Interreg

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CAMPUS

# D.1.4.1 Monitoring System Tool Template Guidelines

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# Introduction to the project

The CAMPUS project addresses the challenges posed by climate change to UNESCO sites, with a particular focus on natural and cultural heritage sites located in Italy and Croatia. Issues such as sea level rise, increasing temperatures, and extreme weather events threaten the conservation of universal heritage. The establishment of monitoring systems and site-specific adaptation plans has therefore become a critical priority.

The primary objective of this project is to develop a shared cross-border framework for monitoring systems, action plans, and climate adaptation measures, aiming to preserve the Outstanding Universal Values (OUV) of the involved UNESCO sites.

The project engages several public and private entities:

- Municipality of Ferrara (Lead Partner) – Italy
- IUAV University of Venice – Italy
- Municipality of Monte Sant'Angelo – Italy
- Veneto Regional Park Authority of the Po Delta – Italy
- Development Agency of Lika-Senj County (LIRA) – Croatia
- Regional Development Agency of Split-Dalmatia County (RERA) – Croatia

Additionally, the Plitvice Lakes National Park and the City of Trogir are involved as associated partners.

The project is composed by 3 Work Packages:

**WP1: Climate change scenarios of the UNESCO sites and risk assessment**

- A.1.1: Analysis of potential impact and data collection

- A.1.2: Vulnerability and risk analysis
- A.1.3: Climate change risk scenarios
- A.1.4: Creation of a cross-border Monitoring System Tool template
- A.1.5: UNESCO sites stakeholders and community perception

**WP2: UNESCO Climate Change Adaptation Plans**
- A.2.1: Activation of "Living Labs" to engage local communities in plan development
- A.2.2: Creation of a UNESCO sites Cross-Border Climate Change Adaptation Guidelines
- A.2.3: Design of UNESCO sites Climate Change Adaptation plans and measures
- A.2.4: Organisation of local integration workshops
- A.2.5: Organisation of Regional Conferences

**WP3: UNESCO Climate Change Adaptation Countermeasures**
- A.3.1: Implementation of NBS and natural restoration solutions
- A.3.2: Implementation of building restoration solutions
- A.3.3: Implementation of light infrastructure solutions
- A.3.4: Assessment of the adopted Climate Change countermeasures in UNESCO sites
- A.3.5: Awareness-raising activities in primary and secondary schools

CAMPUS project aims to provide practical solutions to address climate change in the involved UNESCO sites. One of the key outcomes will be the creation of a cross-border monitoring system to assess the vulnerability, sensitivity, and resilience of these sites using indicators aligned with UNESCO guidelines. Common guidelines will be developed to support local management plans, improving the response capacity of authorities. Concrete measures will be implemented, including nature-based interventions such as habitat restoration and control of invasive species, restoration of historical buildings, and the construction of light infrastructure. The project will actively engage local communities through Living Labs, workshops, and conferences, and will promote climate risk awareness through campaigns targeting students. The collaboration between Italian and Croatian partners will ensure the sharing of methodologies and best practices, contributing to the preservation of the cultural and natural value of UNESCO sites and supporting their sustainable management.

**Description of Activity 1.4**

*As set out in the Application Form (pp. 51–52), Activity A.1.4 aimed to create a shared template for the monitoring of climate risks at the UNESCO sites involved. The activity built on the results of the previous analyses (Activities A.1.1, A.1.2, and A.1.3), translating the methodological framework into an operational tool designed to be used by site managers even beyond the duration of the project.*

*Starting from the indicators already systematised in Deliverable D1.3.2, the activity pursued two objectives: (1) to provide a solid and comparable information base on the priority risks that each site will have to face, useful for guiding the drafting of the Adaptation Plans (WP2); and (2) to structure a permanent monitoring system capable of continuously collecting and updating relevant data, calibrated to the specificities of natural and cultural sites.*

# Introduction to the deliverable

This deliverable documents the formulation and development of a cross-border monitoring tool for climate risks affecting the UNESCO sites involved, aimed at supporting site managers in the structured collection of updated data on vulnerability, management, and adaptation.

The document follows a procedural and methodological structure:
- The first part presents the theoretical framework underpinning the proposal, outlining the key concepts in line with international recommendations on conservation and climate change adaptation (UNESCO, IPCC, IUCN);
- The second part provides a detailed explanation of the structure and logic of the monitoring template, clarifying its objectives, components, compilation procedures, and adaptability criteria.

The main objective of the deliverable is to ensure that the tool is clear, applicable, and useful within the context of site planning and management, facilitating its adoption both at the local level and for official reporting to the UNESCO system.

# Conceptual-theoretical framework

From a methodological perspective, international literature (UNESCO 2004; IPCC 2022) emphasises that an effective monitoring system must be capable of capturing the multidimensional complexity of climate change-related risks, particularly in the context of cultural and natural heritage. To achieve this, it is essential to integrate climatic, ecological, institutional, and participatory indicators, which can reflect not only the trends in environmental variables but also the response capacity of governance systems and local communities.

This approach is in line with the guidelines of IUCN and ICCROM, which recommend the use of mixed indicators—both **qualitative and quantitative**—that can be periodically updated. The integrated use of indicators of different types allows for a more comprehensive understanding of the complexity of UNESCO sites, particularly in natural contexts characterised by ecological, climatic, and socio-institutional dynamics.

Quantitative indicators provide measurable and replicable data, useful for comparative analyses and time series (e.g. temperature, precipitation, number of extreme events). Qualitative indicators, on the other hand, allow for the documentation of dimensions that are more difficult to express numerically, such as the quality of governance, the level of community engagement, risk perception, or social cohesion.

The managing authorities of UNESCO sites have the responsibility of guaranteeing a continuous monitoring of the conservation status of the heritage, in line with the World Heritage Centre's *Operational Guidelines*. This monitoring is implemented mainly through official instruments such as::

- **Periodic Reporting** is the primary long-term monitoring tool of the UNESCO system. Mandatory every six years for all inscribed sites, it serves to standardize the updating of the site's conservation status, management practices, protection measures, and any ongoing or potential threats. The report also includes an assessment of governance, the effectiveness of implemented policies, and compliance with the inscription criteria. The objective is to ensure transparency, facilitate comparison across regions, and promote continuous improvement.
- **Management Plan Review** is the strategic reference document for site management. UNESCO recommends its revision at least every five years in order to incorporate new

scientific knowledge, updated regulatory tools, or emerging risks, such as those related to climate change. An outdated plan may prove inadequate in defining management priorities and conservation measures.

- **State of Conservation (SoC) Reporting** is activated at the request of the World Heritage Committee in the presence of specific and serious threats that may compromise the Outstanding Universal Value (OUV). This report, which is more technical and focused, allows for a detailed description of the identified issues, the mitigation measures adopted, and their level of effectiveness. In particularly critical cases, the State of Conservation (SoC) report may be requested annually, enabling close monitoring and the potential inscription of the site on the List of World Heritage in Danger.
- **Reactive Monitoring** is an emergency monitoring tool, activated in response to sudden events or environmental, social, or political crises (such as natural disasters, armed conflicts, fires, floods). It enables UNESCO to rapidly receive reliable information from managing authorities, assess the extent of the damage, and implement any necessary recommendations or corrective actions.

The variety of tools provided by the UNESCO system reflects the need to collect information encompassing the full spectrum of dimensions that define a site's vulnerability: not only environmental and climatic data but also legal, planning, management, and social aspects. In this context, monitoring cannot be understood as a mere technical activity, but rather as a complex process requiring an integrated and systemic reading of the territory and its evolving dynamics.

# Monitoring template development

Precisely to address this need, the CAMPUS project has developed a monitoring tool designed to complement and strengthen the official mechanisms promoted by the World Heritage Centre. The developed template does not aim to replace existing tools such as the Periodic Reporting, State of Conservation, or Management Plans, but rather to support their compilation, facilitate the continuous updating of information, and enhance site managers' capacity to proactively address the challenges posed by climate change.

The CAMPUS monitoring template has been designed as an operational platform, flexible and adaptable to diverse contexts. Building on the indicators systematized in deliverable D1.3.2, the template translates the interdisciplinary knowledge produced within the project into a practical tool that is easily usable by local managers. Its structure is intended to allow the systematic and comparable input of updated data on climate vulnerability, conservation status, and site response capacity, thereby providing a dynamic and verifiable overview over time.

Organized into thematic modules and comprising both mandatory and optional indicators, the template enables coherence based on site typology (natural, cultural, or mixed) without compromising methodological consistency. This makes it a useful tool not only for the regular management of sites but also for standardizing data at local, national, and transboundary levels, fostering comparison among case studies and the sharing of good practices.

In addition to improving the quality and accessibility of information, the monitoring template contributes to strengthening adaptive management based on the capacity to detect signals of change and respond promptly and thoughtfully. In this regard, it represents an opportunity to **integrate heritage conservation policies with climate adaptation strategies**, enhancing the active role of site managers and promoting governance models that are more resilient, inclusive, and oriented towards the long term.

The CAMPUS monitoring template was designed to address these needs, organized into thematic sections that reflect the classification of indicators defined in D1.3.2:

- **Management and procedural conformance indicators for Unesco sites**
- **Site design indicators**
- **Legal and institutional indicators**
- **Socio-institutional indicators**
- **Indicators for vulnerabilities related to climate change impacts**
- **Indicators for vulnerabilities related to the characteristics of natural and built sites**

To ensure flexible and adaptable monitoring across different contexts, the template is proposed to be structured into:

- A minimum set of ***mandatory*** **indicators**, representing a core group of parameters common to all UNESCO sites, designed to ensure a homogeneous comparative baseline. It includes climatic measures (such as average temperatures and frequency of extreme weather events), basic ecological indicators (such as vegetation cover and air quality), and fundamental management aspects (for example, the existence and updating of the Management Plan), selected based on the standardized analysis conducted in activities 1.1 and 1.3.
- A set of ***specific mandatory*** **indicators**, which integrates the common core with tailored metrics based on the site typology—natural, cultural, or mixed—in order to precisely identify vulnerabilities and potentials: for natural sites, key species and hydrogeological fragilities are considered; for cultural sites, visitor flows, conservation status of monuments, and restoration interventions; while for mixed sites, both profiles are combined, measuring human-environment interactions (such as the impact of tourism on habitats), always aligned with the systematization presented in D1.3.2.
- An ***optional*** **set of indicators** that offers maximum flexibility, allowing each site to include additional metrics not covered by the standardized analysis conducted in activities 1.1 and 1.3. These measurements, defined directly by site managers during the Living Labs, may address aspects such as local community engagement, seasonal tourism occupancy rates, or specific water quality parameters, responding to emerging challenges or strategic priorities identified in the territory.

**Structure and format of the Monitoring Tool**

The monitoring tool is provided as a .docx document, designed to be fully fillable and usable offline. The file enables UNESCO site managers to systematically input qualitative and quantitative information, data, and assessments, with the aim of monitoring the site's evolution over time regarding climate vulnerability and adaptive management capacity.

As previously described, the structure of the tool reflects the thematic organization of the indicators systematized in deliverable D1.3.2 and is divided into main sections, each comprising a series of items corresponding to individual indicators. Each indicator is presented in a standardized format and organized according to a modular logic that facilitates readability and completion.

Each item is equipped with a smart chip, an interactive graphical container designed according to the type of expected data:

- Text boxes for free-text input of descriptions;
- Numeric fields for entering numerical data such as values;
- Checkboxes for dichotomous responses (e.g., yes/no);
- Dropdown menus for selecting predefined options or scaled assessments (from 1 to 5), useful for comparability and standardization;
- Upload boxes for inserting links to any attachments.

Below the smart chip, a detailed description of the indicator is provided, structured into three fundamental components:

- **Content**: precisely defines what the indicator measures;
- **Instructions for data entry**: provides guidance on where to source the data (e.g., official documents, climate data, management reports) and how to enter it correctly;
- **Relevance**: explains the interpretative value of the indicator, illustrating its importance for climate monitoring and adaptive management.

This structure is designed to simplify data entry for site managers, even in the absence of advanced technical skills, while promoting a methodologically rigorous and replicable approach. The variety of formats and accompanying explanatory text ensure accessibility, transparency, and consistency in data collection, valuing both official sources and situated knowledge. Consequently, the tool functions as a smart data input matrix that integrates data collection, interpretative guidance, and user-friendliness, serving as a bridge between technical analysis and daily site management, in line with international standards and local needs.

The content structure of the monitoring template is presented as follows:

# References

IPCC. (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. DOI: 10.1017/9781009325844

UNESCO World Heritage Centre. (2004). Monitoring World Heritage (World Heritage Papers No. 10). Paris: UNESCO. Available at: https://whc.unesco.org/en/series/10

| General information for completion | Assessments methods | |
|---|---|---|
| Site name | Text box | Text |
| Identification number (WHC ID) | Numeric field | n. |
| Date of inscription | Checkbox | ☐ |
| Criteria for inscription | Dropdown list | ●○○○○ |
| | Upload box | Link |

| Section | Entry | Field | Field | Guidelines |
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| **1. Site Management Authority** | | | | |
| | **a. Name of the Managing Authority** | Text | | This indicator formally identifies the authority responsible for managing the UNESCO site. It is completed by entering the full name of the authority in a text box, based on official sources such as statutes, administrative documentation, or management plans. Clear identification of the managing entity is crucial to understand who holds operational, decision-making, and strategic responsibilities for the site's protection. Knowing exactly who is in charge supports effective communication, accountability for actions, and the implementation of climate adaptation strategies. |
| | **b. Type of Managing Authority** | Consortium | Text | This indicator classifies the legal nature of the managing authority by selecting from predefined options (foundation, park authority, consortium, diffuse entity), with the possibility to specify further details. Information can be obtained from the institution's statutes or the site management plan. Understanding the institutional structure helps assess the degree of autonomy, flexibility, and organizational coherence. Certain forms, such as foundations or multi-level consortia, may either facilitate or hinder climate governance, impacting the site's ability to respond to environmental challenges. |
| | **c. Number of Managing Entities** | 1 | Text | This indicator measures the degree of institutional fragmentation by recording how many authorities formally participate in the site's governance. It is completed by selecting a numerical value and providing a brief explanatory note, based on administrative documents or inter-institutional agreements. The aim is to determine whether governance is centralized or shared among multiple actors. Fragmented governance may ensure broader representation, but it can hinder quick and coordinated decision-making, especially in climate emergency situations or long-term planning. |
| **2. Management plan** | | | | |
| | **a. Type of Management Document** | | Text | This indicator identifies the existence and nature of the planning instrument in place at the site, distinguishing between management plans, operational plans, strategic plans, or other similar documents. The information is verified through direct consultation of official documents and selected from a dropdown menu. The aim is to determine the level of strategic organization for site protection and enhancement. The existence of an up-to-date and structured plan is a prerequisite for integrating climate adaptation into everyday site management. |
| | **b. Year of publication** | Text | | This field requires the year in which the current management plan was approved. The information is typically found in the introduction or cover page of the document. It helps assess whether the planning instrument is still current and capable of addressing emerging risks. An outdated plan may no longer respond adequately to environmental monitoring or climate adaptation needs, indicating the necessity of a revision. |
| | **c. Year of Last Update** | Text | | Distinct from the publication year, this indicator notes the most recent revision of the plan. The information can be obtained from the document itself or related administrative acts. It helps determine whether the plan is being regularly updated and how frequently. A recent revision indicates responsiveness to dynamic site conditions and the capacity to integrate new climate knowledge or regulatory developments. |
| | **d. Annex** | Text | | This section is used to confirm whether a digital file or hyperlink to the updated document is available for consultation and transparency. It is filled in by attaching the file or hyperlink. Ensuring the accessibility of the plan is a key element of good management and facilitates comparison and replicability of practices between sites. In addition, documenting climate adaptation strategies in a transparent manner enhances the site's credibility at the international level as well. |
| **3. Legal Adequacy** | | | | |
| | **a. Integration of OUVs into Territorial Planning Tools** | ●○○○○ | Text | This indicator assesses the coherence between territorial planning tools (e.g., local and regional planning instruments) and the safeguarding of the site's Outstanding Universal Values (OUVs). It is verified by analysing official planning documents to determine if and how the site's components—particularly those justifying World Heritage inscription—are explicitly acknowledged, protected, or promoted. The aim is to evaluate whether heritage and territorial governance are effectively integrated. Planning frameworks that incorporate OUVs help avoid land use conflicts, guide interventions, and strengthen the site's resilience to environmental and climate changes. |
| | **b. Adequacy of International Legal Framework** | ●○○○○ | Text | This indicator assesses the site's alignment with international legal instruments for heritage protection (e.g., the 1972 UNESCO Convention, the 1954 Hague Convention). It is completed by assigning a qualitative score from 1 to 5 (where 1 corresponds to poor adequacy and 5 to excellent adequacy), along with a brief comment referencing specific legal instruments. The goal is to verify whether site management is supported by a robust international legal framework. Strong alignment legitimizes protection measures and can facilitate access to international technical support in case of severe climate impacts. |
| | **c. Adequacy of National Legal Framework** | ●○○○○ | Text | This indicator evaluates the extent to which the site's management tools align with national heritage protection laws. It is completed using a qualitative scale (1–5) and a description citing relevant laws, decrees, or regulations. The aim is to determine whether the site operates in a favorable national regulatory environment. A strong national framework facilitates effective responses to emergencies and enables efficient implementation of climate adaptation strategies. |
| | **d. Local regulatory adequacy** | ●○○○○ | Text | This indicator assesses the suitability of local (regional, provincial, or municipal) legal frameworks in supporting the protection and management of the UNESCO site. It is completed using a 1–5 qualitative scale and a summary of relevant regulations or urban planning tools. The objective is to verify whether the site is embedded within a regulatory environment that supports its values and helps implement conservation and adaptation strategies. A coherent local legal framework helps translate heritage protection into operational decisions and enables integrated, place-based governance. |
| | **e. Overall Evaluation of Legal Adequacy** | ●○○○○ | Text | This indicator provides a comprehensive judgment on the effectiveness of the overall legal framework, including international, national, and local levels. It is completed using a qualitative scale and a detailed explanation. It helps determine whether existing laws are not only present but also applied and adapted to the local context. A formal but poorly enforced legal framework can leave the site vulnerable to climate risks and anthropogenic pressures. |
| **4. Site design indicators** | | | | |
| | **a. Total surface area of the site** | ha | Text | This indicator refers to the total size of the UNESCO site, expressed in hectares. The information is verified using official registration documents or updated cartographic data, optionally including a map. The purpose is to assess the site's spatial capacity to sustain ecological, social, and cultural functions under climate pressure. Larger and more contiguous sites generally offer greater ecosystem resilience and buffer capacity against localized disturbances, providing refuge areas for vulnerable species. |
| | **b. Type and continuity of boundaries** | Link | | This indicator analyses the configuration of the site boundaries, assessing their consistency with protection and management requirements. It is verified by analysing updated maps and qualitative descriptions. The indicator aims to identify any discontinuities, fragmentation or lack of buffer zones that could compromise the effectiveness of protection, particularly in contexts of climate pressure or urbanisation. Well-defined and consistent boundaries strengthen the capacity for control, monitoring and intervention in the territory. |
| **5. Monitoring** | | | | |
| | **a. Heritage Impact Assessment (HIA)** | ☐ | Text | This indicator verifies whether Heritage Impact Assessments have been drafted or updated for the site. It is completed by indicating the presence or absence of the document and specifying the most recent year. The HIA is a key tool to understand the direct and indirect effects of projects or transformations, including those related to climate change. Regular assessments indicate strong risk anticipation and management capacity, contributing to the safeguarding of the site's Outstanding Universal Values. |
| | **b. State of Conservation (SOC)** | ☐ | Text | The SOC report is submitted by UNESCO sites to document the site's state of conservation, particularly in terms of historical buildings and urban fabric. This indicator verifies the existence and latest available date of such reports, referencing UNESCO requests or national reports. Its presence reflects responsive and proactive management, capable of identifying and documenting emerging risks, including climate-related ones, with potential access to international technical support. |
| | **c. Presence of Monitoring Systems** | ☐ | Text | This indicator determines whether the site has active monitoring systems covering physical, ecological, or management-related aspects. It is completed via a checkbox and a descriptive field outlining tools, methods, and frequency. The goal is to assess the degree of institutionalization of environmental observation practices, which are essential for data-driven climate adaptation. A site with a structured monitoring system is better prepared to react to early warning signs of degradation. |
| | **d. Number of Assessments Conducted** | n. | Text | This indicator records how often structured assessments have been conducted (e.g., vulnerability, risk management, environmental impact). A numeric value and brief explanation (regarding year or type of assessment) must be provided. It helps determine how actively the site monitors its condition and evaluates the effectiveness of its actions. A higher frequency of assessments often correlates with a more adaptive and quality-driven management approach. |
| **6. Stakeholders** | | | | |
| | **a. Number of Active Stakeholders** | n. | Text | This indicator records the number of institutional, economic, social, or cultural actors currently involved in the site's governance. It is completed by providing a qualitative score (1–5) and a list of stakeholders. Its purpose is to map the existing governance network and determine whether it is broad and diversified. A high number of active stakeholders reflects community engagement and can enhance adaptive capacity through shared responsibilities. |
| | **b. Stakeholders diversity** | ●○○○○ | Text | This indicator focuses on the diversity of powers and competencies among stakeholders. It is completed using a qualitative scale and an explanation regarding the forms of influence (political, economic, social, scientific, educational). It helps assess whether governance is balanced or dominated by partial interests. A diverse and inclusive stakeholder composition supports more robust and legitimate adaptation strategies. |

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| | **c. Cooperation degree** | ●○○○○ | *Text* | This indicator evaluates the level of collaboration between responsible institutions and local/national stakeholders. It is filled in using a 1–5 qualitative scale and an explanatory comment. The goal is to understand the strength and effectiveness of relationships among institutions, local communities, scientific bodies, and economic actors. Strong cooperation is essential for inclusive, resilient governance that can pool resources and responsibilities to face climate challenges. |
| | **d. Perceived Conflict** | ●○○○○ | *Text* | This indicator measures the presence and perception of conflicts among stakeholders involved in site governance. It is completed by selecting a value on a 1–5 qualitative scale and providing a justification, based on observations, interviews, or documentation. It helps detect tension, mistrust, or disagreement that may hinder effective governance. A high level of perceived conflict can reduce coordination capacity, particularly in responding to climate risks. |
| | **e. Number of stakeholders to be involved** | *n.* | *Text* | This indicator estimates the number of strategic actors not yet fully engaged but deemed crucial for effective climate governance. It is completed by entering a number and providing an explanation. The goal is to identify gaps in the participatory network and guide actions to strengthen engagement. Recognizing absent but relevant stakeholders is essential for building systemic response capacity and preventing future conflicts. |
| **7. Preparedness for climate change** | | | | |
| | **a. Adequacy of National Climate Adaptation Legislation** | ●○○○○ | *Text* | This indicator assesses the existence and effectiveness of national laws or regulatory measures that promote climate adaptation in cultural and natural heritage sites. It is completed using a qualitative scale (1–5) along with explanatory notes and legal references. The objective is to verify whether the site operates within an institutional framework that supports the implementation of adaptive strategies. A strong national legal foundation is a key element for systemic protection against climate-related impacts. |
| | **b. Adequacy of Local Climate Adaptation Legislation** | ●○○○○ | *Text* | Similar to the previous indicator, this one focuses on regional or municipal policies that facilitate climate adaptation. It is completed through a qualitative score and a descriptive comment. It evaluates the concreteness of adaptation strategies at the local level, where daily site management occurs. The engagement of local authorities is crucial for implementing timely, integrated, and context-sensitive adaptation measures aligned with the site's characteristics. |
| | **c. Land Surface Temperature (LST)** | *average surface temperature* | *Text* | This indicator reports the average surface temperature of the site using satellite-derived data (Land Surface Temperature). It is filled in by providing a numerical value (in °C) and contextual information, including the source (e.g., Copernicus, Earth Engine). The objective is to monitor thermal trends that affect vegetation health, soil evaporation, and overall ecosystem vulnerability. A sustained increase in LST is an indicator of thermal stress and potential ecological degradation. |
| | **d. Frequency of Drought Episodes** | *n. events/year* | *Text* | This indicator measures how often extended dry periods occur within a year, based on precipitation thresholds defined by historical climate data. It is completed by reporting the number of events per year, their duration in consecutive dry days, and a short explanation. It serves to detect increasing drought conditions that may impair ecosystem functions, alter habitats, and trigger secondary risks like wildfires or water scarcity. It is a direct climate impact metric. |
| | **e. Vegetation Health Index (VHI)** | *Index* | *Text* | The VHI combines NDVI (Normalized Difference Vegetation Index) and LST data to indicate the health status of vegetation cover. It is reported as a value on a 0–100 scale along with a short description of data sources. The indicator aims to track vegetation vitality in response to climatic and environmental stressors. Low VHI values may signal degradation, reduced ecological resilience, or impacts from extreme events. It is a valuable tool for adaptive management of natural landscapes. |
| | **f. Frequency of flood events** | *n. events/year* | *Text* | This indicator records how many flood events have affected the site within a given reference period (typically annually). It is completed by entering the number of events, associated dates, and a brief explanation, based on data from ARPA, DHMZ, or local reports. It helps assess the recurrence of extreme hydrological phenomena driven by increased rainfall intensity. A growing frequency of floods is a clear indicator of the site's hydrogeological vulnerability, especially in riverine, wetland, or coastal areas. |
| | **g. Intensity and frequency of precipitation** | *n.* | *Text* | This indicator captures the highest recorded daily and hourly precipitation values, as a measure of extreme meteorological events. It is completed by entering numeric values (mm/day and mm/hour) and an explanatory note. The purpose is to identify trends in increasing rainfall intensity, which can cause structural damage, erosion, or ecological disruption. It is a critical metric for evaluating exposure to climate-induced hazards. |
| | **h. Flooded Surface Area** | *ha* | *Text* | This indicator monitors the actual land area affected by flood events, expressed in hectares and supported by geospatial mapping. It is based on field observations, GIS analyses, or institutional data. It estimates the site's direct exposure to floods and inundations, particularly relevant for wetlands, floodplains, and sensitive infrastructure. An expanding flooded area suggests the need for structural or nature-based resilience measures. |
| | **i. Maximum wind intensity** | *km/h* | *Text* | This indicator documents the maximum wind speed (in km/h) and direction recorded at the site during a specific timeframe. It is completed with a numeric value and descriptive explanation, using historical or local meteorological data. The purpose is to evaluate the impact of strong wind events on the stability of buildings, vegetation, and infrastructure. Increasing wind intensity is one of the notable local effects of climate change, requiring adaptive site planning and reinforcement. |
| | **l. Frequency of landslide events** | *n. events/year* | *Text* | This indicator tracks the frequency, extent, and key characteristics of landslide events affecting the site. It is completed by providing the number of events, estimated area, timing, and an explanation, based on official landslide registries (e.g., ARPA), site surveys, or geomorphological reports. Its goal is to measure geological instability and the site's exposure to erosion or slope failure, particularly where intense rainfall or prolonged droughts increase vulnerability. Frequent landslides may threaten habitat continuity, visitor access, and infrastructure, highlighting the need for mitigation strategies. |
| **8. Natural sites** | | | | |
| | **a. Local regulatory adequacy for biodiversity** | ●○○○○ | *Text* | This indicator assesses whether the site is subject to local regulations or policies that protect biodiversity, such as habitat plans, protected species, or Natura 2000 areas, SCIs (Sites of Community Importance), SACs (Special Areas of Conservation), and SPAs (Special Protection Areas). It is compiled by assigning a qualitative score (1–5) and indicating the active measures. The objective is to understand whether institutional instruments exist that directly support biological conservation from an adaptive perspective. Well-structured local regulatory coverage is a key element in ensuring the survival of natural components threatened by climate change. |
| | **b. Proportion of habitat or environment types** | *n.* | *Text* | This indicator analyzes the internal ecological composition of the site, expressing the percentage distribution of the main habitat types or environments (e.g., forests, wetlands, agricultural environments, etc.). Compiling it involves entering numerical data and a description of recent changes, based on GIS, Copernicus, or internal surveys. It helps assess the site's ecosystem balance and its sensitivity to environmental changes. Changes in the proportion of habitats may indicate selective pressures or climatic stresses that alter ecosystem function. |
| | **c. Presence of animal species at risk** | *n.* | *Text* | The indicator documents the presence of animal species classified as threatened according to the IUCN categories (Vulnerable, Endangered, Critical). It is compiled by entering the number of species and a short list, based on updated wildlife inventories. Its purpose is to map the components of animal biodiversity most sensitive to climate change, often also used as biological indicators. The presence and survival of these species are strongly linked to habitat stability, ecological connectivity, and the management of climate disruption. |
| | **d. Presence of plant species at risk** | *n.* | *Text* | Similar to the previous indicator, this one concerns the threatened plant species present on the site, according to official classifications (IUCN, national red lists). The data may come from botanical monitoring or conservation studies. Documenting these presences is crucial to guide management efforts toward targeted conservation interventions, protecting the species most sensitive to changes in water regime, temperature, or competition with invasive species. |
| | **e. Presence of Invasive Alien Species (IAS)** | *n.* | *Text* | Similar to the previous indicator, this one concerns the threatened plant species present on the site, according to official classifications (IUCN, national red lists). The data may come from botanical monitoring or conservation studies. Documenting these presences is crucial to guide management efforts toward targeted conservation interventions, protecting the species most sensitive to changes in water regime, temperature, or competition with invasive species. |
| | **f. Presence of ecosystem services** | ●○○○○ | *Text* | This indicator measures the variety of ecosystem services actually provided by the site, such as water regulation, pollination, food production, aesthetic or cultural value. It is compiled by selecting from a list and assessing perceived importance on a qualitative scale. The aim is to recognize the site's functional role in environmental sustainability and local quality of life. Assessing these services also allows us to estimate the benefits the site provides to society and justify nature-based adaptation interventions. |
| | **g. Ecosystem Potential** | ●○○○○ | *Text* | This composite indicator assesses the potential for providing ecosystem services for each land use class within the UNESCO site. Its assessment is based on a qualitative and quantitative analysis, conducted through the application of the Burkhard matrix, as described in the methodology of Activity A1.2. This matrix assigns a score from 0 to 5 to each land use type (e.g., forests, pastures, agricultural areas, wetlands) in relation to its capacity to provide different types of ecosystem services (climate regulation, hydrogeological protection, food production, cultural value, etc.). The indicator's objective is to estimate not only the services currently active, but also those potentially activated through ecological management or restoration interventions. |

| 9. Cultural sites - State of conservation | | | | |
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| *Among the factors influencing a building's sensitivity to the impacts of climate change, the state of conservation is the most variable and therefore requires more frequent monitoring intervals. Distinguishing between physiological deterioration processes and the accelerated decay driven by climate change effects is challenging, due to the combined action of the various factors that typically affect the conservation state of buildings. Monitoring the condition of the different constituent materials over time allows for the development of historical data series that can improve the complex understanding of the interrelation between changes in deterioration patterns and variations in environmental variables responsible for the increasing frequency and intensity of extreme events. Within a planned conservation framework, such data—related to the main deterioration factors amplified by climate change—can support the effective planning of preventive and mitigation actions, reducing the progression of deterioration phenomena that would otherwise require more invasive interventions.* | | | | |
| | **a. Surface regression (Marble and limestone with porosity lower than 25%)** | *n.* | *Text* | The surface recession of marble and limestone (with porosity <25%) is a very slow process that can be monitored through high-precision 3D scans at fixed reference points, carried out periodically to detect potential changes over time. The progression of surface recession (both annual average and cumulative) can also be quantified using equations that correlate measurements with climatic and pollution parameters, such as rainfall amount and pH, temperature, relative humidity, and concentrations of $SO_2$, $HNO_3$, $CO_2$, and particulate matter, in order to assess the factors accelerating deterioration. The calculation of annual surface recession can be performed using the "damage functions" proposed by Lipfert (1989), Bonazza et al. (2009), and Kucera et al. (2007).<br>Climate/pollution parameters da monitorare:<br>• Rain amount<br>• Rain pH<br>• Temperature (T)<br>• Relative humidity (RH)<br>• Sulphur dioxide (SO2)<br>• Nitric acid (HNO3)<br>• Carbon dioxide (CO2)<br>• Particulate matter (PM) |
| | **b. Soiling/ blackening (Carbonate stones in general - sedimentary and metamorphic-, mortars** | *n.* | *Text* | The formation of black crusts, particularly on carbonate stone elements, results from the interaction between the material and atmospheric pollutants. Annual photographic and photogrammetric surveys, together with the mapping of deterioration patterns on selected "sample" surfaces (identified as representative cases within a UNESCO cultural site), allow the monitoring of the formation and progression of this deterioration phenomenon. Following initial sampling to determine the composition, deposit thickness, and conservation state of the carbonate substrate, analyses should be repeated at regular intervals to enable comparisons over time, especially in critical areas where environmental conditions increase exposure to black crust formation and development.<br>The formation of black crusts is linked to the following climatic and pollution parameters:<br>• Rain amount<br>• Temperature (T)<br>• Relative humidity (RH)<br>• Sulphur dioxide (SO2)<br>• Particulate matter (PM)<br>• Carbon fractions of particulate matter (PM): elemental carbon (EC) and organic carbon (OC)<br>(Bonazza A., Sardella A., 2023, p. 3517) |
| | **c. Biodeterioration / Biomass accumulation (Siliceous stones)** | *n.* | *Text* | Biodeterioration and biomass accumulation (particularly on stone surfaces) can lead to material damage and compromise the legibility of surfaces. Photographic and photogrammetric surveys, along with the mapping of deterioration patterns carried out and compared at one-year intervals, allow the monitoring of the development of this type of deterioration. The growth of biological colonisations (e.g., lichens, fungi, algae) is closely linked to the following climatic factors, which are subject to variations driven by the effects of climate change:<br>• Rain amount<br>• Temperature (T)<br>(Bonazza A., Sardella A., 2023, p. 3517) |
| | **d. Thermoclastism (Marble)** | *n.* | *Text* | Temperature fluctuations, caused by the impact of solar radiation on buildings, can generate differential expansion within stone materials (particularly in marble, due to the thermal anisotropy of calcite), leading to the formation of cracks, scaling, and disintegration. Photographic and photogrammetric/laser scanner surveys, combined with the mapping of deterioration patterns and repeated annually, allow the monitoring of deterioration forms triggered by this phenomenon. Furthermore, using an equation that links climate models related to temperature variations with the material's properties, it is possible to develop future projections of this deterioration factor. (Bonazza A., Sardella A. 2023, p. 3518; Bonazza A. et al., 2009.) |
| | **e. Salt crystallization** | *n.* | *Text* | The crystallisation of soluble salts within porous materials (carried by water through capillary rise, marine aerosols, or infiltrations) leads to the formation of efflorescences and sub-efflorescences, which can cause the detachment of material (porous stones in general, brick masonry, and plasters). Understanding the extent of this phenomenon requires knowledge of the mineralogical, morphological, and chemical characteristics of the material (laboratory-based material characterisation) and the distribution of soluble salts (nitrates, chlorides, sulphates). Photographic and photogrammetric surveys, combined with the mapping of deterioration patterns and repeated annually, allow the monitoring of deterioration forms caused by salt crystallisation, which is linked to the following climatic parameters:<br>• Relative humidity (RH)<br>• Temperature (T) |
| | **f. Conservation status of wooden elements** | *n.* | *Text* | Monitoring the conservation status of wooden elements (with particular reference to the roof structures of historic buildings) is based on parameters gathered through visual inspection, supplemented by further diagnostic surveys deemed appropriate by technical experts, depending on their number, type, and spatial distribution. To acquire an adequate understanding of the conservation condition, and specifically regarding roof structures, of the efficiency of individual structural elements and connection nodes, these parameters should include: after identifying the structural hierarchy of the elements, verification of the effective load-bearing cross-section of the beams (to be carried out using non-destructive testing methods, including tools such as resistographs); recording forms of deterioration (deformations, cracks, biodeterioration, etc.); and measuring the moisture content of structural elements. Geometric surveys may be conducted with the support of laser scanning, photogrammetry, and Digital Elevation Models (DEM) to facilitate analysis and temporal comparison of roof structure geometries. The compilation of analysis sheets reporting quantitative and repeatable criteria should be carried out at appropriate time intervals, determined by the technician, to effectively monitor the conservation state of the system under examination. |