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Vulnerability of World Cultural Heritage Sites in developing Asian countries

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While World Cultural Heritage Sites in developing countries are fewer in number, they are over-represented in the List of World Heritage in Danger, and few scientific studies are conducted about them. This study investigates factors that threaten the World Cultural Heritage Sites in selected Asian countries, the intensity of these threats, and the management capacity to respond to them. Linked data from UNESCO Periodic Report (Cycle II), the World Heritage Site database, and the Köppen–Geiger climate classification is analysed using logit and ordered logit models. The results show that the perceived likelihood of a major threat is highest for the factors (i) sudden ecological or geological events ($dy/dx = 0.18$, $p < 0.01$), (ii) climate change and severe weather events ($dy/dx = 0.1$, $p < 0.05$), (iii) local conditions affecting physical fabric ($dy/dx = 0.1$, $p < 0.05$), and (iv) social–cultural use of heritage ($dy/dx = 0.10$, $p < 0.05$), while the likelihood of high management capacity is highest for the factors (i) illegal human activities ($dy/dx = 0.27$, $p < 0.01$) and (ii) invasive/alien or hyper-abundant species ($dy/dx = 0.21$, $p < 0.01$). In addition, sites in the Philippines and Afghanistan are most likely to report threats as major, but least likely to report high management capacity compared to other Asian countries. Further, the sites in this region do not have correspondingly high (or even adequate) management capacity for threats identified as major. The study, therefore, concludes that the studied sites are highly vulnerable to threats primarily from natural rather than socio-economic or human-induced causes. The study contributes novel insights into the risk and vulnerability of the World Cultural Heritage Sites in developing countries.

World Cultural Heritage Sites (WCHS), especially in developing countries, are exposed to multiple significant threats, such as urban development and land use change¹, climate change², natural disasters³, mass tourism^{4,5}, and conflict⁶. Despite the recognised risks, there is a lack of comprehensive analysis of the nature of the threats these sites face and the management capacity to deal with them. Previous studies analyse management reports on the threats and management adaptive capacity of World Heritage Sites in developed countries^{7,8}. However, no such analysis has been done for developing countries. Thus, we do not know the pattern of threats faced by WCHS in developing countries and whether it is similar to or fundamentally different from that of developed countries. Furthermore, as many scholars have pointed out, very few studies have been conducted in developing countries^{9,10}. This study addresses that gap by providing insights into threats and the capacity to manage them at WCHS in Asian countries.

The aim of this study is to examine the vulnerability of WCHS in developing countries. More specifically, it seeks to analyse (i) the extent to which existing site-specific characteristics predict the assessment of a given

factor threatening a WCHS, (ii) the extent to which site-specific characteristics and types of threats predict the degree of intensity of the threats, and (iii) the extent to which site-specific characteristics and types of threats predict the degree of adaptive management capacity to respond to these threats. The site-specific characteristics include the size of the WCHS, its year of inscription, the selection criteria used for its inscription, the climate zone, and the host country.

The study makes several contributions to the related literature. First, to the best of our knowledge, this is the first study to analyse multiple threats and adaptive management capacity with an exclusive focus on WCHS in developing countries. It shows that threats related to natural phenomena and climate change are more likely to be considered major in developing countries—a stark difference from those in developed countries⁸. Consequently, the studied sites could be highly vulnerable to the impacts of rapidly accelerating climate change. Second, the study contributes to a broader theoretical understanding of the risk and vulnerability of WCHS in developing countries through simultaneous analysis of threats and adaptive

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capacities. Previous studies that investigate exposure to threats do not address adaptive capacity¹¹. Third, this study adds to the heritage literature from developing countries, which is quite scant at present. It is known that heritage sites from developing countries are under-represented in the World Heritage List, and fewer studies are conducted about them^{9,11–13}. Previous studies in developing countries have studied antecedents of seeking World Heritage Site designation¹⁴, challenges in conserving a cultural landscape¹⁵, the impact of WHS on tourism¹⁶, and impacts of climate change on WHS¹⁷. Finally, this study also highlights the need to develop more effective strategies for threat management that are tailored to the unique characteristics of sites in developing countries. Several site-specific characteristics—year of inscription, selection criteria, country location, and climate zone, for example—are found to influence the likelihood of factors being assessed as threats. Similarly, there are significant variations among countries in the region, suggesting that tailored conservation approaches are necessary. This study, therefore, represents a significant advancement in our understanding of threat characteristics and our ability to preserve valuable properties in developing countries.

The rest of this paper is structured as follows: First, the conceptual background offers an overview of the general literature on vulnerability and adaptive management capacity regarding cultural heritage sites in developing countries. Section “Methods” describes the empirical model, sources of data, and methods used for analysis. The results are presented in the section “Results”, while the section “Discussion” discusses and concludes the paper by providing a summary of the results and pointing out the limitations of the study.

Conceptual background

Vulnerability of and risks to WCHS in developing countries

Vulnerability is defined as “the degree to which a system is likely to experience harm”¹⁸. Vulnerability research encompasses a wide range of concepts, and much of the related academic literature—including the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC)—defines it as a function of three key parameters or components: (i) exposure to perturbation, stress, hazard, or shock; (ii) sensitivity of the system to those hazardous conditions or stresses; and (iii) capacity of the system to prepare, cope, adapt, or recover from the effects of these stresses^{19–21}. This definition has evolved over time²². Particularly, AR5 and AR6 of the IPCC frame the impacts of climate change in terms of risks defined as “potential for adverse consequences for human or ecological systems” and cite vulnerability as one of three components of risk alongside hazards and exposure^{23,24}. They define vulnerability as the propensity to be negatively affected, with susceptibility to harm and the capacity to adapt as its two elements. Within this framework, the increased frequency or magnitude of hazards, increased exposure to hazards, or increased sensitivity to hazards will increase the risks to the system, while enhancing adaptive capacity will reduce them.

In the context of heritage sites, exposure refers to the sites or cultural assets being located in areas with potential hazards and stresses that may adversely impact their value²³. Previous cultural heritage studies focus primarily on exposure to threats such as natural disasters, climate change, and mass tourism, while adaptive capacity has received very little attention²⁵. As part of its regular monitoring of threats, UNESCO has developed a comprehensive list of factors that may affect World Heritage Sites²⁶. These include threats from both natural and human-induced causes. Many WCHS in Asia are negatively affected by a combination of these factors. The leading natural threats that can lead to the gradual or sudden deterioration of these sites include disasters such as earthquakes^{3,27} and floods^{2,28–30}; effects of climate change, such as rising temperatures, changing sea levels, and extreme weather events^{29,31}; and local conditions of pollution and environmental degradation³². Human-induced threats encompass development pressures such as rapid urbanisation near heritage sites^{33,34}, resource scarcity and exclusion^{35–37}, mass tourism³⁸, and insufficient governance and management. Additional human-induced risks include vandalism, theft, and deliberate destruction of cultural properties^{31,39}. Risk mapping, vulnerability

indices, remote sensing, and geospatial technologies may be useful for determining the extent of exposure to these threats^{25,40}.

Sensitivity is the degree to which a cultural heritage site is affected or modified by hazards and stresses to which it is exposed¹⁹. It is an inherent property of a system²⁰. A site’s material and structural attributes, such as the type of building materials or construction method used, determine its sensitivity to the relevant hazards^{31,41}. Sensitivity levels may also be influenced by surrounding natural and socio-economic environments. For example, urbanisation, encroachment, and mass tourism are having detrimental consequences on several sites in Asia^{33,42}. Higher sensitivity levels may require more intensive heritage protection measures.

The adaptive management capacity of a cultural heritage site refers to the ability of site managers and responsible authorities to effectively plan, implement, and monitor conservation and sustainable management strategies to adjust to potential hazards and cope with consequences⁴³. It is a positive attribute that is shaped by the institutions, management, and governance at hand⁴⁴. The factors that determine adaptive capacity include financial resources, the availability of technical expertise and a skilled workforce, strong institutional frameworks and governance structures, active stakeholder and community participation, and access to new technologies and other innovations^{43,45–47}. Many developing countries in Asia face constraints in these areas¹⁵. Limited financial resources, caused by insufficient funding and a low willingness to pay for maintenance, restoration, and protective measures, pose a major obstacle⁴⁸. Many countries lack specialised training programs and knowledge transfer mechanisms, resulting in a shortage of qualified human resources^{49,50}. Furthermore, complex governance structures, inflexible rules, and inadequate legal protections impede decision-making and execution⁵¹. Compared to industrialised regions like Europe and North America, developing countries in Asia are more likely to face greater adaptation challenges due to disparities in economic growth, resource availability, and unique institutional and governance frameworks³¹.

Operationalisation of vulnerability and risks

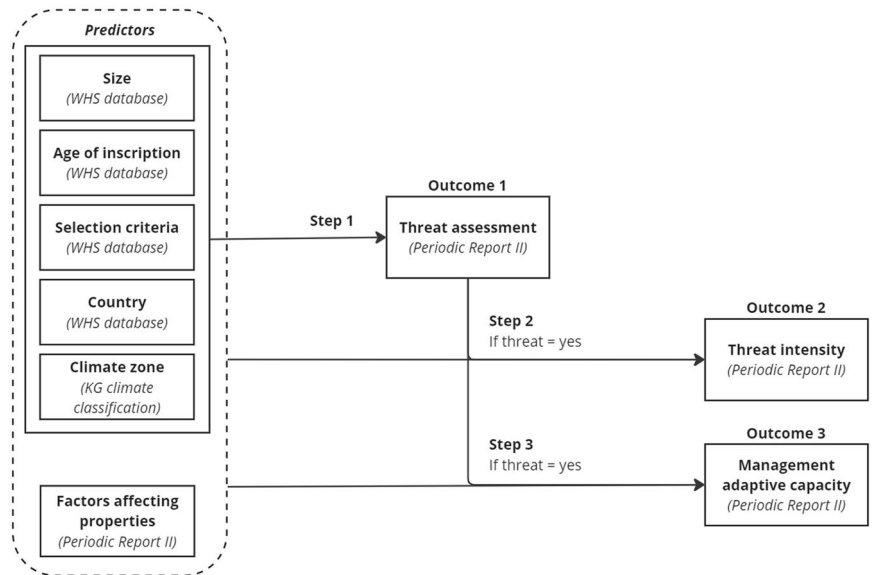
Despite its widespread use, developing a comprehensive measure for the vulnerability of World Heritage Sites may be unrealistic, as it is not an observable phenomenon. Thus, methodologies for assessing vulnerability need to be highly contextual⁵². In this study, a site is considered vulnerable or at risk if it is exposed to a variety of severe threats but has inadequate adaptive management capacity to respond. This approach integrates the constructs of exposure (represented by the types and intensity of threats), sensitivity (implicit in the site’s specific characteristics), and adaptive capacity (reflected in management responses) as discussed earlier. Based on these constructs, previous literature, and available data, this study proposes several key factors that influence the vulnerability of and risks to WCHS.

Factors affecting properties. UNESCO has established a list of 14 primary factors, along with several secondary factors, that affect the outstanding universal value of heritage sites²⁶. This list provides a standardised approach to a wide range of threats to which such sites are exposed, allowing for general assessment across the region. The degree of exposure to these factors, combined with site-specific characteristics and management capacity, determines overall vulnerability.

Size of WCHS. The size of WCHS is also an important determinant of vulnerability. Larger heritage sites often encompass many cultural assets in a single location. Moreover, larger sites tend to extend over different types of terrain, exposing them to multiple disaster risks³¹. The management of larger sites, such as World Heritage Cities or cultural landscapes, is expected to be more challenging than that of smaller sites like individual buildings or monuments. Due to this complexity, larger sites may have a higher vulnerability.

Age or year of inscription. Another crucial factor is the age or year of inscription, which indicates the duration of a site’s engagement with the World Heritage system. Sites that are inscribed early on have more

Fig. 1 | Conceptual framework and empirical approach of the study. The relationship of six predictors is investigated using three outcome variables. In step one, five predictors are modelled for threat assessment. In steps two and three, six predictors are modelled with threat intensity and adaptive management capacity only when factors are assessed as threats. (Source: author's illustration).



experience with heritage conservation; they should therefore be more capable of recognising threats and should have built more adaptive capacities^{8,53}. Furthermore, since recognition as a World Heritage Site mandates the government of the respective nation to develop a system for protection and enables the flow of required resources, sites that are inscribed early on enjoy these benefits for a longer period of time.

Selection criteria. The selection criteria are a set of ten criteria enshrined in the Operational Guidelines for Implementation of the World Heritage Convention⁵⁴. The first six are associated with cultural sites, while the latter four criteria are associated with natural sites. World Heritage Sites must fulfil at least one of these criteria to be included on the list, but they usually fulfil several. Since these criteria reflect the diversity of heritage, sites with different criteria can be expected to have different vulnerability profiles⁵⁵.

Climate zone. The climate zone in which a heritage site is located affects its vulnerability, as it may be exposed to climatic stress factors such as rain, temperature, and humidity. These stress factors can change suddenly or gradually due to climate change. For example, heritage sites located in polar conditions or near coastal areas (where effects of climate change are imminent) can have higher vulnerability than those located in other areas^{56,57}.

Country. The country in which a site is located also impacts its vulnerability, as countries have various levels of economic development and different legal regulations for the protection of cultural heritage⁵⁸. Even when they are located in the same geographic region, host countries vary in terms of economy, demographics, number of World Heritage Sites, and the policy measures undertaken to conserve these sites. Countries where more resources are made available and strong national governance structures are in place to conserve heritage can be expected to have lower vulnerability.

Methods

Empirical approach

This study conducts three analyses in two stages, as indicated in Fig. 1. The first stage involves analysing the assessment of threats and their intensity, while the second stage involves analysing the adaptive management capacity. This empirical approach is based on a similar previous study done in developed countries in order to allow for comparison of the results across the world's regions⁷. However, the simultaneous analysis of threat intensity and adaptive management capacity with a focus on WCHS in developing

Asian countries makes it possible to investigate the degree of vulnerability of these sites.

As in the previous study⁷, this paper assesses threats using a two-step analysis method. The first step is to estimate the likelihood of a WCHS assessing any factor as a threat using binominal logit regression. The second step involves estimating the degree of intensity of threats using ordered logit regression. Threat assessment is a binominal dependent variable, whereas the intensity of threats is an ordinal categorical variable. Therefore, a binary logit model and an ordered logit model are suitable for the respective cases. In both of these models, maximum likelihood estimation is suitable for estimating the parameter of the independent variables⁵⁹. The model specifications are as follows:

$$\text{Threat_assessment} = \beta_0 + \beta_1 \text{Size} + \beta_2 \text{Age} + \beta_3 \text{Selection_criteria} + \beta_4 \text{Country} + \beta_5 \text{Climate_zone} + \varepsilon_1 \quad (1)$$

$$\text{Threat_intensity} = \gamma_0 + \gamma_1 \text{Size} + \gamma_2 \text{Age} + \gamma_3 \text{Selection_criteria} + \gamma_4 \text{Country} + \gamma_5 \text{Climate_zone} + \gamma_6 \text{Threat_type} + \varepsilon_2 \quad (2)$$

where, Threat_assessment is the likelihood of a factor being assessed as a threat by a particular WCHS, and Threat_intensity is the degree of intensity of the threat as indicated in the second cycle of UNESCO's periodic reports. Following the previous study⁷, threat intensity has been reclassified into three categories: negligible, minor, and major. Similarly, γ_0 and β_0 are constants, γ_{1-6} and β_{1-6} are coefficients, and ε_{1-2} are error terms. Size is the area of the site, categorised as small (0–10 ha), medium (10.1–100 ha), large (100.1–1000 ha), or very large (>1000 ha). Age is the period since the site's inscription, categorised as old (1979–1989), medium (1990–1999), or new (≥ 2000). Selection_criteria is one of the six criteria listed by the site at its time of inscription, Country is the nation in which the site is located, Climate_zone is one of five major climatic zones identified by the Köppen–Geiger climate classification system⁶⁰, and Threat_type is a category of the standard list of threats maintained by UNESCO.

The next stage is the analysis of management's capacity to adapt to threats. The model is specified as follows:

$$\text{Adaptive_management_capacity} = \alpha_0 + \alpha_1 \text{Size} + \alpha_2 \text{Age} + \alpha_3 \text{Selection_criteria} + \alpha_4 \text{Country} + \alpha_5 \text{Climate_zone} + \alpha_6 \text{Threat_type} + \varepsilon_3 \quad (3)$$

where, Adaptive_management_capacity is the reported capacity of the site's management to address threats, measured at four levels: (i) no capacity, (ii) low capacity, (iii) medium capacity, or (iv) high capacity. Similarly, α_0 is a constant, α_{1-6} are coefficients of independent variables, and ε_3 is the error term. The independent variables are the same as the ones used in the previous stage.

Standard errors are clustered at site levels for both stages of analysis. Marginal effects are calculated for the logit regressions to quantify the magnitude of the relationship in question.

Data sources and descriptive statistics

The data has been obtained from the UNESCO Periodic Report (Cycle II), the UNESCO World Heritage Site database⁶¹, and the world maps of the Köppen–Geiger climate classification webpage⁶⁰. The inclusion criteria are as follows: (i) cultural heritage sites participating in the second cycle of UNESCO's Periodic Reporting, (ii) sites located in Asia and the Pacific Region, (as of August 2023, UNESCO categorises 45 countries in the list of Asia and the Pacific Region. For a complete list, see <https://whc.unesco.org/en/statesparties/?searchStates=&id=®ion=2>) and (iii) countries categorised as emerging and developing according to the International Monetary Fund⁶². Although transboundary and mixed sites have some cultural aspects, they have not been included in this study to maintain data consistency and homogeneity. Exposure to threats, threat perceptions, and management practices may vary significantly within sites that span national boundaries and sites that have a combination of natural and cultural elements.

For Asia, the Periodic Report (Cycle II) was carried out in 2010, and the final reports were published in 2012. A total of 41 countries participated, representing 198 heritage sites⁶³. While old, this is the most recent data available, and it is still helpful in determining how vulnerable certain WCHS in the area are. Further, the COVID-19 pandemic may have distorted the frequency and extent of human-induced threats in the third reporting cycle. Scanned copies of Section II of the Periodic Report questionnaire stored in the UNESCO data repository are downloaded. Of these, the reports for cultural heritage sites meeting the inclusion criteria have been selected. The sections of the Periodic Reports that contained information about factors affecting properties, (contained information about 2841 factors reported for 112 sites in 25 countries) the intensity of threats (factors considered negative and current), and the capacity of management to deal with those threats (contained information about 1221 factors reported as threats for 101 sites in 23 countries) form the basis for this study's dependent variables. The process of Periodic Reporting under the World Heritage Convention is discussed elsewhere⁶⁴, and both the questionnaire and the reports can be accessed from the UNESCO website⁶¹.

Data on the independent variables—size, country, year of inscription, and selection criteria has been obtained from the World Heritage List database, which is downloadable as a spreadsheet file from the UNESCO website. The spreadsheet also contains information on the latitudes and longitudes of individual sites.

For data on climate variables, the Köppen–Geiger climate classification system is used. One of the climate classification systems used most around the world, it classifies climates into five main categories: (i) Equatorial/Tropical, (ii) Dry/Arid, (iii) Warm Temperate, (iv) Continental/Boreal, and (v) Polar⁶⁵. For this study, a web map containing observed and predicted climate data from 1901 AD to 2100 AD based on the Köppen–Geiger system has been accessed through the software ArcGIS Pro⁶⁶. The map layer containing observed climate data from 1976 AD to 2000 AD has been extracted from the package. Another layer containing the latitudes and longitudes of World Heritage Sites obtained from the UNESCO portal has also been added to the program. A pairwise intersection tool has been used to extract a table of data intersecting heritage sites with climate zones.

Information on site identification numbers has been used to link data from the reporting cycle with data on site properties and their climate zones. The final database used for analysis includes a total of 112 cultural properties in 25 countries and 2841 affecting factors, of which 1221 are assessed as

threats to the sites (see Supplementary Table 1 for a list of the countries and sites).

Descriptive statistics show that the average site size is 3634.2 ha; the average year of inscription is 1995; 2.7% of the sites are on the danger list; most sites were inscribed based on selection criteria 2 (56.3%), 3 (72.3%), or 4 (58%); and most of them are located in the equatorial climate zone (33.9%), while none are located in the polar climate zone. China (25%) and India (20.5%) have the most sites.

Of the total factors reported, 1221 (69.9%) factors affecting sites are reported as negative. Factors like sudden ecological or geological events, invasive/alien or hyper-abundant species, other human activities (including war and deliberate destruction of heritage), pollution, climate change and severe weather events, and local conditions affecting physical fabric are most frequently reported as negative.

As shown in Fig. 2, most of the negative factors or threats are perceived as being in the minor category (42.2%), while around one-third are considered major or catastrophic. Factors related to sudden ecological or geological events are most frequently reported as major threats, whereas factors related to utilities or service infrastructure are most frequently reported as negligible.

For most of these threats, a medium capacity for response is perceived (47.3%). Over 10% of the sites report having no capacity or resources to address climate change and severe weather events, while 42.9% indicate a low capacity to address management and institutional factors. Almost half of the sites (48.5%) report having a high capacity to deal with threats related to human activities (see Table 1).

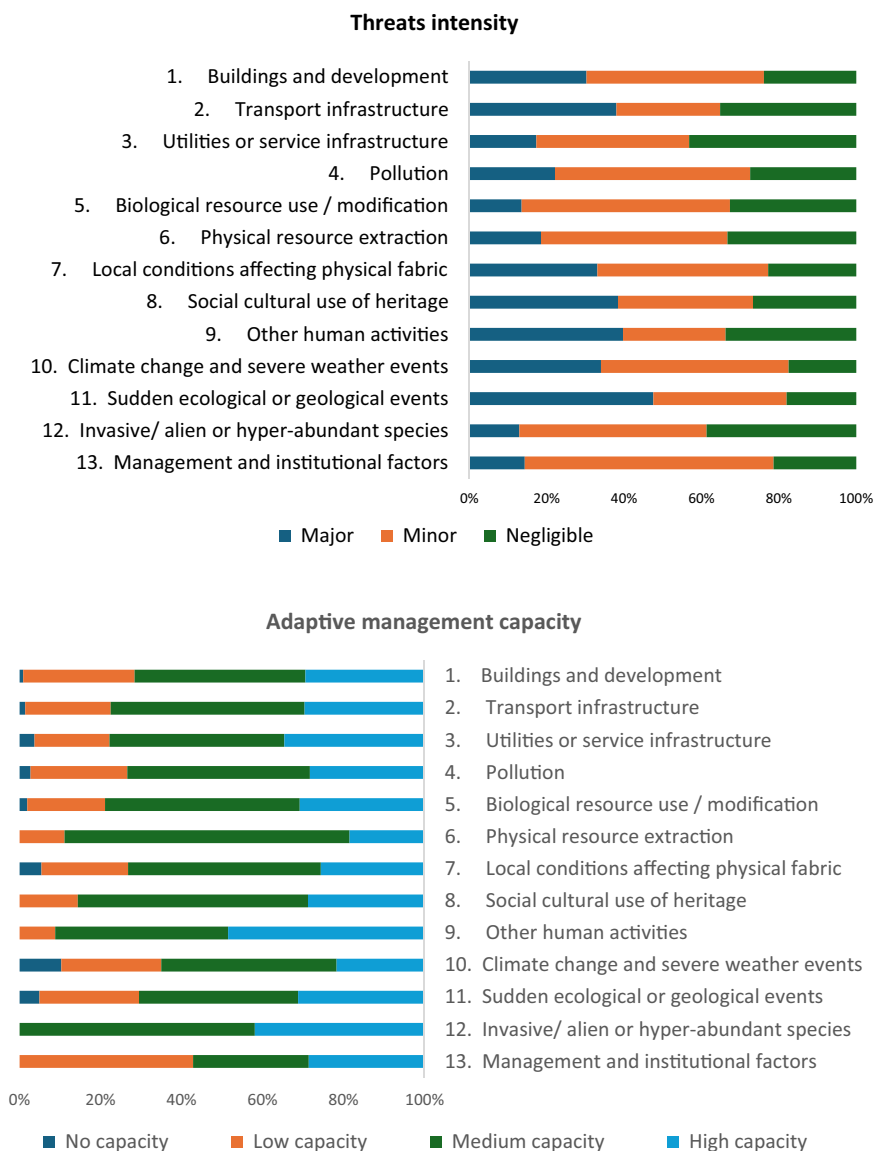
Results

Likelihood of reporting threat and its intensity

The results of the logistic regression (Table 2) show that factors being assessed as threats are significantly related to a site's age of inscription, selection criteria, climate zone, and home country, but not to site size. The marginal effects analysis shows that the sites inscribed between 1990 and 1999 are 15 percentage points ($p < 0.01$) more likely to report threats, and those inscribed before 1990 are 24 percentage points ($p < 0.01$) more likely to report threats than those inscribed after the year 2000. Similarly, sites that fall under selection criterion 5 (indicating an outstanding example of traditional human settlement) are 12 percentage points ($p < 0.05$) more likely to report threats than sites that do not meet this criterion. In the same way, sites located in an equatorial climate (Köppen climate classification A) or a dry/arid climate (classification B) are 20 percentage points ($p < 0.05$) and 16 percentage points ($p < 0.05$) less likely to report threats than those in a continental climate (classification D), respectively. In terms of host countries, the Philippines ($dy/dx = 0.20$, $p < 0.01$) is the most likely to report a threat, while Vietnam ($dy/dx = -0.28$, $p < 0.01$), Iran ($dy/dx = -0.23$, $p < 0.01$), and China ($dy/dx = -0.16$, $p < 0.05$) are less likely to report a threat with reference to countries grouped as others in the sample.

Results of the ordered logit estimation (Table 2) reveal that threat intensity depends on a site's selection criteria, climate zone, host country, and threat factors but not on its size or year of inscription. While selection criteria 5 is associated with a greater likelihood of reporting a threat, selection criteria 6 is associated with higher threat intensity. Similarly, only temperate climates and two countries—the Philippines and Afghanistan—are associated with threat intensity. The average marginal effects show that sites falling under selection criteria 6 (those with a direct association with events or living traditions) are 10 percentage points more likely than those without this criterion to report threats as major ($p < 0.05$). Similarly, sites located in dry/arid climates (Köppen climate classification B) are 18 percentage points less likely to report major threats than sites in continental climates ($p < 0.05$). In terms of host countries with reference to others, the Philippines is 51 percentage points ($p < 0.01$) more likely and Afghanistan is 26 percentage points ($p < 0.05$) more likely to report threats as major. Similarly, with reference to the threat of pollution, the threat of sudden ecological or geological events is 18 percentage points more likely to be reported as a major threat ($p < 0.01$). This likelihood is also 10 percentage

Fig. 2 | Threats intensity and adaptive management capacity ($n = 1221$). Distribution of 1221 threats in terms of their intensity and the adaptive capacity of the respective management. *Source:* Data compiled by author from UNESCO Periodic Report (Cycle II), World Heritage Site database, and other sources.



points higher ($p < 0.05$) for each of the following: local conditions affecting physical fabric, socio-cultural use of heritage, and climate change and severe weather events. Contrarily, biological resource use and modification is eight percentage points less likely to be reported as a major threat than pollution ($p < 0.05$).

In summary, analysis of threat reporting and threat intensity among the WCHS in developing countries within Asia shows that (i) older sites are significantly more likely to report threats compared to newly inscribed sites, although age does not significantly affect the intensity of threats; (ii) sites falling under selection criteria 5 and 6 are more likely to report threats and experience more intense threats, respectively, compared to sites without these criteria; (iii) equatorial and temperate climate zones are associated with a lower likelihood of threat reporting compared to continental climate zones, though only temperate zones show a significant negative association with threat intensity; (iv) compared to other countries, sites in Vietnam, Iran, and China are less likely to report threats, whereas sites in the Philippines and Afghanistan are more likely to report major threats; and (v) sudden ecological or geological events, climate change and severe weather events, social cultural use of heritage, and local conditions affecting physical fabric are more likely to be reported as major threats, while biological resource use is less likely than pollution to be reported as a major threat.

Likelihood of reporting a high degree of adaptive capacity

The results of the ordered logit estimation show that the degree of adaptive management capacity depends upon a heritage site's year of inscription, country, and threat factors but not on its size, climate zone, or selection criteria (Table 3, Supplementary Table 2). The average marginal effects (Table 3) show that having been inscribed during the period 1979–1989 has a significant positive effect on low capacity and a significant negative effect on high capacity. The propensity of these sites to report high adaptive management capacity is 20 percentage points lower than the reference category of sites inscribed after the year 2000 ($p < 0.05$). However, there are no significant effects of the age category 1990–1999 on any adaptive capacity levels. This indicates that older sites, particularly from the period 1979–1989, are more likely to face management and conservation challenges.

Meanwhile, the analysis shows that the country of location has a noticeable effect on adaptive management capacity. When compared to other countries in the region, being located in China has a significant negative effect on low capacity (17 percentage points, $p < 0.05$), but a weak positive effect on high capacity (31 percentage points, $p < 0.1$), indicating a moderate level of adaptive management capacity. Contrarily, being located in Afghanistan has a significant positive effect on a site having no management capacity at all (27 percentage points, $p < 0.01$) or low capacity (24

Table 1 | Descriptive statistics

Panel A: Site characteristics (n = 112)			
Size	Percent	Age	Percent
0–10 ha	32.1	1979–1989	31.3
10.1–100 ha	20.5	1990–1999	30.4
100.1–1000 ha	32.1	≥2000	38.4
>1000 ha	15.2		
Selection criteria	Percent	Country	Percent
C1—Creative genius	37.5	China	25.0
C2—Human values	56.3	India	20.5
C3—Cultural tradition	72.3	Iran	8.0
C4—Human history	58.0	Sri Lanka	5.4
C5—Human settlement	13.4	Pakistan	5.4
C6—Universal significance	39.3	Uzbekistan	3.6
Climate zone		Viet Nam	3.6
A (Equatorial/Tropical)	33.9	Philippines	2.7
B (Arid/Dry)	25.9	Others	25.8
C (Warm temperate)	25.9		
D (Continental)	14.3	Danger list	2.7
Panel B: Factors affecting sites (n = 2841) (percent)			
	Freq	Negative	Current
1. Buildings and development	11.6	54.3	70.7
2. Transport infrastructure	7.3	51.7	75.9
3. Utilities or service infrastructure	7.1	55.9	74.3
4. Pollution	6.2	98.9	65.7
5 Biological resource use/modification	5.7	54.7	72.1
6 Physical resource extraction	2.3	70.8	69.2
7. Local conditions affecting physical fabric	16.9	96.5	77.1
8. Social cultural use of heritage	13.9	49.1	85.1
9. Other human activities	4.5	99.2	54.3
10. Climate change and severe weather events	8.0	97.4	44.3
11. Sudden ecological or geological events	6.7	100.0	32.5
12. Invasive/alien or hyper-abundant species	2.1	100.0	55.0
13. Management and institutional factors	7.7	10.9	88.6
Total	100.0	69.9	69.8

Panel A presents descriptive statistics for 112 sites from 23 countries in Asia included in the study. Panel B presents the distribution of 2841 factors from 112 sites according to management perception as negative and current which are considered threats to the sites.

percentage points, $p < 0.01$). It also has a significant negative effect on medium capacity (32 percentage points, $p < 0.01$) and high capacity (19 percentage points, $p < 0.01$). This indicates that sites in Afghanistan are most likely to have very low adaptive management capacity. Similarly, for sites in the Philippines, the likelihood is 15 percentage points lower for high capacity ($p < 0.05$), 18 percentage points lower for medium capacity ($p < 0.05$), and 22 percentage points higher for low capacity ($p < 0.01$), indicating a lower degree of adaptive management capacity overall.

None of the countries in the study sample have a significantly high or medium capacity to deal with threats categorised as major in the previous

analysis. However, the likelihood of reporting high adaptive management capacity against the threat of other human activities is about 27 percentage points higher ($p < 0.01$) than for the threat of pollution. It is also 21 percentage points higher ($p < 0.05$) for invasive alien or hyper-abundant species.

In summary, the analysis of adaptive management capacity against threats among the WCHS in the developing countries in Asia shows that (i) compared to sites inscribed after the year 2000, sites inscribed in the first decade of the World Heritage Convention are more likely to have a lower degree of adaptive capacity; (ii) sites located in Afghanistan have a significantly lower degree of adaptive management capacity with reference to other groups of countries in the region; (iii) with reference to the threat factor of pollution, there is more likely to be higher adaptive capacity for other human activities and invasive/alien or hyper-abundant species; and (iv) none of the factors identified as major threats were associated with higher management capacity.

Discussion

One important finding of this study is that factors related to the social and cultural use of heritage, climate change, local environmental conditions, and natural disasters are more likely to be reported as major threats. However, the degree of adaptive management capacity regarding these threats is not significantly high. This indicates that sites in developing countries are exposed to a variety of severe threats and are highly vulnerable due to their low levels of management capacity. Other studies conducted in Asia have also reported high vulnerability among these sites^{5,67–69}. The sources of vulnerability identified in this study are primarily natural rather than socio-economic or human-induced. Further, this study finds that the sites tend to have a higher capacity to respond to threats of other human activities (e.g. war, crime) in comparison to pollution. This contrasts with a previous study that surveyed 500 cultural heritage sites in developing countries, which shows that development pressure, unsustainable tourism, insufficient management, looting, and conflict cause 90% of related losses and destruction^{70,71}. However, since most of the sites in the survey are not on the UNESCO list, having UNESCO World Heritage status may reduce some of these vulnerabilities.

A comparison of findings from this study with similar studies conducted in developed countries shows some similarities but with considerable variations. In both developed and developing countries, the size of a cultural heritage site is not a significant predictor of threats, but its year of inscription, host country, selection criteria, climate zone, and the type of threat in question are significant^{7,8}. This suggests that vulnerability and management challenges are not strictly related to the scale of a site and that smaller and larger sites may face similar risks and have comparable levels of preparedness.

The present study finds that the year of inscription seems to play a consistent role across all models, particularly for threat assessment and adaptive management capacity. Older sites are more likely to assess factors affecting their properties as threats but also exhibit lower adaptive management capacity. However, age does not impact the intensity of threats, indicating that both old and new sites perceive threats similarly once they are reported. In contrast, in developed countries, the year of inscription has a negative effect on reporting and is not associated with adaptive management capacity^{7,8}. These findings suggest that there are differences in the ways sites in developing and developed countries interact with the UNESCO system and may indicate a varying political dynamic between the UNESCO system and different economies^{13,72}.

Similarly, while the previous study results indicate that sites representing creative human genius (criterion 1) are associated with reporting threats in developed countries, in the current study, sites representing traditional human settlement (criterion 5) are associated with threat assessment, and sites of universal significance (criterion 6) are associated with the intensity of threats⁷. These criteria likely identify sites that are inherently more vulnerable due to their sensitivity toward various risks. Despite the association of threat assessment and intensity with these selection criteria,

Table 2 | Logit and ordered logit estimations (marginal effects) of reported threats and their intensity to World Cultural Heritage Sites in developing countries in Asia

	Threat reporting			Major threat			Minor threat			Negligible threat		
	dy/dx	sig	z stat	dy/dx	sig	z stat	dy/dx	sig	z stat	dy/dx	sig	z stat
<i>Size (Ref: >1000 ha)</i>												
0–10 ha	0.01		0.11	0.05		0.60	0.00		−0.39	−0.05		0.09
10.1–100 ha	−0.10		−1.60	0.02		0.28	0.00		0.03	−0.02		0.09
100.1–1000 ha	−0.04		−0.68	0.02		0.26	0.00		0.05	−0.02		0.08
<i>Age (Ref: 2000–2010)</i>												
1979–1989	0.24	***	3.95	0.11	*	1.66	−0.01		−0.59	−0.10		−1.65
1990–1999	0.15	***	3.04	0.00		−0.03	0.00		−0.03	0.00		0.07
<i>Selection criteria</i>												
C1—Creative genius	0.02		0.33	0.05		1.06	0.00		−0.47	−0.05		−1.10
C2—Human values	0.07	*	1.67	−0.03		−0.81	0.00		0.57	0.03		0.80
C3—Cultural tradition	0.06		1.52	0.00		−0.01	0.00		0.01	0.00		0.01
C4—Human history	0.03		0.60	0.03		0.44	0.00		−0.32	−0.03		−0.44
C5—Human settlement	0.12	**	2.21	−0.05		−0.67	0.00		−0.11	0.05		0.62
C6—Universal significance	0.06	*	1.66	0.10	**	2.21	−0.01		−0.61	−0.09	**	−2.19
<i>Climate classification (Ref: Continental)</i>												
Equatorial	−0.20	**	−2.48	−0.04		−0.45	0.01		0.45	0.03		0.45
Arid	−0.16	**	−2.20	−0.18	**	−2.31	0.01		0.34	0.17	**	2.56
Temperate	−0.13	*	−1.95	−0.13	*	−1.86	0.02		0.75	0.11	*	1.92
<i>Country (Ref: Others)</i>												
China	−0.16	**	−2.06	−0.15	*	−1.79	−0.05		−1.26	0.20	*	1.73
India	−0.07		−1.04	−0.10		−1.41	−0.02		−0.74	0.12		1.35
Pakistan	0.06		0.73	0.16	*	1.82	−0.05		−1.15	−0.11	*	−1.94
Sri Lanka	0.13		1.30	0.15	*	1.66	−0.04		−1.22	−0.11	*	−1.67
Iran	−0.23	***	−2.62	−0.02		−0.13	0.00		0.04	0.02		0.13
Viet Nam	−0.28	***	−4.16	−0.06		−0.43	0.00		−0.14	0.06		0.39
Philippines	0.20	***	3.41	0.51	***	4.83	−0.29	***	−4.13	−0.22	***	−3.79
Uzbekistan	0.05		0.70	0.13		1.50	−0.04		−1.19	−0.10	*	−1.48
Afghanistan	0.21	*	1.75	0.26	**	2.16	−0.11		−1.46	−0.16	**	−2.45
<i>Threats (Ref: Pollution)</i>												
Buildings & development				0.07		1.32	0.00		0.01	−0.07		−1.33
Transport infrastructure				0.03		0.63	0.00		0.45	−0.04		−0.64
Utilities or service infrastructure				−0.07	*	−1.82	−0.02		−1.49	0.09	*	1.85
Biological resource use/ modification				−0.08	**	−2.01	−0.03		−1.50	0.11	**	1.97
Physical resource extraction				−0.03		−0.63	−0.01		−0.44	0.04		0.59
Local conditions affecting physical fabric				0.10	**	2.37	0.00		−0.42	−0.09	**	−2.22
Social cultural use of heritage				0.10	**	2.33	0.00		−0.28	−0.09	**	−2.51
Other human activities				0.02		0.42	0.00		0.40	−0.03		−0.42
Climate change and severe weather events				0.10	**	2.02	0.00		−0.32	−0.09	**	−2.02
Sudden ecological or geological events				0.18	***	2.75	−0.03		−1.13	−0.15	***	−2.91
Invasive/alien or hyper- abundant species				−0.09	*	−1.89	−0.04		−1.34	0.13	*	1.77
Management and institutional factors				−0.03		−0.31	−0.01		−0.26	0.03		0.30
Number of observations (Threats) = 1221												
Number of sites = 112												

The average marginal effects are calculated for the presence or absence of reporting factors as threats and for three levels of intensity of threats following estimation of logit and ordered logit model in Stata (BE version 18.0), respectively, with cluster adjusted standard errors at site levels. Coefficients and z-stats are disclosed in the Supplementary Table 2.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3 | Ordered logit estimations (marginal effects) of management adaptive capacity of World Cultural Heritage Sites in developing countries in Asia

	No capacity			Low capacity			Medium capacity			High capacity		
	dy/dx	sig	z-stat	dy/dx	sig	z-stat	dy/dx	sig	z-stat	dy/dx	sig	z-stat
<i>Size (Ref: >1000 ha)</i>												
0–10 ha	0.00		0.15	0.01		0.15	0.00		0.13	−0.02		−0.15
10.1–100 ha	0.00		0.20	0.01		0.20	0.00		0.18	−0.02		−0.20
100.1–1000 ha	0.00		0.23	0.01		0.22	0.00		0.19	−0.02		−0.22
<i>Age (Ref: 2000–2010)</i>												
1979–1989	0.03	*	1.88	0.12	**	2.43	0.05		1.30	−0.20	**	−2.35
1990–1999	0.01		0.75	0.04		0.76	0.03		0.80	−0.09		−0.79
<i>Selection criteria (Ref: 0 for each)</i>												
C1—Creative genius	0.01		0.44	0.02		0.46	0.00		0.40	−0.03		−0.45
C2—Human values	−0.01		−1.01	−0.05		−1.10	−0.01		−0.73	0.07		1.10
C3—Cultural tradition	0.01		0.60	0.03		0.58	0.01		0.44	−0.04		−0.57
C4—Human history	−0.01		−0.69	−0.04		−0.75	−0.01		−0.66	0.06		0.76
C5—Human settlement	−0.02		−1.42	−0.07		−1.33	−0.03		−0.78	0.12		1.16
C6—Universal significance	0.01		0.56	0.02		0.56	0.00		0.45	−0.03		−0.56
<i>Climate classification (Ref: Continental)</i>												
Equatorial	−0.03		−0.85	−0.09		−1.10	0.00		−0.14	0.12		1.11
Arid	−0.01		−0.51	−0.05		−0.57	0.01		0.36	0.06		0.57
Temperate	−0.02		−0.96	−0.08		−1.37	0.00		0.12	0.09		1.44
<i>Country (Ref: Others)</i>												
China	−0.03		−1.47	−0.17	**	−2.25	−0.11		−1.10	0.31	*	1.83
India	−0.02		−0.87	−0.08		−1.06	0.00		−0.08	0.09		1.05
Pakistan	−0.03		−1.34	−0.15		−1.43	−0.06		−0.49	0.23		1.04
Sri Lanka	−0.02		−1.08	−0.10		−1.25	−0.01		−0.32	0.13		1.11
Iran	−0.01		−0.30	−0.03		−0.30	0.00		0.34	0.04		0.28
Viet Nam	−0.01		−0.57	−0.05		−0.55	0.00		0.23	0.06		0.52
Philippines	0.12		1.33	0.22	***	2.67	−0.18	**	−2.07	−0.15	**	−2.23
Uzbekistan	0.02		0.73	0.06		0.81	−0.03		−0.78	−0.06		−0.78
Afghanistan	0.27	***	2.71	0.24	***	2.73	−0.32	***	−4.08	−0.19	***	−3.07
<i>Threats (Ref: Pollution)</i>												
Buildings & development	0.00		0.18	0.01		0.18	0.00		0.03	−0.01		−0.18
Transport infrastructure	−0.01		−1.32	−0.05		−1.46	−0.01		−0.95	0.08		1.56
Utilities or service infrastructure	−0.01		−0.85	−0.03		−0.87	−0.01		−0.57	0.04		0.90
Biological resource use/modification	0.00		−0.30	−0.02		−0.31	0.00		−0.25	0.02		0.31
Physical resource extraction	−0.01		−0.90	−0.04		−0.93	−0.01		−0.63	0.05		0.95
Local conditions affecting physical fabric	0.01		0.43	0.02		0.44	0.00		−0.12	−0.02		−0.43
Social cultural use of heritage	−0.01		−1.38	−0.05		−1.56	−0.01		−1.21	0.08	*	1.78
Other human activities	−0.03	**	−2.31	−0.13	***	−3.34	−0.11	***	−3.14	0.27	***	4.42
Climate change and severe weather events	0.02		1.34	0.07		1.54	−0.01		−0.72	−0.07		−1.51
Sudden ecological or geological events	−0.01		−0.69	−0.04		−0.66	−0.01		−0.50	0.05		0.67
Invasive/alien or hyper-abundant species	−0.02	*	−1.85	−0.11	**	−2.21	−0.07	*	−1.72	0.21	**	2.27
Management and institutional factors	−0.01		−0.26	−0.02		−0.26	0.00		−0.15	0.03		0.24
Number of observations (threats) = 1221 Number of sites = 112												

The average marginal effects are calculated for four levels of management adaptive capacity using the ordered logit model in Stata (BE version 18.0) with standard errors cluster adjusted at the site level. Coefficients and z-stats are disclosed in the table in the Supplementary Table 2.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

the criteria do not seem to significantly correlate with adaptive management capacity, pointing to a potential gap in preparedness.

The study also finds that equatorial and arid zones are less likely to report threats compared to continental zones, and temperate zones are less

likely to report major threats. However, the management capacity in these zones does not differ significantly from other zones. This could suggest underreporting in equatorial and arid regions. These findings highlight the importance of improving threat detection and reporting mechanisms,

especially in vulnerable climate zones that may not recognise or address risks early enough.

Country effects are significant across all models, suggesting that national context plays a crucial role in both the perception of threats and the ability to manage them. China, Vietnam, and Iran show lower rates of threat reporting, while the Philippines and Afghanistan report more major threats and have lower adaptive management capacity. This highlights disparities in governance, resource allocation, and site management across different countries. These findings underscore the urgent need for targeted international support and policy interventions in countries where socio-political instability may hinder effective site management.

The starkest variation is evident in the type and intensity of threats. Only four kinds of threats are significant at $p < 0.05$ in this study, in contrast to seven in the previous study⁷. This may imply that certain threats are not being reported, or that the severity of threats is being downplayed in some developing countries. For example, the likelihood of reporting the threat of climate change and severe weather events as major is more than two times higher in developed countries compared to developing countries⁷. The likelihood of buildings and development being reported as major threats is also highly significant in developed countries, but not in developing countries.

Variation between developed and developing countries also exists with respect to adaptive capacity. In developed countries, a high degree of adaptive management capacity in natural heritage sites is found to be significantly and negatively associated with five types of threats; there is also a large degree of overlap between threats identified as major and corresponding adaptive capacity⁸. However, this study finds a disconnect between threats identified as major and corresponding adaptive capacity. Additionally, high capacity is positively associated with responding to threats related to other (illegal) human activities and invasive alien species. The difference may be because natural heritage sites and cultural heritage sites have different threat profiles and capacities to adapt to them.

Conclusion

This is the first study to investigate how site-specific characteristics relate to threat assessment, threat intensity, and degree of adaptive management capacity to handle threats to World Cultural Heritage Sites in developing countries of Asia. Theoretically, the study contributes to a broader understanding of the risk and vulnerability of WCHS in developing countries through simultaneous analysis of threats and adaptive capacities. Further, the study offers a comparison of the patterns of vulnerability of sites in developing and developed countries.

Important managerial and policy implications can be drawn from this study. First, sites with longer durations of engagement with the UNESCO system have an increased awareness of various threats, but not necessarily an improved capacity to manage them. Heritage sites on the UNESCO list enjoy more attention, as well as more national and international protection, than those that are not inscribed. Therefore, more sites in developing countries should be included on the UNESCO list, and they should diversify their development partners and carefully design systems to bolster their management capabilities. Given that older sites are more likely to report threats but have lower adaptive capacity, policymakers must prioritise resources for these sites. This could involve targeted funding for restoration and enhanced monitoring of threats. Second, care should be taken during the transfer of heritage conservation knowledge and technologies from developed to developing countries (or simply from one successful country to another) because threats and adaptive capacities vary between countries and regions of the world. Meanwhile, international organisations and national governments must collaborate to provide technical support, improve institutional capacity, and enhance adaptive management practices in highly vulnerable sites. Finally, with climate-related threats emerging as key risk factors, climate adaptation strategies need to be integrated into heritage sites' management plans. This is particularly important for sites where the threat of climate change may be unknown, underreported, or latent but significant.

This study has several limitations. It uses cross-sectional data from UNESCO's data repository, where Second Cycle reports were compiled in 2012 for Asia. The severity of threats and adaptive management capacity may have evolved in the interim period. Moreover, there are a considerable number of newer sites that were inscribed after the Second Cycle report, meaning data on them is not yet available. Because of the self-reported nature of the questionnaire used in these reports, certain threats or management responses may be under- or over-reported due to various reasons, including different interpretations of questions due to language barriers, political pressure, or funding considerations. Further, it is not possible for the UNESCO data to fully capture the complex, multi-dimensional analytical constructs of vulnerability and adaptive management capacity. Another limitation is that the relationship between threat intensity and adaptive management capacity is not investigated in this study. A future study could model this relationship using simultaneous equation models. Future research could also compare the current results with Third Cycle reports to reveal temporal trends. Other data sources such as State of Conservation reports, textual data from the authoritative documents of relevant cultural heritage institutions like ICOMOS, satellite imaging, remote sensing, participant surveys, and qualitative interviews could be combined with these datasets for more comprehensive analysis. State of Conservation reports and reports from renowned cultural heritage institutions may reduce biases introduced by the self-reported nature of periodic reports. Satellite images and remote sensing datasets, meanwhile, could be used to develop hazard and vulnerability maps, as well as to validate and enhance the accuracy of econometric models. Participant surveys could be used to gather data about threat perception from stakeholders other than site managers, and in-depth interviews with stakeholders could be used to explore the implications of both vulnerabilities and the barriers to addressing them.

Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

List of abbreviations

WCHS	World Cultural Heritage Sites
IMF	International Monetary Fund
KG climate classification	Köppen–Geiger climate classification
UNESCO	United Nations Educational, Scientific and Cultural Organization
WHS	World Heritage Sites

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References

1. Lakhanpal, S. Contesting renewable energy in the global south: a case-study of local opposition to a wind power project in the Western Ghats of India. *Environ. Dev.* **30**, 51–60 (2019).
2. Nguyen, T. L., Asahi, C., Tran, T. A. & Le, N. H. Indicator-based approach for flood vulnerability assessment in ancient heritage city of Hoi An, Central Region of Vietnam. *Nat. Hazards* **114**, 2357–2385 (2022).
3. Karkee, M. B., Cuadra, C. & Sunuwar, L. The challenges of protecting heritage architecture in developing countries from earthquake disasters. *Adv. Archit. Ser.* **20**, 407–419 (2005).
4. Bui, H. T., Le, T. A. & Nguyen, C. H. UNESCO world heritage designation: an opportunity or a threat to Hoi an ancient town (Vietnam)? (eds Baporikar N. et al.) In: *Tourism and Opportunities for Economic Development in Asia* 291–301 (IGI Global, 2017)
5. Caust, J. & Vecco, M. Is UNESCO World Heritage recognition a blessing or burden? Evidence from developing Asian countries. *J. Cult. Herit.* **27**, 1–9 (2017).

6. Levin, N., Ali, S., Crandall, D. & Kark, S. World Heritage in danger: Big data and remote sensing can help protect sites in conflict zones. *Glob. Environ. Change* **55**, 97–104 (2019).
7. Falk, M. & Hagsten, E. A management perspective on threats to cultural world heritage sites. *Int. J. Herit. Stud.* **29**, 167–183 (2023).
8. Falk, M. & Hagsten, E. Threat perception and adaptive capacity of natural world heritage site management. *Environ. Manag.* **71**, 285–303 (2023).
9. Simpson, N. P. et al. Decolonizing climate change-heritage research comment. *Nat. Clim. Change* **12**, 210–213 (2022).
10. Orr, S. A., Richards, J. & Fatoric, S. Climate change and cultural heritage: a systematic literature review (2016–2020). *Hist. Environ. Policy* **12**, 434–477 (2021).
11. Crowley, K. et al. Cultural heritage and risk assessments: gaps, challenges, and future research directions for the inclusion of heritage within climate change adaptation and disaster management. *Clim. Resil. Sustain* **1**, e45 (2022).
12. Labadi, S. A review of the global strategy for a balanced, representative and credible World Heritage List 1994–2004. *Conserv. Manag. Archaeol. Sites* **7**, 89–102 (2005).
13. Yongqi, L., Ruixia, Y., Pu, W., Anlin, Y. & Guolong, C. A quantitative description of the spatial-temporal distribution and evolution pattern of world cultural heritage. *Herit. Sci* **9**, 80 (2021).
14. Ryan, J. & Silvano, S. A brand for all the nations. *Mark. Intell. Plan.* **29**, 305–318 (2011).
15. Rössler, M. & Lin, R. C. H. Cultural landscape in world heritage conservation and cultural landscape conservation challenges in Asia. *Built Herit.* **2**, 3–26 (2018).
16. Hosseini, K., Stefaniec, A. & Hosseini, S. P. World Heritage Sites in developing countries: assessing impacts and handling complexities toward sustainable tourism. *J. Destin. Mark. Manag* **20**, 100616 (2021).
17. Nguyen, K. N. & Baker, S. Climate change impacts on UNESCO World Heritage-listed cultural properties in the Asia-Pacific region: a systematic review of state of conservation reports, 1979–2021. *Sustainability (Switzerland)* **15**, 14141 (2023).
18. Turner, B. L. et al. A framework for vulnerability analysis in sustainability science. *Proc. Natl Acad. Sci. USA* **100**, 8074–8079 (2003).
19. Adger, W. N. Vulnerability. *Glob. Environ. Chang.* **16**, 268–281 (2006).
20. Gallopini, G. C. Linkages between vulnerability, resilience, and adaptive capacity. *Glob. Environ. Chang.* **16**, 293–303 (2006).
21. Smit, B. & Wandel, J. Adaptation, adaptive capacity and vulnerability. *Glob. Environ. Chang.* **16**, 282–292 (2006).
22. Kasthala, S., Parthasarathy, D., Narayanan, K. & Inamdar, A. B. Classification and evaluation of current climate vulnerability assessment methods. *Soc. Indic. Res.* **171**, 605–639 (2024).
23. Field, C. B. & Barros, V. R. *Climate Change 2014—Impacts, Adaptation and Vulnerability: Regional Aspects* (Cambridge University Press, 2014).
24. Pörtner, H.-O. et al. *IPPC 2022: Climate Change 2022: Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Intergovernmental Panel on Climate Change, 2022).
25. Ravan, M., Revez, M. J., Pinto, I. V., Brum, P. & Birkmann, J. A vulnerability assessment framework for cultural heritage sites: the case of the Roman ruins of Tróia. *Int. J. Disaster Risk Sci.* **14**, 26–40 (2023).
26. UNESCO. *List of Factors Affecting the Properties* <https://whc.unesco.org/en/factors/> (2023).
27. Daly, P. et al. Rebuilding historic urban neighborhoods after disasters: balancing disaster risk reduction and heritage conservation after the 2015 earthquakes in Nepal. *Int. J. Disaster Risk Reduct.* **86**, 103564 (2023).
28. Jia, M. Y. et al. Exploring the impact of climate change on flood risk at cultural heritage sites using a GIS-based SCS-CN method: a case study of Shanxi province, China. *Int. J. Disaster Risk Reduct* **96**, 103968 (2023).
29. Kunte, P. D. et al. Multi-hazards coastal vulnerability assessment of Goa, India, using geospatial techniques. *Ocean Coast Manag.* **95**, 264–281 (2014).
30. Wang, J. J. Flood risk maps to cultural heritage: Measures and process. *J. Cult. Herit.* **16**, 210–220 (2015).
31. Li, M. Disaster risk management of cultural heritage: a global scale analysis of characteristics, multiple hazards, and issues based on historical disasters and current DRR measures in world heritage sites. *Int. J. Disaster Risk Reduct* **110**, 104633 (2024).
32. Broomandi, P. et al. Impacts of ambient air pollution on UNESCO world cultural heritage sites in Eastern Asia: dose-response calculations for material corrosions. *Urban Clim.* **46**, 101275 (2022).
33. al-Houdalieh, S. H. & Sauders, R. R. Building destruction: the consequences of rising urbanization on cultural heritage in the Ramallah Province. *Int. J. Cult. Prop.* **16**, 1–23 (2009).
34. Fu, L., Zhang, Q. P., Tang, Y. Z., Pan, J. & Li, Q. Assessment of urbanization impact on cultural heritage based on a risk-based cumulative impact assessment method. *Herit. Sci.* **11**, 15 (2023).
35. Miura, K. A dilemma of World Heritage ideals and challenges in Southeast Asia. *Int. J. Cult. Prop.* **29**, 433–457 (2022).
36. Su, M. & Li, B. Resource management at world heritage sites in China. *Procedia Environ. Sci.* **12**, 293–297 (2012).
37. Yang, X. S., Mu, D. J., Hu, M. J., Xiao, S. Z. & Meng, J. N. Establishment of the management effectiveness assessment system of world natural heritage and empirical analysis—a case study of Fanjingshan. *Herit. Sci* **11**, 124 (2023).
38. Selcuk, O., Karakas, H., Cizel, B. & Ipekci Cetin, E. How does tourism affect protected areas?: a multi-criteria decision making application in UNESCO natural heritage sites. *Nat. Hazards* **117**, 1923–1944 (2023).
39. Renfrew, C. Looting and vandalism (cultural heritage management). In *Encyclopedia of Global Archaeology* (ed. Smith, C) 4552–4554 (Springer New York, New York, NY, 2014).
40. Ravankhah, M., Schmidt, M. & Will, T. An indicator-based risk assessment framework for World Heritage sites in seismic zones: the case of “Bam and its Cultural Landscape” in Iran. *Int. J. Disaster Risk Reduct.* **63**, 102405 (2021).
41. Sabbioni, C., Brimblecombe, P. & Cassar, M. *The Atlas of Climate Change Impact on European Cultural Heritage: Scientific Analysis and Management Strategies* (Anthem Press, 2010).
42. Udeaja, C. et al. Urban heritage conservation and rapid urbanization: insights from Surat, India. *Sustainability* **12**, 2172 (2020).
43. Phillips, H. The capacity to adapt to climate change at heritage sites—the development of a conceptual framework. *Environ. Sci. Policy* **47**, 118–125 (2015).
44. Engle, N. L. Adaptive capacity and its assessment. *Glob. Environ. Chang* **21**, 647–656 (2011).
45. Gupta, J. et al. The Adaptive Capacity Wheel: a method to assess the inherent characteristics of institutions to enable the adaptive capacity of society. *Environ. Sci. Policy* **13**, 459–471 (2010).
46. Mortreux, C. & Barnett J. Adaptive capacity: exploring the research frontier. *Wires Clim.Chang* **8**, e467 (2017).
47. Unakul, M. Refining the adaptive capacity framework for world heritage management. *Nakhara: J. Environ. Des. Plan.* **17**, 25–42 (2019).
48. Tuan, T. H., Seenprachawong, U. & Navrud, S. Comparing cultural heritage values in South East Asia—possibilities and difficulties in cross-country transfers of economic values. *J. Cult. Herit.* **10**, 9–21 (2009).
49. Khoo, S. L. & Lim, Y. M. Dissecting George Town’s human capital challenges in built heritage. *J. Cult. Herit. Manag. Sustain.* **9**, 376–393 (2019).

50. Imon, S. S., DiStefano, L. D. & Lee, H.-Y. UNESCO–ICCROM Asian Academy for Heritage Management initiative to establish interpretation and presentation standards at World Heritage Sites in Asia. *J. Herit. Tour.* **6**, 245–254 (2011).
51. Chechi, A. Non-state actors and the implementation of the World Heritage Convention in Asia: achievements, problems, and prospects. *Asian J. Int. Law* **8**, 461–489 (2018).
52. Hinkel, J. “Indicators of vulnerability and adaptive capacity”: towards a clarification of the science-policy interface. *Glob. Environ. Chang.* **21**, 198–208 (2011).
53. Meskell, L. States of conservation: protection, politics, and pacting within UNESCO’s World Heritage Committee. *Anthropol. Q.* **87**, 217–243 (2014).
54. UNESCO. *The Criteria for Selection* (UNESCO, 2023).
55. Alberts, H. C. & Hazen, H. D. Maintaining authenticity and Integrity at Cultural World Heritage Sites. *Geogr. Rev.* **100**, 56–73 (2010).
56. Kotova, L., Jacob, D., Leissner, J., Mathis, M. & Mikolajewicz, U. (eds) *Climate Information for the Preservation of Cultural Heritage: Needs and Challenges. Transdisciplinary Multispectral Modeling and Cooperation for the Preservation of Cultural Heritage* (Springer International Publishing, Cham, 2019).
57. Kotova, L. et al. Making use of climate information for sustainable preservation of cultural heritage: applications to the KERES project. *Herit. Sci.* **11**, 18 (2023).
58. Bertacchini, E. E. & Saccone, D. Toward a political economy of World Heritage. *J. Cult. Econ.* **36**, 327–352 (2012).
59. Wooldridge, J. M. *Econometric Analysis of Cross Section and Panel Data* (MIT Press, 2010).
60. Rubel, F. & Kottek, M. Observed and projected climate shifts 1901–2100 depicted by world maps of the Köppen–Geiger climate classification. *Meteorol. Z.* **19**, 135 (2010).
61. UNESCO. *Periodic Reporting*. <https://whc.unesco.org/en/periodicreporting/> (2024)
62. International Monetary Fund. *World Economic Outlook Groups and Aggregates Information 2022* (International Monetary Fund, accessed 19 February 2024); <https://www.imf.org/external/pubs/ft/weo/2022/01/weodata/groups.htm#da>
63. Kawakami, K., Weise, K. & Dingwall, P. R. *Understanding World Heritage in Asia and the Pacific—No. 35—The Second Cycle of Periodic Reporting 2010–2012* (UNESCO, 2012).
64. Khalaf, R. W. Periodic Reporting under the World Heritage Convention: Futures and Possible Responses to Loss. *Hist. Environ.: Policy Pract.* **13**, 341–360 (2022).
65. Kottek, M., Grieser, J., Beck, C., Rudolf, B. & Rubel, F. World map of the Köppen–Geiger climate classification updated. *Meteorol. Z.* **15**, 259–263 (2006).
66. *Köppen–Geiger Observed and Predicted Climate Shifts—WGS 84*. Esri (ArcGIS Storymaps) <https://hub.arcgis.com/maps/Story::k%C3%B6ppen-geiger-observed-and-predicted-climate-shifts-wgs-84/about> (2020).
67. Marzeion, B. & Levermann, A. Loss of cultural world heritage and currently inhabited places to sea-level rise. *Environ. Res. Lett.* **9** (2014).
68. 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* **10**, 034001 (2018).
69. Boshier, L., Kim, D., Okubo, T., Chmutina, K. & Jigyasu, R. Dealing with multiple hazards and threats on cultural heritage sites: an assessment of 80 case studies. *Disaster Prev. Manag.* **29**, 109–128 (2019).
70. Global Heritage Fund. *Saving our Vanishing Heritage: Safeguarding Endangered Cultural Heritage Sites in the Developing World* (Global Heritage Fund, 2010).
71. Global Heritage Fund. *Asia’s Heritage in Peril* (Global Heritage Fund, 2012).
72. Morrison, T. H. et al. Political dynamics and governance of World Heritage ecosystems. *Nat. Sustain.* **3**, 947–955 (2020).

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M.B. has conceptualised the study, collected the necessary data, and wrote the main manuscript.

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