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Balancing heritage preservation and tourism development: a case study of Non Nuoc Cao Bang UNESCO Global Geopark, Vietnam

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Abstract. This study assesses the current state of heritage conservation at the Non Nuoc Cao Bang UNESCO Global Geopark (Vietnam) and examines the impact of tourism on historical and cultural sites. Using a survey of 500 respondents, including local community members, tourists and heritage experts, combined with field data analysis and GIS technology, the research reveals that, although public awareness of heritage values is relatively high (74.3%), the effectiveness of conservation efforts remains limited, with only 39.3% of respondents expressing satisfaction with current measures. The adoption of digital technology in conservation is also low (34.6%). Tourism in the geopark has grown at an average annual rate of 12.4%, but this increase has led to the degradation of 30.6% of heritage sites. The study identifies virtual reality (VR), mobile applications and integrated conservation-education models as promising solutions to improve heritage preservation and management. These findings provide valuable insights for developing sustainable tourism strategies that support both the conservation and promotion of historical and cultural values at the Non Nuoc Cao Bang UNESCO Global Geopark.

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1. Introduction

The Non Nuoc Cao Bang UNESCO Global Geopark, designated by UNESCO in 2018, is one of the most geologically, historically and culturally significant regions in Vietnam (UNESCO, 2023). Spanning over 3,000 km², the geopark not only preserves valuable geological heritage but also serves as a historical landmark and a repository of the distinctive cultural traditions of the ethnic minority communities (Nguyen & Kieu, 2024). The geopark is currently organised into four thematic tourism routes: Experience History, Explore Culture, Journey to the Waterfalls and Discover Karst Landscapes, which are designed to connect key geosites and cultural heritage sites and to guide the spatial distribution of tourism activities (Vu et al., 2022). However, in the context of globalisation and rapid tourism development, the conservation and promotion of historical and cultural values in this region face numerous challenges.

The conservation and promotion of historical and cultural heritage are crucial elements of sustainable development strategies (Zyoud & Fuchs-Hanusch, 2017; Brilha, 2018; Gordon et al., 2023). Historical and cultural sites serve as tangible evidence of a nation's historical evolution while contributing significantly to traditional education and economic development, particularly through tourism (Sardak et al., 2020; Hryniuk et al., 2023). However, practical observations indicate that many heritage sites within the Non Nuoc Cao Bang Geopark are at risk of degradation due to both natural and anthropogenic factors. Moreover, tourism activities have not fully succeeded in safeguarding and enhancing these values.

Global research efforts have explored various approaches to heritage conservation and promotion within geoparks (Sardak et al., 2020; Chen et al., 2022; Dai et al., 2024; Ferrando et al., 2024). Studies have examined topics such as the potential for geotourism and cultural tourism development (Song et al., 2025), the impact of geomorphological factors on heritage sites (Doniz-Paez & Becerra-Ramirez 2025), and the exploitation of karst-based tourism (Ruban, 2018). Additionally, research by Khalaf and Abu El-Kheir (2022) proposed sustainable development strategies for selected geoparks, and Pal and Albert (2018) compared different geotourism assessment models to identify the most effective approach. Other studies have focused on the contributions of geoparks to community development, heritage conservation and education (Girault, 2019; Hose, 2000; Wang et al., 2022; Guerini et al., 2023). Indrizal et al. (2024) highlighted the role of geology and tourism in promoting local sustainable development. Turoglu (2025) discussed the conceptualisation of "geoparks" and their influence on public awareness. Stoffelen et al. (2019) examined territorial identity within Dutch geoparks, while Justice (2018) assessed the effectiveness of science communication in UNESCO Global Geoparks. In China, the implementation of a community-based management model has simultaneously safeguarded cultural heritage and generated economic benefits while preserving local identity (Xu & Wu, 2022; Zhuang et al., 2024; Chen, 2025; Song et al., 2025; Zheng et al., 2025). These studies emphasise that effective conservation models must integrate scientific research, local governance and community participation to maximise their impact.

In Vietnam, research on cultural heritage conservation has primarily focused on nationally recognised historical sites, with limited studies on geoparks (Nguyen, 2016). Notable studies have addressed issues such as heritage value zoning for conservation within geoparks (Nguyen & Kieu, 2024), environmental impacts on geological heritage (Nguyen et al., 2018), community resilience in supporting sustainable tourism development (Powell et al., 2018), and geological assessments of potential geopark sites (Nguyen-Thuy et al., 2019). Additionally, research has explored geoproduct development (Hoang et al., 2018) and the geological and geomorphological diversity as a foundation for geopark establishment (Le, 2020). However, most of these studies focus on the geological and eco-tourism aspects (Vu et al., 2022; Nguyen & Kieu, 2024), with limited consideration of the interconnected relationship between geology, history and culture in heritage conservation within global geoparks. Notably, no in-depth study has specifically examined the conservation and promotion of historical and cultural values at the Non Nuoc Cao

Bang UNESCO Global Geopark. This gap highlights the need for comprehensive research to develop sustainable conservation strategies that align with local identity.

Existing studies have not fully addressed the current challenges facing the Non Nuoc Cao Bang Geopark, particularly the impact of tourism and social transformations on indigenous culture (Brilha, 2018; Nguyen & Kieu, 2024). Furthermore, no research has proposed an integrated conservation model that combines geological, historical and cultural factors to establish a comprehensive sustainable development strategy. This study aims to bridge this research gap through a multidisciplinary approach that integrates geology, cultural studies and history to propose effective conservation and promotion solutions. The novelty of this research lies in the development of an integrated conservation model that combines education, sustainable tourism and digital technology to enhance heritage preservation and dissemination. Additionally, the study analyses the impacts of tourism, social changes and other factors on historical and cultural heritage, thereby supporting the formulation of management policies tailored to local characteristics and global tourism trends.

From a scientific perspective, this research contributes to the theoretical framework of heritage conservation in UNESCO Global Geoparks, particularly in mountainous regions with diverse cultural landscapes and complex topography. Practically, it provides a scientific foundation for policy-making while offering concrete guidance for tourism managers, businesses and local communities in pursuing sustainable tourism development. Given the increasing economic and social development pressures, the lack of timely conservation measures may lead to the degradation or overexploitation of historical and cultural heritage sites in Non Nuoc Cao Bang (Vu et al., 2022). Therefore, this study is highly relevant and offers tangible benefits in preserving and promoting historical and cultural heritage in alignment with sustainable development goals.

2. Research materials and methods

2.1. Data and materials

This study employs a comprehensive dataset to provide a robust analysis and evaluation of the conservation and promotion of historical and cultural values at the Non Nuoc Cao Bang UNESCO Global Geopark. The data were gathered from multiple sources, including secondary data from official reports and previous studies, as well as primary data collected through field surveys, expert interviews and community feedback.

Secondary data were sourced from scientific literature, official reports, and databases from relevant organisations. The key sources include: (1) UNESCO and National Geoparks Committee reports (UNESCO, 2023), which provide insights into conservation policies and tourism statistics relevant to the geopark. (2) Published scientific studies, offering research findings on heritage conservation and geological aspects (Mahdi et al., 2009; Doan & Gałka, 2017; Zouros & Valiakos, 2017; Phuc et al., 2018; Ponta et al., 2018; Vu et al., 2022; Nguyen & Kieu, 2024); (3) Tourism and conservation data from local authorities, detailing trends in tourism and ongoing conservation efforts within the region.

To supplement and update the existing literature, primary data were collected to capture real-time information on the current state of conservation and promotion efforts. The primary data collection approach incorporated both qualitative and quantitative methods, providing a multidimensional perspective on the research topic. The following data sources were utilised: (1) Observations and on-site meas-

Table 1. Summarises the types of data sources used in this study

Data type	Source	Main content
Official reports	UNESCO, local authorities	Conservation policies, tourism statistics
Scientific publications	International and national journals	Research on heritage conservation and geology
Field surveys	Observations and on-site measurements	Heritage conservation status, risk assessments
Expert interviews	Researchers, heritage managers	Policy evaluation, proposed solutions
Sociological surveys	Local residents, tourists	Awareness, attitudes, and expectations on conservation

Source: own elaboration

urements were conducted to assess the status of heritage conservation and identify potential risks affecting heritage sites. (2) Interviews with researchers and heritage managers were conducted to evaluate conservation policies and propose sustainable conservation strategies. (3) Surveys of local residents, tourists and community stakeholders provided data on awareness, attitudes and expectations regarding conservation efforts.

The integration of multiple data sources ensures a comprehensive understanding of the current state of historical and cultural heritage conservation at the Non Nuoc Cao Bang UNESCO Global Geopark. Moreover, it enables the formulation of practical and sustainable conservation strategies that are tailored to the local context and aligned with global development trends.

2.2. Methods

This study adopts an interdisciplinary approach that integrates both quantitative methods and advanced analytical techniques to provide a comprehensive assessment of the historical and cultural values of the Non Nuoc Cao Bang UNESCO Global Geopark. The research methodology encompasses a combination of field surveys, Geographic Information System (GIS) technology, big data analytics, quantitative statistical methods, cultural data modelling, and social network analysis (SNA).

Field surveys and GIS application

Field surveys were conducted from September to December 2024 under the framework of the research project coded B2024-TNA-25 to collect detailed data on the status of historical and cultural heritage sites within the Non Nuoc Cao Bang UNESCO Global Geopark. GIS technology was integrated into the field surveys to map the spatial distribution of heritage sites and assess potential threats to their conservation (Chentouf et al., 2023; Jiang & Eastman, 2000). GIS supports the spatial digitisation of heritage sites, allowing for the identification of spatial relationships between cultural areas and facilitating the analysis of conservation risks. By enabling the visualisation of heritage site distributions and risks, GIS enhances decision-making processes in heritage management, enabling targeted risk assessments and optimised conservation planning.

To evaluate the current state of heritage conservation, a structured survey involving 500 respondents was conducted. The sample included 200 local residents, 250 tourists and 50 heritage experts. The group of heritage experts comprised: researchers in heritage studies; conservation managers; archaeologists and historians specialising in heritage; tourism specialists; and scientists from the Vietnam Academy of Social Sciences, Vietnam National University and Thai Nguyen University. The survey focused on four key criteria: (I) awareness of heritage values; (II) effectiveness of current conservation efforts; (III) extent of digital technology application in heritage preservation; and (IV) integration of education into conservation activities. These criteria were selected to provide a multidimensional understanding of public perceptions and the impacts of ongoing conservation initiatives.

Big data analytics

Big data were gathered from various online platforms, including Google Trends, social media, travel review sites, and digital news articles, to assess public interest in the heritage of Non Nuoc Cao Bang Geopark (Lawson-Body et al., 2024; Roßberg & Schmitt, 2025; Zhang et al., 2017). Data mining techniques and artificial intelligence (AI) algorithms were employed to analyse visitor engagement with historical and cultural heritage in the region (Tang, 2024). This approach facilitates the identification of emerging trends, the assessment of visitor preferences and the evaluation of the impact of digital engagement on heritage conservation efforts.

Quantitative statistical analysis

Quantitative statistical methods were employed to analyse data collected from field surveys, tourism statistics and community feedback. Various statistical techniques were applied, including: (1) Regression analysis: Used to examine the relationships between heritage conservation efforts and tourism growth (Gregoire, 2015; Thompson et al., 2017). (2) Hypothesis testing: Applied using t-tests and ANOVA to compare the perceptions of different groups regarding heritage preservation (Berta et al., 2021; Kim & Cribbie, 2018; Liu & Shiraito, 2023). (3) Exploratory factor analysis: Used to identify the key factors influencing heritage conservation (Conway & Huffcutt, 2003; Howard, 2016; Osborne et al., 2011; Watkins, 2018). These statistical methods provide empirical evidence that supports policy recommendations and sustainable conservation strategies for the geopark.

Cultural data modelling

Cultural data modelling was employed to systematically examine the interrelationships between historical, cultural, tourism and socio-economic

development factors. A SWOT analysis (Puyt et al., 2023; Vlados, 2019) combined with the Delphi technique (Seker, 2015; Skinner, 2016) was used to assess the strengths, weaknesses, opportunities and threats related to heritage conservation at the geopark. Additionally, forecasting models were utilised to predict future trends in cultural tourism development, offering valuable insights for long-term conservation planning (Hasanat et al., 2024).

Social network analysis

Social network analysis (SNA) was used to evaluate the interaction dynamics among the various stakeholders involved in heritage conservation and tourism development at the geopark (Yang, 2024). Data were collected from social media platforms such as Facebook, X (formerly Twitter) and TikTok to identify community networks, examine relationships between local authorities and the tourism sector, and assess public engagement in heritage-related discussions. The results of SNA provide a map of communication flows, helping to evaluate the spread of heritage-related information and to develop effective strategies for heritage promotion and public awareness.

3. Research results

3.1. Heritage density and conservation of historical and cultural values

The Non Nuoc Cao Bang UNESCO Global Geopark encompasses 208 historical and cultural heritage sites (UNESCO, 2023), which represent a rich diversity of historical values and cultural evolution over time. These sites include ancient temples, revolutionary landmarks, traditional craft villages and sacred places, illustrating the interconnectedness between nature and human civilisation in the region.

However, the distribution of these heritage sites is uneven, with a higher concentration found in historically significant areas such as Pac Bo Cave, Tran Hung Dao Forest and Dong Khe Battlefield – sites pivotal to Vietnam's revolutionary history. In contrast, other areas, especially those with rugged terrain, have fewer documented cultural sites. This spatial disparity underscores the need for comprehensive conservation strategies that address both high-density heritage zones and lesser-explored regions, ensuring a balanced approach to tourism development, heritage preservation and cultural promotion. A spatial analysis of the density of heritage sites within the Non Nuoc

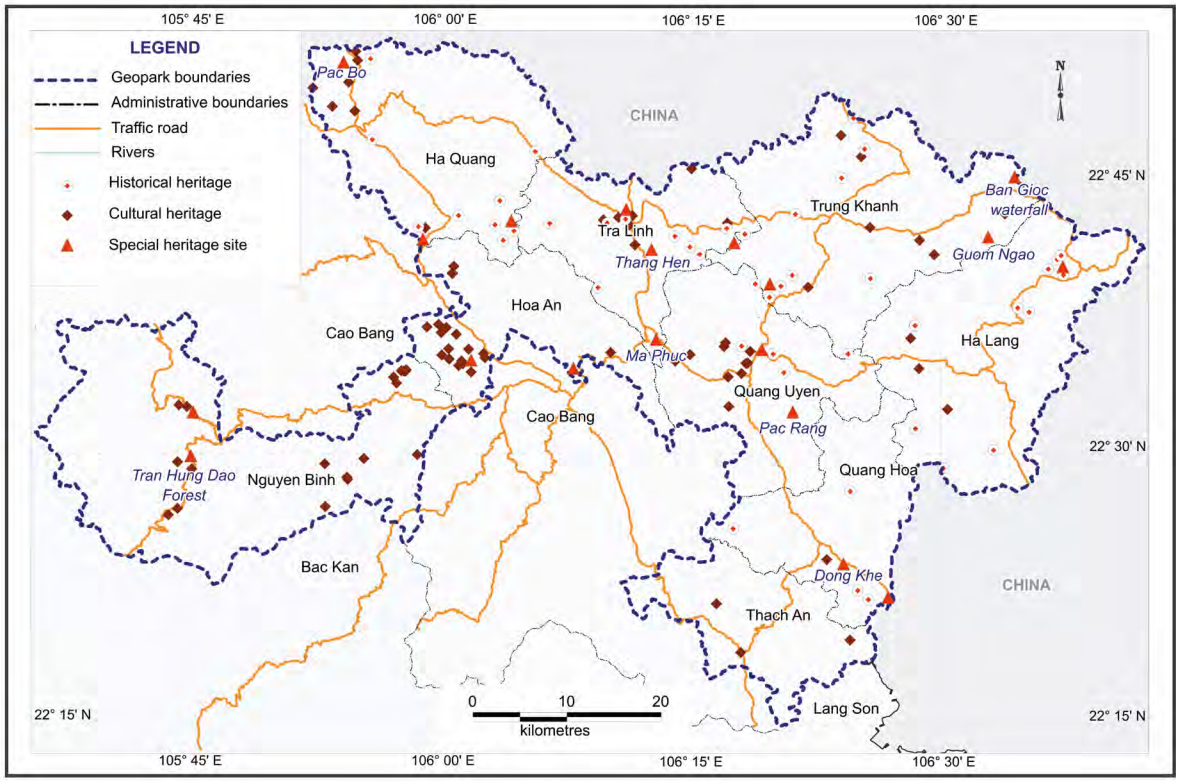

Fig. 1. Heritage density in the Non Nuoc Cao Bang UNESCO Global Geopark.
Source: Management Board of Non Nuoc Cao Bang UNESCO Global Geopark

Cao Bang UNESCO Global Geopark is illustrated in Figure 1.

A survey conducted to assess the conservation of historical and cultural values within the geopark revealed that a significant proportion of respondents (74.3%) demonstrated clear awareness of the historical and cultural significance of the region. However, only 39.3% rated the current conservation efforts as highly effective. Notably, just 34.6% of respondents positively assessed the use of digital technology in conservation, highlighting significant limitations in its application. Additionally, 49.6% of respondents noted that conservation efforts were integrated into educational initiatives, although the level of integration varied across different regions. Table 2 summarises the survey results, categorised into five evaluation levels: Excellent, Good, Average, Poor, and Very Poor.

These findings highlight a key discrepancy: although public awareness of heritage values is relatively high, the effectiveness of conservation efforts remains inadequate. This gap may result from challenges in management, limited resources and technological constraints in heritage preservation (Ferrando et al., 2024; Sardak et al., 2020). Notably, the low adoption of digital technology is evident, with only 34.6% of respondents rating its application as Good or Excellent. Conversely, 30.9% rated it as Average, and 34.5% considered it Poor or Very Poor.

The results also indicate notable progress in integrating education into conservation efforts, with 49.6% of respondents rating this integration as Good or Excellent. However, 20.9% assessed it as Poor or Very Poor, suggesting that further improvements are needed in this area. The survey results emphasise the urgent need for more effective and sustainable conservation strategies, incorporating modern technology and enhanced community education to ensure the preservation and promotion of historical and cultural heritage in the Non Nuoc Cao Bang UNESCO Global Geopark.

3.2. Impact of tourism on the conservation of historical and cultural heritage

Tourism plays a significant role in promoting and raising awareness of the historical and cultural values of the Non Nuoc Cao Bang UNESCO Global Geopark (Vu et al., 2022). However, alongside the economic and cultural benefits, the increasing pressure from tourism poses considerable challenges to heritage conservation, especially at heavily visited sites such as Ban Gioc Waterfall, Nguom Ngao Cave, Pac Bo Relic Site, Thang Hen Lake and traditional cultural villages. To assess the impact of tourism on heritage conservation, data on tourist arrivals and the degree of heritage site degradation between 2018 and 2024 were analysed.

The analysis results indicates that tourist arrivals to the geopark increased at an average annual rate of 12.4% between 2018 and 2024, rising from 250,140 visitors in 2018 to 503,680 in 2024. However, interprovincial and international arrivals declined sharply in 2020–21 due to the COVID-19 pandemic. While recent growth offers opportunities for heritage promotion, it has also imposed significant pressure on the surveyed sites. Field data show that 30.6% of heritage sites exhibit signs of tourism-related degradation, and the number of affected sites has increased steadily over time; notable examples include Ban Gioc Waterfall, Nguom Ngao Cave, the Pac Bo Relic Site and Thang Hen Lake.

The rapid increase in tourist numbers correlates directly with the rising number of heritage sites experiencing degradation. In 2018, only five sites showed signs of deterioration, but by 2024, this number had increased to 18, accounting for over one quarter of the key heritage sites in the region. Observed degradation includes water depletion and erosion at Ban Gioc Waterfall (Fig. 2a), environmental impacts at the Pac Bo Relic Site (Fig. 2b), tourist-generated litter in the Thung Mountain area (Fig. 2c) and environmental

Table 2. Assessment of conservation efforts for historical and cultural heritage in the Non Nuoc Cao Bang UNESCO Global Geopark

Evaluation criteria	Excellent (%)	Good (%)	Average (%)	Poor (%)	Very Poor (%)
Awareness of heritage values	29.2	45.1	14.6	7.9	3.2
Effectiveness of conservation efforts	9.8	29.5	35.4	20.1	5.2
Application of digital technology in conservation	7.9	26.7	30.9	24.6	9.9
Integration of education into conservation activities	14.9	34.7	29.5	15.6	5.3

Source: synthesised from evaluation results

Fig. 2. Selected images illustrating degradation and environmental decline at several tourist sites in the Non Nuoc Cao Bang UNESCO Global Geopark
Source: Management Board of Non Nuoc Cao Bang UNESCO Global Geopark, and own photos

pollution along the shoreline of Thang Hen Lake (Fig. 2d).

Further analysis shows that the impact of tourism varies across different categories of heritage sites. Historically significant sites, such as Pac Bo Relic Site, which is associated with President Ho Chi Minh, attract large numbers of visitors and are more vulnerable to rapid degradation compared to lesser-known sites. In contrast, natural sites like Nguom Ngao Cave and Thang Hen Lake face environmental degradation due to waste accumulation and unregulated tourism activities.

Overall, while tourism has contributed to the promotion of heritage and economic development, it also presents risks of irreversible damage to heritage sites without effective conservation measures. Implementing sustainable tourism management strategies such as visitor flow control at Ban Gioc Waterfall and Nguom Ngao Cave, carefully planned tour routes at Pac Bo Relic Site, and advanced conservation technologies at Thang Hen Lake will be critical for ensuring the long-term preservation and enhancement of historical and cultural heritage in the Non Nuoc Cao Bang UNESCO Global Geopark.

3.3. Solutions for the conservation and promotion of historical and cultural heritage

The advancement of digital technology has opened numerous opportunities for enhancing the conservation and promotion of historical and cultural heritage at the Non Nuoc Cao Bang UNESCO Global Geopark. This study explored the integration of innovative tools such as virtual reality (VR), mobile applications and digitised heritage zoning systems to improve both accessibility to heritage sites and management efficiency.

3.3.1. Application of virtual reality in heritage conservation and education

Pilot projects utilising virtual reality (VR) technology for heritage conservation at iconic sites such as Pac Bo Relic, Nguom Ngao Cave and Ban Gioc Waterfall have demonstrated positive results. The survey data reveal that 83.5% of participants, particularly international tourists and students, highly appreciated their heritage experiences through VR. These virtual models mitigate direct impacts on at-risk heritage sites by offering alternative methods of engagement, thus reducing physical wear-and-tear on sensitive locations. Moreover, VR significantly enhances the educational experience, providing immersive, interactive learning about the region's historical and cultural significance.

The analysis shows that VR applications have not only alleviated pressures on vulnerable sites but also provided visitors with an enriched educational encounter, fostering greater understanding and appreciation of the area's heritage. This finding is consistent with global trends in the use of immersive technologies for heritage preservation (Chentouf et al., 2023).

3.3.2. Development of mobile applications and heritage information management

In parallel with VR, mobile applications designed to provide real-time information about the geopark have been developed and widely deployed. Following a targeted communication campaign, application downloads increased by 45.3%, signalling the growing demand for smart tourism tools. These applications not only help tourists navigate heritage sites but also enable management agencies to monitor the conservation status of these sites through user-generated feedback. The incorporation of these digital tools has led to improved monitoring and the collection of valuable data regarding visitor experiences and the health of heritage sites.

Additionally, the mobile apps have enhanced visitor engagement, allowing tourists to contribute feedback, report environmental concerns and participate in educational initiatives. This has established a two-way communication channel between heritage managers and the public, fostering more dynamic and responsive conservation strategies.

3.3.3. Heritage zoning in the Non Nuoc Cao Bang UNESCO Global Geopark

To balance conservation efforts with the growing demands of tourism, this study implemented heritage zoning based on a thorough evaluation of heritage value, combined with GIS spatial analysis and expert consultations. The zoning system classified the geopark into three primary conservation zones, each with tailored protection strategies to ensure sustainable management and development. The classification results are presented in Table 3, showing the three conservation zones and their respective strategies:

These zones reflect a strategic approach to ensuring that the most culturally and ecologically significant areas receive the highest level of protection. The strict conservation zone has been expanded compared to previous studies (Nguyen & Kieu, 2024; Vu et al., 2022) to provide more comprehensive safeguards for key heritage sites.

The spatial distribution of these zones, as shown in Figure 3, demonstrates how conservation priorities are matched to heritage values. The zoning system supports the integration of both conservation

Table 3. Zoning, sub-zoning, and conservation solutions for the Non Nuoc Cao Bang UNESCO Global Geopark

Conservation zone	Sub-Zoning	Conservation strategies
Strict conservation zone (54,023 ha)	Core areas of national parks, nature reserves, geological heritage sites, Level 1 historical and cultural relics	Strict conservation, minimal human impact, establishment of protective corridors, community awareness enhancement
Moderate conservation zone (126,178 ha)	Palaeontological heritage, rock heritage, cultural heritage, buffer zones of national parks	Eco-tourism development, environmental protection, preservation of traditional festivals
Low conservation zone (160,046 ha)	Agricultural and forestry zones, residential areas	Economic development integrated with conservation, development corridors planning

Source: own elaboration

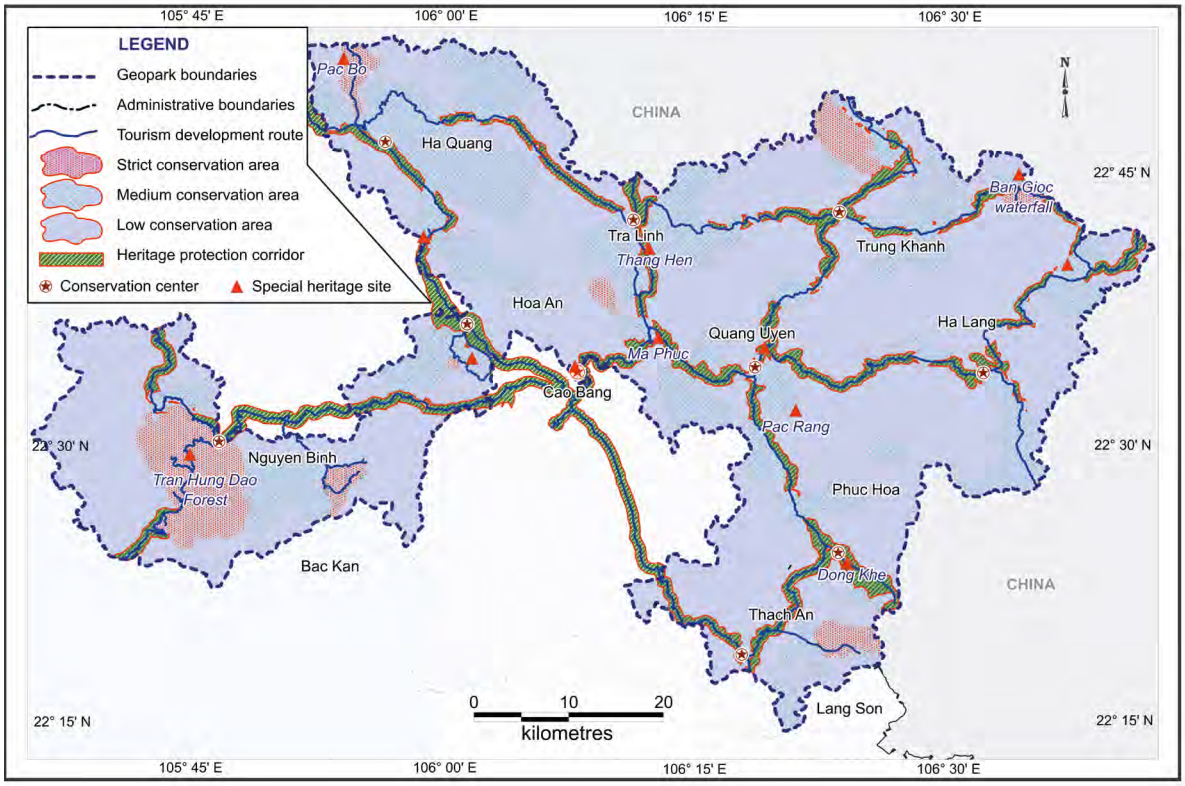

Fig. 3. Heritage zoning map of the Non Nuoc Cao Bang UNESCO Global Geopark
Source: own elaboration

and development, providing a structured framework for managing tourism while protecting the most valuable sites.

3.3.4. Proposed model for heritage conservation integrating education and sustainable tourism

This study also tested a conservation model that integrates education and sustainable tourism to promote heritage preservation while enhancing visitor experiences (Zafeiropoulos & Drinia, 2023). The model encourages visitors to not only observe but also engage in interactive activities such as heritage workshops and field programmes, thereby fostering a deeper connection with the cultural and historical context of the sites.

Survey results from the implementation of this model at Pac Bo, Khuoi Ky Stone Village and Phuc Sen Blacksmithing Village indicate a 30.7% increase in visitor satisfaction compared to traditional tourism models. Furthermore, public awareness of cultural heritage within the local community improved by 41.6%, as demonstrated by increased community participation in conservation efforts.

As illustrated in Table 4, the integrated conservation–education–tourism model has proven highly effective in improving both community awareness and visitor satisfaction. The model fosters a more immersive experience that promotes responsible tourism practices while reinforcing the value of preserving local heritage. This approach offers signifi-

Table 4. Impact of the heritage conservation model integrating education and sustainable tourism

Evaluation criteria	Before experiment (%)	After experiment (%)	Increase (%)
Visitor satisfaction level	65.2	95.9	+30.7
Community awareness of heritage	49.5	91.1	+41.6

Source: own elaboration

cant benefits and could serve as a key strategy for future heritage conservation and promotion in the Non Nuoc Cao Bang UNESCO Global Geopark.

4. Discussion

The findings of this study reveal important insights into the current state of heritage conservation and the promotion of historical and cultural values at the Non Nuoc Cao Bang UNESCO Global Geopark. The study indicates that, although public awareness of heritage values is relatively high, with 74.3% of participants rating their awareness as good or very good, the effectiveness of conservation efforts remains limited. Only 39.3% of respondents expressed strong satisfaction with current conservation measures, highlighting a significant gap between awareness and effective conservation. This discrepancy points to the urgent need for more robust and efficient conservation strategies.

A key finding of this study is the low adoption of digital technologies in heritage conservation, with only 34.6% of participants rating the application of these technologies positively. This reflects a broader trend observed in Vietnam, where the integration of technology in conservation has not yet reached the level seen in many Western countries. The findings align with the research by Nguyen-Thuy et al. (2019), which identified similar challenges in applying technology and effectively managing heritage resources in Vietnam. The limited use of digital tools highlights the necessity for modern technological solutions to improve conservation efforts, which can enhance both the protection of heritage sites and the overall visitor experience.

When compared to global studies, the results of this study echo the conclusions of Hryniuk et al. (2023), who assessed the role of public awareness in the conservation of historical and cultural heritage in the Carpathian region. Public awareness plays a significant role in shaping the success of conservation efforts, but this awareness must be complemented by concrete action and effective management strategies. In line with Sardak et al. (2020), community engagement is vital for the development of sustainable historical and cultural tourist destinations. However, digital heritage conservation strategies in countries such as those in Europe, as noted by Kotsiubivska and Baranskyi (2020), are more advanced, suggesting that Vietnam could benefit from further investments in digital infrastructure for heritage management.

The analysis of tourism impacts revealed a significant increase in tourist arrivals to the Non Nuoc Cao Bang Geopark, with an average annual increase of 12.4% from 2018 to 2024. While tourism contributes to heritage promotion, it also creates significant pressure on conservation efforts, particularly at popular sites such as Ban Gioc Waterfall, Nguom Ngao Cave and Pac Bo Relic Site. The number of heritage sites showing signs of degradation rose from five in 2018 to 18 in 2024, emphasising the need for more effective management practices to mitigate the negative effects of tourism. This trend is consistent with Le et al. (2021), who documented the impact of tourism overload on the heritage sites of Hue, Vietnam, noting a decline in conservation quality due to increasing visitor numbers.

Interestingly, the impact of tourism on heritage sites varies depending on the type of site. Historical sites such as Pac Bo Relic Site, associated with significant historical figures like President Ho Chi Minh, are more vulnerable to degradation due to higher visitor numbers. In contrast, natural sites like Thang Hen Lake are facing environmental degradation from waste accumulation and unregulated tourism activities. These findings highlight the need for tailored conservation strategies for different categories of heritage sites, an issue that has been similarly addressed by Chetverikov et al. (2024), who suggested that advanced monitoring techniques could help mitigate the tourism-induced degradation of heritage sites.

Several innovative conservation strategies have shown promising results. Virtual reality (VR) applications, for example, have been well received by 83.5% of participants, reflecting a global trend toward the use of digital technologies in heritage conservation (Van Onselen et al., 2022). VR offers an immersive and interactive way for visitors to engage with heritage without placing direct pressure on at-risk sites. Additionally, the development of mobile applications, which saw a 45.3% increase in downloads following a communication campaign, has proven effective in raising public awareness and assisting in the management of heritage sites. These applications allow visitors to explore sites while providing real-time data on conservation status, facilitating proactive management by heritage authorities.

Heritage zoning, which categorised the geopark into three conservation zones, has proven to be an effective tool in balancing conservation and tourism development. The strict conservation zone has been expanded to include key heritage sites, ensuring optimal protection. This zoning strategy aligns with previous conservation models (Brilha, 2018; Zouros & Valiakos, 2017) but also presents challenges related to enforcement and resource allocation, as pointed out by Zyoud and Fuchs-Hanusch (2017). Moreover, the integration of education and sustainable tourism

into conservation efforts has shown positive outcomes. Implementing the model at sites like Pac Bo, Khuoi Ky Stone Village and Phuc Sen Blacksmithing Village led to a 30.7% increase in visitor satisfaction and a 41.6% increase in community awareness of heritage. These results suggest that combining conservation with education and responsible tourism offers a promising pathway for future heritage management in the region.

These findings are consistent with the work of Jelen et al. (2021), who proposed a typology of historical cultural landscapes based on cultural elements and emphasised the importance of systematic zoning in conservation. Similarly, Sedek et al. (2024) reinforced the significance of adopting digital monitoring techniques for heritage preservation, underlining the value of innovative, technology-driven approaches.

Despite the significant contributions of this study, there are limitations that should be addressed in future research. Firstly, the reliance on surveys and field analysis may not fully capture the socio-economic factors influencing conservation efforts, a better understanding of which could provide a more nuanced understanding of the challenges at hand. Secondly, the digital solutions and models proposed in this study are still in the experimental phase, and their long-term effectiveness requires further evaluation. Future studies should focus on developing data-driven conservation management models that integrate Big Data and Artificial Intelligence (AI) to enhance monitoring efficiency and inform decision-making. Additionally, research on the socio-economic influences on heritage conservation is essential for refining policy recommendations and creating more effective, context-specific strategies. Furthermore, exploring the potential of ecotourism and experiential tourism models could provide valuable insights into balancing tourism development with sustainable heritage conservation.

This study underscores the importance of integrating technology, community participation and strategic zoning in heritage conservation. While challenges persist, aligning conservation efforts with global best practices and leveraging emerging technologies holds the potential to significantly enhance the sustainability of cultural heritage sites in Vietnam. By addressing the limitations identified in this study and continuing to experiment with innovative conservation approaches, the Non Nuoc Cao Bang UNESCO Global Geopark can constitute a model for other geoparks worldwide.

5. Conclusions

This study provides an in-depth assessment of the current state of historical and cultural heritage conservation at the Non Nuoc Cao Bang UNESCO Global Geopark, examines the impact of tourism and proposes sustainable conservation solutions. The findings indicate that, although community awareness of heritage values is relatively high (74.3%), the effectiveness of conservation efforts remains limited, with only 39.3% of respondents expressing satisfaction with current conservation measures. A notable challenge is the low adoption of digital technology, with just 34.6% of participants rating its application positively in heritage conservation.

Tourism has contributed to economic development, with an average annual increase in tourist arrivals of 12.4%. However, this growth has placed significant pressure on heritage sites, with 30.6% of them showing signs of degradation. This underscores the need for targeted conservation strategies that can mitigate the negative effects of tourism while enhancing the positive impacts.

Several conservation strategies have demonstrated effectiveness, including the application of virtual reality (VR), the development of mobile applications and the implementation of heritage zoning. These approaches have improved management efficiency and provided innovative tools for both conservation and visitor engagement. Notably, the integrated model combining conservation, education and sustainable tourism has resulted in a 30.7% increase in visitor satisfaction and a 41.6% improvement in community awareness of heritage preservation.

These results highlight the critical role of integrating conservation efforts with education and sustainable tourism practices. Furthermore, they underscore the need for comprehensive and adaptive management policies that incorporate modern technologies, community participation and tourism management strategies to ensure the long-term sustainability of heritage conservation efforts. To achieve lasting success, future conservation initiatives must continue to evolve, addressing emerging challenges and aligning with global best practices.

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