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Climate Change monitoring with Art-Risk 5: New approach for environmental hazard assessment in Seville and Almería Historic Centres (Spain)

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Abstract

Currently, climate change is significantly impacting historic cities, altering energy demands, and influencing tourism patterns. In this context, the analysis of extensive datasets derived from satellite imagery offers a means to monitor the effects of climate change on both urban and territorial scales.

Art-Risk 5.0 is an open digital tool designed to easily track temperature variations, precipitation patterns, urban heat islands, and vegetation health using satellite resources. The applications in two historic cities in southern Spain, Almeria and Sevilla was analyzed to assess the impact of climate change.

The outcomes of Art-Risk 5.0 have provided valuable data for diagnosing the impact of climate change in these historic cities. The major climatic hazards identified in southern Spain are high temperatures, torrential rainfall, and droughts. Additionally, over the past 20 years, an increase in maximum temperatures and drought intensity has been observed in Sevilla and Almeria. On the urban scale, urban heat islands are concentrated in neighborhoods with limited green and blue infrastructure.

The ability to analyze time series of climate data from satellite images makes Art-Risk 5.0 an extremely useful tool for monitoring the impact of climate change and promoting sustainable adaptation policies.

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1. Introduction.

Climate change is affecting citizens and Cultural Heritage in historic cities. Increases in temperature, changes in precipitation patterns, and the occurrence of extreme weather phenomena such as heavy storms, floods, and wildfires have serious worldwide consequences (Bonazza, 2020; Cacciotti et al., 2021; Fatorić & Seekamp, 2017; Kapsomenakis et al., 2022; Sesana et al., 2018).

The impact of climate change on historic cities largely depends on the characteristics of each city and its ability to confront these threats (Bonazza et al., 2020; Crowley et al., 2022; Hofmann, 2021). For this reason, one of the main challenges for researchers is to gather information and develop efficient methods and digital tools to monitor climate hazards at the local level. Having this information is essential for developing comprehensive risk assessment. These models assess the presence of threats in the environment, the vulnerability of cities and populations, and their resilience, which is influenced by prevention and mitigation measures implemented by governments (Mendes et al., 2021). The primary advantage of these models is they enable the design of adaptation and mitigation measures tailored to the real needs and the evaluation of the effectiveness of implemented actions.

In this context, satellite resources have become a crucial and continuously expanding data source. Advances in remote sensing have significantly increased the variety of available satellite resources including multispectral images, Synthetic Aperture Radar images, estimated meteorological products, and climate reanalysis. These satellite products provide free, up-to-date, and consistent information for analyzing extensive areas over extended periods at local scale (Di & Yu, 2023).

The complexity involved in managing extensive satellite datasets has necessitated the development of new tools and methodologies, enabling cloud-based analysis. A prime example of this is Google Earth Engine (GEE) (https://earthengine.google.com/), a platform that stores satellite images collected by National Aeronautics and Space Administration (NASA), European Space Agency (ESA), and other institutions over the past 50 years (Amani et al., 2020; Gorelick et al., 2017; Kumar & Mutanga, 2018). GEE stores vast amounts of satellite imagery in cloud-based storage, ensuring efficient retrieval. Users query these datasets through a web-based platform, specifying desired parameters. The platform processes and analyzes the data in the cloud, leveraging parallel computing for rapid results. Once analysis is complete, users can visualize results online or download them for further use. This system streamlines remote sensing tasks, making large-scale analyses feasible. However, a significant drawback of GEE is its absence of a desktop interface, a feature available in other satellite analysis software such as SNAP or ArcGIS. This limitation can be overcome through the development of web-based applications designed to visualize the analyses. The creation of these applications not only aids in accessing satellite data but also streamlines the process of extracting valuable information, thus enhancing overall usability. Currently, the analysis of large volumes of data in these types of applications allows for assessing vegetation health and density (https://abocin.users.earthengine.app/view/foresthealth), sampling soil carbon presence (https://charliebettigole.users.earthengine.app/view/stratifi-beta-v21), or promoting the conservation of endangered species (https://species.mol.org/species/map/Perdix_dauurica), among many other possible applications.

Applied to risk management in historic cities and cultural landscapes the significant potential of GEE, cloud analysis, and geo-big data analysis has been emphasized (Agapiou, 2017; Cuca & Hadjimitsis, 2017; Moreno et al., 2022a). The first methods to monitor hazards related to climate change in heritage environments and assess the reliability of satellite resources are very recent (Elfadaly et al., 2022; Moreno et al., 2022b). In this context, designing digital tools in GEE allows replication of the proposed methodologies in others study cases and enhances the impact of research. An example of this is Art-Risk 5 (https://artrisk50.users.earthengine.app/view/art-risk5), a digital tool that calculates statistical maps and sequential graphs with precipitation, temperature, and vegetation values using the methodology for analyzing series of satellite images proposed by Moreno et al. (2023b; 2022b).

This study aims to describe the architecture and functioning of the Art-Risk 5.0 system, as well as to assess its applicability as a tool for monitoring the climate impact at a local scale in historic cities. The analyses carried out in Art Risk 5.0 have aimed to address three key aspects: 1) Identify most hazardous areas in southern Spain based on temperature and precipitation; 2) Graph meteorological values of temperature and precipitation from the last 20 years in Seville and Almeria; 3) Monitoring the presence of Urban Heat Island (UHI) in Seville and Almeria.

2. System Architecture of Art-Risk 5.0 and methodology

Art Risk 5.0 (https://artrisk50.users.earthengine.app/view/art-risk5), current register number: IPRUPO2023-010) is a digital application that leverages the statistical calculation capabilities of GEE to compute descriptive statistics, including means, medians, standard deviations, maximums, minimums, and percentiles, based on pixel values within a time series of satellite images. Through the utilization of reducers, functions, and map algebra, it facilitates the analysis of meteorological image datasets to derive climatic maps and evaluate the environmental hazard level.

Art Risk 5.0 facilitates map creation across four key categories: 1) Precipitation: satellites like Persiann-Climate Data Record CDR (with daily data intake since 1982 and coverage extending from 60° S–60°N Latitude and 0°–360° longitude at 0.25° spatial resolution) and Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) (with daily data intake from 1981 and a spatial resolution of 0.05 degrees) are utilized. Calculations provided include summation, maximum, minimum, and the Standardized Precipitation Index (SPI). 2) Land surface temperature (LST): Moderate Resolution Imaging Spectroradiometer (MODIS. intake of data daily since 2000. Spatial resolution of 250-500-1000 meters) is used to produce maps of daytime, nighttime, and differential temperatures, as well as a frost count. 3) Urban heat islands are identified using Landsat 8 (revisit time of 16 days, launched in 2013. Spatial resolution of 30-100 meters), highlighting LST index percentiles. 4) Vegetation health is gauged with MODIS on board of Terra and Aqua satellites, and Sentinel-2 (revisit time of 5 days. Spatial resolution of 10-20-60 meters), with a focus on Normalized Difference Vegetation Index (NDVI), percentiles post cloud corrections.

Art-Risk 5.0 has a user-friendly interface (Fig. 1) divided into two main sections: a control panel on the left, and an interactive map on the right. Within the control panel, divisions are made for period selection, climatic variable choice, and area of interest specification. The analysis period is determined through three inputs: year, starting month, and ending month, with constraints ensuring no selection before 2002. Once set, between one to three climatic variables can be chosen, and, if required, a preferred satellite is selected. The area of interest is defined either by country selection from a dropdown or by drawing on the interactive map. All countries located between latitudes 60°S and 60°N can be selected, which includes most European, Asian, African, American, and Australian countries. Now, it is available in Spanish and English version.

Upon selection completion and the "Calculate" button's activation, maps are generated at the bottom right. A section emerges to the map's left for map downloads of different variables as geotiff files. When clicked within the designated area, graphs depicting the climatic variable's annual progression from 2002 are displayed. An arrow icon on each graph allows for viewing in a new tab, with multiple download formats available (*csv, *svg, and *png).

In the application to Seville and Almeria downtown, Art Risk 5.0 enabled the mapping of accumulated precipitation values, extreme rainfall events, drought, maximum temperatures, and temperature fluctuations in southern Spain, as well as the generation of trend graphs depicting maximum temperatures and drought values recorded between 2020 and 2022 in the historic cities of Sevilla and Almeria. The produced cartography was downloaded and migrated to a GIS for normalization based on a traffic light-type hazard scale.

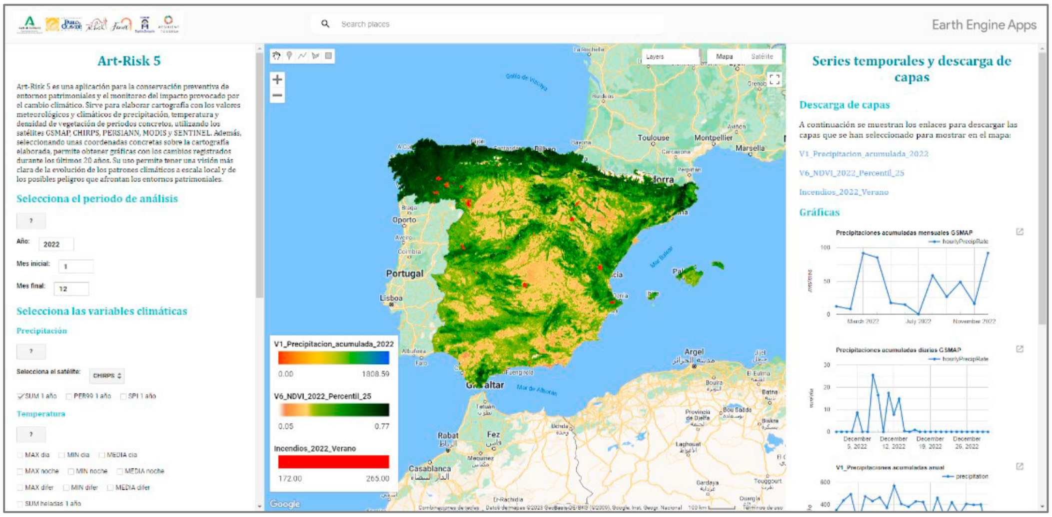

Fig. 1. Art Risk 5 interface (https://artrisk50.users.earthengine.app/view/art-risk5)

3. Climatic hazards and urban heat island in Southern Spain: Sevilla and Almeria

The maps obtained from Art-Risk 5.0 provide a visual representation of the climatic conditions in southern Spain and level of hazard of various meteorological factors. Figure 2 shows maps generated to assess maximum (a) and temperature fluctuations (b) based on MODIS LST images from 2022. All territory exhibits high hazard levels due to elevated LST, and particularly the Guadalquivir River valley in the centre of the region (Fig 2.a). Graphs (plots in Fig 2.a) show the same statistical calculations for the years between 2000 and 2022 for Seville and Almeria and confirm an increase in maximum temperatures in both cities, with Sevilla experiencing a more pronounced rise. Along the coastal areas, including Almeria, the moderating effect of the sea acts as a thermal regulator, reducing maximum temperatures and increasing minimums, thereby diminishing thermal oscillations (Fig 2.b).

Figure 3 presents the results of calculations from CHIRPS for accumulated precipitation (mm), intensity of extreme rainfall (mm), and occurrence of droughts (SPI) throughout 2022. In 2022, the Southwest region experienced more intense extreme precipitation (Fig 3.b), while the eastern region was the most affected by recurrent droughts (Fig 3.c). The geographical location and topography differences between Sevilla and Almeria result in distinct climatic peculiarities. Sevilla's proximity to the Guadalquivir River and its flat topography contribute to a continental Mediterranean climate, while Almeria exhibits an arid and desert climate. In this context, graphs (plots in Fig 3.c) illustrate SPI values for the past 20 years (2002-2021) in Sevilla and Almeria, indicating an increase in severity of droughts in recent years.

Figure 4 shows the local-scale impact of high temperatures recorded in Seville and Almeria in 2022, and the location of UHI according to Landsat images. UHIs are warmer microclimates resulting from factors such as building materials that absorb and retain heat, heat emissions from human activities like traffic and industry, poor air circulation, and a lack of vegetation in specific city areas. In Seville (Figure 4.a), UHIs are primarily found in the eastern neighbourhoods, which are distant from the river and green infrastructure, where heat-absorbing and heat-retaining construction materials are predominant. The city of Almeria has a larger urban area affected by UHIs, especially in neighbourhoods distant from the coast. The figures obtained for both case studies (Fig. 4.a and Fig. 4.b) highlight the essential role played by green and blue infrastructures in reducing high temperatures and creating cooler and healthier urban environments. This is mainly because rivers, coast, parks and gardens promote air circulation, provide shade, and have a cooling evaporative effect on the surrounding air (Veerkamp et al., 2021).

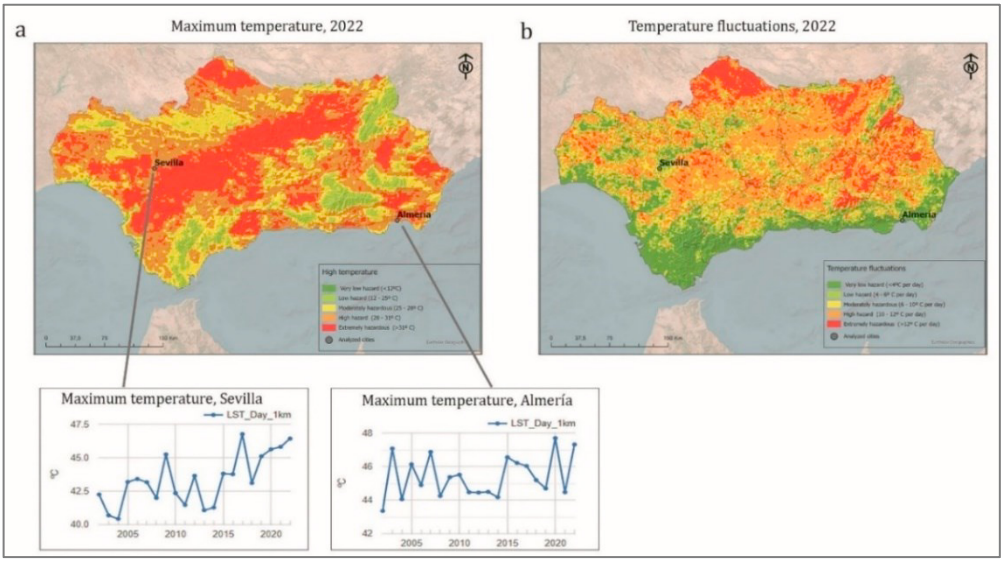

Fig. 2. Hazards by temperatures in southern Spain: (a) Map of maximum temperatures in 2022, and graph with maximum temperatures between 2000 and 2022 in Seville and Almeria; (b) Map of thermal fluctuations in 2022. Data obtained from Art-Risk 5.

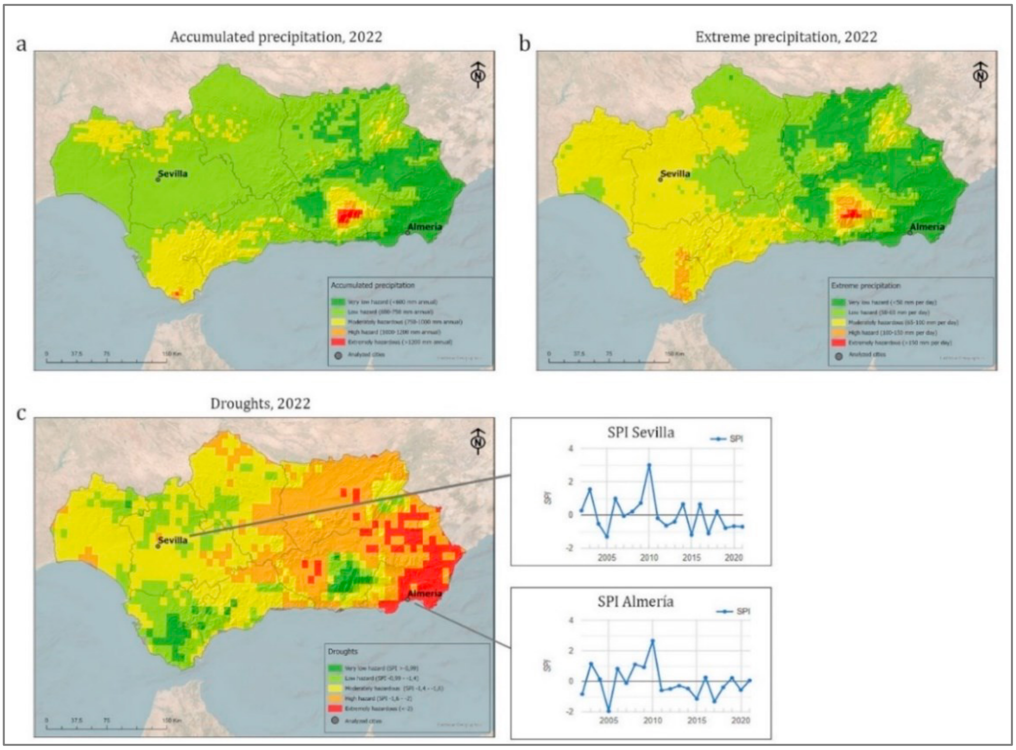

Fig. 3 Hazards by precipitation in southern Spain: (a) Map of accumulated precipitation in 2022; (b) Map of extreme precipitation in 2022; (c) Map of Droughts in 2022 and graph with annual SPI values between 2000 and 2022 in Seville and Almeria. Data obtained from Art-Risk 5.

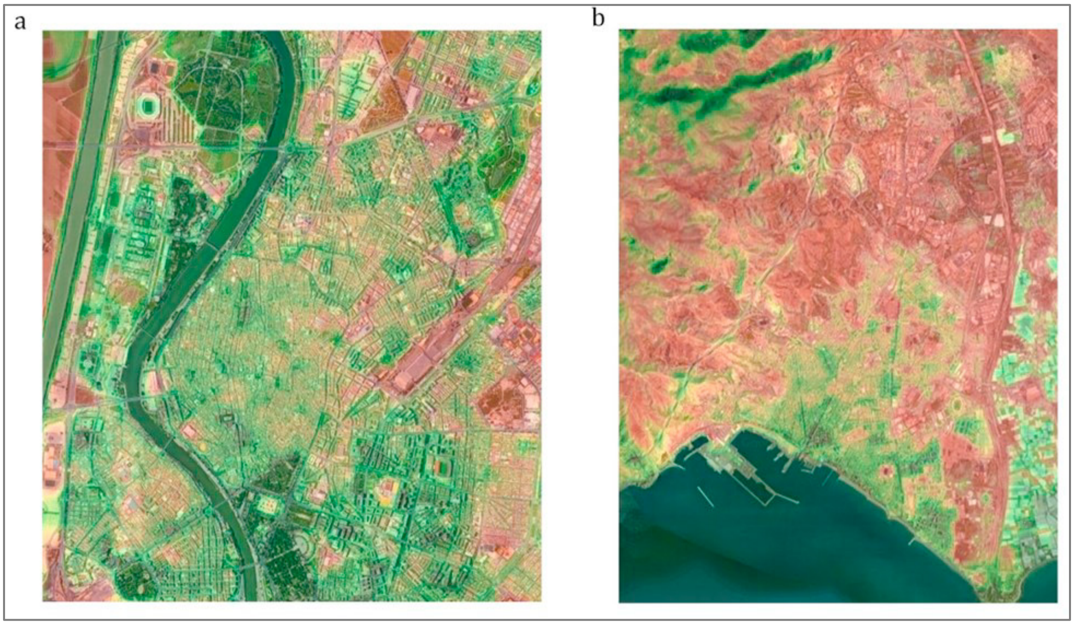

Fig.4: UHIs. (a) Seville; (b) Almeria. Green: cooler areas, red: warmer areas. Data obtained from Art-Risk 5.

4. Discussion

In this contribution an example of the effectiveness of ArtRisk 5.0 in visualizing precipitation and temperature hazards in Southern Spain, detecting the changes occurred in the last 20 years in Sevilla and Almeria, and in identifying the urban areas most affected by UHIs at a local scale, has been proved.

Cartography indicate that high temperatures, intense rainfall, and drought contribute to a high level of climatic hazard across much of southern Spain. This climate type is characterized by long, hot summers with temperatures often exceeding 30°C. In contrast, winters are mild, with temperatures rarely dropping below freezing. Precipitation is limited, typically concentrated during the autumn and winter months, often leading to the occurrence of heavy rainfall (Ministerio de Medio Ambiente, 2011).

The generated graphs revealed an increase in maximum temperature values in Seville and Almeria over recent years. These data suggest an alarming trend towards warmer and drier climatic conditions in the region, which could have significant consequences for the environment, cultural heritage, and society. The rise in droughts in Seville and Almeria align with other climate projections. Fig. 5 presents the Intergovernmental Panel on Climate Change (IPCC) forecast under the best-case scenario (SSP1-2.6), enabling a correlation of the recorded values in southern Spain with global precipitation climate trends. Even if the Paris Agreement (United Nations, 2015) is adhered to and greenhouse gas emissions are significantly reduced, changes in precipitation patterns are anticipated on a global scale (Masson-Delmotte et al., 2021; P.R. Shukla et al., 2020). According to IPCC forecast, an increase in droughts (yellow areas) is expected in all the Mediterranean basin, Central America, South Africa, and South America. Meanwhile, increased precipitation (blue areas) in Northern Europe, North America, Asia, and Africa heightens the risk of flooding in numerous historic cities.

In this context, the Art-Risk 5 tool facilitates the monitoring of climate change impacts at a local scale, enabling the generation of climatic hazard maps that can be seamlessly integrated into existing GIS models employed for heritage asset assessment and urban risk evaluation (Moreno et al., 2022c). Consequently, the utilization of Art-Risk 5 proves to be of substantial utility for historic city administrators.

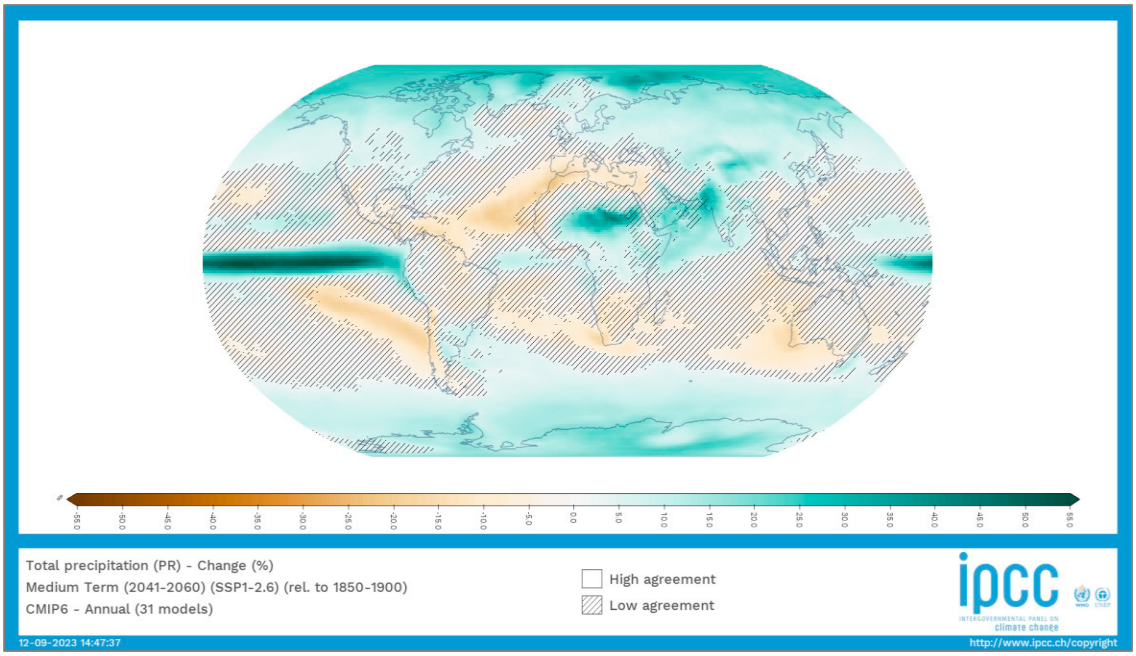

Fig.5. Forecast of mid-term precipitation patterns according to an emission scenario SSP1-2.6. Map obtained from the IPCC Working Group I Interactive Atlas (https://interactive-atlas.ipcc.ch/)

Further studies to integrate methodologies based on artificial intelligence into Art-Risk 5.0 could offer significant advantages. This combination could allow a retrospective assessment of critical environmental patterns using historical satellite imagery. Furthermore, the use of advanced algorithms would enhance analytical and pattern detection capabilities, expediting data processing and enabling real-time monitoring of environmental change impacts. This facilitates the identification of the most effective measures for climate protection and mitigation, thus contributing to well-informed decision-making in the context of sustainable management practices for historic cities.

5. Conclusions

Art-Risk 5.0 tool allowed to assess satellite data spanning up to 20 years, calculate climate statistics and maps of hazards in Seville and Almeria (Spain). This enabled to assess the level of hazard based on precipitation and temperature in southern Spain, with a focus on two historic cities: Almeria and Seville.

The results indicate that high temperatures, droughts, and heavy rainfall were the most hazardous factors. At the urban scale, the analysis of UHIs reveals that the presence of green and blue infrastructures in cities plays a protective role against high temperatures. Furthermore, analysis of satellite data from 2002-2021 revealed an increase in maximum temperatures and drought intensity in recent years in both Seville and Almeria. These results are aligned with the climate projections of the IPCC, which anticipate a continued rise in temperatures and the frequency of droughts between 2041 and 2060.

The situation observed in Southern Spain could have serious consequences for many historic cities if mitigation and adaptation measures to climate change are not taken. In this context, the use of digital tools like Art-Risk 5.0 by the urban managers allows and early anticipation and detection of climate and environmental changes, facilitating informed decision-making regarding available resources and the implementation of climate adaptation and mitigation measures. Additionally, Art-Risk 5.0 could help to assess the effectiveness of actions taken and contributes to raising awareness and promoting public understanding of climate issues.

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References

Agapiou, A. (2017). Remote sensing heritage in a petabyte-scale: satellite data and heritage Earth Engine© applications. *International Journal of Digital Earth*, *10*(1), 85–102. https://doi.org/10.1080/17538947.2016.1250829

Bonazza., A. (2020). *ProteCHt2Save - Web GIS Tool for Risk Mapping*. https://www.protecht2save-wgt.eu/

Bonazza, A., Sardella, A., & Nuntiis, P. De. (2020). Strengthening resilience of cultural heritage at risk in an extreme changing environment. *EGU General Assembly Conference Abstracts*, *2*, 22398.

Amani, M., Ghorbanian, A., Ahmadi, S. A., Kakooei, M., Moghimi, A., Mirmazloumi, S. M., Moghaddam, S. H. A., Mahdavi, S., Ghahremanloo, M., Parsian, S., Wu, Q., & Brisco, B. (2020). Google Earth Engine Cloud Computing Platform for Remote Sensing Big Data Applications: A Comprehensive Review. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, *13*, 5326–5350. https://doi.org/10.1109/JSTARS.2020.3021052

Cacciotti, R., Kaiser, A., Sardella, A., De Nuntiis, P., Drdácký, M., Hanus, C., & Bonazza, A. (2021). Climate change-induced disasters and cultural heritage: Optimizing management strategies in Central Europe. *Climate Risk Management*, *32*, 100301. https://doi.org/10.1016/J.CRM.2021.100301

Crowley, K., Jackson, R., O'Connell, S., Karunarthna, D., Anantasari, E., Retnowati, A., & Niemand, D. (2022). Cultural heritage and risk assessments: Gaps, challenges, and future research directions for the inclusion of heritage within climate change adaptation and disaster management. *Climate Resilience and Sustainability*, *1*(3), e45. https://doi.org/10.1002/CLI2.45

Cuca, B., & Hadjimitsis, D. G. (2017). Space technology meets policy: An overview of Earth Observation sensors for monitoring of cultural landscapes within policy framework for Cultural Heritage. *Journal of Archaeological Science: Reports*, *14*, 727–733. https://doi.org/10.1016/j.jasrep.2017.05.001

Di, L., & Yu, E. (2023). *Remote Sensing Big Data*. https://doi.org/10.1007/978-3-031-33932-5

Elfadaly, A., Abutaleb, K., Naguib, D. M., & Lasaponara, R. (2022). Detecting the environmental risk on the archaeological sites using satellite imagery in Basilicata Region, Italy *The Egyptian Journal of Remote Sensing and Space Science, 25(1), 181-193.*. https://doi.org/10.1016/j.ejrs.2022.01.007

Fatorić, S., & Seekamp, E. (2017). Are cultural heritage and resources threatened by climate change? A systematic literature review. *Climatic Change*, *142*(1–2), 227–254. https://doi.org/10.1007/s10584-017-1929-9

Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., & Moore, R. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. *Remote Sensing of Environment*, *202*, 18–27. https://doi.org/10.1016/j.rse.2017.06.031

Hofmann, S. Z. (2021). 100 Resilient Cities program and the role of the Sendai framework and disaster risk reduction for resilient cities. *Progress in Disaster Science*, *11*, 100189. https://doi.org/10.1016/J.PDISAS.2021.100189

Kapsomenakis, J., Douvis, C., Poupkou, A., Zerefos, S., Solomos, S., Stavraka, T., Melis, N. S., Kyriakidis, E., Kremlis, G., & Zerefos, C. (2022). Climate change threats to cultural and natural heritage UNESCO sites in the Mediterranean. *Environment, Development and Sustainability*, 1–26. https://doi.org/10.1007/S10668-022-02677-W/FIGURES/11

Kumar, L., & Mutanga, O. (2018). Google Earth Engine applications since inception: Usage, trends, and potential. *Remote Sensing*, *10*(10). https://doi.org/10.3390/rs10101509

Masson-Delmotte, V., Zhai, P., Chen, Y., Goldfarb, L., Gomis, M. I., Matthews, J. B. R., Berger, S., Huang, M., Yelekçi, O., Yu, R., Zhou, B., Lonnoy, E., Maycock, T. K., Waterfield, T., Leitzell, K., & Caud, N. (2021). *Climatic Change 2021: The Physical Science Basis. Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change Edited by* (IPCC (ed.)). www.ipcc.ch

Mendes, J. M., Kalonji, G., Jigyasu, R., & Chang-Richards, A. (2021). Strengthening Disaster Risk Governance to Manage Disaster Risk. In *Strengthening Disaster Risk Governance to Manage Disaster Risk*. Elsevier. https://doi.org/10.1016/B978-0-12-818750-0.09991-8

Ministerio de Medio Ambiente, y M. R. y M. A. E. de M. (2011). Iberian Climate Atlas, Gobierno de España.

Moreno, M., Ortiz, R., & Ortiz, P. (2023a). Analysis of the impact of green urban areas in historic fortified cities using Landsat historical series and Normalized Difference Indices. *Scientific Reports*, 13(1), 8982

Moreno, M., Bertolín, C., Arlanzón, D., Ortiz, P., & Ortiz, R. (2023b). Fire, Climate Change and Cultural Landscapes in the Mediterranean Basin: An Analysis of Fires Regime in Southern Spain by Remote Sensing. *Heliyon*, *2*(3), 54–59.

Moreno, M., Ortiz, R., & Ortiz, P. (2022a). Review of satellite resources to assess environmental threats in rammed earth fortifications. *Ge-Conservacion*, *21*(1), 309–328. https://doi.org/10.37558/gec.v21i1.1132

Moreno, M., Bertolín, C., Ortiz, P., & Ortiz, R. (2022b). Satellite product to map drought and extreme precipitation trend in Andalusia, Spain: A novel method to assess heritage landscapes at risk. *International Journal of Applied Earth Observation and Geoinformation*, *110*, 102810. https://doi.org/10.1016/J.JAG.2022.102810

Moreno, M., Ortiz, R., Cagigas-Muñiz, D., Becerra, J., Martin, J. M., … & Ortiz, P. (2022c). ART-RISK 3.0 a fuzzy—based platform that combine GIS and expert assessments for conservation strategies in cultural heritage. *Journal of Cultural Heritage*, 55, 263-276.

O'Neill, B. C., Oppenheimer, M., Warren, R., Hallegatte, S., Kopp, R. E., Pörtner, H. O., Scholes, R., Birkmann, J., Foden, W., Licker, R., MacH, K. J., Marbaix, P., Mastrandrea, M. D., Price, J., Takahashi, K., Van Ypersele, J. P., & Yohe, G. (2017). IPCC reasons for concern regarding climate change risks. *Nature Climate Change* 1(1), 28–37. https://doi.org/10.1038/nclimate3179

P.R. Shukla, J. Skea, R. Slade, S. Connors, Vyas, E., & Huntley k. (2020). *An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* (IPCC (ed.)).

Sesana, E., Gagnon, A. S., Bertolin, C., & Hughes, J. (2018). Adapting Cultural Heritage to Climate Change Risks: Perspectives of Cultural Heritage Experts in Europe. *Geosciences, 8*(8), 305. https://doi.org/10.3390/GEOSCIENCES8080305

United Nations. (2015). *Paris Agreement*. https://unfccc.int/sites/default/files/spanish_paris_agreement.pdf

Veerkamp, C. J., Schipper, A. M., Hedlund, K., Lazarova, T., Nordin, A., & Hanson, H. I. (2021). A review of studies assessing ecosystem services provided by urban green and blue infrastructure. *Ecosystem Services*, *52*, 101367. https://doi.org/10.1016/J.ECOSER.2021.101367