

## SAFEGUARDING CULTURAL HERITAGE FROM NATURAL AND MAN-MADE DISASTERS



# PROTHEGO

Protection of European Cultural Heritage from Geo - Hazards

Geo-Hazards and UNESCO WH sites, from satellite monitoring to local scale conservation policies and management: the PROTHEGO Project approach

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Prothego project Manager

Joint Communication Event in the framework of Interreg Central Europe ProteCHt2save and Contract EAC-2016-0248

## RATIONALE: WH Sites "in danger"



1073

Properties

37

Transboundary

2

Delisted

54

In Danger

832

Cultural

206

Natural

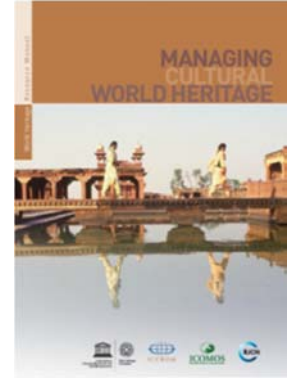
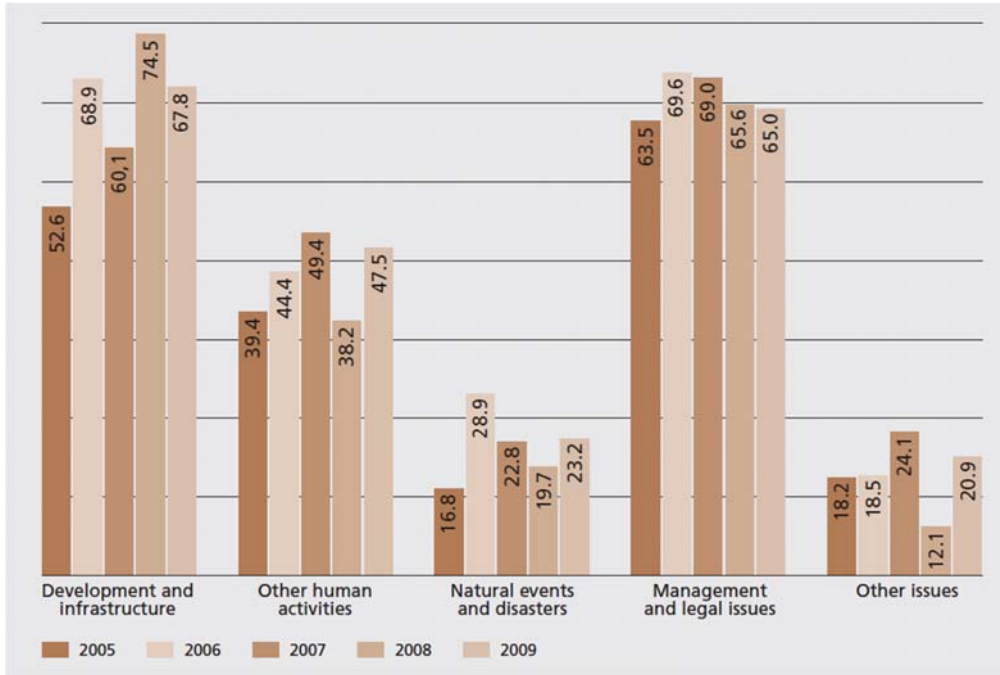
35

Mixed

167

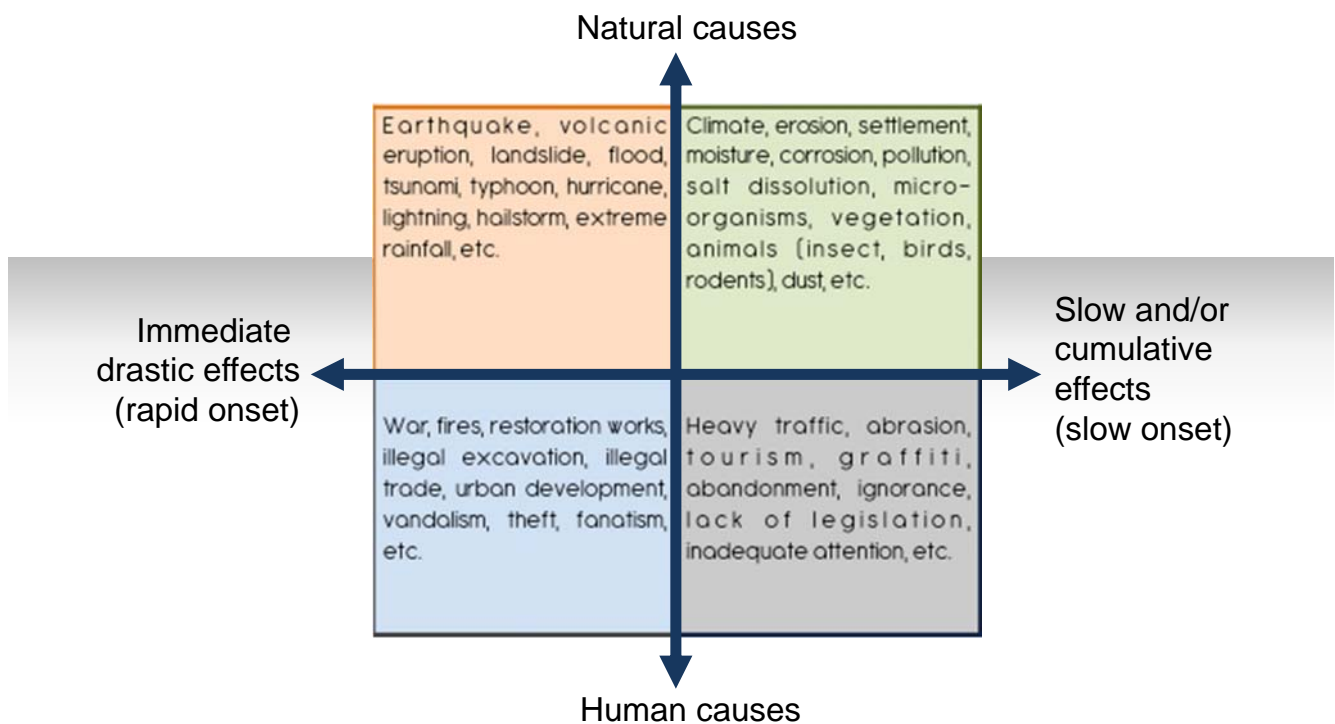
States Parties

UNESCO World Heritage List  
Jan. 2018



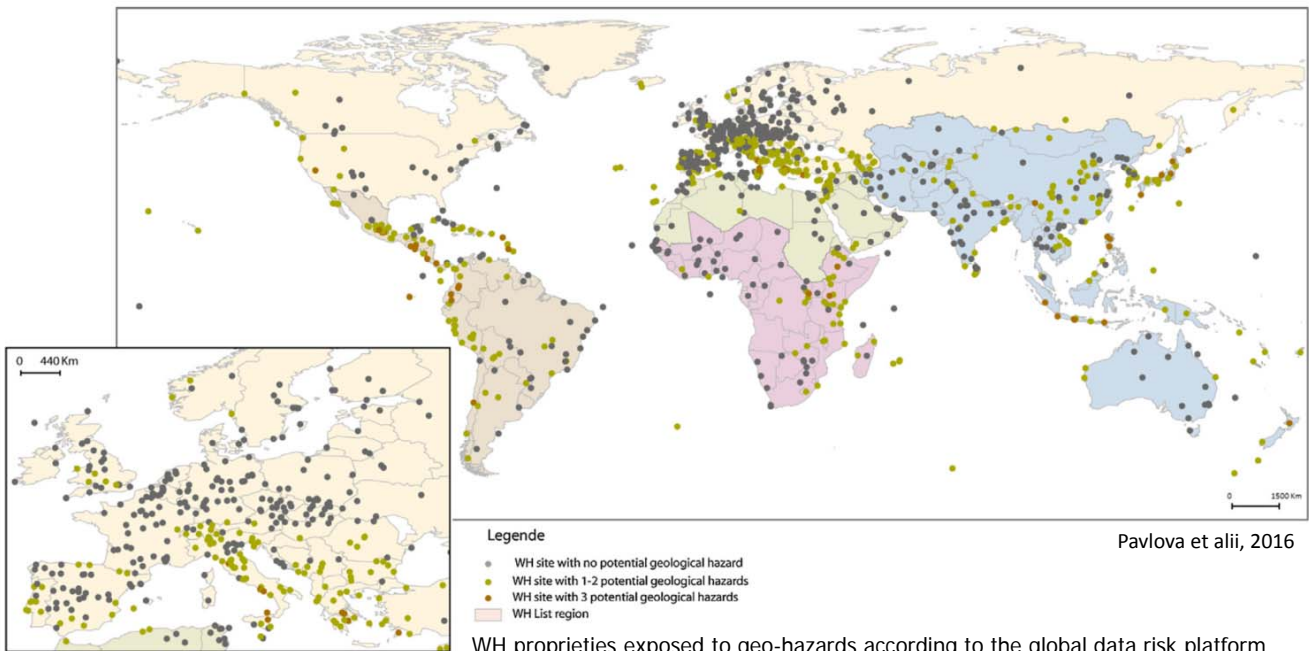
Source: UNESCO (2013)

Diagram 4: Percentage of World Heritage properties affected by each primary group of threats (years progressing from 2005 to 2009, from left to right)<sup>30</sup>



**76%** whole World Heritage is potentially affected by at least one geo- hazards

Article 11 of the Convention (Protection of WH) include sites threatened also by armed conflicts, accelerated deterioration, calamities and cataclysms, and rapid urban or tourist development



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## Project Participants



**PROTHEGO** Project Scientific Coordinator  
Claudio MARGOTTINI

Project started: Dec 2015  
Ends: March 2018

**ISPRA** Project Manager:  
Daniele SPIZZICHINO



**NERC**  
Emma J. BEE

[www.prothego.eu](http://www.prothego.eu)



**CUT**  
Kyriacos THEMISTOCLEOUS



**UNIMIB**  
Giovanni CROSTA



**IGME**  
José Antonio FERNÁNDEZ MERODO



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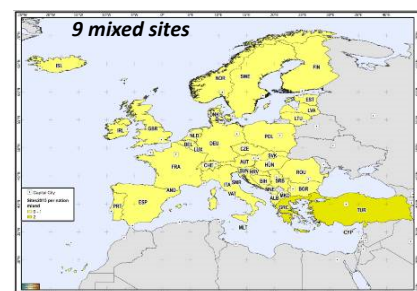
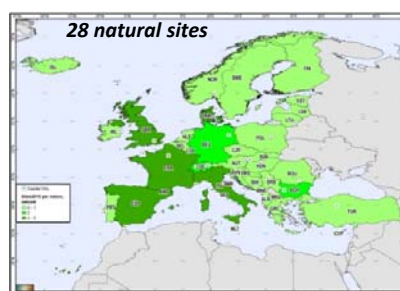
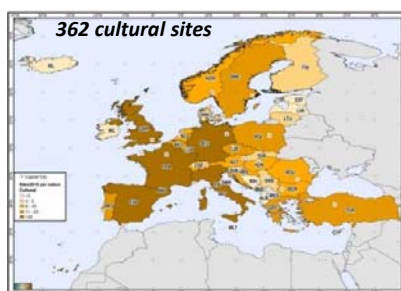




No	Support letter	AP - typology	Role in the project
1	ESA – European Space Agency [Pier Giorgio Marchetti]	European Agency	Steering Committee
2	EGS – Eurogeosurveys [Luca Demicheli]	Association of the European Geological Surveys	Steering Committee
3	Petra Archaeological Park - Jordan [Emad Hjazzen]	World Heritage Site	Steering Committee
4	ICL International Consortium on Landslides [Kyjij Sassa]	International Research consortium	Stakeholders
5	ISCR Istituto Superiore per la Conservazione ed il Restauro [DG Arch. Gisella Capponi]	Public Agency	Stakeholders
6	CRSS Cyprus Remote Sensing Society [Dr. Giorgos Papadavid]	SVE	Stakeholders
7	Politecnica Madrid - Alert geo-materials Royal Academy of Sciences Seville [Manuel Pastor]	Public University	Stakeholders
8	CSPrea [CEO Eng. Paolo Segala]	SVE	Stakeholders
9	Association of Cypriot Archaeologists [D. Filides & V. Lyssandrou]	Non-profit Scientific Association	Stakeholders
10	Patronato de la Alhambra y generalife	Public Authority	Demonstration Site Stakeholders Alhambra, Spain
11	Sovrintendenza Capitolina – Roma Capitale [Claudio Parisi Prisco]	Technical body of the municipality of Rome	Demonstration Site Stakeholders Historic Centre of Rome, Italy
12	Landscape Research & Management [Dr. Andy Heward]	Geo-archaeological landscape consultancy	Demonstration Site Stakeholders
13	Derwent Valley Mills - World Heritage Site [Mark Suggitt]	World Heritage Site Board	Derwent Valley Mills, UK
14	Trent & Peak Archaeology and the York Archeological Trust [Dr. David Knight]	Archeological heritage Services provider	[via the project "Managing Climate Change in the Derwent Valley", commissioned by English Heritage]

## Main goals of the project

Cultural Heritage are continuously impacted and weathered by several internal and external factors, with both rapid and slow onset, including natural hazards, such as landslides, sinkholes, settlement, subsidence, earthquakes or extreme meteorological events.

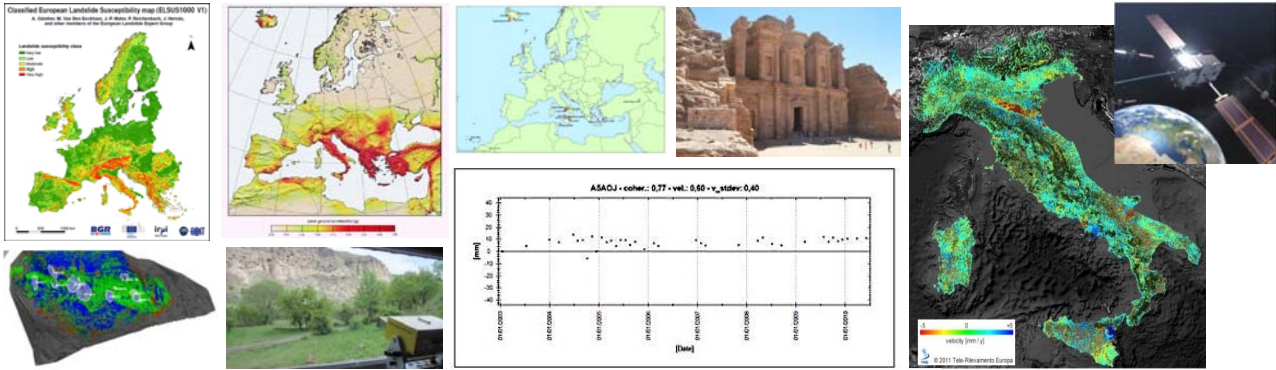


- ✓ To make an innovative contribution towards the analysis of geo-hazards in areas of Cultural Heritage in Europe;
- ✓ To apply novel space technology based on radar interferometry (InSAR) to monitor monuments and sites in Europe which are potentially unstable due to geo-hazards;
- ✓ To combine remotely sensed information on ground stability and motion with geo-hazard datasets available for Europe to identify the most endangered sites across Europe.

WP7 - Dissemination and communication

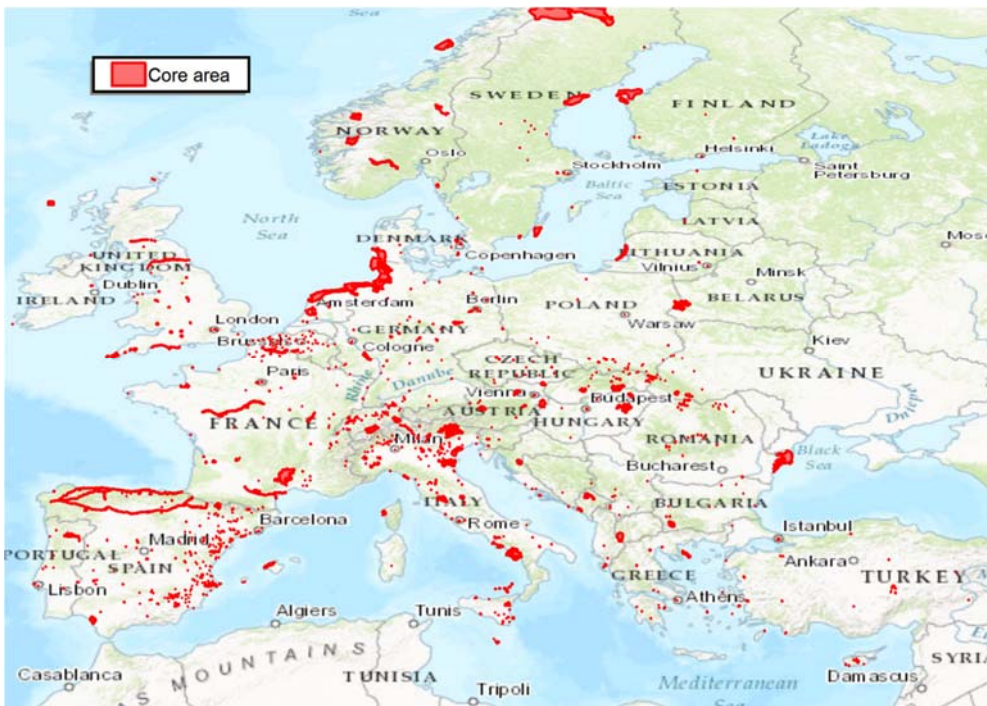


WP8 - Project Management



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WP1, European WH vs. Geo-hazards:  
WHL Boundaries, Europe

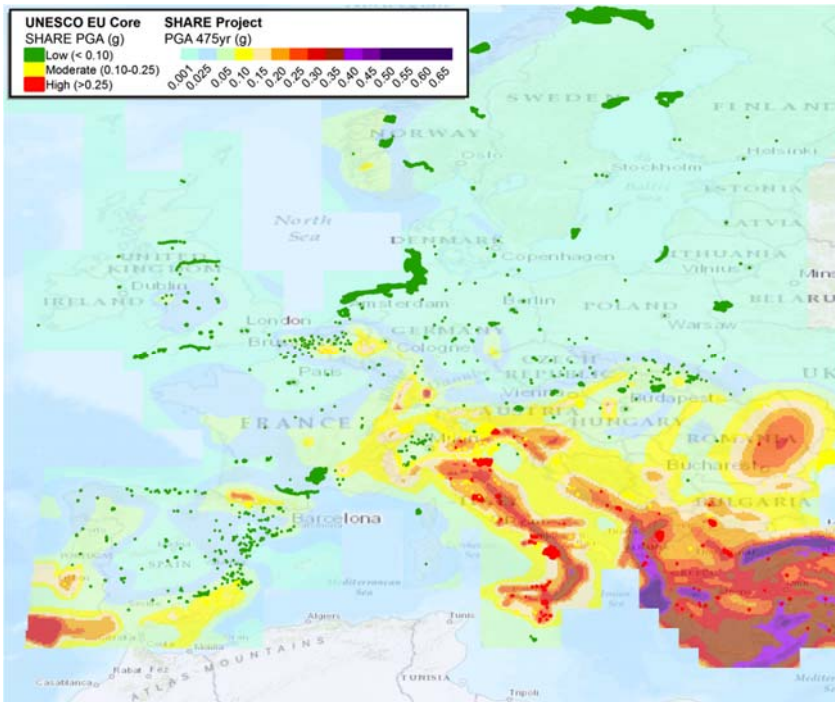


WHL Sites	399
WHL Core polygons	2351
WHL parts > 50	5 45 - 700 (50% of tot)
WHL avg. parts	2.7
Min polygon area	5 (m <sup>2</sup> )
Max polygon area	10 000 (km <sup>2</sup> )
Avg. polygon area	80 (km <sup>2</sup> )

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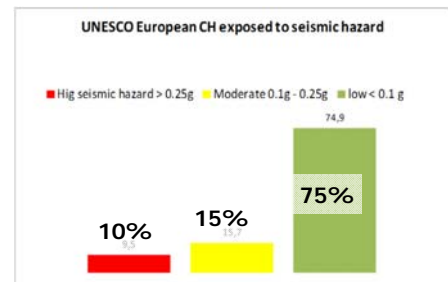
# WP1 European WH Vs Geo-hazards: WH vs. Seismic Hazard



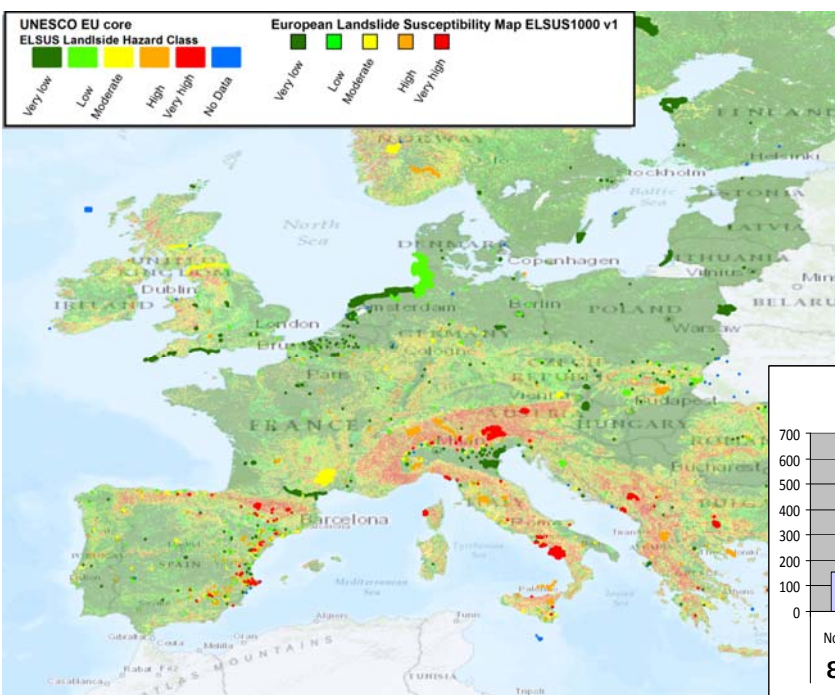
## SHARE

European Earthquake Catalog  
(Peak Ground Accelerations map for Europe)

- 3 hazard classes
- Cell size ~ 8 km
- update 2013
- 475 yrs Return Time



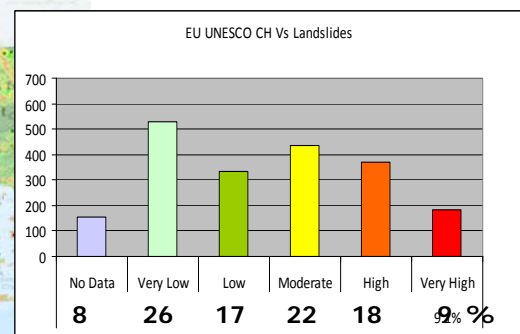
# WP1 European WH Vs Geo-hazards: WH vs. Landslide Hazard



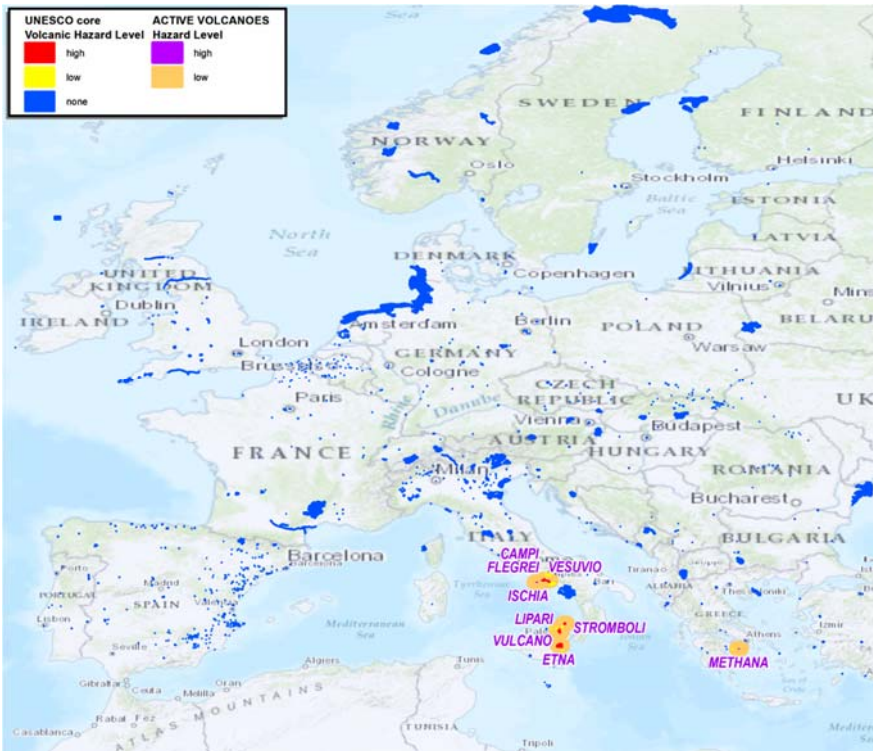
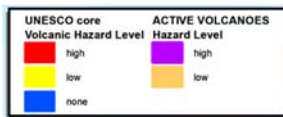
## ELSUS

European Landslide  
SUSceptibility Map  
(ELSUS1000) v1

- 5 hazard classes [Low-High]
- Cell size 1 km
- update 2013

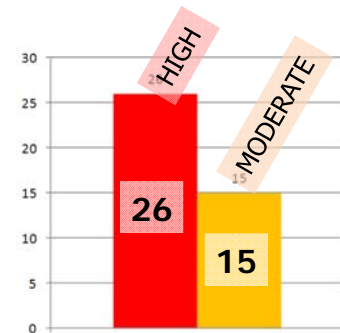


# WP1 European WH Vs Geo-hazards: WH vs. Volcanic Hazard



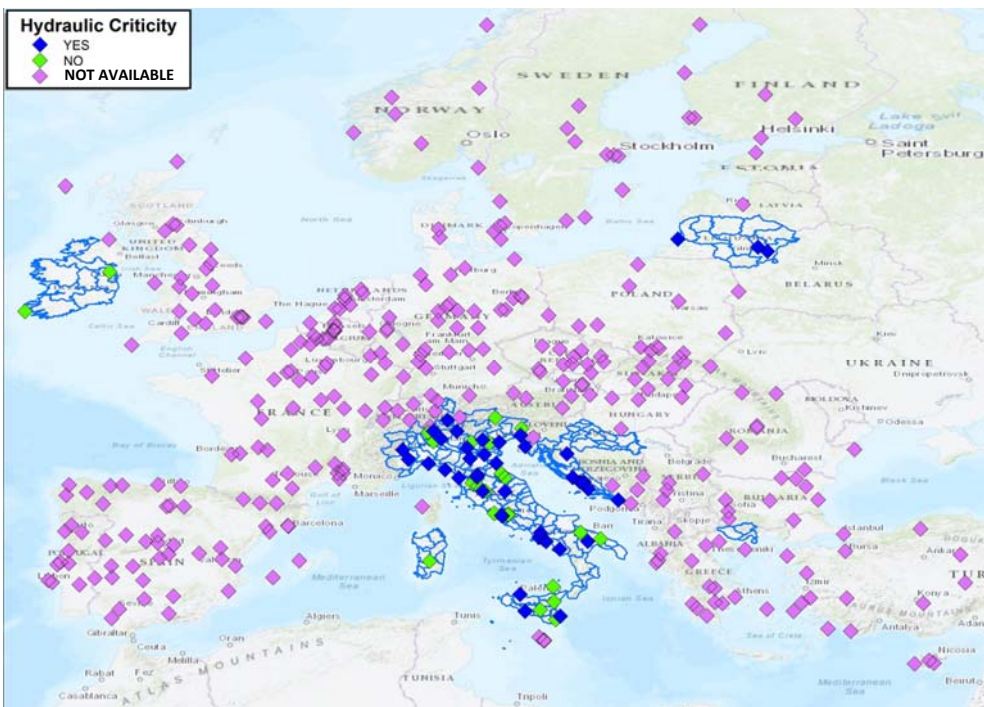
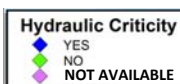
11 volcanoes in Europe can produce effects on WHL Sites.  
7 of these Sites are in Italy.

WHL Core Area interested by Volcanic effects



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# WP1 European WH Vs Geo-hazards: WH vs. Hydraulic criticality



EC Flood Directive  
2007/60

Sites with available data on Hydraulic Critical areas	40
Sites without Hydraulic Critical areas	24
Sites without available data on Hydraulic Critical areas	335

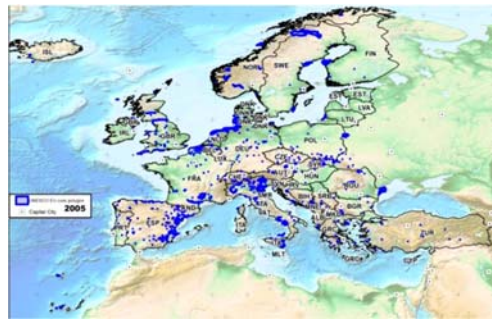
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# WP1 first output: European WH vs. Geo- Hazards

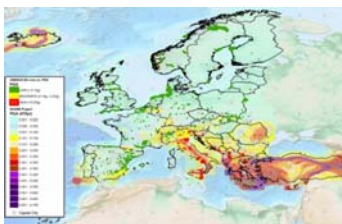


399 UNESCO European CH

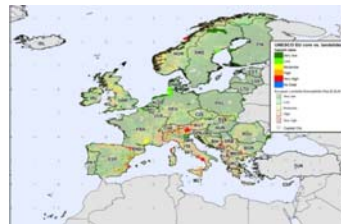


2351 single polygons CH

## UNESCO WH Geo-Hazard preliminary analysis



10% high seismic hazard



27% high and very high landslide hazard



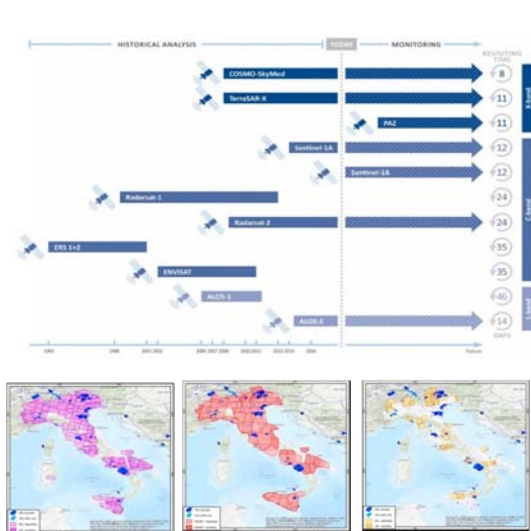
41 single CH affected by volcanic hazard

# WP2: Harmonization of PS data and creation of digital factsheets

Overview of satellite SAR missions in C-, X- and L-band, their operational lifetime and typical revisiting times  
(© TRE ALTAMIRA 2016;  
<http://tre-altamira.com/technology/>)

### DATA SOURCES

1. PS datasets from the ESA-GMES Terrafirma project
2. PS datasets from the Italian EPRS-E
3. PS datasets made available via other projects
4. Literature review



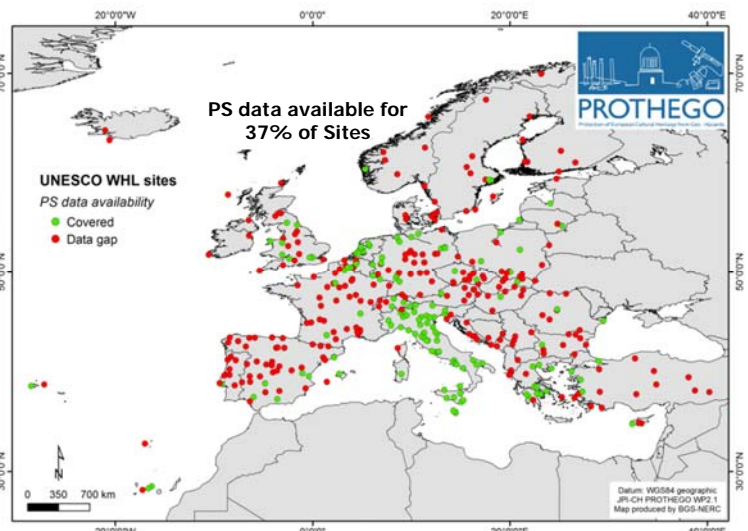
ERS  
2008-2010



ENVI  
2010-2012

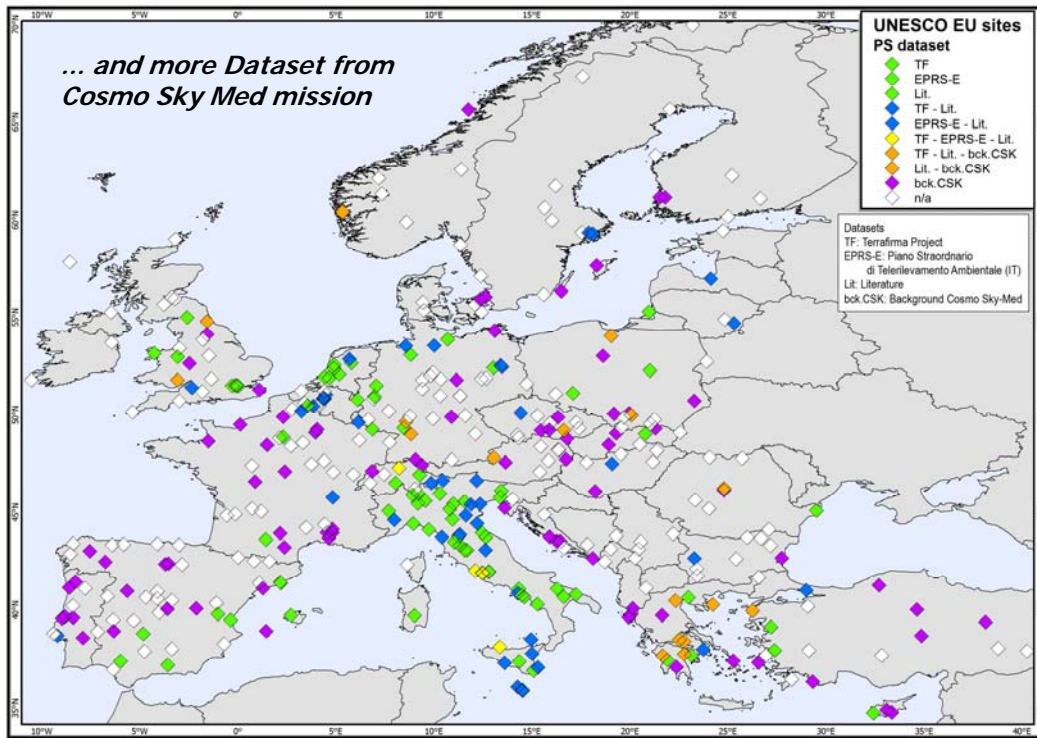


CSK  
2011-2014



Overall coverage of the UNESCO WHL sites of Europe with PS ground motion data.





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For all the EUROPEAN UNESCO WH Sites a synthetic **digital factsheets** was implemented and fulfilled with all collected data concerning level of Geo-Hazard and SAR data (where available)

**UNESCO World Heritage Sites**

Property | Description and Criteria | Overall Hazard Risk

Satellite Data Availability | Detailed Hazard Risk and Satellite Data Availability

**SITE DESCRIPTION:**  
Much of the landscape of Cornwall and West Devon was transformed in the 18th and early 19th centuries as a result of the rapid growth of pioneering copper and tin mining. Its deep underground mines, engine houses, foundries, new towns, smallholdings, ports and harbours, and their ancillary industries together reflect prolific innovation which, in the early 19th century, enabled the region to produce two-thirds of the world's supply of copper. The substantial remains are a testimony to the contribution Cornwall and West Devon made to the Industrial Revolution in the rest of Britain and to the fundamental influence the area had on the mining world at large. Cornish technology embodied in engines, engine houses and mining equipment was exported around the world. Cornwall and West Devon were the heartland from which mining technology rapidly spread.

**CRITERIA:** Null

**SATELLITE DATA AVAILABILITY ACROSS THE ENTIRE SITE**

**ERS Data (Entire Site):** No ERS satellite data available

**Envisat Data (Entire Site):** No Envisat satellite data available

**Combined ERS and Envisat Data (Entire Site):** No combined ERS and Envisat satellite data available

**CSK Data (Entire Site):** No CSK satellite data available

Create PDF

**UNESCO World Heritage Sites**

Property | Description and Criteria | Overall Hazard Risk

Satellite Data Availability | Detailed Hazard Risk and Satellite Data Availability

**GEOHAZARD RISK ACROSS ENTIRE SITE**

**LANDSLIDE RISK**  
**Risk Category (Entire Site):** Medium (3)  
**Explanation:** Content still to come

**SEISMIC RISK**  
**Risk Category (Entire Site):** Low (1)  
**Explanation:** Content still to come

**VOLCANIC RISK**  
**Risk Category (Entire Site):** No hazard present  
**Explanation:** Content still to come

Create PDF

**UNESCO World Heritage Sites**

Property | Description and Criteria | Overall Hazard Risk

Satellite Data Availability | Detailed Hazard Risk and Satellite Data Availability

Please click on a specific polygon (yellow point) to receive detailed site information

Create PDF

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## WP3&WP4: Integration of PS and geohazard products and implementation of *multicriteria* methodology

### Risk analysis based on PROTHEGO methodology

#### a) Definition of the type of WHL site

Reclassification of the cultural heritage places on the basis of the **classes defined** by the International Council on Monuments and Sites (*ICOMOS, The World Heritage List: Filling the Gaps - an Action Plan for the Future*)

#### b) Identification of the hazards affecting the WHL sites

A **Hazard level** (reclassified from 0 to 1) at each WHL site has been calculated based on:

- 1) Seismic Hazard Map (*European seismic hazard model, EPEHR*).
- 2) European Landslide Susceptibility Map (*ELSUS1000*).
- 3) Hazard map of active Volcanoes in Europe

#### c) Potential Damage Vector

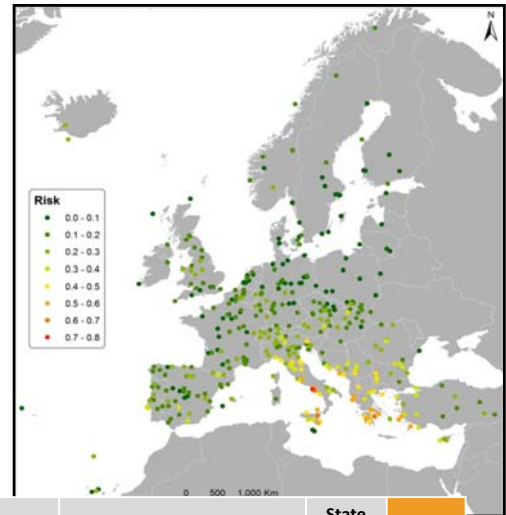
The **Potential damage vector** for each hazard is based on 5 level from very low (score = 1) to very high (score = 5) for each site classification:

- type vulnerability score, TYP
  - people vulnerability score, PEO
  - position vulnerability score, POS
- } **Potential damage vector**

#### d) Risk and Total Risk

**Risk = Potential damage vector x Hazard**

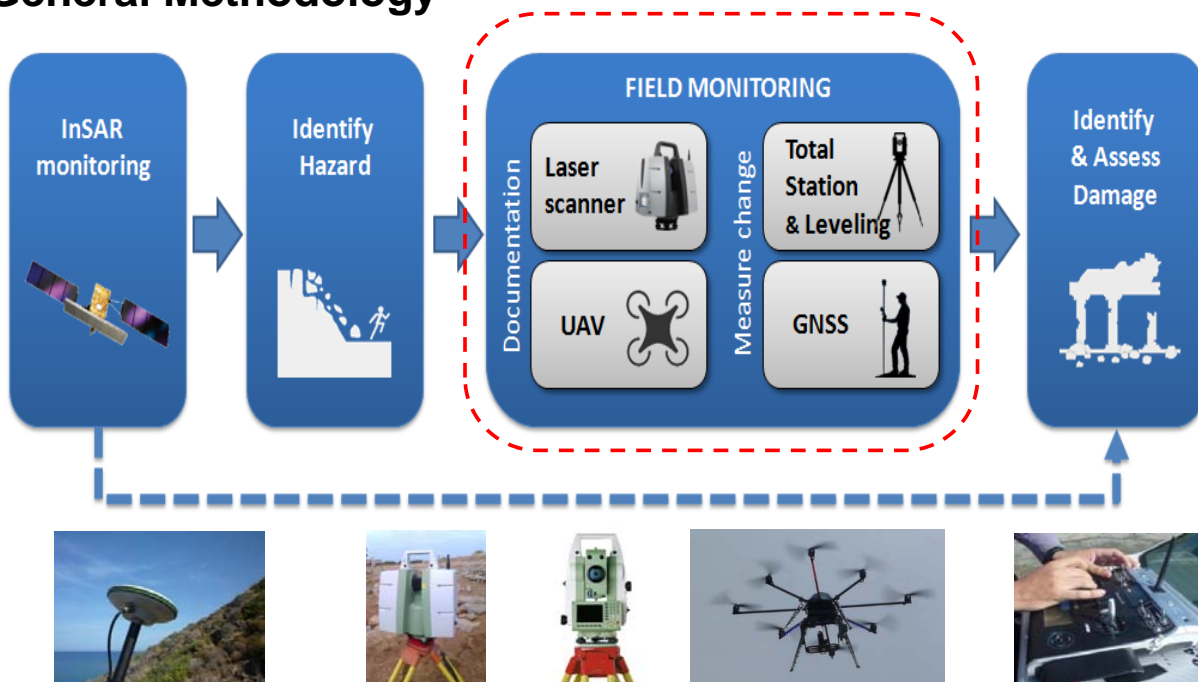
**Total Risk** defined as the **sum of each Risk score normalized from 0 to 1**



Position	Site Name	State Name	Total Risk
1	Historic Centre of Naples	Italy	0.756
2	Archaeological Areas of Pompei, Herculaneum and Torre Annunziata	Italy	0.697
3	Sanctuary of Asklepios at Epidaurus	Greece	0.647
4	Mount Etna	Italy	0.612
5	Historic Centres of Berat and Gjirokastra	Albania	0.580
6	Costiera Amalfitana	Italy	0.575

## WP5: Local scale monitoring

### General Methodology

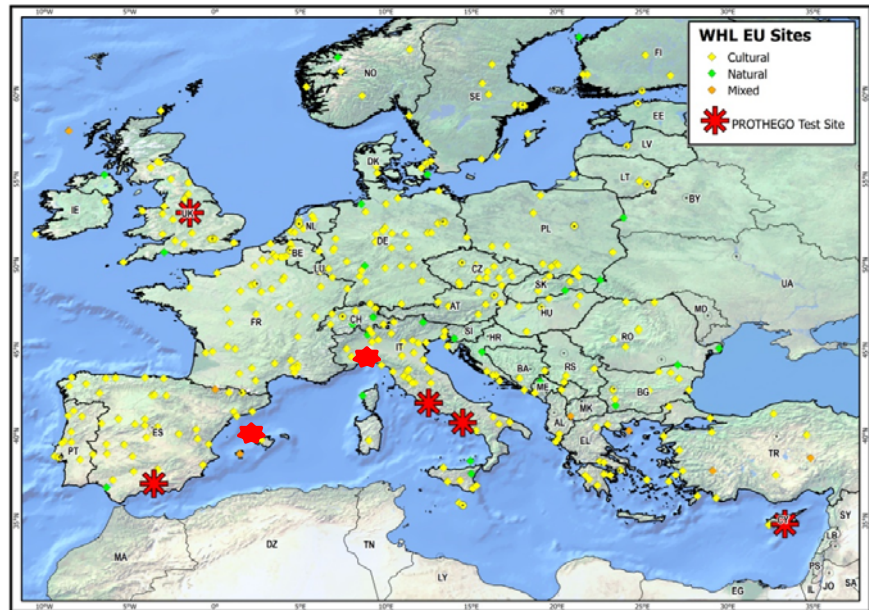




The Satellite Interferometry analysis, will be validated, calibrated and tested through site scale field survey, geotechnical advanced model and detailed monitoring data

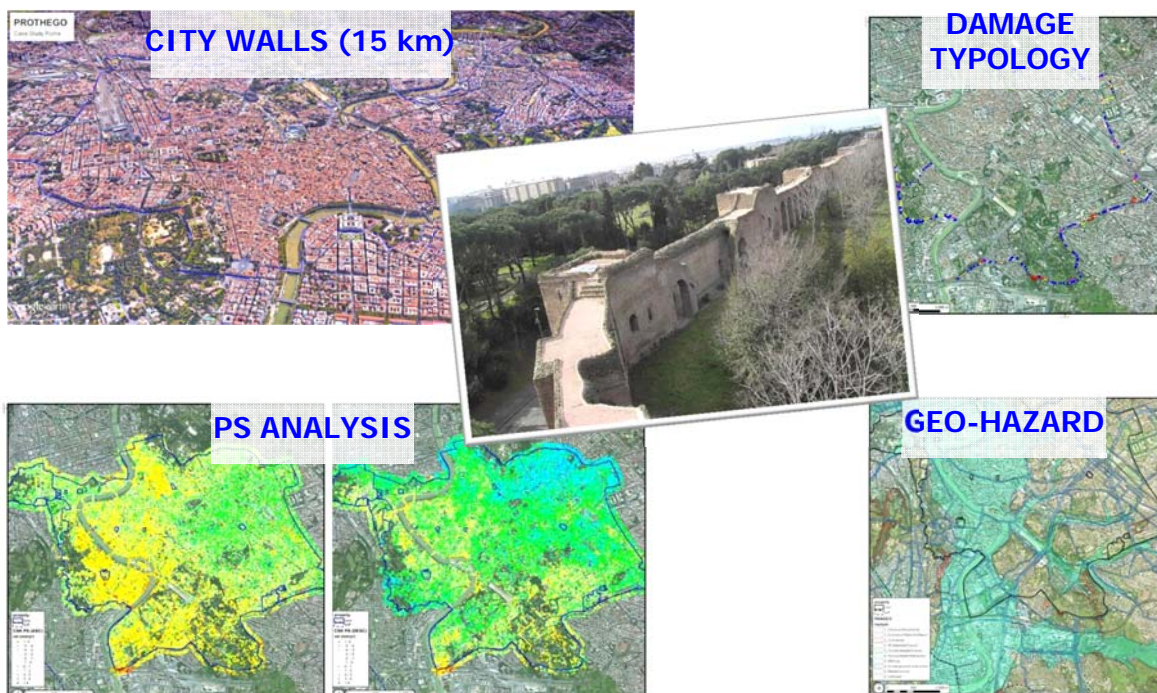
### 7 Test Sites:

1. Rome (IT);
2. Pompei (IT);
3. Derwent Valley Mills (UK);
4. Alhambra (ES);
5. Choirikoitia (CY).
6. Cinqueterre (IT)
7. The Tramuntana Range (SP)



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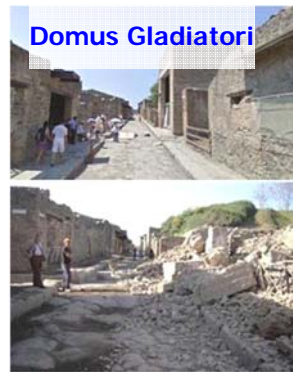
## WP6: Test Site 1 Rome Historic Centre (IT)



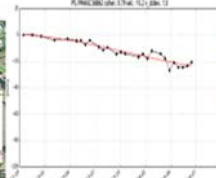
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35 structural and geological phenomena occurred in the last ten years in the sites were investigated through back analysis using SAR data

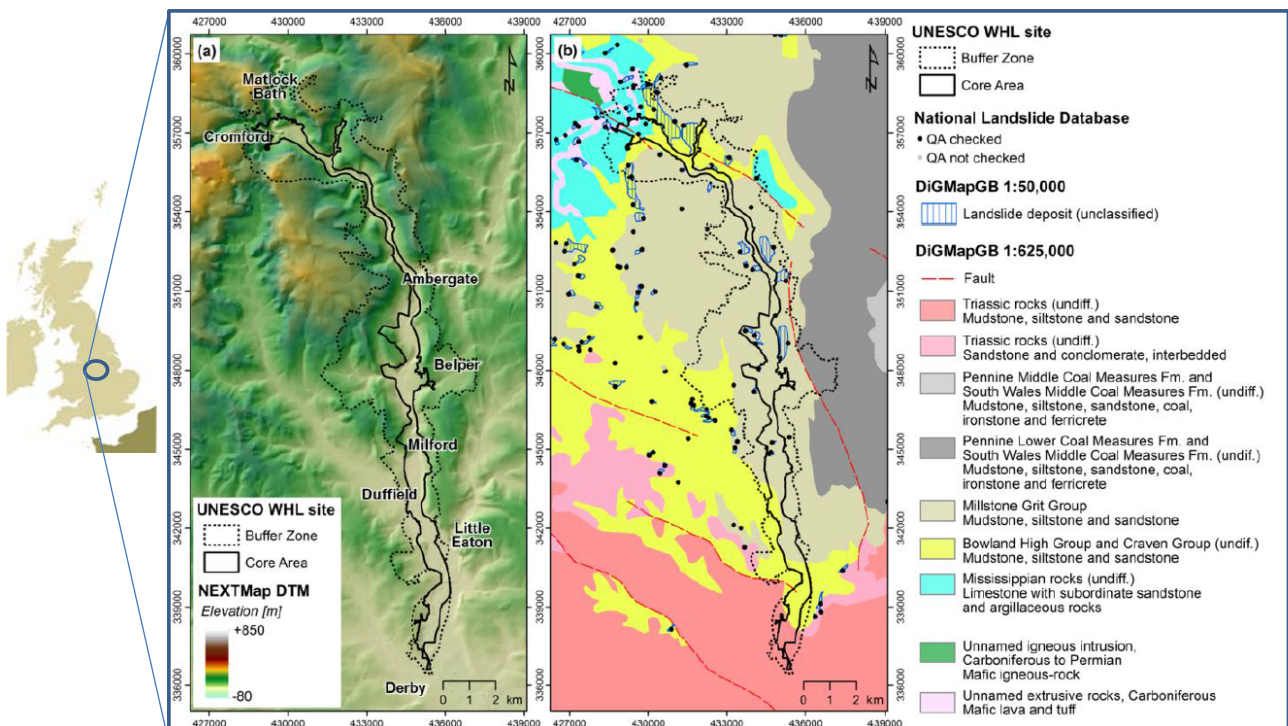


Necropoli  
Porta  
Nocera



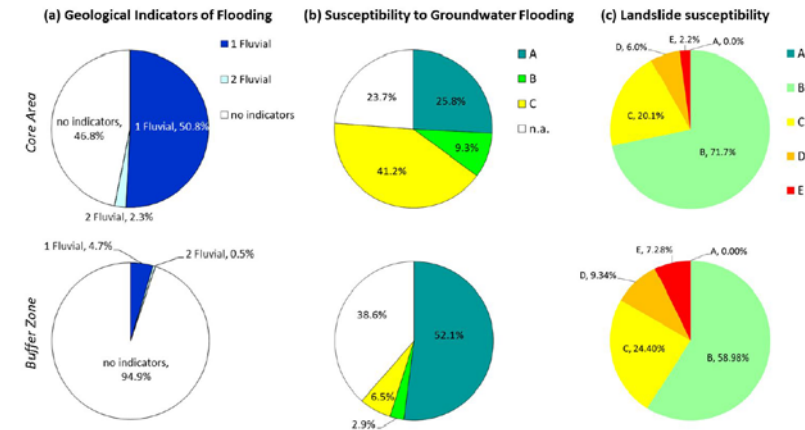
WP6: Test Site 3 Derwent  
Valley Mills (UK)

Topographical and geological setting





## Geohazard mapping in DVMWHS in present day climate conditions



Pie charts showing the relative areal coverage of hazard classes within the core area and buffer zone based on 3 BGS datasets

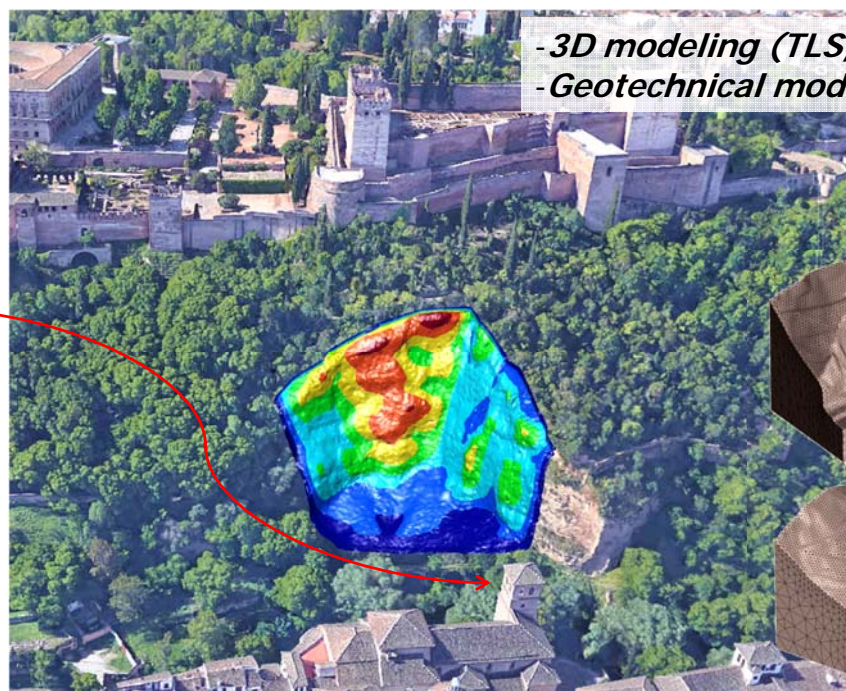


## Alhambra Generalife y Albaicín de Granada



Terrestrial Laser Scanner  
University of Granada

- 18/04/2007
- 01/2013 event  
*Small debris flow*
- 13/02/2013
- 27/12/2013
- 06/05/2014
- 14/10/2014
- 24/09/2015



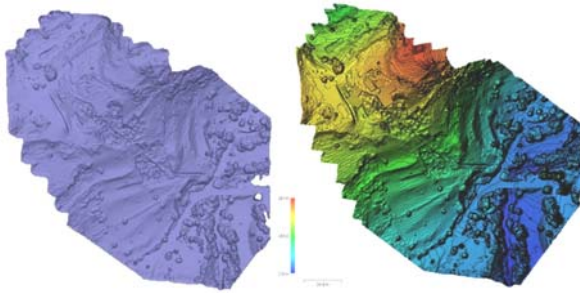
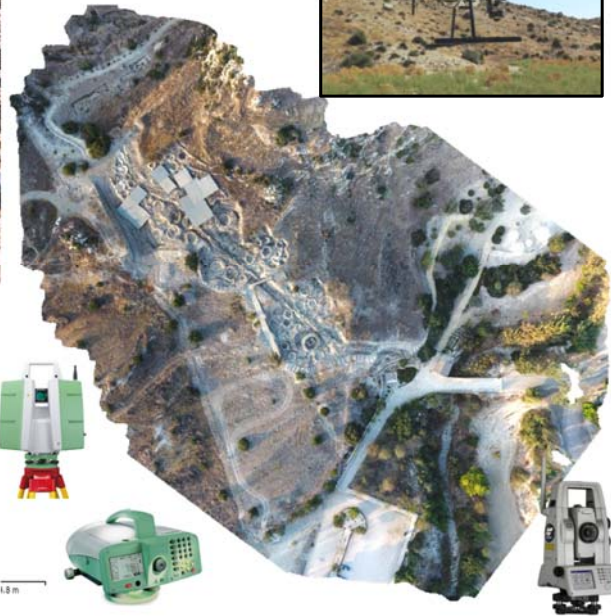
- 3D modeling (TLS, UAV)  
- Geotechnical modeling







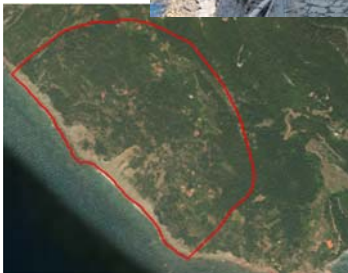
- 3D modeling (TLS, UAV)  
- Geotechnical modeling



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Rockfall  
areas



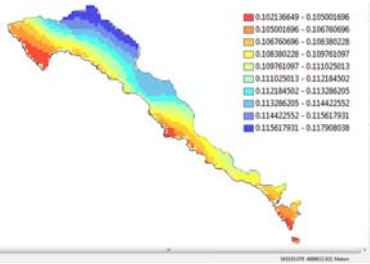
Punta  
Persico  
DSGSD



*A panoramic view of Cinque Terre*

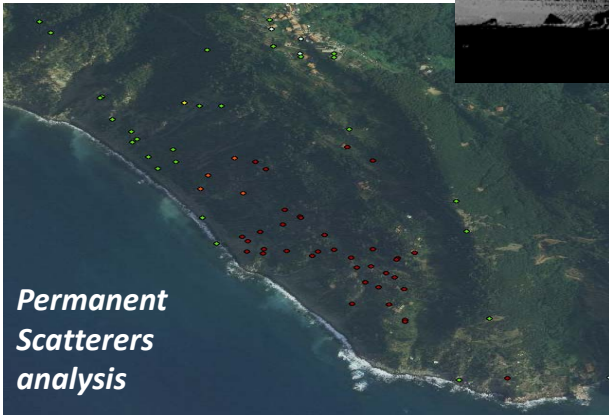
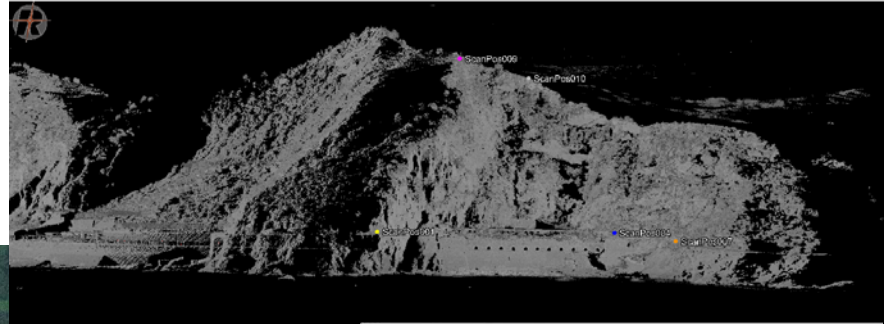
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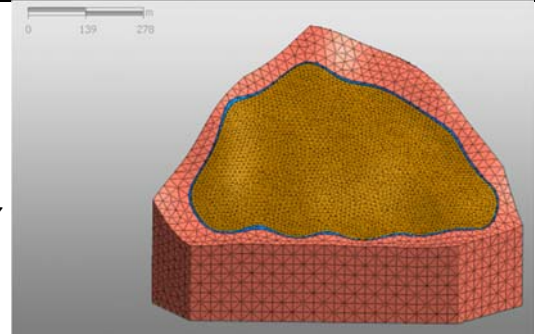
Risk assessment (PGA)

LiDaR interferometry: 2017



Permanent  
Scatterers  
analysis

3D mesh  
with GTS NX



The Tramuntana Range (Mallorca, Spain)



Roman cistern



Arabian dry stone walls

Cultural heritage at risk

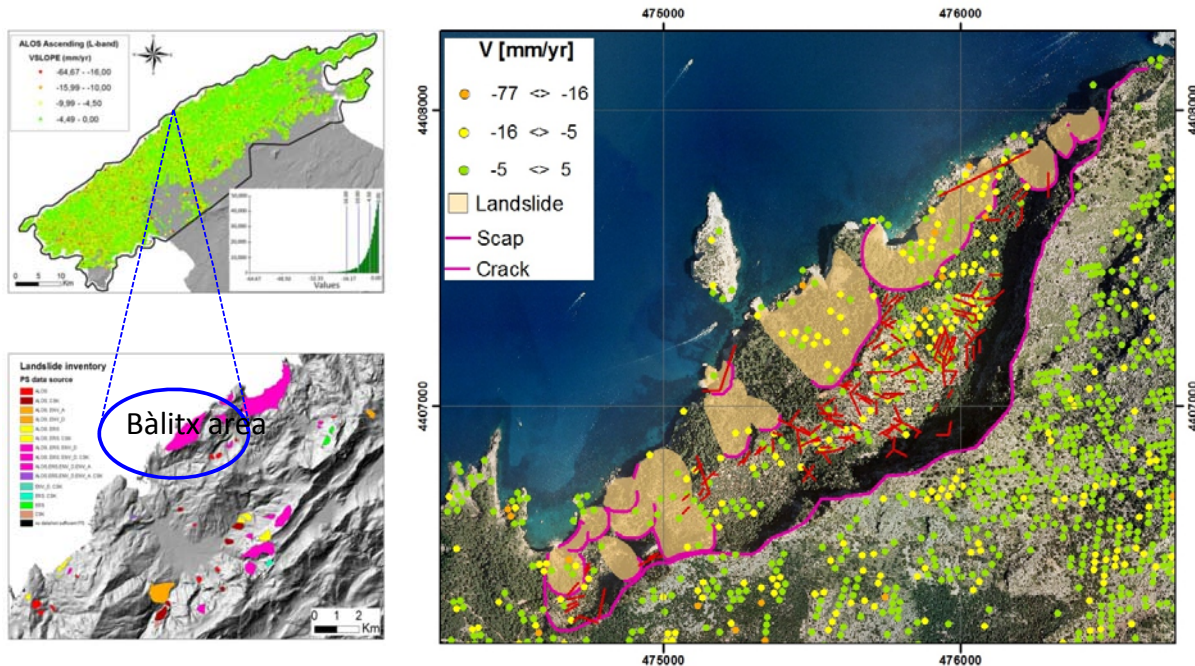
Landslides  
(lateral spreading)



Cultural Landscape of the Serra de Tramuntana Was declared in 2011 a World Heritage Site by UNESCO.

"... paths, terraces, walls and traditional constructions in dry stone, a mark left by humans integrated with nature harmoniously..."

## SAR Interferometry analysis: ALOS, L-band (2007-2010)



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PROTHEGO  
Protection of European Cultural Heritage from Geo - Hazards

- ✓ Updated general overview of UNESCO European CH affected by geo-hazard from static to dynamic hazard assessment with the Satellite monitoring;
- ✓ Ranking the WHL site in order to prioritize the resources, conservation, management and policies actions
- ✓ Downscaling the approach and methodologies with PS ground motion data;
- ✓ Identify, assess and monitor risks, strengthening disaster preparedness at heritage properties;
- ✓ Enhancement of cultural heritage risk awareness and risk management
- ✓ Strengthen institutional support and governance through knowledge and innovation;

We are planning a final project event to invite WHS managers and stakeholders at the UNESCO headquarters in Paris (end of March 2018) in order to share and disseminate the final results and database



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PROTHEGO  
Protection of European Cultural Heritage from Geo - Hazards



# Thank you



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