

## MONITORING HERITAGE AT RISK WITH SENTINEL-2

*Sentinel-2 provides timely and objective information to assess the condition of heritage sites at risk in the Middle East and North Africa.*

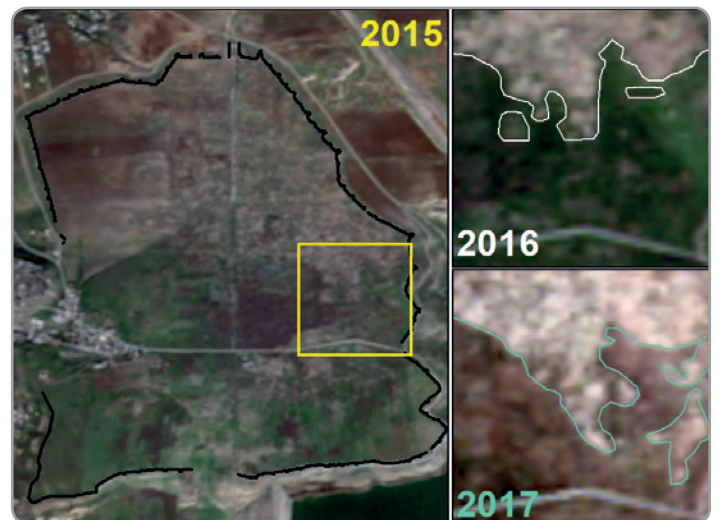
### The challenge

During conflicts, cultural heritage sites are vulnerable to illegal diggings by looters searching for goods to feed the clandestine market trafficking antiquities. In ordinary times, anthropogenic modifications (e.g. urbanisation) can impact the conservation of local heritage and the surrounding cultural landscape. In both these circumstances, the challenge for heritage stakeholders such as national or regional UNESCO offices, government heritage bodies and site managers, is to be able to monitor the condition of heritage assets, and repeat the assessment on a regular basis or in case specific events of damage occur. This task requires timely data of sufficient spatial resolution that can provide objective information and allow for multi-temporal comparative measures. Common constraints for users are the costs to access very high-resolution satellite imagery (mostly provided by commercial providers) and the availability of in-house expertise for data processing and interpretation.

### The space based solution

The freely accessible time series acquired by the Copernicus Sentinel-2 constellation can address this challenge. Images are acquired systematically and globally with consistent parameters, spatial resolution of 10 m in the visible bands, and every few days (e.g. 5 days over the Mediterranean countries). Our research tests of multi-temporal change detection on the archaeological site of Apamea in Syria (being looted on a massive scale since 2012) prove that Sentinel-2 data can distinctively depict clusters of several adjacent looting holes, allow for delineation of new areas of illegal digging, and estimate looting rates. Owing to a clear contrast in the reflectance of looted areas with respect to the surrounding greening land, new looting is found south-east of the theatre, west

of the Cardo Maximus and the Agora and in the eastern portion of the archaeological site, along the second main Decumanus. The high temporal frequency of Sentinel-2 images increases the timeliness in recording new incidents of looting, thus bringing in an improved capability compared to satellite-based assessments based on single images acquired on demand on a monthly or yearly basis. Feature extraction analysis through long time series of Sentinel-2 can be used to capture the appearance, over time, of new manmade features due to urbanisation across the landscape, e.g. new roads, clusters of buildings or excavation sites. Around the modern town of Shahat in Libya, this approach allowed us to map the changing degree of exposure of vulnerable heritage and to identify a hotspot south of the UNESCO World Heritage Site of Cyrene, close to the Sanctuary of Demeter and Kore.



Multi-temporal mapping of new archaeological looting in the heritage site of Apamea in Syria, based on Sentinel-2 images. Credit: Copernicus Sentinel data (2015-2017)

Thematic Area



CULTURAL HERITAGE, TOURISM AND LEISURE

Region of Application



(I) HAMA, SYRIA; AND  
(II) CYRENAICA, LIBYA

Sentinel mission used



S2

Copernicus Service used



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Usage Maturity Level



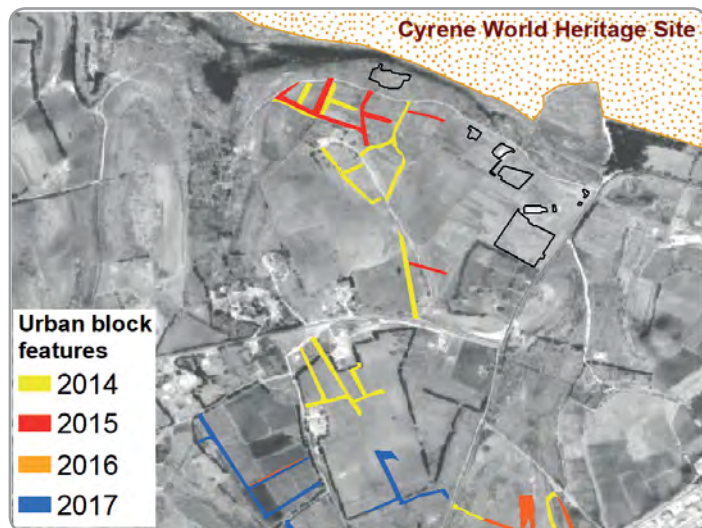
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## Benefits to Citizens

Public authorities for heritage conservation and site managers need to assess and monitor the condition of heritage at risk. Some international organisations such as UNITAR and the ASOR (American Schools of Oriental Research) Cultural Heritage Initiatives already use very high-resolution optical satellite data to monitor and document damage at heritage sites of the Middle East and North Africa, and provide proof of concept of the value that services based on regular satellite monitoring could bring. Therefore, in an operational perspective, the condition assessment of cultural heritage sites based on Sentinel-2 time series would enable heritage stakeholders to:

- produce weekly or monthly condition reports and damage maps
- locate areas of major concern
- anticipate where concerns may arise

This Sentinel-2 space-based solution could be applied either to monitor heritage hotspots of known vulnerability or to screen wider regions.



Mapping urban block features in UNESCO World Heritage Site of Cyrene, Libya, based on Sentinel-2 time series.

*Credit: Contains Copernicus Sentinel data [2017]*

“... using satellite imagery databases we are able to go back in time and compare the status of cultural heritage areas during different time intervals...”

*UN Institute for Training and Research (UNITAR)*

## Outlook to the future

Automatic processing chains (e.g. based on machine learning) are expected to be a technological development accelerator towards an operational use of Sentinel-2 imagery for the condition assessment and monitoring of local to wide areas of study. This automation should therefore complement the analyst-driven methods that currently represent the state-of-the-art in this field and, ideally, help to mitigate the drawbacks of manual examination (e.g. time-consumption, subjectivity). Initiatives of capacity building and training would then contribute to fill the knowledge and expertise gaps that frequently constrain the heritage user uptake of new satellite technologies.

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## ABOUT COPERNICUS4REGIONS

This Copernicus User Story is extracted from the publication “**The Ever Growing use of Copernicus across Europe's Regions: a selection of 99 user stories by local and regional authorities**”, 2018, Edited by NEREUS, the European Space Agency and the European Commission.

The model cases focus on local and regional authorities who successfully applied Copernicus data in 8 major public policy domains. The views expressed in the Copernicus User Stories are those of the Authors and can in no way be taken to reflect the official opinion of the European Space Agency or of the European Commission.

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## PROTECTION OF EUROPEAN CULTURAL HERITAGE FROM GEOHAZARDS

*Application of innovative EO techniques for geohazards assessment in the Derwent Valley Mills (WHS).*

### The challenge

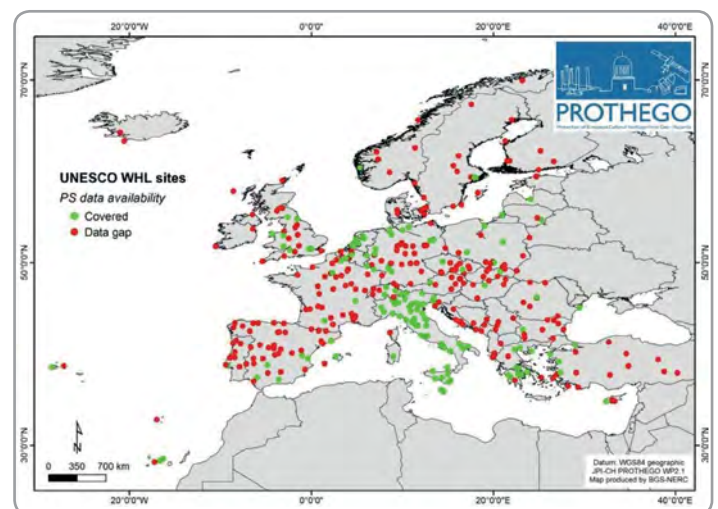
Tangible cultural heritage includes various categories of monuments and sites, from individual architecture to cultural landscapes, and from archaeological complexes to historic centres. Many of these sites are affected by a variety of factors, with rapid or slow onset. They include natural hazards, such as landslides, settlement, subsidence, earthquakes or extreme meteorological events, which could be worsened by climate change and/or human interaction. A comprehensive picture of cultural sites affected by geohazards is not yet available. The PROTECTION of European Cultural HERitage from GeOHazards, (PROTHEGO) project provides an overview of remote sensing capabilities for monitoring these threats by focusing on properties on the UNESCO World Heritage List (WHL) in Europe. These properties will serve as a reference case for all EU heritage properties.

### The space based solution

PROTHEGO applies novel space technologies based on radar interferometry (InSAR) to monitor monuments and sites in Europe which are potentially unstable due to geohazards. These technologies can play a crucial role in developing site management strategies sustainable for the preservation of cultural heritage and landscape. Remotely sensed information on ground stability conditions is combined with In order to assess observed motions and understand geological processes, an analysis of remotely sensed data in conjunction with local-scale geological analysis was implemented for each test site. Advanced modelling and field surveying were also carried out. At least one site for each partner country (i.e. Italy, United Kingdom, Cyprus and Spain) was chosen to validate and calibrate the methodology.

The Derwent Valley Mills World Heritage Site (DVMWHS), managed by the Derwent Valley Mills Partnership, is one of the PROTHEGO

case study sites selected for local scale monitoring, investigation and advanced modelling. The Derwent Valley, with its associated mill complexes, industrial housing and infrastructure, was inscribed on the UNESCO World Heritage List in 2001 in recognition of its importance as the birthplace of the modern factory system. In order to monitor the current state of activity of the identified geohazards, Sentinel-1 space-borne imagery acquired between 2015 and 2017 was processed using the InSAR technique. The project identified fluvial and groundwater flooding and landslides as key threats to the Valley's cultural heritage resource, for example, at Belper, where radar data identified damage possibly connected to a recent flooding event.



UNESCO WHL sites of Europe covered by PS ground motion data, derived by satellite radar interferometry. Base map data © ESRI. World Heritage Site data Credit © 1992 - [2016] UNESCO/World Heritage Centre. All rights reserved. Map produced by BGS, © NERC/UKRI. Green dots indicate PS data available for site, red dots indicate PS data not available.

### Benefits to Citizens

PROTHEGO's goal is to enhance cultural heritage management practices at the national level, reinforcing institutional support

Thematic Area



CULTURAL HERITAGE, TOURISM AND LEISURE

Region of Application



ITALY  
CYPRUS  
SPAIN

Sentinel mission used



S1

Copernicus Service used



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Usage Maturity Level



3