

**Joint Programming Initiative on Cultural Heritage and Global Change**  
HERITAGE PLUS Call



# PROTHEGO

Protection of European Cultural Heritage from Geo - Hazards

*JPI-CH Heritage Plus collaborative research project [2015-2018]*

**Document Reference**

WP2: Harmonisation of PS data, and creation of digital factsheets

Deliverable: D.02.01

## **Available satellite InSAR data for the European WHL sites**

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Author(s):	CIGNA, F., TAPETE, D. [NERC-BGS]	15/03/2017
Reviewed by:	SPIZZICHINO, D., LEONI, L. [ISPRA], FRATTINI, P. [UNIMIB]	24/03/2017
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## Revision history

Revision	Date	Author(s)	Description
-	-	-	-

## Executive summary

PROTHEGO (*PRO*Tection of European Cultural *HER*itage from *GeO*-hazards) is a collaborative research project funded in 2015–2018 in the framework of the Joint Programming Initiative on Cultural Heritage and Global Change (JPI-CH) – Heritage Plus. The project aims to make an innovative contribution towards the analysis of geohazards in areas of cultural heritage, and uses novel space technology based on Interferometric Synthetic Aperture Radar (InSAR) to retrieve information on ground stability and motion in the UNESCO World Heritage List (WHL) monuments and sites of Europe.

This report introduces PROTHEGO's Work Package (WP) 2: *Harmonisation of available PS data, and creation of digital factsheets*, led by the Natural Environment Research Council (NERC) – British Geological Survey (BGS) and aimed to define, catalogue and assess the availability of satellite-derived ground motion information from multi-temporal InSAR and Persistent Scatterers (PS) techniques for the UNESCO WHL sites of Europe. WP2 consists of two main tasks: 2.1 – *Analysis of satellite InSAR and PS datasets available at European scale*; and 2.2 – *Harmonisation of InSAR and PS ground motion information and creation of digital factsheets*. Their goal is to generate a GIS catalogue of the available satellite InSAR data for the UNESCO WHL sites of Europe, and digital factsheets summarising the observed ground motion velocities and deformation histories of the PS reflectors within each WHL site, alongside two technical reports.

This is the first report describing the methodology adopted for, and results obtained from, the analysis of the availability of ground motion information for the WHL sites of Europe (i.e. Task 2.1). This information is based on InSAR processing of satellite radar imagery that was carried out in the framework of ongoing or recent European, national and/or research projects (such as ESA-GMES TerraFirma, and the Italian Extraordinary Plan of Environmental Remote Sensing EPRS-E), as well as those available through published literature (e.g., scientific papers, project reports). Information on data availability for the WHL sites was recorded in an *ad hoc* catalogue, together with metadata on the retrieved ground stability and motion datasets (e.g., data source, satellite and sensor, monitoring period, acquisition mode).

The analysis allowed the delineation of a general overview of the coverage of InSAR datasets for the UNESCO sites at European scale, as well as the identification of data coverage gaps. The results reveal that, as of the end of 2016, 147 sites (i.e. 37% of the analysed 399 sites of PROTHEGO) are covered by existing datasets and/or published literature, whereas there is a data coverage gap for 252 sites (i.e. 63%). Therefore InSAR information can or may be accessible to study geohazards in more than one-third of the total European UNESCO sites. It is to be noted, however, that in addition to the datasets and literature found so far, many other unpublished studies may exist, as well as other digital datasets that could be made available to PROTHEGO via other projects, suggesting that even more sites than the 37% figure provided in this report may be already covered.

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## 1 Introduction

### 1.1 The project

Funded in the framework of the Joint Programming Initiative on Cultural Heritage and Global Change (JPICH, [www.jpich-culturalheritage.eu/](http://www.jpich-culturalheritage.eu/)) – Heritage Plus, the project PROTHEGO – *PRO*Tectio*n of European Cultural HE*ritage from *GeO*-hazards [2015–2018] aims to make an innovative contribution towards the analysis of geohazards in areas of cultural heritage in Europe.

A comprehensive picture of sites threatened by geohazards is not available as yet. Only some of the endangered sites are inscribed on UNESCO’s World Heritage in Danger list, whilst it is known that many could be affected by geological processes and ground instability.

PROTHEGO makes an effort to fill this gap by applying novel space technology based on Interferometric Synthetic Aperture Radar (InSAR) to retrieve information on ground motion and map geohazards in the UNESCO World Heritage List (WHL) monuments and sites of Europe.

Geological interpretation, advanced modelling and field surveying will be carried out for the most endangered sites to determine the causes and the extent of the observed motions and to provide an enhanced understanding of any geological processes affecting the heritage properties. At least one demonstration site in each Project Partner’s country (i.e. Italy, United Kingdom, Cyprus and Spain) will be used to demonstrate the methodological approach at the local scale.

PROTHEGO is coordinated by the Italian Institute for Environmental Protection and Research (ISPRA), and carried out with the British Geological Survey (BGS) part of the Natural Environment Research Council (NERC), Cyprus University of Technology (CUT), University of Milano-Bicocca (UNIMIB) and the Geological and Mining Institute of Spain (IGME). PROTHEGO’s five Principal Investigators and contact points from these organisations are: Dr C. Margottini for ISPRA (also acting as PROTHEGO Project Coordinator), Dr F. Cigna for NERC-BGS, Dr K. Themistocleous for CUT, Prof G.B. Crosta for UNIMIB, and Dr J.A. Fernández Merodo for IGME.

Within the Heritage Plus funding model, these five Project Partners receive co-funding from the respective National Organisation participating in the JPI-CH: the Ministry for Cultural Heritage Activities and Tourism (MIBACT) and Ministry of Education, Universities and Research (MIUR) in Italy, the Arts & Humanities Research Council (AHRC) in the UK, the Research Promotion Foundation (RPF) in Cyprus, and the Ministry of Economy and Competitiveness (MINECO) in Spain.

## 1.2 WP2: Harmonisation of PS data, and creation of digital factsheets

This report introduces PROTHEGO's Work Package (WP) 2: *Harmonisation of available PS data, and creation of digital factsheets*, led by NERC-BGS and aimed to define, catalogue and assess the availability of satellite-derived ground motion information from multi-temporal InSAR and Persistent Scatterers (PS) techniques for the UNESCO WHL sites of geographical Europe.

WP2 is a research and technological development (RTD) activity, planned to run from PROTHEGO's month M7 (i.e. 1<sup>st</sup> March 2016) and until M15 (i.e. 30<sup>th</sup> November 2016). An extension until M20 was agreed at the end of the 2<sup>nd</sup> year of the project (i.e. 30<sup>th</sup> April 2017) (Figure 1).

Table 1 defines the timeline for the planned activities and two main tasks in WP2:

- 2.1 – Analysis of satellite InSAR and PS datasets available at European scale (see section 2)
- 2.2 – Harmonisation of InSAR and PS ground motion information and creation of digital factsheets (see section 3)

These tasks will generate a GIS catalogue of the available satellite InSAR data for the UNESCO WHL sites of Europe (see section 2.2.1), and digital factsheets summarising the observed ground motion velocities and deformation histories of the PS reflectors within each WHL site (see section 3), alongside two paper deliverables (Table 2), the first of which consists of this report (D.02.01).

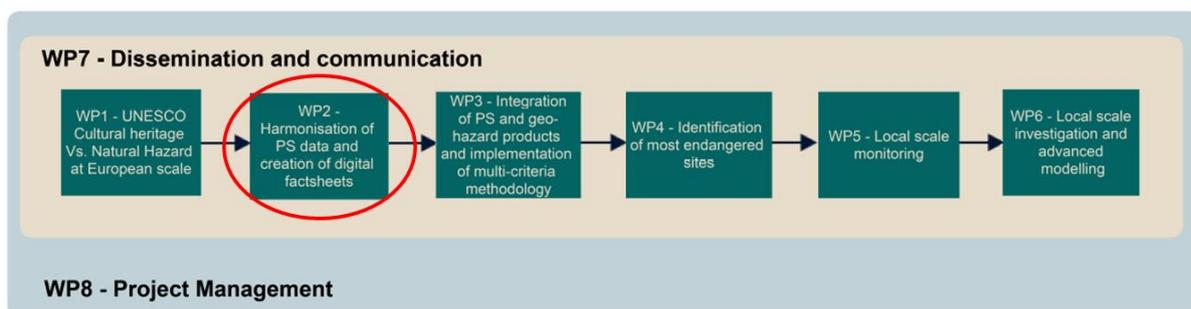


Figure 1: Location of PROTHEGO's WP2 (red circle) in the project flow chart, outlining its relationship with the other technical (WP1, 3-6) and managerial (WP7-8) work packages (after Margottini et al. 2014).

This report describes the methodology adopted for and results obtained from the analysis of availability of ground motion information for the WHL sites of Europe, based on InSAR processing of satellite radar imagery that was carried out in the framework of ongoing or recent European, national and/or research projects, as well as information available through published literature. Information on InSAR data availability was recorded in an *ad hoc* GIS catalogue (see section 2.2.1),

together with metadata on the retrieved ground stability and motion datasets (e.g., source, satellite and sensor, monitoring period, acquisition mode), and allowed the delineation of a general overview of the coverage of InSAR datasets for the UNESCO sites at European scale (see section 2.2.2). WHL sites not covered by any InSAR or PS products were also identified (see section 2.2.2), outlining the spatial distribution of data gaps for future exploitation of InSAR methods over sites not yet monitored.

An analysis and harmonisation of ground motion information for the WHL sites will be carried out during task 2.2 (see section 3), when statistics on the observed annual, minimum and maximum deformation will be extracted based on the datasets identified through task 2.1.

Table 1: Updated PROTHEGO’s WP2 GANTT, accounting for the extension agreed at the end of the 2<sup>nd</sup> year of the project (modified from Margottini et al. 2014). Green = WP Leadership; Orange = Tasks.

Activity [Leader]	Title	Months (M)																													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
WP2 [NERC]	Harmonisation of available PS data, and creation of digital factsheets																														
Task 2.1 [NERC]	Analysis of satellite InSAR and PS datasets available at European scale																														
Task 2.2 [NERC]	Harmonisation of InSAR and PS ground motion information and creation of digital factsheets																														

Table 2: PROTHEGO’s WP2 deliverables, accounting for the extension agreed at the end of the 2<sup>nd</sup> year of the project. R = report; PU = public (modified from Margottini et al. 2014).

Del. No.	Deliverable name	Nature	Dissemination level	Delivery date
D.02.01	Available satellite InSAR data for the European WHL sites (Report & GIS catalogue)	R	PU	M17
D.02.02	Digital Factsheets with ground stability information for each WHL site	R	PU	M20

## 2 Analysis of available satellite InSAR data

This section describes the data sources that were explored to retrieve an overview of the availability of PS ground motion datasets and information for the UNESCO WHL sites of Europe (see section 2.1), and provides a summary of the results obtained by geographical area (2.2.2). A description of the generated GIS catalogue of available data is also provided in section 2.2.1, and the identified data gaps are discussed in section 2.2.2.

The radar data stacks mentioned in the following sections are from a number of past and/or current satellite missions carrying onboard SAR sensors capturing images of the Earth’s surface in the radar domain; generally, in C-band: 4-8 GHz, X-band: 8-12.5 GHz, or L-band: 1-2 GHz (Figure 2).

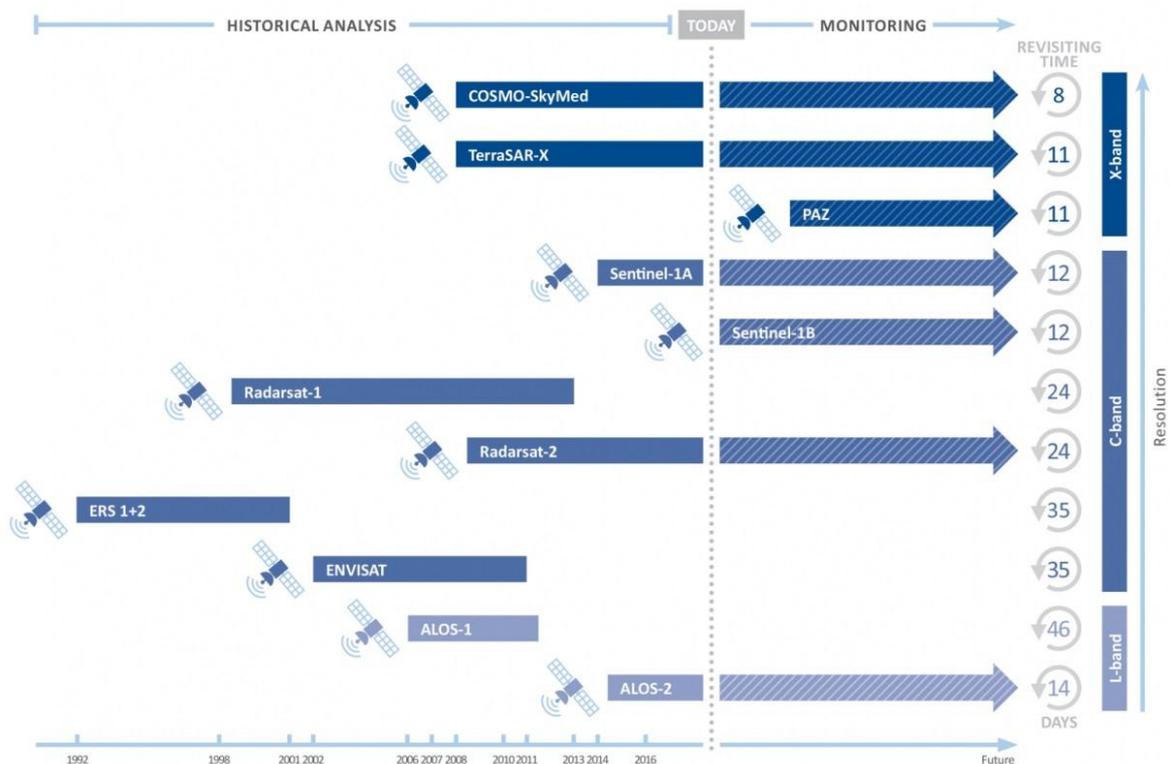


Figure 2: Overview of satellite SAR missions in C-, X- and L-band, their operational lifetime and typical revisiting times (©TRE ALTAMIRA 2016; <http://tre-altamira.com/technology/>)

Today a range of multi-temporal processing approaches exist and are available to the community to process stacks of SAR images and retrieve information about ground stability and any motion occurring in the monitored areas during the investigated period, with centimetre up to millimetre

precision. A non-exhaustive list of these processing approaches is provided as follows: PSInSAR™ or Permanent Scatterers InSAR (Ferretti *et al.* 2001), SqueeSAR™ (Ferretti *et al.* 2011), CPT or Coherent Pixels Technique (Blanco *et al.* 2006), PSP-DIFSAR or Persistent Scatterers Pairs - Differential InSAR (Costantini *et al.* 2014), IPTA or Interferometric Point Target Analysis (Werner *et al.* 2003), SBAS or Small Baseline Subset at low (Berardino *et al.* 2002) and full resolution (Lanari *et al.* 2004), ISBAS or Intermittent SBAS (Sowter *et al.* 2013), CPT-TSC or Coherent Pixel Technique – Temporal Sublook Coherence (Iglesias *et al.* 2015), SPN or Stable Point Network (Duro *et al.* 2005), DePSI or Delft Persistent Scatterer Interferometry (Sousa *et al.* 2010).

Papers on how these data and processing methods can be used to analyse stability and instability due to geological hazards in areas of cultural heritage include: Cigna *et al.* 2012, 2014; Tapete & Cigna 2012; Tapete *et al.* 2012.

## 2.1 Data sources

The input data considered for this analysis consist of already processed, point-wise datasets of ground stability and motion information based on stacks of satellite radar imagery processed outside PROTHEGO and, in particular:

- PS datasets from the ESA-GMES TerraFirma project (see section 2.1.1);
- PS datasets from the Italian EPRS-E (see section 2.1.2);
- PS datasets made available via other international/national projects (see section 2.1.3);
- Literature review (see section 2.1.4).

Data availability was checked for the list of 399 UNESCO WHL sites identified by ISPRA during WP1: *UNESCO Cultural heritage Vs Natural hazards at European scale* (Spizzichino *et al.* 2016), and against the site centroid location made available by UNESCO through their website, as well as site boundaries (i.e. Core Areas and, when available, Buffer Zones) as provided by ISPRA on 04/05/2016 and in revised form on 17/11/2016 and 30/12/2016. To assess whether a UNESCO WHL site was covered, the footprints of the processed InSAR datasets were intersected with the location and detailed boundaries of the site. No threshold on the minimum number of radar targets or minimum density of targets per unit area was applied.

It is worth noting that the data listed above only include InSAR datasets that are already processed. The potential to cover a much wider portion of UNESCO WHL sites exists via the processing of other SAR data available from the archives of the various space agencies, such as ERS, ENVISAT and

Sentinel-1 C-band data from ESA or RADARSAT-1/2 data from the Canadian Space Agency (CSA), X-band COSMO-SkyMed data from the Italian Space Agency (ASI) or TerraSAR-X data from the German Aerospace Center (DLR), or L-band ALOS-1/2 data from the Japanese Space Agency (JAXA) (Figure 2). The analysis of available raw satellite data from the archives is, however, beyond the scope of this task.

### 2.1.1 ESA Terrafirma project

PROTHEGO's first source of InSAR ground motion datasets is the over 10year-long project Terrafirma (<http://www.terrafirma.eu.com/>). Within the Global Monitoring for Environment and Security (GMES) Service Element programme of the European Space Agency (ESA), the Terrafirma project delivered a number of satellite Earth Observation (EO) based Geohazard Land Motion Services. The project aim was to use the latest technology to measure terrain motion from satellite radar data to provide essential support in the process of risk assessment and mitigation to a wide range of entities including civil protection agencies, disaster management organisations and costal, rail and motorway authorities. Whilst stage 1 (2003-2006) concentrated on the consolidation of a standardised and qualified terrain motion service, stage 2 (2006-2009) focused on scaling up the service by delivering InSAR and PS data to each of the 27 EU member states and running a highly successful service validation. Stage 3 (2009-2013) concentrated on four thematic lines for terrain motion analysis: Tectonics, Coastal Lowland Subsidence and Flood Defence, Hydrogeology (including groundwater issues, landslides and inactive mines) and Wide Area Mapping (Figure 3).

Through its final stage 4 in 2014-2015, that was partly devoted to securing long-term on-line availability of PS products via the OneGeology-Europe Portal, the project Terrafirma made available more than 100 PS ground motion products depicting average motion velocities and time histories for the last two decades for a number of towns, cities and river basins, as well as entire provinces or regions across several European countries.

Access to the Terrafirma products was granted free-of-charge to PROTHEGO on 20/10/2016, under the *Terrafirma User Licence (141219\_TF 1GE\_Terms Conditions\_v3)* signed by NERC. The data are for non-commercial use only in PROTHEGO, and under the understanding that products derived from Terrafirma datasets will include acknowledgement of the project, copyright and source of the satellite SAR data (e.g. *ESA data copyright 1992-2000*), as well as of the PS supplier who performed the image processing. This information was included in the respective fields of the GIS catalogue generated by PROTHEGO for this task (see section 2.2.1).

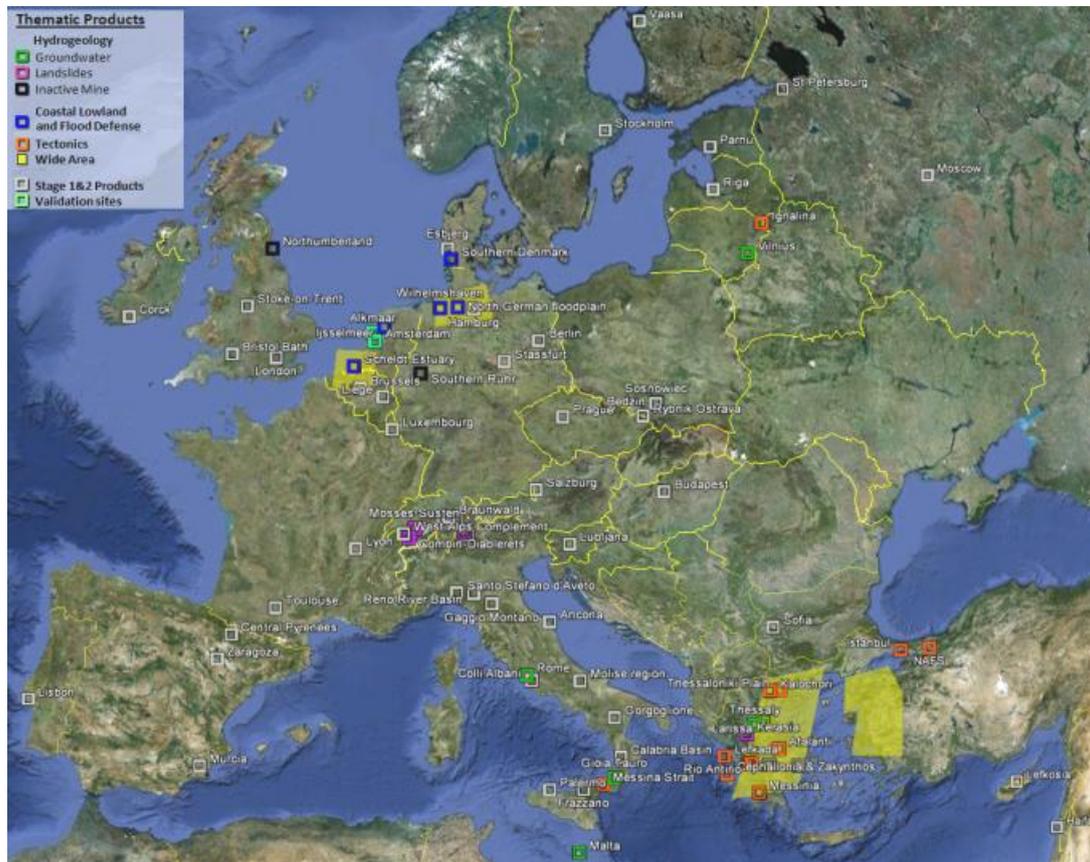


Figure 3: Coverage of TerraFirma PS data (source: [http://www.terrafirma.eu.com/service\\_coverage.htm](http://www.terrafirma.eu.com/service_coverage.htm)).

Data made available by the TerraFirma project include a total of 108 digital datasets of point-wise PS ground motion information (point id, coordinates, coherence, height, annual velocity, and their standard deviations, plus full time histories) and associated processing reports, covering 61 areas of interest. For many of these areas more than one PS dataset is available, e.g. from the same satellite mission but two different acquisition geometries (ascending and descending) and/or different missions and monitoring intervals (e.g. ERS data for 1992-2000 and ENVISAT for 2002-2008).

The total number of UNESCO sites covered by the TerraFirma datasets made available to PROTHEGO is 37 out of the 399 sites analysed in PROTHEGO (i.e. 9%). These sites are mainly located in Belgium (6 sites), Germany (6 sites), Italy (5 sites), France (4 sites) and Malta (3 sites). Typically, the datasets include an ERS dataset covering the 1990s and a more recent ENVISAT dataset covering the 2000s. When ERS-ENVISAT datasets are combined they cover a longer monitoring period. Image processing techniques are varied, and span from the PSInSAR™ implemented by TRE Srl, the SPN by Altamira Information, IPTA used by Fugro NPA, DePSI used by Hansje Brinker, to PSI by the German Aerospace Center.

It is worth noting that other PS datasets were produced by the Terrafirma project, e.g. in the Netherlands over Alkmaar and Amsterdam; in Switzerland in Bernina, Braundwald, Combin Diablerets, Fuorn-Bernardino, Graubuenden Canton, Lumnez, Mosses-Susten and Kloster-Conters; in Spain over Zaragoza and Central Pyrenees; in the UK over London and Northumberland-Durham; as well as over vast portions of Greece, Northern Germany, Turkey, and the Scheldt estuary. These datasets are not openly available in digital format, hence the respective references to the project reports and publications were collected through the literature review and were used to assess whether these datasets might cover European UNESCO sites (see section 2.1.4).

### 2.1.2 Extraordinary Plan of Environmental Remote Sensing (EPRS-E)

In addition to the Terrafirma datasets, the second main source of PS and InSAR data that was made available to PROTHEGO is the nationwide InSAR database of Italy, i.e. *Piano Straordinario di Telerilevamento Ambientale* (PST-A), or Extraordinary Plan for Environmental Remote Sensing (EPRS-E), funded by the Italian Ministry for the Environment, Land and Sea (MATTM).

The EPRS-E consists of 3 main satellite databases of ground motion data generated based on the processing of ERS-1/2, ENVISAT and COSMO-SkyMed imagery, respectively (Figure 4). Image processing of the ERS-1/2 1992-2000 data was undertaken by TRE Srl using the PSInSAR™ technique (Ferretti *et al.* 2001), while ENVISAT data for 2002-2010 were processed by eGEOS with the PSP-DIFSAR approach (Costantini *et al.* 2009). COSMO-SkyMed satellite imagery for the 2011-2014 period also allowed the integration of the ERS-1/2 and ENVISAT databases with more recent information at higher spatial and temporal resolution through COSMO-SkyMed data processed with the PSP-DIFSAR algorithm (Costantini *et al.* 2014, 2016). Figure 5 shows an overview of the six datasets composing the nationwide ground motion database obtained.

Data from the EPRS-E were made available to PROTHEGO's Coordinator at ISPRA by MATTM on 13/07/2016 and include several data frames covering the WHL sites of Italy, plus Holy See and San Marino, as well as a site in Switzerland located nearby the border with Italy.

In particular, the following 354 datasets were made available for the project: 98 descending and 66 ascending mode ERS datasets; 66 descending and 69 ascending mode ENVISAT datasets; and 28 ascending and 27 descending mode COSMO-SkyMed datasets. Each of these datasets consists of a PS ground motion database (including point id, coordinates, coherence, height, annual velocity, and their standard deviations, plus full time histories) and associated metadata.

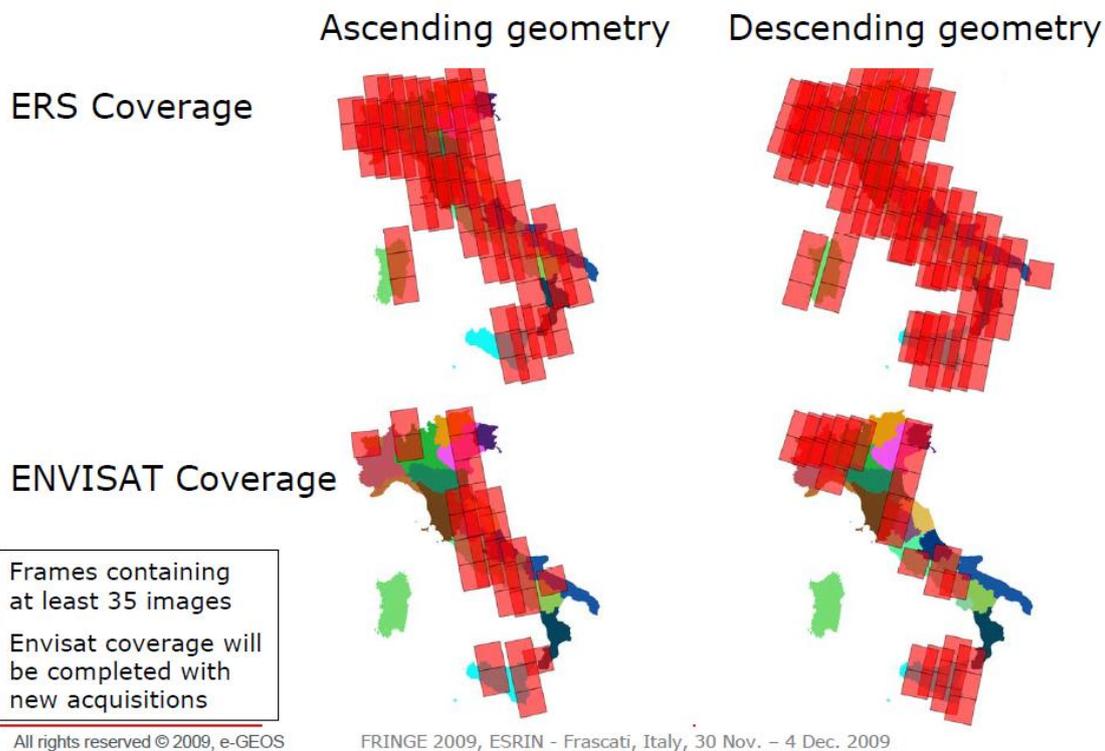


Figure 4: Coverage of ERS and ENVISAT PS ground motion data from the EPRS-E (Costantini et al. 2009).

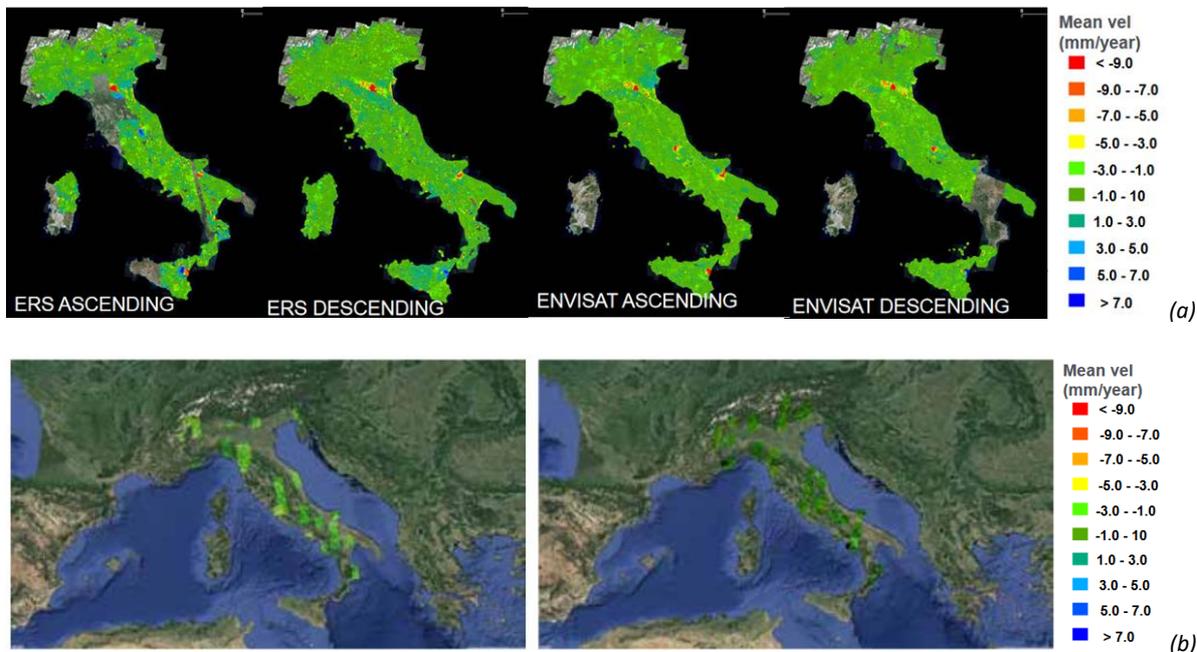


Figure 5: (a) ERS ascending and descending PS data in the period 1992-2000, and ENVISAT ascending and descending PS data in the period 2003-2010 available from the EPRS-E; and (b) coverage of COSMO-SkyMed PS data acquired in 2011-2014 as of mid-2016 (Costantini et al. 2016).

It is worth noting that ENVISAT PS data are generally characterised by a coverage sparser than ERS PS data, due to the lack – for some portions of Italy – of archives of input imagery sufficiently populated (i.e.  $\geq 35$  scenes) to be processed with multi-interferometric techniques.

As a result, a total of 54 sites out of the 399 sites analysed in PROTHEGO (i.e. 14%) are covered by PS data from at least one of the 3 databases of the EPRS-E. In particular, the full set of 51 UNESCO WHL sites of Italy is covered by at least one PS dataset, thus resulting in a complete coverage of the Italian territory with information on ground stability and motion. Moreover, 3 more sites outside Italy are also covered, i.e. 1 in the Holy See (i.e. *Vatican City*), 1 in San Marino (i.e. *San Marino Historic Centre and Mount Titano*), and 1 in Switzerland (i.e. *Benedictine Convent of St John at Müstair*).

With regard to the different datasets, in particular, the analysis reveals that:

- the **ERS datasets** in descending mode cover a total of 54 sites: the full set of 51 WHL sites in Italy [including the 2 transnational sites of: (i) *Prehistoric Pile dwellings around the Alps*, and (ii) *Historic Centre of Rome, the Properties of the Holy See in that City Enjoying Extraterritorial Rights and San Paolo Fuori le Mura*], plus 1 in the Holy See, 1 in San Marino, and 1 in Switzerland; on the other hand, the ERS datasets in ascending mode cover a total of 41 sites: 39 WHL sites in Italy, plus 1 in Holy See and 1 in San Marino;
- the **ENVISAT datasets** in descending mode cover a total of 51 sites: 48 WHL sites in Italy, plus 1 in Holy See, 1 in San Marino, and 1 in Switzerland; on the other hand, the ENVISAT datasets in ascending mode cover a total of 52 sites: 50 WHL sites in Italy, plus 1 in Holy See and 1 in San Marino;
- the **COSMO-SkyMed datasets** in descending mode cover a total of 20 sites: 19 WHL sites in Italy, plus 1 in Holy See; on the other hand, the COSMO-SkyMed datasets in ascending mode cover a total of 23 sites: 22 WHL sites in Italy, plus 1 in Holy See.

Overall, 13 out of the 51 WHL sites in Italy are covered by all the three sets of ERS, ENVISAT and COSMO-SkyMed PS data in both modes (ascending and descending), meaning that information about ground stability for these sites are available for the entire monitoring period 1992-2014 in both imaging geometries. The same applies to the WHL site of Vatican City in the Holy See.

### 2.1.3 Other projects

To assess the availability of PS data at European scale, we can also account for additional data sources from past and current research projects and platforms developed or accessible by PROTHEGO's PIs, such as: NERC-BGS' projects, with a focus on a number of UK urban and rural areas of interest; IGME's projects, with a focus on case studies in the Pyrenees and urban areas of Spain; CUT's projects such as ATHENA H2020 and JPI-CH CLIMA for the Cypriot UNESCO WHL sites.

When made available in digital format to the PIs of PROTHEGO and provided that agreements are put in place to grant their use in PROTHEGO, the respective databases and derived products will also be considered for the analysis of ground stability and motion within the WHL sites during Task 2.2 (see section 3).

### 2.1.4 Literature review

To retrieve an overview of the existing published literature on satellite PS and InSAR data covering the UNESCO WHL sites of Europe, Elsevier's Scopus, the largest abstract and citation database of peer-reviewed literature, including: scientific journals, books and conference proceedings, was exploited. Additional references and information available from the so-called 'grey literature', i.e. reports/deliverables from past or current projects (e.g., open access reports available online, or known to the authors of the present deliverable), were also included in the list of available literature.

Two types of literature were considered: (i) papers/reports specifically focussed on the application of satellite InSAR or PS data and techniques to monitor ground stability and motion in UNESCO WHL sites of Europe; and (ii) any other paper/report using these techniques to examine areas of interest that, although not on purpose, encompass one or more European UNESCO WHL sites.

In terms of temporal reference, the results of the literature review refer to 31/12/2016, meaning that any relevant reference published as of the end of 2016 was included in the analysis.

The results of the review reveal a patchy distribution of papers and reports across Europe, with a clear peak in the number of papers covering one or more WHL sites occurring in the Netherlands, Italy, Greece and Germany. Overall, 114 out of the 399 sites analysed in PROTHEGO are covered by published literature (i.e. 29%).

Although some more references and studies that this literature review has not captured through this analysis might exist, the output overview obtained is believed to represent very well the current availability of InSAR and geohazards literature for the UNESCO WHL sites of Europe.

As discussed in section 2.1.1, some of the processed datasets from the ESA-GMES TerraFirma project are not freely available because they are either part of the validation exercise of TerraFirma or protected by commercial copyright. For these sites, during the literature review as many as possible reports and published papers using those data were collected to make sure that the coverage analysis was as complete as possible to account for those datasets. Examples are the PS data for the sites of London and Northumberland-Durham in the UK, for which the published papers were listed in the catalogue, despite unavailability of the digital data for open distribution. The literature review therefore complements the quantitative and spatial assessment that was undertaken based on accessible digital InSAR data.

Similarly, reports from European projects such as the EU-FP7 PanGeo and SubCoast were accounted for and collected during the literature review.

## 2.2 Results overview

This section explains the structure that was adopted for the creation of the GIS-based catalogue of available satellite datasets (see section 2.2.1), and presents the output statistics and coverage of WHL sites of Europe that was achieved through this analysis (see section 2.2.2). WHL sites that are not covered by any PS database were also identified (see section 2.2.2), to highlight the distribution of data gaps for future exploitation of InSAR methods over not yet monitored sites.

### 2.2.1 Digital catalogue

A GIS-based catalogue of the available PS ground motion datasets was generated for each WHL site including the key metadata of the dataset(s): e.g., satellite, orbital mode, monitoring period, processing algorithm, accessibility and other resources. Table 3 shows the structure of the catalogue with an artificial example of the syntax used.

Table 3: Structure of the catalogue of available PS ground motion datasets, and example of the syntax used.

ID	Country	Name	Terrafirma	EPRS-E	Literature
268	Holy See	Vatican City	ERS desc PSInSAR 1992-2000 processed by TRE; ENV desc PSInSAR 2003-2005 processed by TRE	ERS desc; ERS asc; ENV desc; ENV asc; CSK desc; CSK asc	Cigna et al. 2014; Costantini et al. 2014
<i>Etc.</i>	<i>Etc.</i>	<i>Etc.</i>	<i>Etc.</i>	<i>Etc.</i>	<i>Etc.</i>

For each WHL site, the fields used are:

- *ID, Country, Name*: UNESCO unique identification number, name and country of origin
- *Terrafirma*: available PS datasets from the ESA-GMES Terrafirma project (see section 2.1.1)
- *EPRS-E*: available PS datasets from the Italian EPRS-E (see section 2.1.2)
- *Literature*: published papers/reports identified from the literature review (see section 2.1.4)

The following list explains the acronyms used for the satellite data:

- *ERS*: ERS-1/2 SAR in C band
- *ENV*: ENVISAT Advanced SAR (ASAR) in C band
- *CSK*: COSMO-SkyMed in StripMap HIMAGE mode, in X band
- *TSX*: TerraSAR-X SAR in StripMap mode, in X band

The following abbreviations were used for the six *EPRS-E* datasets:

- *ERS desc*: ERS-1/2 descending mode PSInSAR 1992-2000 processed by TRE
- *ERS asc*: ERS-1/2 ascending mode PSInSAR 1992-2000 processed by TRE
- *ENV desc*: ENVISAT descending mode PSP-DIFSAR 2002-2010 processed by eGEOS
- *ENV asc*: ENVISAT ascending mode PSP-DIFSAR 2002-2010 processed by eGEOS
- *CSK desc*: COSMO-SkyMed descending mode PSP-DIFSAR 2011-2014 processed by eGEOS
- *CSK asc*: COSMO-SkyMed ascending mode PSP-DIFSAR 2011-2014 processed by eGEOS

The following list explains the acronyms used in the *Terrafirma* field to indicate the different providers of the InSAR or PS datasets:

- *FNPA*: Fugro NPA, now CGG NPA Satellite Mapping (<http://npa.cgg.com/>)
- *TRE*: TeleRilevamento Europa Srl, now TRE-ALTAMIRA (<http://tre-altamira.com/>)
- *ALM*: Altamira Information, now TRE-ALTAMIRA (<http://tre-altamira.com/>)

- *HB*: Hansje Brinker BV, now SkyGeo (<https://skygeo.com/>)
- *DLR*: German Aerospace Center (<http://www.dlr.de>)
- *GAMMA*: GAMMA Remote Sensing and Consulting (<https://www.gamma-rs.ch/>)
- *eGEOS*: eGEOS, an Italian Space Agency (ASI) – Telespazio company (<http://www.e-geos.it/>)

When no sources of information were identified, this was indicated in the fields *Terrafirma*, *EPRS-E* and *Literature* by using “N/A”, i.e. Not Available.

A list of the full references of the papers and reports cited in the *Literature* field, is also provided as an appendix to the catalogue.

### 2.2.2 Coverage overview and data gaps

In sections 2.1.1, 2.1.2 and 2.1.4 a summary of the UNESCO WHL sites covered by each data source was provided. To recap the findings, the analysis revealed that:

- 37 sites can be covered by ESA-GMES Terrafirma digital datasets, i.e. 9%
- 54 sites are covered by the Italian EPRS-E, i.e. 14%
- 114 sites are covered by published literature, i.e. 29%

Accounting for the fact that for some WHL sites two or even three of the above sources of data are available, the overall total of WHL sites covered amounts to 147 out of the 399 sites that are analysed in PROTHEGO (i.e. 37%; Figure 6). This means that InSAR information can or may be accessible to study geohazards in more than one-third of the total European UNESCO sites.

This percentage is a considerable proportion of the European UNESCO sites, considering the fact that the vast majority of the sites were not formerly covered on purpose. In other words, the UNESCO sites frequently fall within a processed area that was analysed for other purposes, and not specifically to analyse ground motion in the UNESCO site, but this can be a resource.

Nevertheless, in addition to the datasets and literature found so far, many other unpublished studies may exist, as well as other digital datasets (see section 2.1.3) that could be made available to PROTHEGO via other projects, suggesting that even more sites than the 37% figure provided in this report may be already covered.

The systematic analysis carried out via WP2 also allowed the identification of the European UNESCO heritage sites not yet covered by satellite PS ground motion data, thus highlighting the knowledge gaps and suggesting in which countries these techniques can be further promoted and applied (cf.



### 3 Conclusions

This study analysed the availability of PS and InSAR datasets for the 399 UNESCO WHL sites of Europe that are the focus of the project PROTHEGO. This activity was the goal of Task 2.1: *Analysis of satellite InSAR and PS datasets available at European scale*, part of WP2: *Harmonisation of available PS data, and creation of digital factsheets*, led by NERC-BGS and aimed to define, catalogue and assess the availability of satellite-derived ground motion information from multi-temporal InSAR and PS techniques for the UNESCO WHL sites of Europe.

The analysis was based on the assessment of a number of already processed, InSAR datasets of ground stability and motion information derived based on long stacks of satellite radar imagery processed outside PROTHEGO and, in particular: (i) PS datasets from the ESA-GMES Terrafirma project (see section 2.1.1); (ii) PS datasets from the Italian EPRS-E (see section 2.1.2); and (iii) a literature review (see section 2.1.4).

The results of this assessment reveal that, as of the end of 2016, 147 sites (i.e. 37% of the analysed 399 sites of PROTHEGO) are covered by existing datasets and/or published literature, whereas there is a data coverage gap for 252 sites (i.e. 63%).

It is to be noted however that, in addition to the datasets and literature found so far, many other unpublished studies may exist, as well as other digital datasets (see section 2.1.3) that could be made available to PROTHEGO via other projects, suggesting that even more sites than the 37% figure provided in this report may be already covered.

During Task 2.2: *Harmonization of InSAR and PS ground motion information and creation of digital factsheets*, NERC-BGS will design standards and rules for the harmonisation and analysis of the available InSAR and PS datasets, that will be shaped based on the Users' requirements that are being gathered in WP7. In collaboration with ISPRA and IGME, NERC-BGS will then analyse in detail the retrieved and catalogued InSAR and PS datasets in order to extract summary ground motion statistics of the PS reflectors found within the boundaries of and in close proximity to each UNESCO site, and create hands-on digital factsheets showing an overview of observed ground motion scenario for each analysed site. This will form PROTHEGO's forthcoming Deliverable *D02.02: Digital Factsheets with ground stability information for each WHL site*.

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## Appendix A

### Catalogue: PS data availability for the UNESCO WHL sites of Europe

ID	Rev	Country	Name	Terrafirma	EPRS-E	Literature
569	Bis	Albania	Historic Centres of Berat and Gjirokastra	N/A	N/A	N/A
570	ter	Albania	Butrint	N/A	N/A	N/A
1160	Bis	Andorra	Madriu-Perafita-Claror Valley	N/A	N/A	N/A
784		Austria	Historic Centre of the City of Salzburg	ERS desc SPN 1992-2000 processed by ALM; ERS-ENV desc SPN 2001-2007 processed by ALM	N/A	ESA 2009;
785		Austria	Semmering Railway	N/A	N/A	N/A
786		Austria	Palace and Gardens of Schönbrunn	N/A	N/A	N/A
806		Austria	Hallstatt-Dachstein / Salzkammergut Cultural Landscape	N/A	N/A	N/A
931	Bis	Austria	City of Graz - Historic Centre and Schloss Eggenberg	N/A	N/A	N/A
970		Austria	Wachau Cultural Landscape	N/A	N/A	N/A
1033		Austria	Historic Centre of Vienna	N/A	N/A	N/A
1363		Austria, France, Germany, Italy, Slovenia, Switzerland	Prehistoric Pile dwellings around the Alps	ERS desc PSInSAR 1992-2000 processed by TRE; ENV desc PSInSAR 2004-2007 processed by TRE	ERS desc; ERS asc; ENV desc; ENV asc; CSK desc	Auflīč et al. 2015; ESA 2009;
772	Rev	Austria, Hungary	Fertő / Neusiedlersee Cultural Landscape	N/A	N/A	N/A
33	Ter	Belarus, Belarus, Poland, Poland	Bialowieza Forest	N/A	N/A	N/A
855		Belgium	Flemish Béguinages	ERS-ENV desc IPTA 1992-2005 processed by FNPA	N/A	ESA 2009;
856		Belgium	The Four Lifts on the Canal du Centre and their Environs, La Louvière and Le Roeulx (Hainaut)	N/A	N/A	N/A
857		Belgium	La Grand-Place, Brussels	ERS desc PSInSAR 1992-2003 processed by TRE	N/A	Browitt et al. 2007; Declercq et al. 2005; Devleeschouwer et al. 2006; ESA 2005; ESA 2009; Walstra & Declercq 2016;

ID	Rev	Country	Name	TerraFirma	EPRS-E	Literature
996		Belgium	Historic Centre of Brugge	N/A	N/A	N/A
1005		Belgium	Major Town Houses of the Architect Victor Horta (Brussels)	ERS desc PSInSAR 1992-2003 processed by TRE	N/A	Browitt et al. 2007; Declercq et al. 2005; Devleeschouwer et al. 2006; ESA 2005; ESA 2009; Walstra & Declercq 2016;
1006		Belgium	Neolithic Flint Mines at Spiennes (Mons)	N/A	N/A	N/A
1009		Belgium	Notre-Dame Cathedral in Tournai	N/A	N/A	N/A
1185		Belgium	Plantin-Moretus House-Workshops-Museum Complex	N/A	N/A	N/A
1298		Belgium	Stoclet House	ERS desc PSInSAR 1992-2003 processed by TRE	N/A	Browitt et al. 2007; Declercq et al. 2005; Devleeschouwer et al. 2006; ESA 2005; ESA 2009; Walstra & Declercq 2016;
1344	Rev	Belgium	Major Mining Sites of Wallonia	ERS-ENV desc IPTA 1992-2005 processed by FNPA	N/A	ESA 2009;
943	Bis	Belgium,France	Belfries of Belgium and France	ERS-ENV desc IPTA 1992-2005 processed by FNPA	N/A	ESA 2009;
946	Rev	Bosnia and Herzegovina	Old Bridge Area of the Old City of Mostar	N/A	N/A	N/A
1260		Bosnia and Herzegovina	Mehmed Paŭa Sokolovic Bridge in Viŭegrad	N/A	N/A	N/A
42		Bulgaria	Boyana Church	ERS desc PSInSAR 1992-2003 processed by TRE	N/A	ESA 2005; ESA 2009;
43		Bulgaria	Madara Rider	N/A	N/A	N/A
44		Bulgaria	Thracian Tomb of Kazanlak	N/A	N/A	N/A
45		Bulgaria	Rock-Hewn Churches of Ivanovo	N/A	N/A	N/A
216		Bulgaria	Rila Monastery	N/A	N/A	N/A
217		Bulgaria	Ancient City of Nessebar	N/A	N/A	N/A
219	Bis	Bulgaria	Srebarna Nature Reserve	N/A	N/A	N/A
225	Bis	Bulgaria	Pirin National Park	N/A	N/A	N/A
359		Bulgaria	Thracian Tomb of Sveshtari	N/A	N/A	N/A
95	bis	Croatia	Old City of Dubrovnik	N/A	N/A	N/A
97		Croatia	Historical Complex of Split with the Palace of Diocletian	N/A	N/A	N/A
98	Bis	Croatia	Plitvice Lakes National Park	N/A	N/A	N/A
809		Croatia	Episcopal Complex of the Euphrasian Basilica in the Historic Centre of Porec	N/A	N/A	N/A

Ref: WP2: Harmonisation of available PS data, and creation of digital factsheets;

Deliverable: D02.01: Available satellite InSAR data for the European WHL sites

Version: 1.0

Date: 27/04/2017



ID	Rev	Country	Name	Terrafirma	EPRS-E	Literature
810		Croatia	Historic City of Trogir	N/A	N/A	N/A
963		Croatia	The Cathedral of St James in èibenik	N/A	N/A	N/A
1240		Croatia	Stari Grad Plain	N/A	N/A	N/A
79		Cyprus	Paphos	N/A	N/A	Michalis et al. 2014;
848	Bis	Cyprus	Choirokoitia	N/A	N/A	N/A
351	Bis	Cyprus,Cyprus	Painted Churches in the Troodos Region	N/A	N/A	N/A
616	Bis	Czech Republic	Historic Centre of Prague	ERS-ENV desc IPTA 1992-2005 processed by GAMMA	N/A	ESA 2009; Kadlecík et al. 2010; Schenk et al. 2009; Schenk et al. 2006;
617		Czech Republic	Historic Centre of Cesk <sup>2</sup> Krumlov	N/A	N/A	N/A
621		Czech Republic	Historic Centre of Telc	N/A	N/A	N/A
690		Czech Republic	Pilgrimage Church of St John of Nepomuk at Zelená Hora	N/A	N/A	N/A
732		Czech Republic	Kutná Hora: Historical Town Centre with the Church of St Barbara and the Cathedral of Our Lady at Sedlec	N/A	N/A	N/A
763		Czech Republic	Lednice-Valtice Cultural Landscape	N/A	N/A	N/A
859	Rev	Czech Republic	Holy Trinity Column in Olomouc	N/A	N/A	N/A
860		Czech Republic	Gardens and Castle at Kromerýx	N/A	N/A	N/A
861		Czech Republic	Holašovice Historic Village	N/A	N/A	N/A
901		Czech Republic	Litomyšl Castle	N/A	N/A	N/A
1052		Czech Republic	Tugendhat Villa in Brno	N/A	N/A	Lazecky et al. 2016;
1078		Czech Republic	Jewish Quarter and St Procopius' Basilica in Třebíč	N/A	N/A	N/A
695	rev	Denmark	Roskilde Cathedral	N/A	N/A	N/A
696	Rev	Denmark	Kronborg Castle	N/A	N/A	N/A
697		Denmark	Jelling Mounds, Runic Stones and Church	N/A	N/A	N/A
1416		Denmark	Stevns Klint	N/A	N/A	N/A
1468		Denmark	Christiansfeld, a Moravian Church Settlement	N/A	N/A	N/A
1469		Denmark	The par force hunting landscape in North Zealand	N/A	N/A	N/A

ID	Rev	Country	Name	Terrafirma	EPRS-E	Literature
1314	Ter	Denmark,Germany,Netherlands	Wadden Sea	ERS desc IPTA 1992-2000 processed by FNPA; ENV asc DePSI 2002-2010 processed by HB; ENV desc DePSI 2003-2010 processed by HB; ENV desc SPN 2004-2009 processed by ALM; TSX desc DePSI 2010-2011 processed by HB; TSX asc DePSI 2010-2011 processed by HB	N/A	[No author name available] 2015; Adam et al. 2013; Adam et al. 2011; ESA 2009; ESA 2013; Liebhart et al. 2012; Romeiser et al. 2005; Siegmund et al. 2004; Wolf 2012;
822	Bis	Estonia	Historic Centre (Old Town) of Tallinn	N/A	N/A	N/A
579	Rev	Finland	Bronze Age Burial Site of Sammallahtenmõki	N/A	N/A	N/A
582	Bis	Finland	Old Rauma	N/A	N/A	N/A
583		Finland,Finland	Fortress of Suomenlinna	N/A	N/A	N/A
584		Finland,Finland	Petöjovesi Old Church	N/A	N/A	N/A
751		Finland,Finland	Verla Groundwood and Board Mill	N/A	N/A	N/A
898	Bis	Finland,Sweden	High Coast / Kvarken Archipelago	N/A	N/A	N/A
80	Bis	France	Mont-Saint-Michel and its Bay	N/A	N/A	N/A
81	Bis	France	Chartres Cathedral	N/A	N/A	N/A
83	Bis	France	Palace and Park of Versailles	N/A	N/A	N/A
84	Bis	France	Vúzelay, Church and Hill	N/A	N/A	N/A
85		France	Prehistoric Sites and Decorated Caves of the VúzPre Valley	N/A	N/A	N/A
160		France	Palace and Park of Fontainebleau	N/A	N/A	N/A
162	Bis	France	Amiens Cathedral	N/A	N/A	N/A
163	Bis	France	Roman Theatre and its Surroundings and the "Triumphal Arch" of Orange	N/A	N/A	N/A
164		France	Arles, Roman and Romanesque Monuments	N/A	N/A	N/A
165	Bis	France	Cistercian Abbey of Fontenay	N/A	N/A	N/A
203	Bis	France	From the Great Saltworks of Salins-les-Bains to the Royal Saltworks of Arc-et-Senans, the Production of Open-pan Salt	N/A	N/A	N/A
228	rev	France	Historic Centre of Avignon: Papal Palace, Episcopal Ensemble and Avignon Bridge	N/A	N/A	N/A
229		France	Place Stanislas, Place de la CarriPre and Place d'Alliance in Nancy	N/A	N/A	N/A
230		France	Abbey Church of Saint-Savin sur Gartempe	N/A	N/A	N/A

ID	Rev	Country	Name	Terrafirma	EPRS-E	Literature
258		France	Gulf of Porto: Calanche of Piana, Gulf of Girolata, Scandola Reserve	N/A	N/A	N/A
344	Bis	France	Pont du Gard (Roman Aqueduct)	N/A	N/A	N/A
345	rev	France	Historic Fortified City of Carcassonne	N/A	N/A	N/A
495		France	Strasbourg û Grande ́le	N/A	N/A	N/A
600		France	Paris, Banks of the Seine	N/A	N/A	El Raia & Simonetto 2009; Fabriol et al. 2009; Fruneau & Sarti 2000; Kaveh et al. 2010; Le Mouélic et al. 2005; Le Mouélic et al. 2002; Rohmer & Raucoules 2012;
601		France	Cathedral of Notre-Dame, Former Abbey of Saint-RÚmi and Palace of Tau, Reims	N/A	N/A	N/A
635	bis	France	Bourges Cathedral	N/A	N/A	N/A
770		France	Canal du Midi	ENV asc SPN 2002-2007 processed by ALM	N/A	N/A
868		France	Routes of Santiago de Compostela in France	N/A	N/A	N/A
872		France	Historic Site of Lyons	ERS desc IPTA 1992-2000 processed by ALM	N/A	ESA 2005; ESA 2009;
873	Rev	France	Provins, Town of Medieval Fairs	N/A	N/A	N/A
932		France	Jurisdiction of Saint-Emilion	N/A	N/A	N/A
933		France	The Loire Valley between Sully-sur-Loire and Chalonnes	N/A	N/A	N/A
1153	rev	France	The Causses and the CÚvennes, Mediterranean agro-pastoral Cultural Landscape	N/A	N/A	N/A
1181		France	Le Havre, the City Rebuilt by Auguste Perret	N/A	N/A	N/A
1256		France	Bordeaux, Port of the Moon	N/A	N/A	N/A
1283		France	Fortifications of Vauban	N/A	N/A	N/A
1337		France	Episcopal City of Albi	N/A	N/A	N/A
1360		France	Nord-Pas de Calais Mining Basin	N/A	N/A	Guéguen et al. n.d.; Gueguen et al. 2007; Raucoules et al. 2008;
1425		France	The Climats, terroirs of Burgundy	N/A	N/A	N/A
1426		France	Decorated Cave of Pont d'ÆArc, known as Grotte Chauvet-Pont d'ÆArc, ArdPche	N/A	N/A	N/A
1465		France	Champagne Hillsides, Houses and Cellars	N/A	N/A	N/A
773	Bis	France,Spain	PyrÚnÚes - Mont Perdu	N/A	N/A	N/A

ID	Rev	Country	Name	Terrafirma	EPRS-E	Literature
3	bis	Germany	Aachen Cathedral	N/A	N/A	Krasbutter et al. 2013;
168		Germany	Speyer Cathedral	N/A	N/A	Alshawaf et al. 2015; Fuhrmann et al. 2015; Fuhrmann et al. 2016;
169	Bis	Germany	W <sup>3</sup> rzburg Residence with the Court Gardens and Residence Square	N/A	N/A	N/A
187	bis	Germany	St Mary's Cathedral and St Michael's Church at Hildesheim	N/A	N/A	N/A
271	Bis	Germany	Pilgrimage Church of Wies	N/A	N/A	N/A
272	Bis	Germany	Hanseatic City of L <sup>3</sup> beck	N/A	N/A	Adam et al. 2013; Adam et al. 2011; ESA 2013; Liebhart et al. 2012; Wolf 2012;
288		Germany	Castles of Augustusburg and Falkenlust at Br <sup>3</sup> hl	N/A	N/A	N/A
292	Bis	Germany	Cologne Cathedral	N/A	N/A	Krasbutter et al. 2013;
367		Germany	Roman Monuments, Cathedral of St Peter and Church of Our Lady in Trier	N/A	N/A	N/A
515	Bis	Germany	Abbey and Altenm <sup>3</sup> nster of Lorsch	N/A	N/A	Alshawaf et al. 2015; Fuhrmann et al. 2015;
532	Ter	Germany	Palaces and Parks of Potsdam and Berlin	ERS desc SPN 1995-2000 processed by ALM	N/A	N/A
534	Rev	Germany	Garden Kingdom of Dessau-W <sup>3</sup> rlitz	N/A	N/A	N/A
535	rev	Germany	Collegiate Church, Castle and Old Town of Quedlinburg	N/A	N/A	N/A
546	rev	Germany	Maulbronn Monastery Complex	N/A	N/A	Fuhrmann et al. 2015;
623	ter	Germany	Mines of Rammelsberg, Historic Town of Goslar and Upper Harz Water Management System	N/A	N/A	N/A
624		Germany	Town of Bamberg	N/A	N/A	N/A
687		Germany	V <sup>3</sup> lklingen Ironworks	N/A	N/A	Samsonov et al. 2013;
720	Bis	Germany	Messel Pit Fossil Site	N/A	N/A	N/A
729		Germany	Bauhaus and its Sites in Weimar and Dessau	N/A	N/A	N/A
783		Germany	Luther Memorials in Eisleben and Wittenberg	N/A	N/A	N/A
846		Germany	Classical Weimar	N/A	N/A	N/A
896		Germany	Museumsinsel (Museum Island), Berlin	ERS desc SPN 1995-2000 processed by ALM	N/A	[No author name available] 2015; ESA 2005; ESA 2009; Kampes & Adam 2003;
897		Germany	Wartburg Castle	N/A	N/A	N/A

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974		Germany	Monastic Island of Reichenau	N/A	N/A	N/A
975		Germany	Zollverein Coal Mine Industrial Complex in Essen	N/A	N/A	Wegmuller et al. 2000;
1066		Germany	Upper Middle Rhine Valley	N/A	N/A	N/A
1067		Germany	Historic Centres of Stralsund and Wismar	N/A	N/A	N/A
1087		Germany	Town Hall and Roland on the Marketplace of Bremen	N/A	N/A	Adam et al. 2013; Adam et al. 2011; ESA 2013; Liebhart et al. 2012; Wolf 2012;
1155		Germany	Old town of Regensburg with Stadtamhof	N/A	N/A	N/A
1239		Germany	Berlin Modernism Housing Estates	ERS desc SPN 1995-2000 processed by ALM	N/A	[No author name available] 2015; ESA 2005; ESA 2009; Kampes & Adam 2003;
1368		Germany	Fagus Factory in Alfeld	N/A	N/A	N/A
1379		Germany	Margravia Opera House Bayreuth	N/A	N/A	N/A
1413		Germany	Bergpark Wilhelmshöhe	N/A	N/A	N/A
1447		Germany	Carolingian Westwork and Civitas Corvey	N/A	N/A	N/A
1467		Germany	Speicherstadt and Kontorhaus District with Chilehaus	ERS-ENV asc PSI 1993-2005 processed by DLR	N/A	Adam et al. 2013; Adam et al. 2011; Brcic & Adam 2013; ESA 2009; ESA 2013; Liebhart et al. 2012; Wolf 2012;
1127		Germany,Poland	Muskauer Park / Park Muzakowski	N/A	N/A	N/A
1133	bis	Germany,Slovakia,Ukraine	Primeval Beech Forests of the Carpathians and the Ancient Beech Forests of Germany	N/A	N/A	N/A
430	Ter	Germany,United Kingdom of Great Britain and Northern Ireland	Frontiers of the Roman Empire	N/A	N/A	Banton et al. 2013; Cigna 2015;
392		Greece	Temple of Apollo Epicurius at Bassae	N/A	N/A	Adam et al. 2013; Duro et al. 2015; ESA 2013; Rodriguez Gonzalez et al. 2013;
393		Greece	Archaeological Site of Delphi	N/A	N/A	Adam et al. 2013; Duro et al. 2015; ESA 2013; Rodriguez Gonzalez et al. 2013;

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404		Greece	Acropolis, Athens	ERS desc PSInSAR 1992-1999 processed by TRE	N/A	Adam et al. 2013; Duro et al. 2015; ESA 2005; ESA 2009; ESA 2013; Foumelis 2012; Foumelis et al. 2009; Foumelis et al. 2008; Kotsis et al. 2008; Parcharidis & Foumelis 2005; Parcharidis et al. 2006; Rodriguez Gonzalez et al. 2013;
454		Greece	Mount Athos	N/A	N/A	Adam et al. 2013; Duro et al. 2015; ESA 2013; Rodriguez Gonzalez et al. 2013;
455		Greece	Meteora	N/A	N/A	N/A
456		Greece	Paleochristian and Byzantine Monuments of Thessalonika	N/A	N/A	Adam et al. 2013; Costantini et al. 2016; Duro et al. 2015; ESA 2013; Mouratidis et al. 2011; Raspini et al. 2016; Raucoules et al. 2008; Rodriguez Gonzalez et al. 2013; Svigkas et al. 2015;
491		Greece	Sanctuary of Asklepios at Epidaurus	N/A	N/A	Adam et al. 2013; Duro et al. 2015; ESA 2013; Rodriguez Gonzalez et al. 2013;
493		Greece	Medieval City of Rhodes	N/A	N/A	N/A
511		Greece	Archaeological Site of Mystras	N/A	N/A	N/A
517		Greece	Archaeological Site of Olympia	N/A	N/A	Adam et al. 2013; Duro et al. 2015; ESA 2013; Parcharidis et al. 2009; Rodriguez Gonzalez et al. 2013;
530		Greece	Delos	N/A	N/A	N/A
537		Greece	Monasteries of Daphni, Hosios Loukas and Nea Moni of Chios	ERS desc PSInSAR 1992-1999 processed by TRE	N/A	Adam et al. 2013; Duro et al. 2015; ESA 2005; ESA 2009; ESA 2013; Rodriguez Gonzalez et al. 2013;
595		Greece	Pythagoreion and Heraion of Samos	N/A	N/A	N/A
780		Greece	Archaeological Site of Aigai (modern name Vergina)	N/A	N/A	Adam et al. 2013; Duro et al. 2015; ESA 2013; Rodriguez Gonzalez et al. 2013;

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941		Greece	Archaeological Sites of Mycenae and Tiryns	N/A	N/A	Adam et al. 2013; Duro et al. 2015; ESA 2013; Rodriguez Gonzalez et al. 2013;
942		Greece	The Historic Centre (Chorß) with the Monastery of Saint-John the Theologian and the Cave of the Apocalypse on the Island of Pßtmos	N/A	N/A	N/A
978		Greece	Old Town of Corfu	N/A	N/A	N/A
286		Holy See	Vatican City	ERS desc PSInSAR 1992-2000 processed by TRE; ENV desc PSInSAR 2003-2005 processed by TRE	ERS desc; ERS asc; ENV desc; ENV asc; CSK desc; CSK asc	Cigna et al. 2014; Costantini et al. 2014;
91		Holy See,Italy	Historic Centre of Rome, the Properties of the Holy See in that City Enjoying Extraterritorial Rights and San Paolo Fuori le Mura	ERS desc PSInSAR 1992-2000 processed by TRE; ENV desc PSInSAR 2003-2005 processed by TRE	ERS desc; ERS asc; ENV desc; ENV asc; CSK desc; CSK asc	Cigna et al. 2014; Comerci et al. 2015; Delgado et al. 2015; ESA 2009; Fornaro & Pascazio 2014; Manunta et al. 2008; Scifoni et al. 2016; Stramondo et al. 2008; Tapete & Cigna 2012; Tapete et al. 2012; Tapete et al. 2015; Zeni et al. 2011;
400	Bis	Hungary	Budapest, including the Banks of the Danube, the Buda Castle Quarter and Andrßssy Avenue	ERS-ENV desc SPN 1995-2005 processed by ALM	N/A	ESA 2009; Füsi et al. 2007; Grenerczy et al. 2009; Grenerczy et al. 2008; Oberle 2009;
401	rev	Hungary	Old Village of Hollßko and its Surroundings	N/A	N/A	N/A
474	Rev	Hungary	Hortobßgy National Park - the <i>Pusztai</i>	N/A	N/A	N/A
758		Hungary	Millenary Benedictine Abbey of Pannonhalma and its Natural Environment	N/A	N/A	N/A
853	Rev	Hungary	Early Christian Necropolis of Pßcs (Sopianae)	N/A	N/A	N/A
1063		Hungary	Tokaj Wine Region Historic Cultural Landscape	N/A	N/A	N/A
725	Ter	Hungary,Slovakia	Caves of Aggtelek Karst and Slovak Karst	N/A	N/A	N/A
1152		Iceland	Þingvellir National Park	N/A	N/A	N/A
1267		Iceland	Surtsey	N/A	N/A	N/A
659		Ireland	Br- na Bßinne - Archaeological Ensemble of the Bend of the Boyne	N/A	N/A	N/A
757		Ireland,Ireland	Sceilg MhichÝl	N/A	N/A	N/A

ID	Rev	Country	Name	Terrafirma	EPRS-E	Literature
93		Italy	Church and Dominican Convent of Santa Maria delle Grazie with <i>ôThe Last Supperö</i> by Leonardo da Vinci	N/A	ERS desc; ERS asc; ENV desc; ENV asc; CSK desc; CSK asc	N/A
94		Italy	Rock Drawings in Valcamonica	N/A	ERS desc; ERS asc; ENV desc; ENV asc	N/A
174		Italy	Historic Centre of Florence	N/A	ERS desc; ENV desc; ENV asc	Pazzi et al. 2016; Pratesi et al. 2016; Pratesi et al. 2015; Pratesi et al. 2015; Tapete & Cigna 2012; TRE Altamira 2016;
175		Italy	Medici Villas and Gardens in Tuscany	N/A	ERS desc; ENV desc; ENV asc; CSK desc; CSK asc	Pratesi et al. 2015;
394		Italy	Venice and its Lagoon	N/A	ERS desc; ERS asc; ENV desc; ENV asc	Bock et al. 2012; Bock et al. 2012; Bovenga et al. 2010; Carbognin et al. 2004; Kourkouli et al. 2012; Kourkouli et al. 2014; Nitti et al. 2009; Strozzi et al. 2003; Teatini et al. 2012; Teatini et al. 2005; Tosi et al. 2010; Tosi et al. 2013;
395	Bis	Italy	Piazza del Duomo, Pisa	N/A	ERS desc; ENV desc; ENV asc; CSK desc; CSK asc	Solari et al. 2016;
398	rev	Italy	Castel del Monte	N/A	ERS desc; ERS asc; ENV asc	N/A
549	rev	Italy	18th-Century Royal Palace at Caserta with the Park, the Aqueduct of Vanvitelli, and the San Leucio Complex	N/A	ERS desc; ERS asc; ENV desc; ENV asc	N/A
550		Italy	Historic Centre of San Gimignano	N/A	ERS desc; ENV desc; ENV asc	N/A
670		Italy	The Sassi and the Park of the Rupestrian Churches of Matera	N/A	ERS desc; ERS asc; ENV asc; CSK asc	N/A
712	bis	Italy	City of Vicenza and the Palladian Villas of the Veneto	N/A	ERS desc; ERS asc; ENV desc; ENV asc; CSK desc; CSK asc	N/A

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717		Italy	Historic Centre of Siena	N/A	ERS desc; ENV desc; ENV asc	N/A
726	Bis	Italy	Historic Centre of Naples	N/A	ERS desc; ERS asc; ENV desc; ENV asc; CSK desc; CSK asc	Bonano et al. 2013; Tapete et al. 2016; Terranova et al. 2015;
730		Italy	Crespi d'Adda	N/A	ERS desc; ERS asc; ENV desc; ENV asc; CSK asc	N/A
733	Bis	Italy	Ferrara, City of the Renaissance, and its Po Delta	N/A	ERS desc; ERS asc; ENV desc; ENV asc	Bitelli et al. 2015; Codegone et al. 2016; Wegmüller et al. 2009;
787		Italy	The <I>Trulli</I> of Alberobello	N/A	ERS desc; ERS asc; ENV desc; ENV asc	N/A
788		Italy	Early Christian Monuments of Ravenna	N/A	ERS desc; ERS asc; ENV desc; ENV asc	Artese et al. 2016; Fiaschi et al. 2016;
789		Italy	Historic Centre of the City of Pienza	N/A	ERS desc; ERS asc; ENV desc; ENV asc	N/A
797	Rev	Italy	City of Verona	N/A	ERS desc; ERS asc; ENV desc; ENV asc; CSK desc; CSK asc	N/A
823	bis	Italy	Residences of the Royal House of Savoy	N/A	ERS desc; ERS asc; ENV desc; ENV asc; CSK desc; CSK asc	N/A
824		Italy	Botanical Garden (Orto Botanico), Padua	N/A	ERS desc; ERS asc; ENV desc; ENV asc	Tosi et al. 2010;
825		Italy	Archaeological Area and the Patriarchal Basilica of Aquileia	N/A	ERS desc; ERS asc; ENV desc; ENV asc	N/A
826		Italy	Portovenere, Cinque Terre, and the Islands (Palmaria, Tino and Tinetto)	N/A	ERS desc; ENV desc; ENV asc; CSK desc	N/A
827		Italy	Cathedral, Torre Civica and Piazza Grande, Modena	N/A	ERS desc; ENV desc; ENV asc	N/A
828		Italy	Historic Centre of Urbino	N/A	ERS desc; ERS asc; ENV desc; ENV asc; CSK desc	N/A

ID	Rev	Country	Name	Terrafirma	EPRS-E	Literature
829		Italy	Archaeological Areas of Pompei, Herculaneum and Torre Annunziata	N/A	ERS desc; ERS asc; ENV desc; ENV asc; CSK desc; CSK asc	N/A
830		Italy	Costiera Amalfitana	N/A	ERS desc; ERS asc; ENV desc; ENV asc; CSK desc; CSK asc	N/A
831		Italy	Archaeological Area of Agrigento	N/A	ERS desc; ENV desc; ENV asc	Tapete & Cigna 2012;
832		Italy	Villa Romana del Casale	N/A	ERS desc; ERS asc; ENV desc; ENV asc	N/A
833		Italy	Su Nuraxi di Barumini	N/A	ERS desc	N/A
842		Italy	Cilento and Vallo di Diano National Park with the Archeological Sites of Paestum and Velia, and the Certosa di Padula	N/A	ERS desc; ERS asc; ENV desc; ENV asc; CSK desc; CSK asc	N/A
907		Italy	Villa Adriana (Tivoli)	ERS desc PSInSAR 1992-2000 processed by TRE; ENV desc PSInSAR 2003-2005 processed by TRE	ERS desc; ERS asc; ENV desc; ENV asc; CSK asc	Bozzano et al. 2015; Bozzano et al. 2015; ESA 2009; Floris et al. 2014; Nais Srl 2016;
908		Italy	Isole Eolie (Aeolian Islands)	N/A	ERS desc; ENV desc; ENV asc	Antonello et al. 2004; Ferretti et al. 2008;
990		Italy	Assisi, the Basilica of San Francesco and Other Franciscan Sites	N/A	ERS desc; ERS asc; ENV desc; ENV asc; CSK desc; CSK asc	Ardizzone et al. 2011; Bovenga et al. 2013; Bovenga et al. 2010; De Novellis et al. 2016;
1024	Rev	Italy	Late Baroque Towns of the Val di Noto (South-Eastern Sicily)	N/A	ERS desc; ERS asc; ENV desc; ENV asc	N/A
1025		Italy	Villa d'Este, Tivoli	N/A	ERS desc; ERS asc; ENV desc; ENV asc; CSK asc	N/A
1026	Rev	Italy	Val d'Orcia	N/A	ERS desc; ERS asc; ENV desc; ENV asc	N/A
1068	Rev	Italy	< >Sacri Monti</ > of Piedmont and Lombardy	N/A	ERS desc; ERS asc; ENV desc; ENV asc; CSK desc; CSK asc	N/A
1158		Italy	Etruscan Necropolises of Cerveteri and Tarquinia	ERS desc PSInSAR 1992-2000 processed by TRE	ERS desc; ERS asc; ENV desc; ENV asc	ESA 2009;

ID	Rev	Country	Name	Terrafirma	EPRS-E	Literature
1200		Italy	Syracuse and the Rocky Necropolis of Pantalica	N/A	ERS desc; ERS asc; ENV desc; ENV asc	Canova et al. 2012; Mattia et al. 2012;
1211		Italy	Genoa: <i>Le Strade Nuove</i> and the system of the <i>Palazzi dei Rolli</i>	N/A	ERS desc; ENV desc; ENV asc	N/A
1237	Rev	Italy	The Dolomites	N/A	ERS desc; ERS asc; ENV desc; ENV asc; CSK desc; CSK asc	Belitz et al. 2004; Bossi et al. 2016; Casagli et al. 2016; lasio et al. 2012; lasio et al. 2011; Mulas et al. 2016; Mulas et al. 2015;
1287		Italy	Mantua and Sabbioneta	N/A	ERS desc; ERS asc; ENV desc; ENV asc	N/A
1318		Italy	Longobards in Italy. Places of the Power (568-774 A.D.)	N/A	ERS desc; ERS asc; ENV desc; ENV asc; CSK desc; CSK asc	N/A
1390	Rev	Italy	Vineyard Landscape of Piedmont: Langhe-Roero and Monferrato	N/A	ERS desc; ERS asc; ENV desc; ENV asc	Meisina et al. 2008; Notti et al. 2013;
1427		Italy	Mount Etna	N/A	ERS desc; ERS asc; ENV desc; ENV asc; CSK asc	Bonforte & Guglielmino 2015; Bonforte et al. 2011; Greco et al. 2016; Neri et al. 2007; Ruch et al. 2010;
1487		Italy	Arab-Norman Palermo and the Cathedral Churches of Cefal' and Monreale	ERS desc PSInSAR 1992-2003 processed by TRE	ERS desc; ENV desc; ENV asc; CSK desc; CSK asc	ESA 2005; ESA 2009;
1090	Bis	Italy,Switzerland	Monte San Giorgio	N/A	ERS desc; ERS asc; ENV desc; ENV asc; CSK asc	N/A
1276		Italy,Switzerland	Rhaetian Railway in the Albula / Bernina Landscapes	N/A	ERS desc; ERS asc; ENV desc; ENV asc	Ambrosi & Crosta 2015;
852		Latvia	Historic Centre of Riga	ERS desc IPTA 1992-2000 processed by FNPA	N/A	ESA 2009;
541	Bis	Lithuania	Vilnius Historic Centre	ERS desc IPTA 1992-2000 processed by FNPA	N/A	ESA 2009;
1137		Lithuania	Kernave Archaeological Site (Cultural Reserve of Kernave)	N/A	N/A	N/A

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994		Lithuania,Lithuania,Russian Federation,Russian Federation	Curonian Spit	N/A	N/A	Graniczny et al. 2015; Holley 2012; Przylucka et al. 2013;
699		Luxembourg	City of Luxembourg: its Old Quarters and Fortifications	ERS desc SPN 1993-2000 processed by ALM	N/A	ESA 2009;
130		Malta	Hal Saflieni Hypogeum	ERS desc IPTA 1992-2000 processed by FNPA	N/A	ESA 2009;
131		Malta	City of Valletta	ERS desc IPTA 1992-2000 processed by FNPA	N/A	ESA 2009;
132		Malta,Malta,Malta	Megalithic Temples of Malta	ERS desc IPTA 1992-2000 processed by FNPA	N/A	ESA 2009;
100	Bis	Montenegro	Durmitor National Park	N/A	N/A	N/A
125		Montenegro	Natural and Culturo-Historical Region of Kotor	N/A	N/A	N/A
965		Netherlands	Rietveld Schröderhuis (Rietveld Schröder House)	N/A	N/A	Caro Cuenca et al. 2012; Caro Cuenca et al. 2011; Hanssen & Caro Cuenca 2012; Hopman et al. 2013;
1349		Netherlands	Seventeenth-Century Canal Ring Area of Amsterdam inside the Singelgracht	N/A	N/A	Caro Cuenca et al. 2012; Caro Cuenca et al. 2011; Crosetto et al. 2009; ESA 2005; ESA 2009; Gee et al. 2016; Hanssen et al. 2008; Hanssen & Caro Cuenca 2012; Hopman et al. 2013;
1441		Netherlands	Van Nellefabriek	N/A	N/A	Caro Cuenca et al. 2012; Caro Cuenca et al. 2011; Hanssen & Caro Cuenca 2012; Hopman et al. 2013; Peduto et al. 2017;
739		Netherlands,Netherlands	Schokland and Surroundings	N/A	N/A	Caro Cuenca et al. 2012; Caro Cuenca et al. 2011; Hanssen & Caro Cuenca 2012; Hopman et al. 2013;

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759		Netherlands,Netherlands	Defence Line of Amsterdam	N/A	N/A	Caro Cuenca et al. 2012; Caro Cuenca et al. 2011; Crosetto et al. 2009; ESA 2005; ESA 2009; Gee et al. 2016; Hanssen et al. 2008; Hanssen & Caro Cuenca 2012; Hopman et al. 2013;
818		Netherlands,Netherlands	Mill Network at Kinderdijk-Elshout	N/A	N/A	Caro Cuenca et al. 2012; Caro Cuenca et al. 2011; Hanssen & Caro Cuenca 2012; Hopman et al. 2013;
867		Netherlands,Netherlands	Ir.D.F. Woudagemaal (D.F. Wouda Steam Pumping Station)	ENV desc DePSI 2003-2010 processed by HB	N/A	Caro Cuenca et al. 2012; Caro Cuenca et al. 2011; ESA 2012; Hanssen & Caro Cuenca 2012; Hanssen & Van Leijen 2008; Hanssen & Van Leijen 2008; Hopman et al. 2013;
899		Netherlands,Netherlands	Droogmakerij de Beemster (Beemster Polder)	N/A	N/A	Caro Cuenca et al. 2012; Caro Cuenca et al. 2011; Crosetto et al. 2009; ESA 2009; Gee et al. 2016; Hanssen et al. 2008; Hanssen & Caro Cuenca 2012; Hopman et al. 2013;
55	Bis	Norway	R°ros Mining Town and the Circumference	N/A	N/A	N/A
58		Norway	Urnes Stave Church	N/A	N/A	N/A
352		Norway	Rock Art of Alta	N/A	N/A	N/A
1195		Norway	West Norwegian Fjords û Geirangerfjord and Nµr°yfjord	N/A	N/A	N/A
1486		Norway	Rjukan-Notodden Industrial Heritage Site	N/A	N/A	N/A
59		Norway,Norway,Norway	Bryggen	N/A	N/A	Dehls 2015;
1143		Norway,Norway,Norway, Norway	Vega°yan -- The Vega Archipelago	N/A	N/A	N/A
29	bis	Poland	Historic Centre of Krak¼w	N/A	N/A	N/A
30	Bis	Poland	Historic Centre of Warsaw	N/A	N/A	Ziolkowski et al. 2016;

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31		Poland	Auschwitz Birkenau  <small>German Nazi Concentration and Extermination Camp (1940-1945)</small>	N/A	N/A	N/A
32	Ter	Poland	Wieliczka and Bochnia Royal Salt Mines	N/A	N/A	Perski et al. 2009; Szczygieł 2015; Wojciechowski et al. 2008;
564		Poland	Old City of Zamosc	N/A	N/A	N/A
835		Poland	Medieval Town of Torun	N/A	N/A	N/A
847		Poland	Castle of the Teutonic Order in Malbork	N/A	N/A	Graniczny et al. 2015; Holley 2012; Przylucka et al. 2013;
905		Poland	Kalwaria Zebrzydowska: the Mannerist Architectural and Park Landscape Complex and Pilgrimage Park	N/A	N/A	N/A
1053	Rev	Poland	Wooden Churches of Southern Malopolska	N/A	N/A	N/A
1054		Poland	Churches of Peace in Jawor and Swidnica	N/A	N/A	N/A
1165		Poland	Centennial Hall in Wroclaw	N/A	N/A	Perski et al. 2007; Perski et al. 2008;
1424		Poland,Ukraine	Wooden <em>Tserkvas</em> of the Carpathian Region in Poland and Ukraine	N/A	N/A	N/A
206		Portugal	Central Zone of the Town of Angra do Heroismo in the Azores	N/A	N/A	N/A
263	Bis	Portugal	Monastery of the Hieronymites and Tower of BelÚm in Lisbon	ERS desc PSInSAR 1992-2003 processed by TRE; ERS-ENV desc SPN 1992-2006 processed by ALM	N/A	Catalao et al. 2011; Catalão et al. 2016; ESA 2005; ESA 2009; Henriques et al. 2011; Roque et al. 2015; Roque et al. 2016;
264		Portugal	Monastery of Batalha	N/A	N/A	N/A
265		Portugal	Convent of Christ in Tomar	N/A	N/A	N/A
361		Portugal	Historic Centre of Évora	N/A	N/A	N/A
505		Portugal	Monastery of Alcobaça	N/A	N/A	N/A
723		Portugal	Cultural Landscape of Sintra	N/A	N/A	N/A
755		Portugal	Historic Centre of Oporto, Luiz I Bridge and Monastery of Serra do Pilar	N/A	N/A	N/A
934		Portugal	Laurisilva of Madeira	N/A	N/A	N/A
1031		Portugal	Historic Centre of Guimarães	N/A	N/A	N/A
1046		Portugal	Alto Douro Wine Region	N/A	N/A	N/A

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1117	Rev	Portugal	Landscape of the Pico Island Vineyard Culture	N/A	N/A	Catita et al. 2005; Martins et al. 2008;
1367	Bis	Portugal	Garrison Border Town of Elvas and its Fortifications	N/A	N/A	N/A
1387		Portugal	University of Coimbra û Alta and Sofia	N/A	N/A	N/A
866	Bis	Portugal,Spain	Prehistoric Rock Art Sites in the C1ja Valley and Siega Verde	N/A	N/A	N/A
588		Romania	Danube Delta	N/A	N/A	Poncos et al. 2013;
596	Bis	Romania	Villages with Fortified Churches in Transylvania	N/A	N/A	N/A
597		Romania	Monastery of Horezu	N/A	N/A	N/A
598	Bis	Romania	Churches of Moldavia	N/A	N/A	N/A
902		Romania	Historic Centre of Sighisoara	N/A	N/A	Negula 2016; Negula 2016; Negula & Poenaru 2015; Negula & Poenaru 2015; Negula et al. 2015;
904		Romania	Wooden Churches of Maramures	N/A	N/A	N/A
906		Romania	Dacian Fortresses of the Orastie Mountains	N/A	N/A	N/A
1245		San Marino	San Marino Historic Centre and Mount Titano	N/A	ERS desc; ERS asc; ENV desc; ENV asc	N/A
96		Serbia	Stari Ras and Sopocani	N/A	N/A	N/A
389		Serbia	Studenica Monastery	N/A	N/A	N/A
724	Bis	Serbia	Medieval Monuments in Kosovo	N/A	N/A	N/A
1253		Serbia	Gamzigrad-Romuliana, Palace of Galerius	N/A	N/A	N/A
618	rev	Slovakia	Historic Town of Banská ètiavnica and the Technical Monuments in its Vicinity	N/A	N/A	N/A
620	Bis	Slovakia	Levoca, Spišusk <sup>2</sup> Hrad and the Associated Cultural Monuments	N/A	N/A	Casagli et al. 2016;
622	rev	Slovakia	Vlkolýnec	N/A	N/A	N/A
973		Slovakia	Bardejov Town Conservation Reserve	N/A	N/A	N/A
1273		Slovakia	Wooden Churches of the Slovak part of the Carpathian Mountain Area	N/A	N/A	N/A
390		Slovenia	èkocjan Caves	N/A	N/A	N/A
1313	Rev	Slovenia,Spain	Heritage of Mercury. AlmadÚn and Idrija	N/A	N/A	Žibret & Žibret 2017;
310	Bis	Spain	Cave of Altamira and Paleolithic Cave Art of Northern Spain	N/A	N/A	N/A
311		Spain	Old Town of Segovia and its Aqueduct	N/A	N/A	N/A

ID	Rev	Country	Name	Terrafirma	EPRS-E	Literature
312	bis	Spain	Monuments of Oviedo and the Kingdom of the Asturias	N/A	N/A	N/A
313	bis	Spain	Historic Centre of Cordoba	N/A	N/A	N/A
314	bis	Spain	Alhambra, Generalife and Albayzín, Granada	N/A	N/A	Fernandez et al. 2009; Lee & Liu 2000; Notti et al. 2016; Pérez-Peña et al. 2015; Ruiz et al. 2007; Sousa 2009; Sousa et al. 2010; Sousa et al. 2011; Sousa et al. 2014;
316	Bis	Spain	Burgos Cathedral	N/A	N/A	N/A
318		Spain	Monastery and Site of the Escorial, Madrid	N/A	N/A	N/A
320	Bis	Spain	Works of Antoni Gaudí	N/A	N/A	Crosetto et al. 2016; Crosetto et al. 2015; Crosetto et al. 2014; Devanthery et al. 2013; Devanthery et al. 2012; Devanthery et al. 2011; Monells et al. 2010;
347		Spain	Santiago de Compostela (Old Town)	N/A	N/A	N/A
348	bis	Spain	Old Town of Llívia with its Extra-Muros Churches	N/A	N/A	N/A
378	Bis	Spain	Mudejar Architecture of Aragon	N/A	N/A	N/A
379		Spain	Historic City of Toledo	N/A	N/A	N/A
380		Spain	Garajonay National Park	N/A	N/A	N/A
381	rev	Spain	Old City of Salamanca	N/A	N/A	N/A
383	bis	Spain	Cathedral, Alcázar and Archivo de Indias in Seville	N/A	N/A	Ruiz-Armenteros et al. 2016;
384		Spain	Old Town of Cáceres	N/A	N/A	N/A
417	Rev	Spain	Ibiza, Biodiversity and Culture	N/A	N/A	N/A
518	rev	Spain	Poblet Monastery	N/A	N/A	N/A
522	Rev	Spain	Renaissance Monumental Ensembles of Medina and Baeza	N/A	N/A	N/A
664		Spain	Archaeological Ensemble of Mérida	N/A	N/A	N/A
665		Spain	Royal Monastery of Santa María de Guadalupe	N/A	N/A	N/A
669	Bis	Spain	Routes of Santiago de Compostela: Camino Francés and Routes of Northern Spain	N/A	N/A	N/A
781		Spain	Historic Walled Town of Cuenca	N/A	N/A	N/A
782		Spain	La Lonja de la Seda de Valencia	N/A	N/A	Delgado et al. 2015;

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803		Spain	Las MÚdulas	N/A	N/A	N/A
804	Bis	Spain	Palau de la M·sica Catalana and Hospital de Sant Pau, Barcelona	N/A	N/A	Crosetto et al. 2006; Crosetto et al. 2008; Crosetto et al. 2013; Crosetto et al. 2016; Devanthery et al. 2014; Devanthery et al. 2016; Devanthery et al. 2016;
805		Spain	San Millŕn Yuso and Suso Monasteries	N/A	N/A	N/A
874		Spain	Rock Art of the Mediterranean Basin on the Iberian Peninsula	N/A	N/A	Crosetto et al. 2006; Crosetto et al. 2008; Crosetto et al. 2013; Devanthery et al. 2016;
875	Rev	Spain	Archaeological Ensemble of Tŕrraco	N/A	N/A	N/A
876		Spain	University and Historic Precinct of Alcalŕ de Henares	N/A	N/A	N/A
929		Spain	San Cristŕbal de La Laguna	N/A	N/A	Carrasco et al. 2000; Eff-Darwich et al. 2009; Eff-Darwich et al. 2012; Fernŕndez et al. 2004; Fernŕndez et al. 2002; Fernŕndez et al. 2005; Fernandez et al. 2009; Fernŕndez et al. 2003; Samsonov et al. 2008;
930		Spain	Palmeral of Elche	N/A	N/A	N/A
987		Spain	Roman Walls of Lugo	N/A	N/A	N/A
988		Spain	Catalan Romanesque Churches of the Vall de Boŕ	N/A	N/A	N/A
989		Spain	Archaeological Site of Atapuerca	N/A	N/A	N/A
1044		Spain	Aranjuez Cultural Landscape	N/A	N/A	N/A
1217		Spain	Vizcaya Bridge	N/A	N/A	N/A
1258		Spain	Teide National Park	N/A	N/A	Carrasco et al. 2000; Eff-Darwich et al. 2009; Eff-Darwich et al. 2012; Fernŕndez et al. 2004; Fernŕndez et al. 2002; Fernŕndez et al. 2005; Fernandez et al. 2009; Fernŕndez et al. 2003; Samsonov et al. 2008;
1312		Spain	Tower of Hercules	N/A	N/A	N/A
1371		Spain	Cultural Landscape of the Serra de Tramuntana	N/A	N/A	Bianchini et al. 2013;
685	Bis	Spain,Spain,Spain,Spain	Doŕana National Park	N/A	N/A	N/A
555		Sweden	Birka and Hovgŕrden	N/A	N/A	N/A

ID	Rev	Country	Name	Terrafirma	EPRS-E	Literature
556	rev	Sweden	Engelsberg Ironworks	N/A	N/A	N/A
557	rev	Sweden	Rock Carvings in Tanum	N/A	N/A	N/A
558	rev	Sweden	SkogskyrkogÖrden	ERS desc IPTA 1992-2000 processed by FNPA	N/A	ESA 2009;
559		Sweden	Royal Domain of Drottningholm	ERS desc IPTA 1992-2000 processed by FNPA	N/A	ESA 2009;
731		Sweden	Hanseatic Town of Visby	N/A	N/A	N/A
762		Sweden	Church Town of Gammelstad, Luleå	N/A	N/A	N/A
774		Sweden	Laponian Area	N/A	N/A	N/A
871		Sweden	Naval Port of Karlskrona	N/A	N/A	N/A
968		Sweden	Agricultural Landscape of Southern Åland	N/A	N/A	N/A
1027		Sweden	Mining Area of the Great Copper Mountain in Falun	N/A	N/A	N/A
1134		Sweden	Grimeton Radio Station, Varberg	N/A	N/A	N/A
1282	rev	Sweden	Decorated Farmhouses of Hölmsingland	N/A	N/A	N/A
267		Switzerland	Old City of Berne	N/A	N/A	N/A
268		Switzerland	Abbey of St Gall	N/A	N/A	N/A
269		Switzerland	Benedictine Convent of St John at M <sup>3</sup> stair	N/A	ERS desc; ENV desc	Casagli et al. 2016;
884		Switzerland	Three Castles, Defensive Wall and Ramparts of the Market-Town of Bellinzona	N/A	N/A	N/A
1037	Bis	Switzerland	Swiss Alps Jungfrau-Aletsch	N/A	N/A	Strozzi et al. 2008; Strozzi et al. 2009; Strozzi et al. 2011;
1179		Switzerland	Swiss Tectonic Arena Sardona	N/A	N/A	ESA 2009;
1243		Switzerland	Lavaux, Vineyard Terraces	N/A	N/A	N/A
1302		Switzerland	La Chaux-de-Fonds / Le Locle, Watchmaking Town Planning	N/A	N/A	N/A
99	Ter	the Former Yugoslav Republic of Macedonia	Natural and Cultural Heritage of the Ohrid region	N/A	N/A	N/A
356		Turkey	Historic Areas of Istanbul	ERS desc PSInSAR 1992-2002 processed by TRE; ENV desc PSInSAR 2003-2010 processed by TRE; ENV asc PSInSAR 2002-2009 processed by TRE	N/A	Calò et al. 2015; Diao et al. 2016; Diao et al. 2016; ESA 2005; ESA 2009; Manzo et al. 2014; Walter 2014;
357		Turkey	Göreme National Park and the Rock Sites of Cappadocia	N/A	N/A	N/A
358		Turkey	Great Mosque and Hospital of Divrigi	N/A	N/A	N/A

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377		Turkey	Hattusha: the Hittite Capital	N/A	N/A	N/A
448		Turkey	Nemrut Dag	N/A	N/A	N/A
484		Turkey	Xanthos-Letoon	N/A	N/A	N/A
485		Turkey	Hierapolis-Pamukkale	N/A	N/A	N/A
614		Turkey	City of Safranbolu	N/A	N/A	N/A
849		Turkey	Archaeological Site of Troy	N/A	N/A	Adam et al. 2013; Rodriguez Gonzalez et al. 2013;
1018		Turkey	Ephesus	N/A	N/A	Adam et al. 2013; Rodriguez Gonzalez et al. 2013;
1366		Turkey	Selimiye Mosque and its Social Complex	N/A	N/A	N/A
1405		Turkey	Neolithic Site of Aatalh÷y³k	N/A	N/A	N/A
1452		Turkey	Bursa and Cumalikizik: the Birth of the Ottoman Empire	N/A	N/A	N/A
1457		Turkey	Pergamon and its Multi-Layered Cultural Landscape	N/A	N/A	Adam et al. 2013; Rodriguez Gonzalez et al. 2013;
1488		Turkey	Diyarbakir Fortress and Hevsel Gardens Cultural Landscape	N/A	N/A	N/A
369		United Kingdom of Great Britain and Northern Ireland	Giant's Causeway and Causeway Coast	N/A	N/A	N/A
370	Bis	United Kingdom of Great Britain and Northern Ireland	Durham Castle and Cathedral	N/A	N/A	Banton et al. 2013; Cigna 2015;
371		United Kingdom of Great Britain and Northern Ireland	Ironbridge Gorge	N/A	N/A	N/A
372	Bis	United Kingdom of Great Britain and Northern Ireland	Studley Royal Park including the Ruins of Fountains Abbey	N/A	N/A	N/A
373	Bis	United Kingdom of Great Britain and Northern Ireland	Stonehenge, Avebury and Associated Sites	N/A	N/A	N/A
374		United Kingdom of Great Britain and Northern Ireland	Castles and Town Walls of King Edward in Gwynedd	N/A	N/A	Cigna et al. 2014;

ID	Rev	Country	Name	Terrafirma	EPRS-E	Literature
387	bis	United Kingdom of Great Britain and Northern Ireland	St Kilda	N/A	N/A	N/A
425		United Kingdom of Great Britain and Northern Ireland	Blenheim Palace	N/A	N/A	N/A
426	Bis	United Kingdom of Great Britain and Northern Ireland	Palace of Westminster and Westminster Abbey including Saint Margaret's Church	N/A	N/A	Aldiss et al. 2014; Boni et al. 2016; Boyle et al. 2000; Cigna 2015; Cigna et al. 2015; ESA 2009; Mason et al. 2015;
429	Rev	United Kingdom of Great Britain and Northern Ireland	New Lanark	N/A	N/A	N/A
488		United Kingdom of Great Britain and Northern Ireland	Tower of London	N/A	N/A	Aldiss et al. 2014; Boni et al. 2016; Boyle et al. 2000; Cigna 2015; Cigna et al. 2015; ESA 2009; Mason et al. 2015;
496		United Kingdom of Great Britain and Northern Ireland	Canterbury Cathedral, St Augustine's Abbey, and St Martin's Church	N/A	N/A	N/A
514		United Kingdom of Great Britain and Northern Ireland	Heart of Neolithic Orkney	N/A	N/A	N/A
728		United Kingdom of Great Britain and Northern Ireland	Old and New Towns of Edinburgh	N/A	N/A	N/A
795		United Kingdom of Great Britain and Northern Ireland	Maritime Greenwich	N/A	N/A	Aldiss et al. 2014; Boni et al. 2016; Boyle et al. 2000; Cigna 2015; Cigna et al. 2015; ESA 2009; Mason et al. 2015;
984		United Kingdom of Great Britain and Northern Ireland	Blaenavon Industrial Landscape	N/A	N/A	Bateson et al. 2015; Cigna et al. 2013; Cigna et al. 2014;

ID	Rev	Country	Name	Terrafirma	EPRS-E	Literature
1028		United Kingdom of Great Britain and Northern Ireland	Saltaire	N/A	N/A	N/A
1030		United Kingdom of Great Britain and Northern Ireland	Derwent Valley Mills	N/A	N/A	N/A
1084		United Kingdom of Great Britain and Northern Ireland	Royal Botanic Gardens, Kew	N/A	N/A	Aldiss et al. 2014; Boni et al. 2016; Boyle et al. 2000; Cigna 2015; Cigna et al. 2015; ESA 2009; Mason et al. 2015;
1150		United Kingdom of Great Britain and Northern Ireland	Liverpool û Maritime Mercantile City	N/A	N/A	N/A
1215		United Kingdom of Great Britain and Northern Ireland	Cornwall and West Devon Mining Landscape	N/A	N/A	N/A
1303		United Kingdom of Great Britain and Northern Ireland	Pontcysyllte Aqueduct and Canal	N/A	N/A	Cigna et al. 2014;
1485		United Kingdom of Great Britain and Northern Ireland	The Forth Bridge	N/A	N/A	N/A
428		United Kingdom of Great Britain and Northern Ireland, United Kingdom of Great Britain and Northern Ireland	City of Bath	ERS-ENV desc IPTA 1992-2005 processed by FNPA	N/A	ESA 2009;
1029		United Kingdom of Great Britain and Northern Ireland, United Kingdom of Great Britain and Northern Ireland	Dorset and East Devon Coast	N/A	N/A	N/A