Copernicus Program: Artificial Intelligence in Cultural Heritage

Janaina Cardoso de Mello[1*]
[1]Federal University of Sergipe; [2]Department of History, Education and Human Sciences Center, (LADOC - UFS/CNPq); Aracaju, Sergipe, Brazil

This work presents satellite remote sensing research to map data to archaeological sites at risk in regions of war conflicts, supporting the Copernicus Program and the application of Artificial Intelligence to analyze the collected information. It seeks to identify the process of using digital tools to safeguard cultural heritage in the 21st century. The qualitative, exploratory, and explanatory methodology followed the bibliographic survey, as well as the handling of the Copernicus Platform for the analysis of prototyping. The analysis of case studies of Cyprus, Pakistan, and Syria establishes a digital timeline containing the impacts of deterioration of the areas for the proposition of conservation, protection, and restoration measures.
Keywords: Remote Sensing. Satellite. Artificial Intelligence. Cultural Heritage. Safeguard.

Introduction

Created for the collection and sharing of satellite and in-situ data, the Copernicus Program has favored observing the physical conditions of planet Earth. Developed within the scope of the European Union and collaborative partnerships with some Latin American countries such as Brazil, Chile, and Colombia. An agenda of satellite missions, called Sentinel, coordinated by the European Space Agency (ESA), the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU Agencies and Mercator Ocean, focuses on an aspect of observation of the Earth, atmosphere, oceans, and land cover. The images generate data for weather forecasts, land use and land cover, coastal areas, and oceans, monitoring the atmosphere. Environmental issues receive special attention in providing information on air quality, carbon emissions, and the state of the ozone layer [1].

Received on 20 December 2022; revised 18 February 2023.
Address for correspondence: Janaina Cardoso de Mello. Av. Gonçalo Rollemberg Leite, 2143/601, Ed. Itatiaia, Aracaju - Sergipe, SE- Brazil. Zipcode: 49045-280. E-mail: janainamello.ufs@gmail.com.

J Bioeng. Tech. Health 2023;6(1):45-51

The advances in artificial intelligence (AI) made possible the consolidation of the Copernicus Program since it integrates the definition of a system's ability to interpret external data correctly, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation [2]. Recent AI successes attributed to new ML techniques include building models in their internal representations. They are support vector machines (SVMs), random forests, probabilistic graphical models, reinforcement learning (RL), and deep learning neural networks (DL) [3].

Integrated with IT research and application in identifying, cataloging, and preserving cultural heritage, AI data from the Copernicus program seeks to detect archaeological objects with images obtained by satellites equipped with AI – capable of recognizing even very subtle variations in vegetation. Due to the intensity of the flow and a large amount of information and images, AI can help reduce manual work and optimize the delivery of more accurate analysis. The initiative came from the Italian Institute of Technology (IIT) in partnership with the European Space Agency (ESA) in the creation of the Cultural Landscapes Scanner (CLS) project, allowing for a broader reading of the soil and more accurate results with the help of Artificial Intelligence. The project was led by Arianna Traviglia, coordinator of the Cultural Heritage Technology Center (CCHT) of the IIT in Venice, whose research area is dedicated to technological mediation in the studies and management of cultural heritage [4].

As a general objective, it seeks to analyze the cultural heritage protection processes provided using digital technologies with satellite images. The specifics objectives of the study are:

1. To Publicize the application of digital technology resources in mapping, data collection, analysis, and protection of cultural heritage;
2. To present the potential of using the Copernicus Platform and the derived projects for applying AI in the analysis of data and images of archaeological sites;
3. To demonstrate how land surface data collected by satellite can help preserve archaeological heritage from the effects of climate degradation.

The hypothesis of the study comprises:

1. In emerging economy countries, there is still a significant lack of knowledge about the application of digital technologies in safeguarding cultural heritage;
2. There is no significant difference between prospective teachers in their awareness of healthy dietary habits concerning the following background variables;
3. Greater dissemination of the Copernicus Platform can build digital skills for future generations of archaeologists from different geographies aimed at preserving sites, avoiding the high cost of invasive prospecting;
4. Monitoring environmental impacts such as global warming provide more data requiring human and digital cognition in decision-making.

Significance of the Study

Studies of cultural heritage in the 21st century have demanded the use of digital technologies capable of aggregating information to analog procedures previously used, discovering new perspectives previously thought of, with high potential for information analysis, storage, and sharing with researchers from different geographies. Essential knowledge of ancestral civilizations comes from forgotten topographies, hidden by dense vegetation or submerged in fresh or saltwater flows (rivers, lakes, and seas) formed from melting or changing paths. These spaces, seen with the naked eye by researchers, do not show the social uses of the past, the buried artifacts, and the composition of the cultural landscape itself. The digital elevation model (DEM) is most frequently generated from airborne sensors, drones, terrestrial laser scanners, and satellite remote sensing (with an overview of the semantic categorization of potentials and practicality of such platforms for elevation data acquisition) [5]. With unprecedented data acquired continuously, the Copernicus satellite constellations provide essential information for analyzing and monitoring the Earth's surface and atmosphere [6].

The use of Copernicus data combined with AI in guaranteeing the analysis of a more significant amount of data in less time demonstrates the possibility of making the management of archaeological and cultural heritage in several countries more efficient. Studies that favor disseminating AI and remote sensing via satellite in the treatment of cultural heritage are essential to reinforce the continuity of funding and international cooperation, inspiring new research and researchers, especially in developing countries.

Review of Related Studies

Studies reveal that the use of Machine Learning (ML) techniques within Cultural Heritage (CH) is still limited [7]. As state-of-the-art techniques become popular in other fields such as CH, it is intuitive that more classical classification and regression techniques, such as Linear and Logistic regression, have a distinct and valuable application within CH. While these can be applied in conservation efforts, such as historical building integrity prediction, for example, the application of

Support Vector Machines (SVM) refined the hyper-parameter estimation to support multiple instances of learning for recognizing iconographic elements in artworks. With increasing efforts to digitize CH assets, the progression to Deep Learning models is natural, where modern data-trained models are fine-tuned to CH data.

Borie and colleagues [8] show that remote sensing archaeology in recent years has emphasized using high-precision and high-accuracy tools to achieve the detailed documentation of archaeological elements. The researchers claim that satellite remote sensing has also benefited from increased spatial and spectral resolution of the sensors, enabling the discovery and documentation of new archaeological features and sites worldwide. Thus, they studied a vast area of the Atacama Desert in Northern Chile, covering 22,500 km^2.

That airborne and spaceborne remote sensing in archaeology generates at least two critical issues for discussion: technology and visualization [9]. Technology opens new cognitive perspectives for archaeology and keeps researchers increasingly fascinated by its capabilities. Acquired data, primarily via remote sensing methods, can be studied after processing and visualizing. The research raises several issues related to the new cognitive situation of archaeologists facing the development of new technologies within remote sensing methods. These issues are discussed from ontological, epistemological, and discursive perspectives, supporting an exploration of the role of technology and visualization. Analyzing the most significant volumes of data efficiently by human operators is exceptionally challenging [10].

The English Heritage National Mapping Program (primarily aerial image interpretation) achieves a coverage rate of approximately 1 km^2 per person per day; this project has been running for over 20 years employing on average 15-20 staff, and has covered an area of 52,000 km^2 by 2012, in contrast, the Baden-Württemberg study, whilst still a primarily manual approach, took advantage of automated processing where possible, allowing an estimated coverage rate of over 35,000 km^2 by a single operator in six years. Exist an indication of the speed advantages of integrating automated processes into an analysis workflow.

With current advances in computing power, the potential to pre-process entire national datasets in weeks rather than decades is now a distinct possibility. This approach would be precious for countries that do not have many existing historical site records; a rapid Artificial Intelligence (AI) scan would provide a primary database that could be developed further as more resources become available. Due to the few time and cost overheads required for automated processing, there can be complementarity between achieving the quantity of the automated results *versus* the quality of traditionally generated databases, which can proceed to be created as usual in tandem with the automated processing. Even if imprecise, these machine learning tools could identify the more significant trends in the data, allowing human resources to be prioritized to the areas with many potential sites for detailed precision mapping. Especially when sites are under threat from development, rapid identification and mapping will give cultural heritage managers more time to act.The studies about the Copernicus platform observed that the dataflow concepts provide mechanisms to handle diverse challenges. The Copernicus architecture integrated two components aimed specifically at sampling problems: A peer-to-peer network and a workflow execution engine [11]. The software network layer handles the infrastructure and communication within the system, even as the underlying physical network change. With heterogeneous computing resources, it is portable and written in Python 2.7, available on virtually all *nix systems. Furthermore, it was designed to handle different types of network setups by using its peer-to-peer features. The network comprises three components communicating securely using Transport Layer Security (TLS).

Materials and Methods

The research on the digital technological procedures used in the satellite mapping of archaeological sites configured as cultural heritage adopted qualitative, exploratory, and explanatory procedures, based on the collection of data in books, articles, websites, and the use of the Copernicus platform.

The digital tools used in this research covered the manipulation of the Copernicus Platform, with the projection of sectorial information and the experimental treatment of the cartography inserted in the case studies.

The monitored topography includes satellite and AI digital technology projects applied to archeology in the following geographies: Cyprus, Pakistan, and Syria.

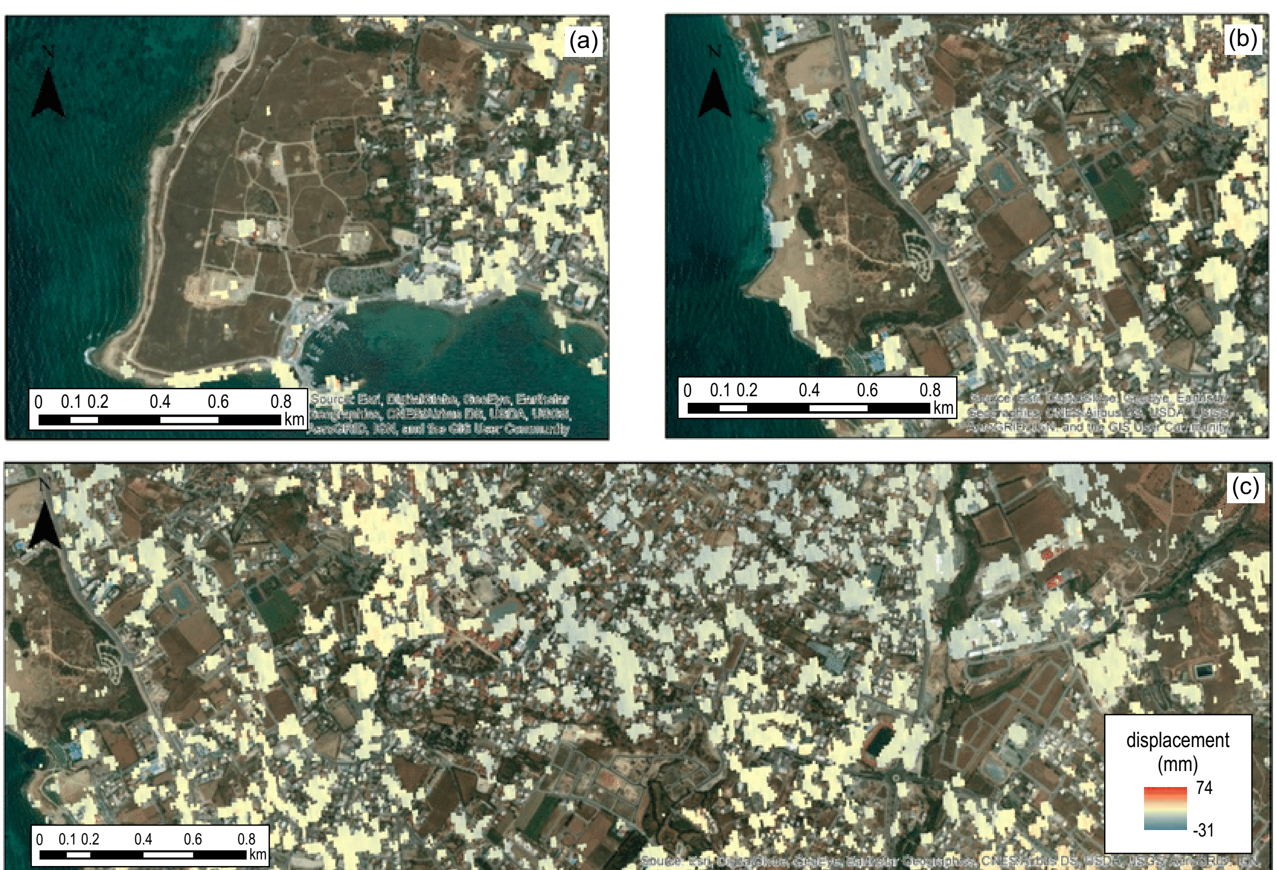
Results and Discussion

In 2015, the island of Cyprus was hit by a magnitude 5.6 earthquake. Researchers used Sentinel-1 SAR images to map two UNESCO World Heritage sites: Nea Paphos and the Tombs of the Kings (Figure 1) [12].

D-InSAR investigation was the first step to map the displacement pattern over large areas, such as the Paphos district, with cultural heritage sites, providing fast and reliable information to local stakeholders and policymakers about the hazard. Vulnerability maps were developed based on this evaluation and considering the structural stability of standing and/or buried monuments. For authors, D-InSAR processing can be part of a continuously updated risk management plan of cultural heritage sites and landscapes aligned with state-of-the-art geoinformation technologies such as those provided under the Copernicus umbrella [12].

Other researchers used data from Copernicus Sentinel-1 and Sentinel-2 to analyze the Cholistan

Figure 1. Final displacement map at (a) Nea Paphos; (b) Tombs of the Kings; and (c) the historic center of Paphos [12].



Desert area in Pakistan, historically linked to the Bronze-Age Indus Civilization, to detect archaeological mounds from this era [13]. A combination of multitemporal, multi-polarisation, and multiangle SAR bands, like multitemporal optical bands, were analyzed. The research showed more mounds over a larger area than previously recorded. Also detected were small to large mounds that suggest a continuous shift of settlements likely due to changes in the climate and hydrological network throughout history (Figure 2).

As attested in a deep study, the dataset provides a collection of Sentinel 1 and Sentinel 2 spectral signatures for mound-like archaeological features in drylands. The resulting mound locations can now be addressed regarding RF probability values [13].

The Copernicus platform services have also been used to identify areas of military conflict, terrorism, and depredation of cultural heritage, such as the geographies of Iraq and Syria.

Thus, Copernicus Optical and SAR imagery has also been used by researchers to establish a systematic monitoring tool for looting observation and prevention by detecting so-called looting pits, which typically appear as dark/black holes and can be recognized thanks to their sharp color contrast with the surrounding sand/grass surface. Similarly, another group of researchers from the European Union Satellite Centre, which implements Copernicus SEA, used satellite imagery to evaluate the extent and severity of damage on the important ancient sites of Nineveh and Nebi Yunus in Iraq, as well as looting and smuggling activities in Iraq in the context of ISIL's domination over the area. The results showed that looting activities existed even before the armed conflict. However, during ISIL's presence looting and smuggling were replaced by military and fundamentalist activities [14].

In Figure 3, the first image shows the UNESCO World Heritage Ancient City Limits of Aleppo in a 30 m resolution Global Digital Elevation Model ASTER (GDEM), indicating the Citadel's elliptical track. ASTER GDEM is a product of METI and NASA. The second photo contains the view of the walls of the Citadel from August 1, 2005 (Source: Wikimedia Commons). Finally, the third image is a view of the Citadel of Aleppo (Syria) from Sentinel-2 images acquired at very high resolution

Figure 2. Distribution of newly detected mounds about regional land cover [13].

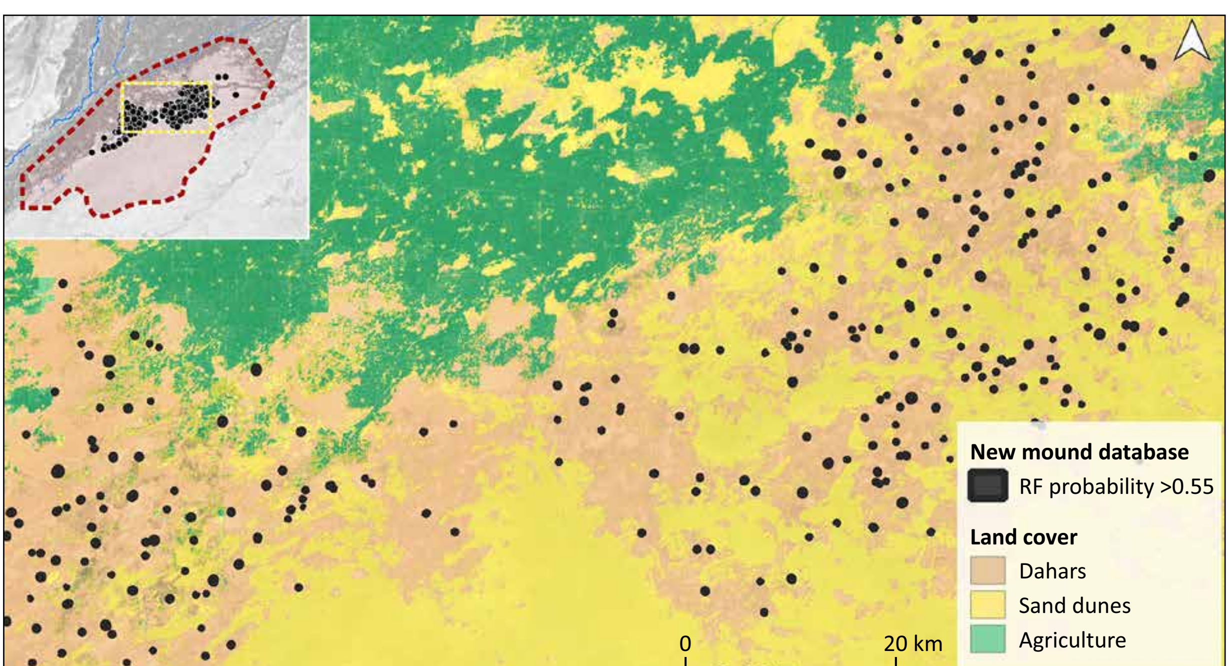
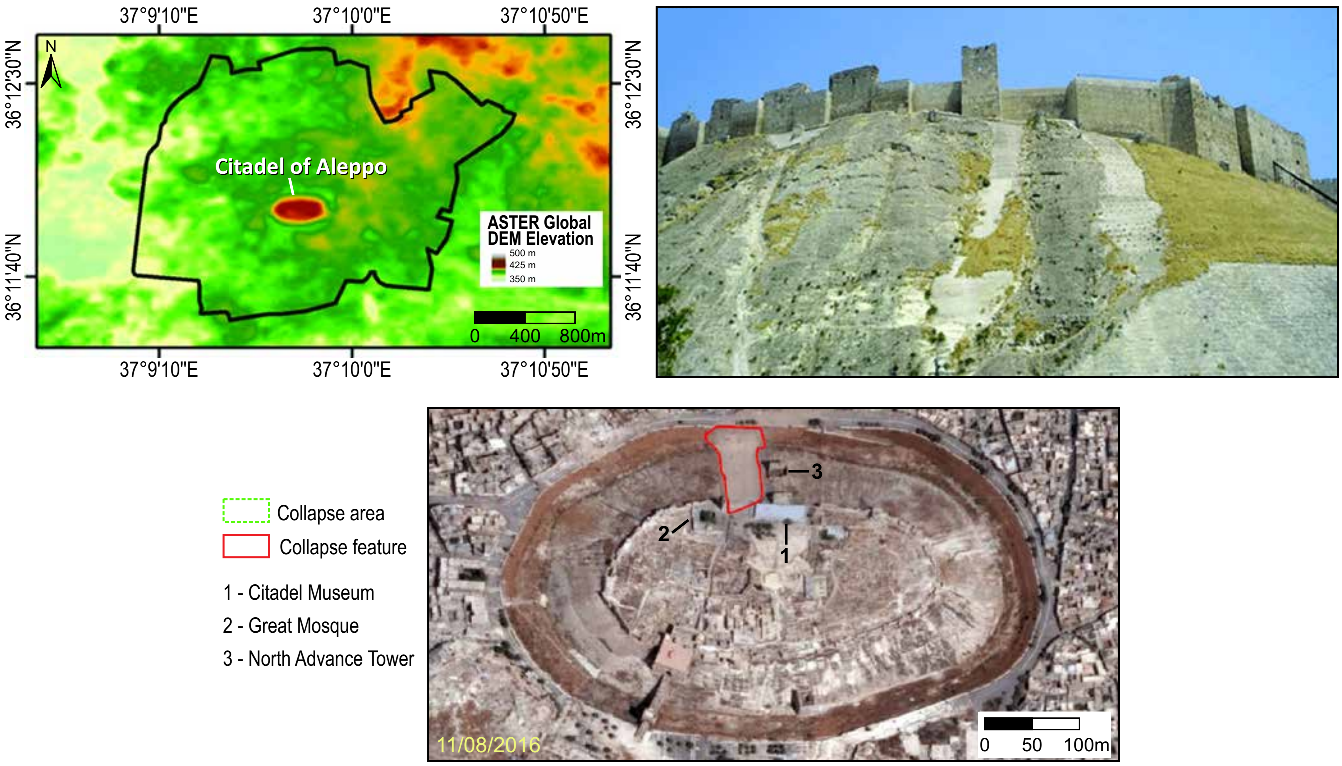


Figure 3. UNESCO World Heritage Ancient City Limits of Aleppo in three moments [15].



(VHR) Google Earth image taken on August 11, 2016. Labels and polygons indicate the area of the wall collapse that took place on August 11, 2016 (Sources: European Space Agency - ESA; Google Earth Image © 2018 DigitalGlobe) [15].

Conclusion

The study of digital satellite mapping tools with data capture of changes in topography allows applying Artificial Intelligence to quantify the information, favoring qualitative analyzes capable of defining parameters to safeguard cultural heritage in high-risk regions.

Acknowledgments

Acknowledgments to the National Council for Scientific and Technological Development (CNPq, Brazil).

References

1. RNP. Copernicus: tecnologia aliada à Observação da Terra. Available at: <https://www.rnp.br/noticias/copernicus-tecnologia-aliada-observacao-da-terra>. 2020. Accessed on May 5, 2021.
2. Haenlein M, Kaplan A. A brief history of artificial intelligence: On the past, present, and future of artificial intelligence. California Management Review, 2019.
3. Gunning D et. al. XAI-Explainable artificial intelligence. Science Robotics 2019;4(37), eaay7120.
4. Torres W. Inteligência Artificial será usada para descobrir sítios arqueológicos ocultos. Yahoo! Available at: <https://esportes.yahoo.com/noticias/intelig%C3%AAncia-artificial-ser%C3%A1-usada-para-132000792.html>. Accessed on Jun 18, 2022.
5. Tapete D et al. Regional-scale systematic mapping of archaeological mounds and detection of looting using cosmo-skymed high-resolution dem and satellite imagery. Remote Sensing 2021;13(16):1-29.
6. Guzzonato E et al. RUS Copernicus: An expert service for new sentinel data users. IOP Conference Series: Earth and Environmental Science 2020;509:1-3.

7. Fiorucci M et. al. Machine learning for cultural heritage: A survey pattern recognition letters 2020;133:102-108.
8. Borie C et al. Beyond Site Detection: The Role of Satellite Remote Sensing in Analysing Archaeological Problems. A Case Study in Lithic Resource Procurement in the Atacama Desert, Northern Chile. Remote Sensing, 2019;11(869):5-31.
9. Raczkowski W. Power and/or penury of visualizations: Some thoughts on remote sensing data and products in archaeology. Remote Sensing 2020;12(2996):33-55.
10. Gallwey J et al. Bringing lunar LiDAR back down to earth: Mapping our industrial heritage through deep transfer learning. Remote Sensing 2019;11(1994):57-78.
11. Pouya I et. al. Copernicus, a hybrid dataflow, and peer-to-peer scientific computing platform for efficient large-scale ensemble sampling. Future Generation Computer Systems 2017;71:18-31.
12. Tzouvaras M et al. The use of Sentinel-1 Synthetic Aperture Radar (SAR) images and open-source software for cultural heritage: An example from Paphos area in Cyprus for mapping landscape changes after a 5.6 magnitude earthquake. Remote Sensing 2019;11 (15):1-13.
13. Orengo HA et. al. Automated detection of archaeological mounds using machine-learning classification of multisensor and multitemporal satellite data. PNAS 2020;117(31):18240-18250.
14. Copernicus Observer. How does Copernicus help discover, monitor, and protect archaeological and cultural sites? Available at: <https://www.copernicus.eu/pt-pt/node/10702>. Accessed on Dec 19, 2021.
15. Tapete D., Cigna F. Appraisal of opportunities and perspectives for the systematic condition assessment of heritage sites with Copernicus Sentinel-2 high-resolution multispectral imagery. Remote Sensing 2018;10(4); 1-22.