of changes in climate extremes, such as **dry spells or intense precipitation**, will exploit software tools which are being developed in the framework of the Copernicus C3S project MAGIC (C3S 34a lot2) by ISAC-CNR (http://portal.c3s-magic.eu/).
The tools are collected in an integrated software tool (ESMValTool) and provide indices to evaluate **statistics of extreme events for temperature and precipitation** and to compare with observed extremes. They implement standard indices defined by the Expert Team on Climate Change Detection Indices (ETCCDI) and other indices measuring hydroclimatic intensity.



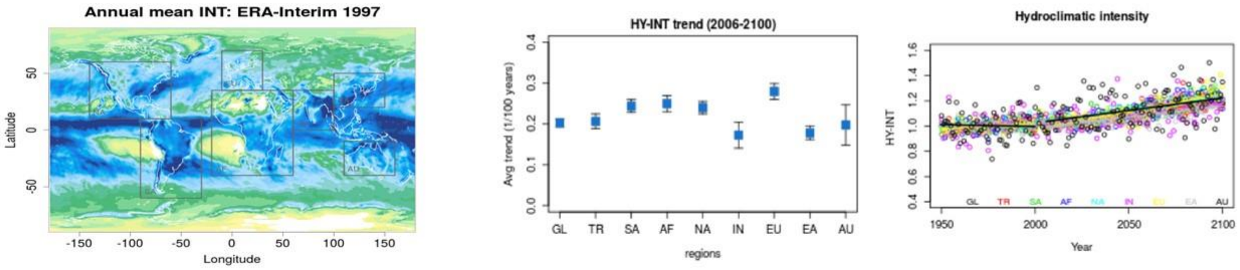


Figure 2. Tools and methodology selected for the assessment of risk prone areas in Central Europe to extreme events

Data from models will be used for the production of : i) maps of changes of principal climate variables (temperature and precipitation) and ii) maps related to climate extremes by using the following indexes selected among those defined by the CCl/WCRP/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI) (http://www.climdex.org/indices.html):

1. SU, *Number of summer days*.
   Annual count of days when TX (daily maximum temperature) > 25ºC.
   Let TX_{ij} be daily maximum temperature on day i in year j. Count the number of days where:
   TX_{ij} > 25ºC.

2. TR, *Number of tropical nights*.
   Annual count of days when TN (daily minimum temperature) > 20ºC. Let TN_{ij} be daily minimum temperature on day i in year j. Count the number of days where: TN_{ij} > 20ºC.

3. TX_x, *Monthly maximum value of daily maximum temperature*.
   Let TX_x be the daily maximum temperatures in month k, period j. The maximum daily maximum temperature each month is then: $TX_{xkj}=\max(TX_{xkj})$

4. TN_x, *Monthly maximum value of daily minimum temperature*.
   Let TN_x be the daily minimum temperatures in month k, period j. The maximum daily minimum temperature each month is then: $TN_{xkj}=\max(TN_{xkj})$

5. TX_n, *Monthly minimum value of daily maximum temperature*.
   Let TX_n be the daily maximum temperatures in month k, period j. The minimum daily maximum temperature each month is then: $TX_{nkj}=\min(TX_{nkj})$

6. TN_n, *Monthly minimum value of daily minimum temperature*.

Let TN_n be the daily minimum temperatures in month *k*, period *j*. The minimum daily minimum temperature each month is then: $TN_{nkj}=\min(TN_{nkj})$

7. WSDI, *Warm speel duration index*.
   Annual count of days with at least 6 consecutive days when TX > 90th percentile. Let TX_{ij} be the daily maximum temperature on day *i* in period *j* and let $TX_{in}90$ be the calendar day 90th percentile centred on a 5-day window for the base period 1961-1990. Then the number of days per period is summed where, in intervals of at least 6 consecutive days: $TX_{ij} > TX_{in}90$

8. Rx5day, *Monthly maximum consecutive 5-day precipitation*.
   Let RR_{kj} be the precipitation amount for the 5-day interval ending $_{k}$, period *j*. Then maximum 5-day values for period *j* are:
   $Rx5day_j = \max (RR_{kj})$

9. R10mm *Annual count of days when PRCP≥ 10mm*.
   Let RR_{ij} be the daily precipitation amount on day *i* in period *j*. Count the number of days where:
   $RR_{ij} \geq 10mm$

10. R20mm *Annual count of days when PRCP≥ 20mm*.
    Let RR_{ij} be the daily precipitation amount on day *i* in period *j*. Count the number of days where:
    $RR_{ij} \geq 20mm$

11. CDD. *Maximum length of dry spell, maximum number of consecutive days with RR < 1mm*.
    Let RR_{ij} be the daily precipitation amount on day *i* in period *j*. Count the largest number of consecutive days where:
    $RR_{ij} < 1mm$

12. CWD. *Maximum length of wet spell, maximum number of consecutive days with RR ≥ 1mm*.
    Let RR_{ij} be the daily precipitation amount on day *i* in period *j*. Count the largest number of consecutive days where:
    $RR_{ij} \geq 1mm$

3. PREVIOUS PROJECTS, DATABASE ON LOSS EVENTS DUE TO NATURAL HAZARDS AND EXISTING NATIONAL PLANS

ProteCHt2save will build on the results achieved by successful projects related to the assessment of the impact (i.e. both risk and damage assessment) of climate change on cultural heritage sites, comprising cultural landscape, built heritage and indoor objects collections:

1) EU FP6 Project Noah's Ark (2004-2007) [1-3], coordinated by CNR-ISAC with ITAM as partners, has for the first time produced a Vulnerability Atlas and Guidelines for Cultural Heritage protection towards climate change. The Noah's Ark coupled climatology with conservation science expertise, acquired a unique know-how in delivering future forecast of cultural heritage vulnerabilities induced by outdoor climate changes, including extreme weather related events. The scientific approach developed within Noah's Ark was the base for the research enhancement carried out by the FP7 Project Climate for Culture.

2) EU FP7 Project Climate for Culture (CfC, 2009-2014) coordinated by FRAUNHOFER [4-8] with CNR-ISAC in the partnership. In the CfC Project, hazard and damage projections were forecasted to assess the impact of the slow ongoing climate change rather than extreme events effects on outdoor and indoor cultural heritage sites. The research methodology developed coupling climatology, building engineering and conservation science expertise, allowed to create more than 55000 maps for the assessment of vulnerability of historic building envelopes as well as of artworks indoors preserved. In addition, predictions for sea level rise, a potential threat to many coastal regions and their cultural heritage, up to the year 2100 was calculated using the scenario simulation with a global climate model [9] and the data from the regionally coupled atmosphere-ocean model [10].

ProteCht2save will also take advantage from the ISCR-MiBACT risk maps for Cultural Heritage in Italy [11]. Regarding projects on mitigating the impact of natural hazard on cultural heritage sites, outcomes from the FP6 CHEF project (2007-2010, ITAM participating) and the subsequent Czech NAKI Programme (2012-2015) on the protection of Cultural Heritage against flooding will be exploited [12, 13]. State of the art and recommendations proposed within the project "Safeguarding Cultural Heritage from Natural and Man-Made Disasters A comparative analysis of risk management in the EU" funded by DG-EAC will be of major consideration [14].

Synergies will be also fostered with the recently H2020 funded projects aimed at enhancing the resilience in facing the climate changes effects and natural hazards HERACLES and STORM [15, 16].

Finally, the NatCatSERVICE database on loss events due to natural hazards resulting in property damage or bodily injury will be exploited This is the most comprehensive natural catastrophe loss database currently available where approximately 1000 events are recorded and analysed every year [17].

It has to be underlined that existing measures on climate change adaptation aiming at Cultural Heritage safeguarding are still not exhaustively integrated in strategies and plans at national level. Current policy documents linking climate change and Cultural Heritage are almost exclusively drafted by heritage organisations and institutions (see, for instance, the Policy document on the impacts of climate change on world heritage properties of the UNESCO World Heritage Centre). At national level, sporadic recent attempts to integrate Cultural Heritage into the wider national and international policies have been made. The Italian and French National Strategies for Adaptation to Climate Change represents an encouraging example in this direction and will be of significant value for the development of WP T3 Elaboration/implementation of plans for cultural heritage protection in emergency situations.

4. ELABORATION OF DATA COLLECTED

In this section the data collected in D.T1.1.1 at different territorial levels (local/regional/national/international) for each Country/Region involved in ProteCHt2save are elaborated with the aim of identifying strengths and weakness in the risk management process with focus on cultural heritage safeguarding. All the data collected and recorded by each partner involved were included in D.T1.1.1 (see ANNEX 1-7).

4.1. Past Disaster

Type and number of extreme events occurred since 1900 and documented in the countries of Central Europe participating in the project, with particular reference to the areas where the pilot sites are located, are elaborated in Figures 3 and 4. A number of total events ranging from 8 to 24 are documented at different scales (local, regional and national).

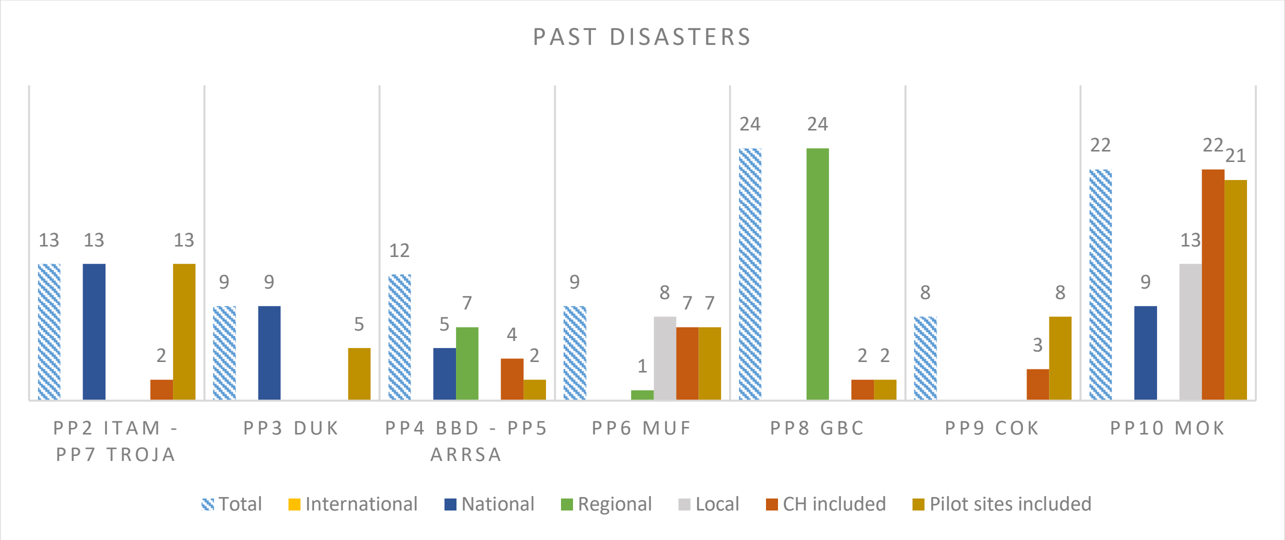


Figure 3. Total number of past disasters documented since 1900 by the consortium in the areas under study.

The highest frequency of events refers to flood and events of heavy rain/storm, which have been experienced at all investigated areas. An event of sea flood has been documented for the city of Kastela (Croatia - COK). Earthquake episodes occurred in Austria (DUK) and Ferrara (MUF), while fire are reported in Hungary (GBC) and in the Municipality of Kastela (COK). Impact on built heritage has been recorded for the Municipality of Troja, Ferrara, Kastela and Kocevje, for the Bielsko-Biala district in Poland and Baranya County in Hungary.

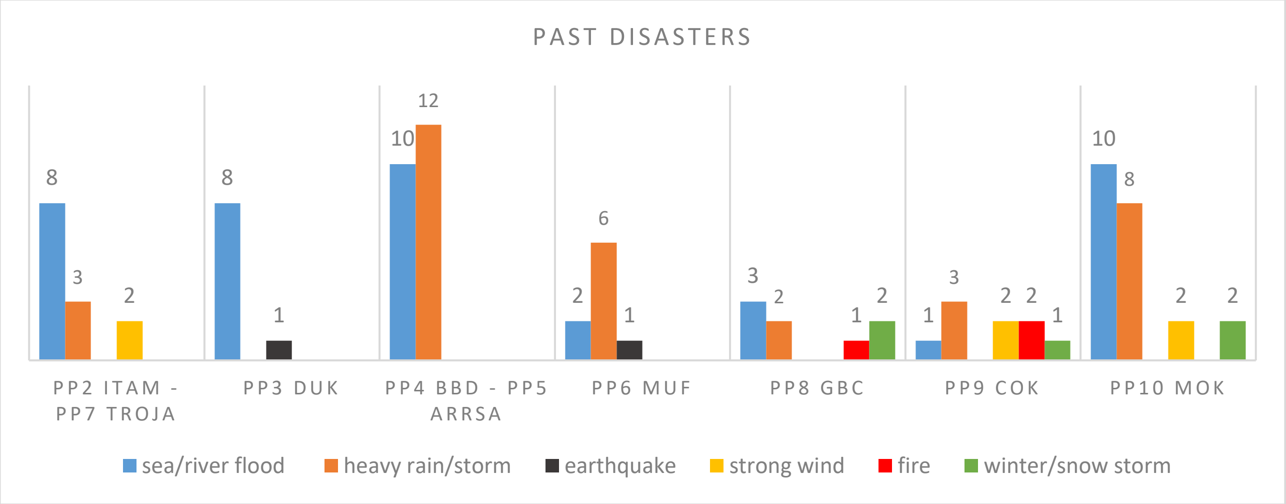


Figure 4. Typology of past disasters documented by the consortium in the areas under study.

4.2. Plans & Strategies

The number of existing plans and strategies at European, national, regional and local level on risk management and resilience measures against natural disasters and extreme weather actions in the areas under study are illustrated in Figure 5. The number of plans and strategies including ProteCHt2save pilot sites are highlighted as well as those taking into consideration built heritage (Bielsko-Biala, Ferrara, Kastela and Kocevje).

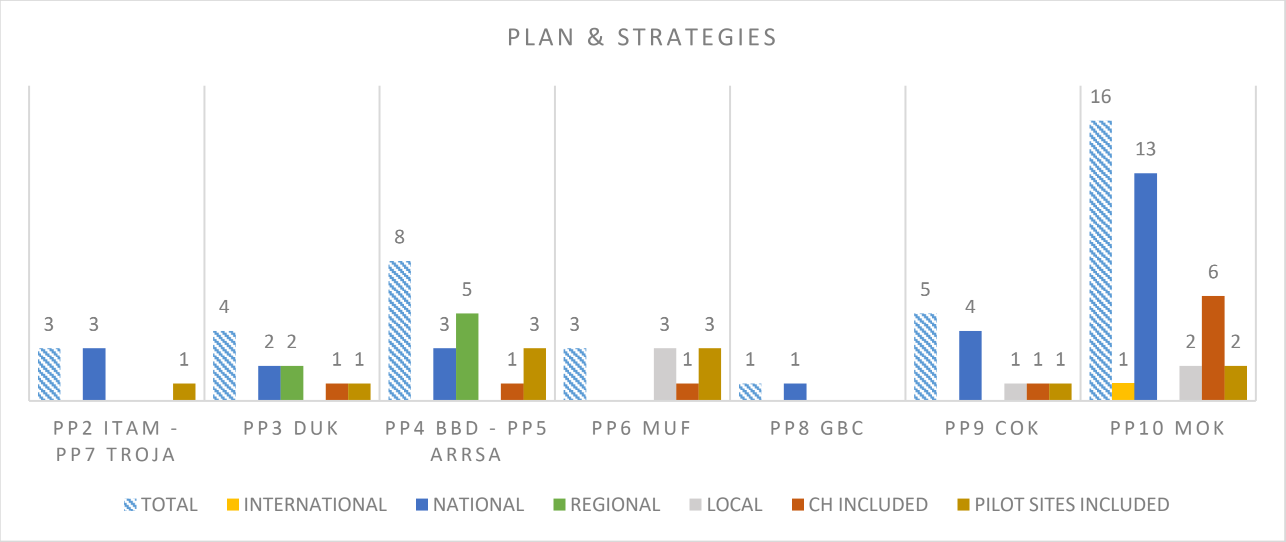


Figure 5. Exiting Plans and Strategies in the areas under study.

Figure 6 shows which main hazards the plans and strategies relate to highlighting that flood is included in plans and strategies in all regions interested by the project.

With “various” we refer to:
1) flood, heavy rain, fire and strong wind for Poland (BBD - ARRSA);
2) flooding, inland water, local water damage, lightning flood, extraordinary weather, earthquake, landslide, collapse and subsidence for Hungary (GBC);
3) flood, heavy rain, fire, earthquakes, drought and technical disasters for Croatia (COK);

4) flood, heavy rain, fire and natural disaster for Slovenia (MOK).

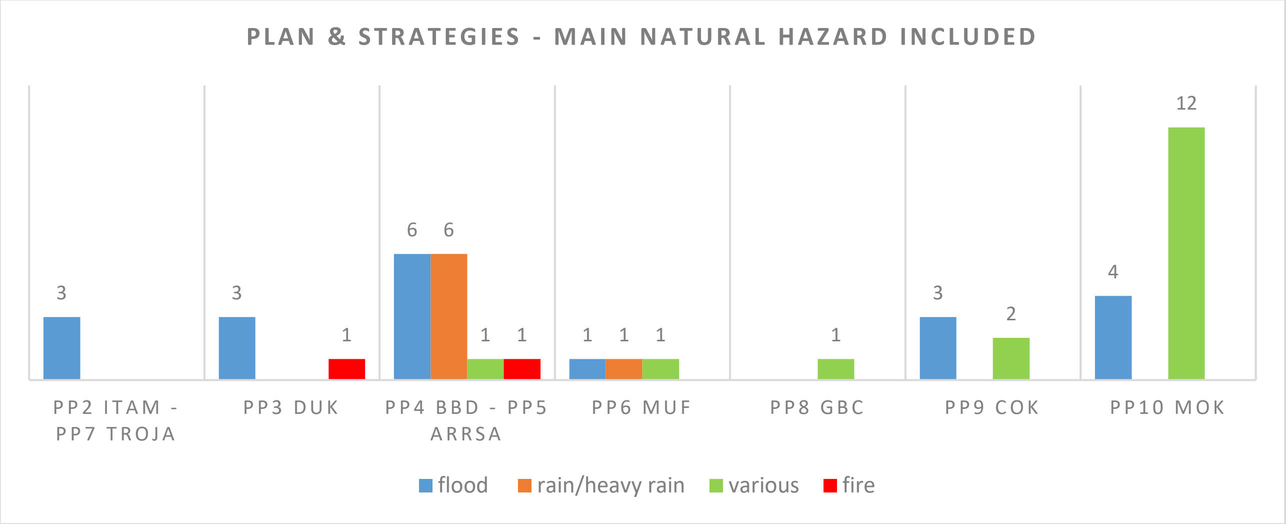


Figure 6. Main natural hazards included in Plans and Strategies recognized.

4.3. Project outputs

Number of projects and related outputs (maps/atlas/database…) from past and current local, Regional, National and International Projects on the identification of risk areas and risk assessment due to floods, heavy rain, fire caused by drought are shown in Figures 7 and 8. Additionally, Figure 8 evidences the inclusion of cultural heritage (Czech Republic, Hungary and Slovenia) while Figure 9 highlights the main natural hazard considered.

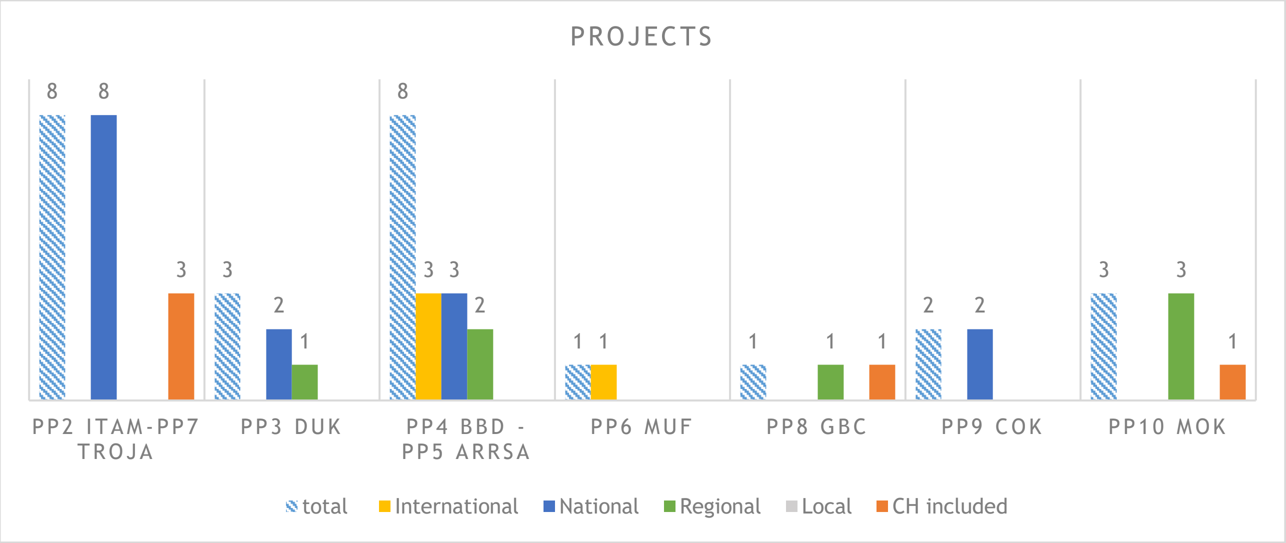


Figure 7. Distribution of the Projects based on territorial competences.

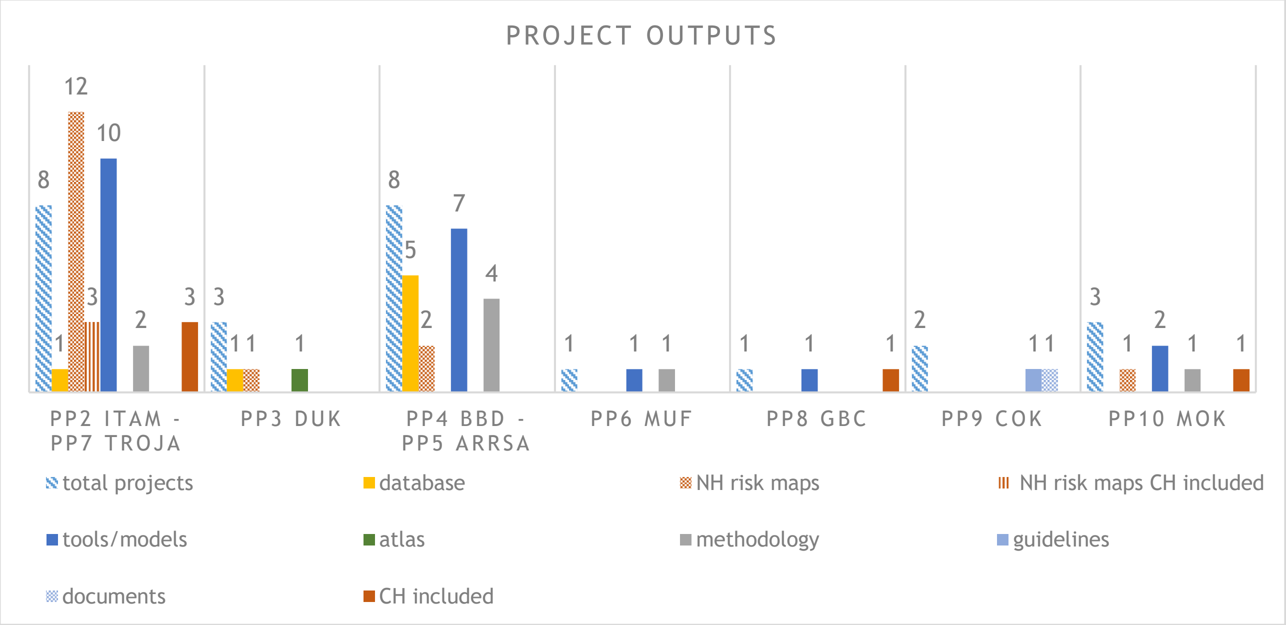


Figure 8. Number and typology of main outputs resulting from projects recognized.

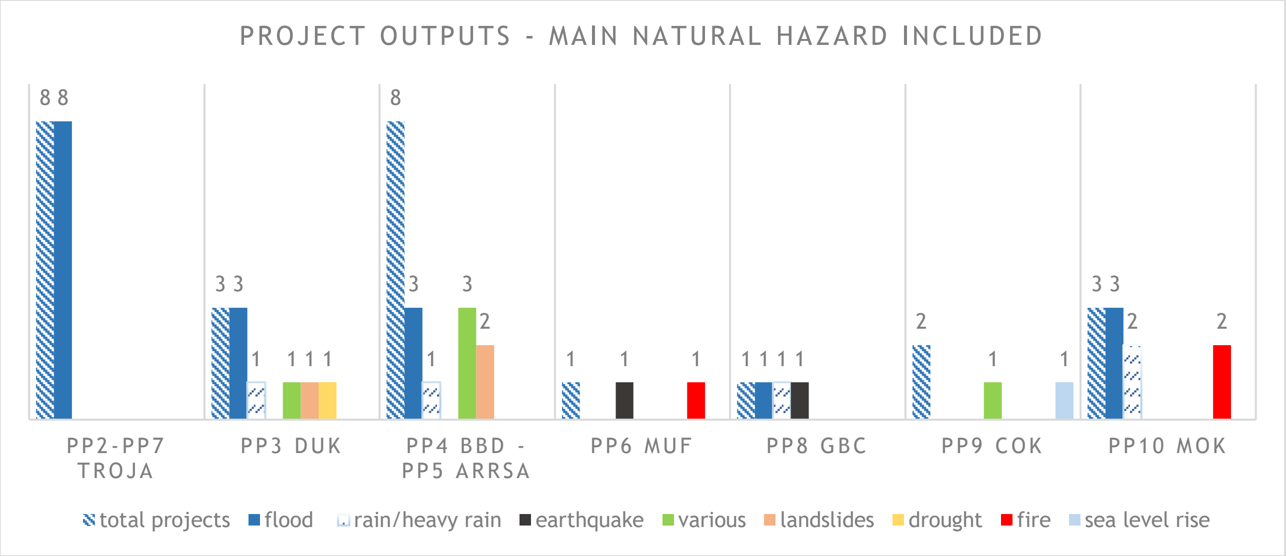


Figure 9. Main Natural Hazards included in the projects.

4.4. Maps and GIS Platforms

Figure 10 and 11 illustrate the number of available vulnerability/risk maps and GIS Platforms at different scale in the Regions/Countries participating at ProteCHt2save that can be useful for the assessment of potential threats to cultural sites by selected natural and anthropogenic influences. It should be underlined that cultural heritage is reported as taken into consideration in maps for Czech Republic and Poland and in GIS platforms only for Czech Republic.

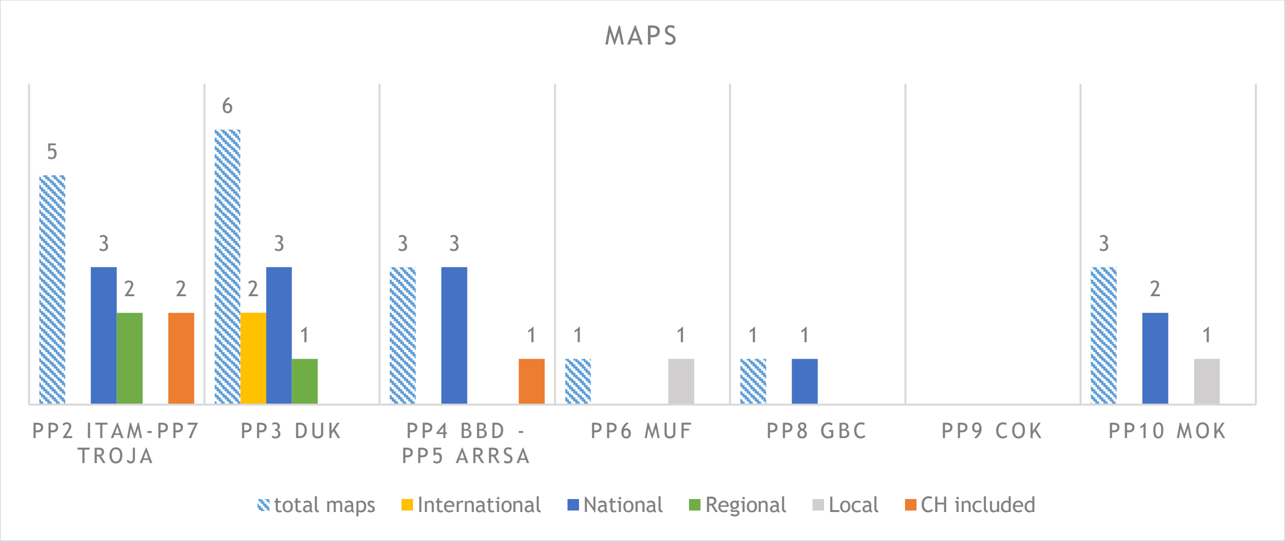


Figure 10. Vulnerability/Risk maps available at different territorial scales.

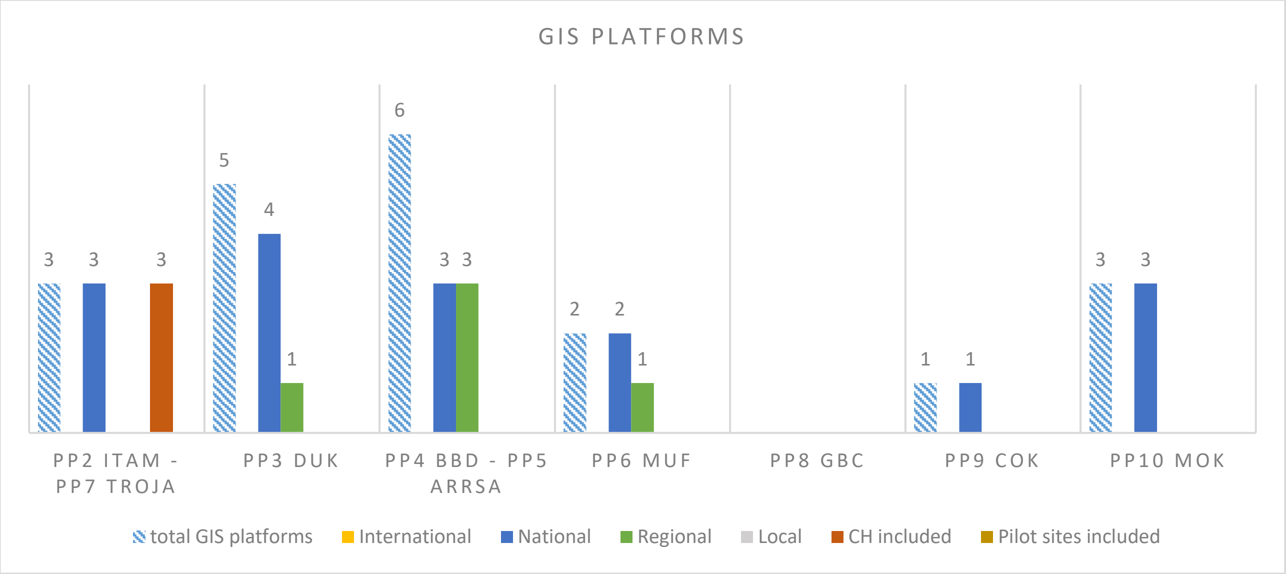


Figure 11-. GIS Platforms available at different territorial scales.

Figures 12 and 13 elaborate the data with reference to the main hazards that are taken into consideration by the documented maps and GIS platforms.

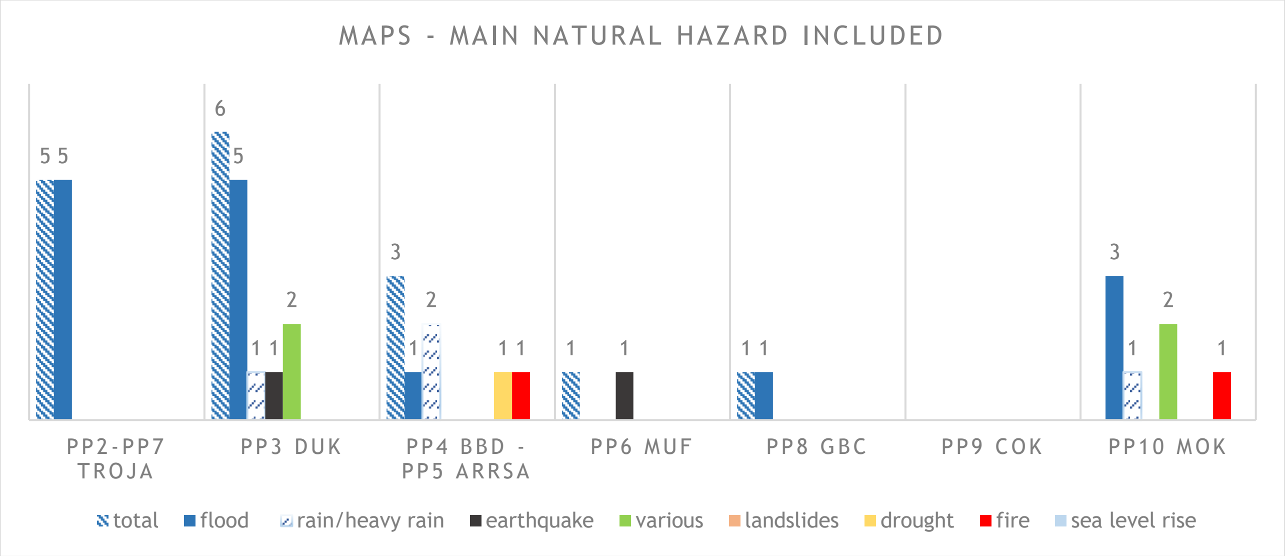


Figure 12. Main Natural Hazards included in the available maps.

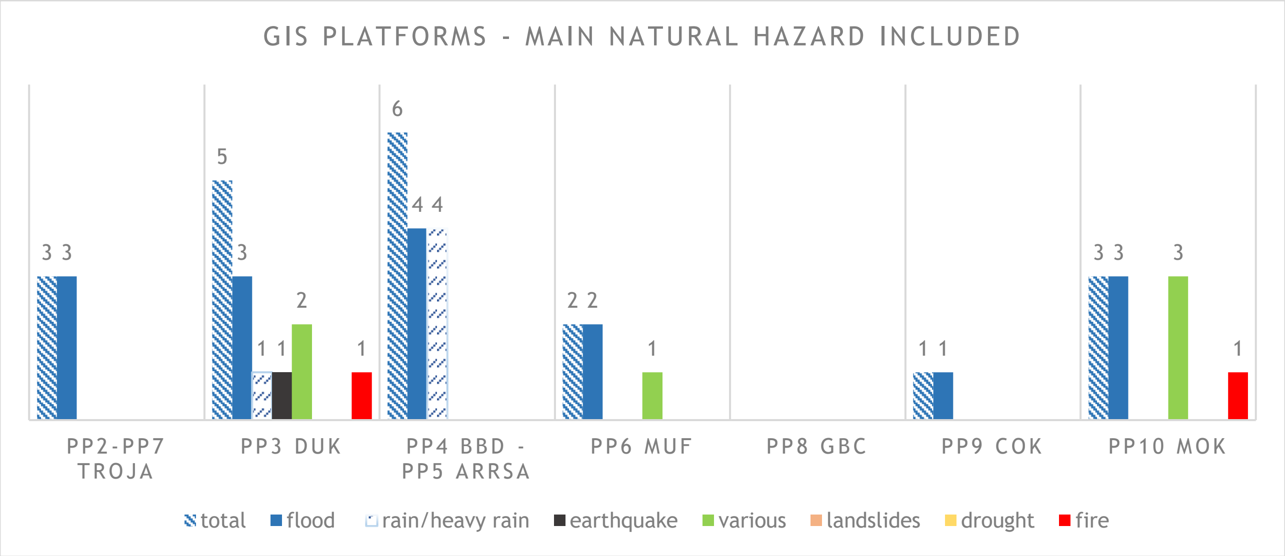


Figure 13. Main Natural Hazards considered by the available GIS platforms.

4.5. Monitoring stations

The list of existing officially recognized monitoring stations of climate parameters (monitoring at least Temperature, Relative Humidity, Precipitation) in the proximity of the pilot sites were collected. As already detailed in D.T1.1.1. *Identification of appropriate procedures for the assessment of climate impact on cultural heritage*, these data will be useful for evaluating continuously the meteorological situation and identifying main deterioration processes due to climate parameters that can occur at the case studies. Additionally, measured data are necessary for possible corrections of the simulated ones from climate models.

5. FINAL REMARKS

With the development of the present deliverable effort have been devoted to select and report the most appropriate tools for risk evaluation. The climate models and tools for data analysis and downscaling identified (section 2), as well as results from previous funded project on climate change and hazards impact on cultural heritage (section 3), will be fundamental for the implementation of D.T1.2.2 *Development of map creator on line tool* and of D.T1.2.3 *Elaboration of maps with hot-spots of extreme potential impacts on cultural heritage*. The elaboration of data collected by the partnership (section 4, Past Disasters, Plans and Strategies, Project outputs, Vulnerability an Risk Maps, GIS Platforms and Monitoring Stations) evidenced weakness and strengths in the existing measures and tools for risk management in response to disasters and extreme events aiming at the protection and safeguarding of built/cultural heritage. The obtained results will be of paramount importance in the elaboration/implementation of plans for cultural heritage protection in emergency situations (WPT3) and the subsequent testing and implementation on site (WPT4).

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