



Research article

Assessing the impact of green finance on sustainable tourism development in China

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ABSTRACT

The escalating urgency to address environmental degradation and promote sustainable development globally has emphasized the critical role of Green Finance (GF) in fostering responsible practices across industries. The tourism sector has drawn significant attention due to its substantial environmental impact, necessitating the implementation of robust financial mechanisms to mitigate its ecological footprint. China, recognized as a key player in the global tourism arena, the convergence of rapid economic expansion and the imperative for environmental conservation presents a distinctive set of challenges and opportunities. The study employed the Fuzzy Analytic Hierarchy Process (AHP) and Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methodologies to systematically evaluate the impact of GF. The findings of fuzzy AHP indicate the critical role of environmental sustainability measures (GF2) as the topmost impacting factor. This refers to the practice of utilizing financial mechanisms and instruments to support initiatives that promote environmental conservation, minimize ecological footprints, and foster sustainable development. While financial allocation and effectiveness (GF1) and policy and regulatory framework impact (GF4) also hold significant importance in shaping sustainable tourism development. Moreover, the results of fuzzy TOPSIS identified top strategies such as green bond innovation for ecosystem regeneration (S1) and circular economy integration (S4), which can play a significant role in promoting sustainable tourism practices by facilitating initiatives aimed at ecosystem regeneration and integrating circular economy principles into the tourism industry.

1. Introduction

The global spotlight on both economic growth and environmental sustainability underscores their significance as shared challenges and responsibilities for the world [1]. Sustainable development has become a global imperative, urging industries and economies to adopt practices that balance economic growth with environmental and social well-being. Within this paradigm, green finance (GF) emerges as a crucial tool, encompassing financial strategies and instruments that prioritize environmental sustainability in investment decisions. Its application in fostering sustainable projects has been vital, particularly in the domain of sustainable tourism. The United

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Nations Environment Programme (UNEP) defines green funding as raising the amount of money coming into sustainable development initiatives from the public, private, and not-for-profit sectors (from banking, microcredit, insurance, and investment) [2]. Improving the management of social and environmental risks, seizing opportunities that offer environmental benefits as well as a respectable rate of return, and increasing responsibility are all important.

GF projects aim to direct capital toward initiatives that reduce environmental impact, enhance energy efficiency, and promote conservation. These projects span a spectrum of industries, from renewable energy infrastructure to sustainable agriculture and eco-friendly tourism ventures. Within the context of sustainable tourism, initiatives supported by GF play a fundamental role in fostering practices that minimize the ecological footprint of tourism activities, preserve cultural heritage, and promote community engagement [3]. Additionally, the ecological footprint facilitates temporal and spatial comparisons of sustainability, aiding in the evaluation of the efficacy of pertinent policy measures [4]. The concept of sustainable tourism, rooted in the Brundtland commission's definition of sustainable development, seeks to meet the needs of present tourists and host regions while safeguarding and enhancing opportunities for the future [5]. The integration of environmental, socio-cultural, and economic considerations lies at the core of sustainable tourism practices. Various theories such as the triple bottom line (TBL) approach, carrying capacity theory, and stakeholder theory serve as guiding frameworks in understanding and implementing sustainable tourism initiatives [6].

Nevertheless, unregulated tourism expansion, particularly in well-visited destinations, may result in detrimental consequences if adequate sustainability measures are not implemented. Challenges such as over-tourism, excessive demand on local resources, erosion of cultural integrity, and environmental degradation, encompassing habitat destruction and heightened pollution, can compromise the fundamental principles of sustainable tourism [7]. Neglecting to harmonize tourism development with environmental preservation and socio-cultural safeguarding could lead to enduring repercussions, impacting not only natural ecosystems but also the well-being of local communities. Therefore, while exploring the potential benefits of GF in sustainable tourism, it is imperative to acknowledge and mitigate the risks associated with unsustainable tourism practices [8]. Conversely, the integration of GF into sustainable tourism initiatives presents a promising avenue for positive impacts. GF mechanisms offer a means to support and incentivize eco-friendly infrastructure, community-based tourism enterprises, and conservation projects within the tourism sector. When effectively employed, these financial instruments not only facilitate the preservation of natural landscapes and cultural heritage but also stimulate economic growth [9]. By fostering sustainable tourism practices, GF has the potential to attract conscientious tourists seeking authentic, environmentally responsible experiences. This, in turn, can bolster local economies, create job opportunities, and foster community development. Furthermore, strategic investments in sustainable tourism, backed by GF, can contribute to enhanced resilience against environmental challenges while maintaining the allure and longevity of tourism destinations.

China, as a global economic powerhouse and country rich in diverse natural and cultural resources, stands as a significant focal point for the exploration of sustainable tourism development [10]. With a focus on preserving its rich cultural heritage and diverse natural landscapes, strategic investments through GF can foster the growth of sustainable tourism initiatives. The research investigates the relationship between economic growth, corruption, natural resource rents, and environmental degradation, challenging conventional notions and offering targeted policy recommendations. The impact of economic growth on the ecological footprint across different income groups reveals significant variations [11]. China's proactive policies aimed at promoting ecotourism, conservation efforts, and eco-friendly infrastructure align well with the principles of GF [12]. By allocating funds to projects that prioritize environmental conservation, community engagement, and the preservation of cultural heritage sites, China can not only bolster its position as a global tourism destination but also stimulate regional economic development. Moreover, the integration of GF into sustainable tourism practices can serve as a model for other nations, showcasing the viability of environmentally responsible tourism development strategies. Multi-criteria decision-making (MCDM) methods provide structured frameworks for decision-making by considering multiple criteria or factors simultaneously [13].

In the context of assessing the impact of GF on sustainable tourism in China, the utilization of MCDM methods, specifically fuzzy Analytical Hierarchy Process (AHP) and fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), provides a systematic framework for the comprehensive evaluation and comparison of various aspects. The fuzzy AHP method plays a pivotal role in the assessment process by systematically evaluating the criteria and sub-criteria relevant to sustainable tourism development. By incorporating fuzzy logic, this method accommodates the inherent uncertainties and subjectivity in decision-making. On the other hand, the fuzzy TOPSIS method is instrumental in assessing and ranking the strategies identified in the study. It takes into account the evaluated criteria and sub-criteria, providing a structured approach to determine the most effective strategies for promoting sustainable tourism development. This method considers the ideal and negative-ideal solutions, providing a balanced perspective that aligns with the multifaceted nature of sustainable tourism initiatives. In this regard, the combination of fuzzy AHP and fuzzy TOPSIS methodologies in our study allows for a thorough assessment of criteria, sub-criteria, and strategies related to GF and sustainable tourism development in China.

2. Literature review

Sustainable tourism intersects significantly with climate change concerns, forming a crucial nexus in addressing environmental impact. Climate change poses a considerable threat to tourist destinations worldwide, affecting landscapes, biodiversity, and local communities. The escalating levels of atmospheric carbon dioxide have led to profound environmental challenges, including global warming and glacier melting. Scientists are increasingly investigating the link between economic progress and environmental degradation [14]. Another research emphasizes the vulnerability of tourism to climate change-induced events like extreme weather and shifts in ecosystems [15]. Sustainable tourism practices, as advocated by the UNWTO report, play a pivotal role in mitigating these effects. Strategies such as promoting low-carbon transport, reducing energy consumption in accommodations, and engaging in carbon

offset programs are integral to sustainable tourism's contribution to climate change mitigation and adaptation within the tourism sector. Implementing and advocating for sustainable tourism practices not only minimizes the industry's carbon footprint but also fosters resilience against climate-related risks, ensuring the long-term viability of tourism destinations [16].

Sustainable initiatives, including ecotourism and conservation efforts, align with China's commitment to responsible tourism practices. Another study investigates the impact of trade openness and foreign direct investment (FDI) on carbon neutrality, revealing an M-shaped decoupling trend between economic growth and carbon emissions [17]. However, challenges such as over-tourism and maintaining cultural authenticity persist alongside opportunities in technological advancements and niche tourism segments. Government policies and post-pandemic recovery efforts underscore the industry's resilience and potential for future expansion on both domestic and international fronts [18].

Research exploring the convergence of GF and sustainable tourism elucidates the symbiotic relationship between financial mechanisms and sustainable development in the tourism sector. Study by Ref. [19], and high-profile reports like those from the global sustainable tourism council (GSTC) investigate how investments in sustainable tourism can bolster economic growth, promote local livelihoods, and preserve natural and cultural resources. Collectively, the literature indicates a growing momentum toward integrating GF into sustainable tourism practices globally, with China emerging as a significant player.

2.1. Sustainable tourism-based studies on MCDM

This literature review examines the impact of green finance on sustainable tourism and the theoretical foundations of this study's methods. Previous research has employed Fuzzy MCDM approaches to discover and assess sustainable tourism destinations in China. The sustainable tourism based MCDM studies are illustrated in Table 1.

2.2. Research gap

There is an extensive amount of literature on sustainable tourism, but not much of it looks at how fuzzy MCDM techniques could help green finance boost sustainable tourism growth in developing nations. More research is required to determine the advantages of using such approaches in developing nations. To fill this research vacuum, the present study investigates the ways in which fuzzy AHP and fuzzy TOPSIS techniques could support decision-making related to sustainable tourism. This study aims to bridge this gap by leveraging robust evaluative frameworks and empirical methodologies to precisely assess the relationship between GF interventions and tangible sustainable tourism outcomes in China.

Table 1
Sustainable tourism-based studies on MCDM.

Scope	Method	Description	Ref.
Sustainable Ecotourism	TOPSIS	The study identifies key strategies for sustainable ecotourism in Iran's Lafour region, highlighting the importance of investment, healthcare facilities, and diversified tourism services for achieving sustainable development goals.	[20]
E-service quality in sustainable tourism	AHP-TOPSIS	The study assesses leading attributes of travel websites based on sustainable e-service quality, highlighting security, hedonic value, and efficiency as crucial drivers influencing customer choice emerging as the top preference.	[21]
Policy framework for sustainable tourism	DEMATEL-DANP-VIKOR	The study employs hybrid MCDM methods to propose an optimal improvement plan for Taiwan's tourism policy, utilizing DEMATEL, DANP, and VIKOR to evaluate influential dimensions and criteria.	[22]
Sustainable tourism analysis in European countries	MCDM	This paper offers a critical overview and empirical research on sustainable tourism in European countries, utilizing Grey Systems Theory and MCDM for robust evaluation and dynamic analysis.	[23]
Sustainable rural tourism prioritization	OWA-AHP	The study prioritizes rural tourism activities in Isfahan province using MCDM, highlighting mountaineering and canyoning as optimal options for tourism development based on risk assessment.	[24]
Sustainable island tourism development framework	Fuzzy MCDM	The paper introduces a framework using a hybrid approach for sustainable island-based tourism development, demonstrating its applications and highlighting the preference for a medium-size development plan.	[25]
Economic impact on sustainable tourism	CRITIC-VIKOR	The paper aims to address over tourism in Spain by proposing indicators using an integrated MCDM approach, highlighting economic indicators' negative impact on sustainable tourism.	[26]
Cycling routes for sustainable tourism development	AHP-ELECTRE	This study uses MCDM to assess cycling routes for tourism in the Franciacorta area, offering insights for prioritizing paths for public administrators	[27]
Assessing the sustainable agri-tourism	AHP-TOPSIS	Identifying key factors for agri-tourism success in India, aiding practitioners, and highlighting limitations in geographic coverage.	[28]
Sustainable tourism stakeholder perspectives	AHP	The study aims to revitalize Turkey's villages through sustainable rural tourism, preventing cultural erosion and economic decline.	[29]
Renewable energy implementation for sustainable tourism	MCDM	The paper proposes a framework to link renewable energy implementation in islands with tourism development, highlighting different strategies and drivers influencing their integration.	[30]

3. Criteria and strategies for sustainable tourism development

We conducted an extensive literature review and engaged with experts in the field to establish the standards and approaches for assessing the effects of GF on sustainable tourism in China when developing the assessment methodology. These standards were chosen due to their significance to the corpus of existing knowledge and the distinctive characteristics of China that are related to sustainable tourism. The selected criteria's and strategies, which emphasize the value of this region's distinctive qualities and cultural aspects, provide a strong foundation in this concern. Thus, these criteria and methodologies suit this case study analysis. The geographical territory of China is shown in Fig. 1.

3.1. Identification of criteria and sub-criteria

The study adopts a well-organized framework to thoroughly assess the influence of GF on sustainable tourism development in China. This structured framework incorporates a wide range of criteria and sub-criteria, spanning from policy considerations to socio-environmental equilibrium. Table 2 provides the criteria and sub-criteria for this study.

3.2. Identification of strategies for sustainable tourism

For the case study, various strategies have been identified. These strategies, ranging from ground-breaking financial instruments to cutting-edge technological integrations, epitomize a paradigm shift towards sustainable practices within the sector. Each strategy presented here embodies a proactive approach, aiming not just to mitigate the negative impacts of tourism but also to foster regenerative approaches that uphold environmental integrity, community empowerment, and economic viability. In this study, we created these prominent strategies, as illustrated in Fig. 2.

3.2.1. Green bond innovation for ecosystem regeneration

This strategy focuses on the creation of innovative green bonds tailored to fund projects specifically aimed at rejuvenating ecosystems impacted by tourism activities. These bonds prioritize initiatives centered on rehabilitating natural habitats and fostering biodiversity, mitigating the adverse effects of tourism on fragile ecosystems [51].

3.2.2. Digital twin technologies for sustainable infrastructure

The utilization of digital twin technologies aims to replicate and optimize sustainable infrastructure development within the tourism sector. By creating virtual models of physical assets and systems, this strategy facilitates efficient resource allocation and reduced environmental impact in the design and management of tourism infrastructure [52].

3.2.3. Data-driven predictive analytics for sustainable tourism

Leveraging advanced predictive analytics and machine learning, this strategy anticipates and mitigates potential negative repercussions of tourism on ecosystems. By proactively analyzing data, it enables informed decision-making, allowing for pre-emptive measures to sustainably manage tourism activities and their impacts on the environment [53].



Fig. 1. The geographical territory of China, Source [31].

Table 2
Identification of criteria and sub-criteria.

Criteria	Sub-criteria	Description
Financial Allocation and Effectiveness (GF1)	Investment Efficiency (GF11)	This criterion investigates into the extent to which financial resources allocated to sustainable tourism projects are effectively utilized, emphasizing the optimization of funds towards sustainable outcomes and initiatives [32].
	Economic Viability Enhancement (GF12)	Assessing the impact of financial contributions on the economic growth and overall sustainability of sustainable tourism initiatives, focusing on their long-term economic viability and positive growth trajectory within the tourism sector [33].
	Green Finance Innovations (GF13)	This sub-criterion involves exploring the level of creativity and uniqueness within financial mechanisms supporting sustainable tourism, including innovative approaches like green bonds and crowdfunding, aiming to foster sustainable practices and initiatives [34].
	Return on Sustainable Investment (GF14)	ROSI specifically measures the financial returns generated from investments in sustainable tourism projects, offering a quantifiable evaluation of the financial benefits obtained from these sustainable ventures [35].
Environmental Sustainability (GF2)	Carbon Footprint Mitigation (GF21)	Evaluation of the impact of financial interventions, such as investments in green energy, specifically targeting the reduction of carbon emissions resulting from tourism activities [36].
	Biodiversity Conservation Funding (GF22)	Assessment of the allocated funds aimed at the preservation and protection of biodiversity within the realm of tourism, emphasizing financial support for biodiversity conservation initiatives [37].
	Resource-Efficient Investments (GF23)	Examination of financial strategies and investments designed to optimize the use of natural resources within tourism, focusing on initiatives that enhance resource efficiency and reduce wastage [38].
	Eco-friendly Infrastructure Development (GF24)	Evaluation of financial efforts directed towards the establishment of eco-friendly infrastructure within the tourism sector, emphasizing the development of sustainable infrastructure to minimize environmental impacts [39].
Social and Community Development Initiatives (GF3)	Community Empowerment (GF31)	Evaluation of the role played by green finance, including crowdfunding initiatives, in empowering and uplifting local communities actively engaged in sustainable tourism endeavors [40].
	Cultural Preservation Investments (GF32)	Assessment of financial support directed towards the preservation and promotion of cultural heritage and traditional practices within the tourism landscape, emphasizing investments preserving cultural identity [41].
	Social Equity through Finance (GF33)	Focus on ensuring equitable distribution of financial benefits among communities engaged in sustainable tourism, aiming for fair and just allocation of financial gains and opportunities [42].
	Capacity Building and Skill Enhancement (GF34)	Evaluation of financial initiatives dedicated to enhancing the capacities and skill sets within local communities involved in sustainable tourism, emphasizing skill development to foster active participation and sustainable growth [43].
Policy and Regulatory Framework Impact (GF4)	Financial Policy Efficacy (GF41)	Assessment of the effectiveness of financial policies embedded within the regulatory framework, specifically aimed at promoting and advancing sustainable practices within the tourism industry [44].
	Governmental Support and Financial Backing (GF42)	Evaluation of the level of involvement and financial support provided by governmental bodies towards sustainable tourism initiatives, emphasizing their contribution to fostering sustainability [37].
	Financial Transparency and Accountability (GF43)	Focus on ensuring transparency and accountability in the implementation of green finance instruments, including green bonds, within the development of tourism, aiming for clear financial operations and responsible practices [45].
	Policy Adaptability and Resilience (GF44)	Assessment of the adaptability and resilience demonstrated by financial policies within the regulatory framework, emphasizing their capacity to flexibly respond to changing circumstances and evolving needs within sustainable tourism [46].
Innovation and Technological Advancement in Finance (GF5)	Innovative Financial Instruments (GF51)	Evaluation of the development and implementation of pioneering financial tools, like green bonds and crowdfunding, specifically tailored to support and foster sustainable tourism initiatives [47].
	Technological Integration in Financial Strategies (GF52)	Assessment of the integration and utilization of technology-based financial approaches, emphasizing their role in supporting and enhancing sustainable tourism projects through innovative technological solutions [48].
	Financial Infrastructure Development (GF53)	Focus on investments made in financial infrastructure, particularly in areas like green energy, aimed at bolstering and facilitating the growth of sustainable tourism within the financial domain [49].
	Data-Driven Decision-Making (GF54)	Evaluation of the incorporation and utilization of data-centric approaches in financial strategies, highlighting the use of data analytics to drive informed decision-making processes in sustainable tourism finance [50].

3.2.4. Circular economy integration

This strategy emphasizes the transition toward a circular economy within the tourism sector. It focuses on financing initiatives that champion waste reduction, recycling, and optimizing resource use. By promoting circular practices, it aims to minimize waste generation and maximize resource efficiency in tourism operations [54].



Fig. 2. Key strategies towards sustainable tourism via GF.

3.2.5. Promotion of green technology adoption

Encouraging the integration of sustainable technology solutions in the tourism industry, this strategy incentivizes and supports the adoption of eco-friendly technologies. Financial support and incentives drive the adoption of green technologies, fostering a shift towards more sustainable practices and operations within the sector [55].

3.2.6. Eco-certifications and standards

This strategy incentivizes compliance with eco-certifications and sustainable standards within the tourism sector. By offering

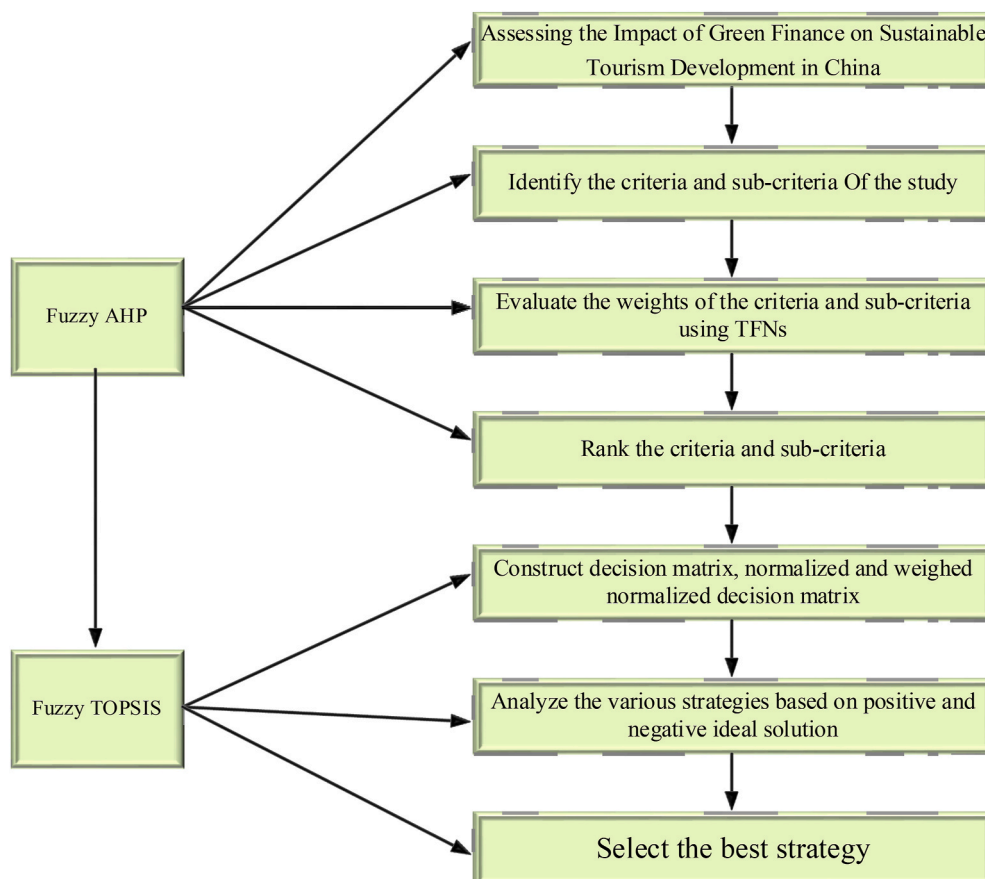


Fig. 3. Research methodology.

financial rewards or preferential treatment to businesses adhering to these standards, it encourages a commitment to sustainability and responsible practices in the industry [56].

3.2.7. Incentivizing green investments

Implementation of policies and incentives aims to stimulate investments in sustainable tourism. By offering financial advantages or tax benefits to entities supporting eco-friendly practices, this strategy promotes investments that prioritize sustainability, fostering a more environmentally conscious tourism landscape [57].

4. Methodology

This study interprets the comprehensive approach utilized to assess the impact and effectiveness of innovative strategies, presenting a fusion of qualitative and quantitative methodologies. The study elucidates the systematic process, emphasizing the utilization of Fuzzy AHP and Fuzzy TOPSIS methodologies to derive comprehensive insights into the transformative potential of GF in fostering sustainable tourism practices within the Chinese context. Fig. 3 presents the methodology of current study.

4.1. Fuzzy AHP method

The fuzzy AHP technique considers uncertain and imprecise information by assigning fuzzy numbers to decision-making criteria [58]. In complex and uncertain scenarios, this makes the decision-making dilemma more realistic. Triangular Fuzzy Numbers (TFNs) scale used in the study is presented in Table 3.

Step 1 Triangular fuzzy matrix (TFM):

$$X_i = (l_i, m_i, u_i) \quad (1)$$

After, the first TFM is created with the middle TFM:

$$X_m = [x_{ijm}] \quad (2)$$

Next, the second TFM is established for the upper and lower bounds of TFN using a geometric mean approach:

$$X_g = [\sqrt{x_{iju}x_{ijl}}] \quad (3)$$

Step 2 Create and compute the weight vector and lambda max based on the Saaty method.

Step 3 Create consistency index (CI):

$$CI_m = \frac{\lambda_{max}^m - n}{n - 1} \quad (4)$$

$$CI_g = \frac{\lambda_{max}^g - n}{n - 1} \quad (5)$$

Step 4 Create the consistency ratio (CR):

$$CR_m = \frac{CI_m}{RI_m} \quad (6)$$

$$CR_g = \frac{CI_g}{RI_g} \quad (7)$$

If the consistency ratio goes below a specified threshold, as being less than 0.10, it is regarded that the pairwise comparisons have reached consistency. The RI scale is shown in Table 4.

Table 3
TFNs scale [59].

Number	TFNs	Linguistic variable
1	(1,1,3)	Equally preference
2	(1,3,5)	Weak preference
3	(3,5,7)	Strong preference
4	(5,7,9)	Very strong preference
5	(7,9,11)	Extremely strong preference

The Fuzzy AHP process involves several steps [60], including.

Table 4

RI scale [60].

n	1	2	3	4	5	6	7	8	9	10
RI_m	0	0	0.48	0.79	1.07	1.19	1.28	1.34	1.37	1.40
RI_g	1	2	0.17	0.26	0.35	0.38	0.40	0.41	0.43	0.44

4.2. Fuzzy TOPSIS

The Fuzzy TOPSIS is widely used in various fields, including sustainable tourism. The TOPSIS method was proposed by Hwang and Yoon in 1981 and has since been applied in many decision-making problems [61]. The TFNs are utilized to assess the alternatives based on the sub-criteria of the research. The scale for TFNs can be found in Table 5.

The basic steps of the Fuzzy TOPSIS technique are given below [63].

Step 1 Let $\tilde{K} = (k_1, k_2, k_3)$, $\tilde{L} = (l_1, l_2, l_3)$ are the two fuzzy numbers:

$$\tilde{K} + \tilde{L} = (k_1, k_2, k_3) + (l_1, l_2, l_3) = (k_1 + l_1, k_2 + l_2, k_3 + l_3) \quad (8)$$

$$\tilde{K} \times \tilde{L} = (k_1, k_2, k_3) \times (l_1, l_2, l_3) = (k_1 l_1, k_2 l_2, k_3 l_3) \quad (9)$$

Step 2 Let $\tilde{K}_i = (k_{i1}, k_{i2}, k_{i3})$ are the TFNs for $i \in I$. Then, normalized the fuzzy number of each \tilde{K}_i is signified as:

$$\tilde{D} = [d_{ij}]_{m \times n} \quad (10)$$

where $i = 1, 2, 3, \dots, m$ and $j = 1, 2, 3, \dots, n$.

Step 3 Construct the weighted normalized fuzzy decision matrix:

$$\tilde{V} = [v_{ij}]_{m \times n} \quad (11)$$

$$i = 1, 2, 3, \dots, m \text{ and } j = 1, 2, 3, \dots, n$$

where $v_{ij} = d_{ij} \times w_j$.

Step 4 Recognize the distance between positive and negative ideal solution:

$$d_i^+ = (v_1^+, v_2^+, v_3^+, \dots, v_n^+) \quad (12)$$

where $V_j^+ = (1, 1, 1)$ and $j = 1, 2, 3, \dots, n$.

$$d_i^- = (v_1^-, v_2^-, v_3^-, \dots, v_n^-) \quad (13)$$

where $V_j^- = (0, 0, 0)$ and $j = 1, 2, 3, \dots, n$.

Step 5 Construct the closeness coefficient (CC_i):

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad (14)$$

where $i = 1, 2, 3, \dots, m$; d_i^+ is the distance from positive ideal solution and d_i^- is the distance from a negative ideal solution.

Table 5

TFNs scale [62].

No	Linguistic variables	TFNs
1	Very unsatisfactory	(1,2,3)
2	unsatisfactory	(2,3,4)
3	Medium unsatisfactory	(3,4,5)
4	Medium	(4,5,6)
5	satisfactory	(5,6,7)
6	Medium unsatisfactory	(6,7,8)
7	Very unsatisfactory	(7,8,9)

Step 6 Determine the most suitable alternative by arranging it in descending order of their CC_i values.

In this context the Fuzzy AHP and Fuzzy TOPSIS methods are used to analyze the impact of GF on sustainable tourism development in China.

4.3. Case study

This case study, situated within a specific geographic and operational domain of the Chinese tourism sector, aims to provide an in-depth exploration of the practical applications and outcomes of innovative strategies. The selection of this case study involves a meticulous process, considering parameters such as ecological vulnerability, financial investment, community engagement, and technological integration within the tourism framework. The growth of community-based tourism and the adoption of sustainable tourism certifications have been a beacon of hope for our environment and society. They've empowered local communities, ensuring their inclusion while preserving our natural wonders. These efforts haven't just improved the quality of sustainable travel experiences but have also made significant strides in protecting our planet and fostering unity among people [64]. Partnerships between public and private sectors have been crucial. They've brought together diverse expertise and resources, uniting people for a common cause. Despite these advancements, challenges persist. We still grapple with the need for better collaboration among all involved and the urgency to enhance education and training opportunities [65]. The integration of advanced analytical methodologies, notably the fuzzy AHP and fuzzy TOPSIS, serves as the foundation of this case analysis. These methodologies enable the systematic assessment and ranking of diverse criteria and sub-criteria, providing an understanding of the complex interdependencies between GF initiatives and their tangible impacts on sustainable tourism within the chosen context.

5. Result and discussion

In this section, the main criteria, sub-criteria, and solution strategies has been examined using fuzzy AHP and fuzzy TOPSIS methods. this approach provides structured, quantitative evaluation to the impact of GF on sustainable tourism development in China.

5.1. Findings of main criteria using fuzzy AHP

The assessment of criteria based on their weighted importance, derived from the fuzzy AHP analysis, aligns with the trends observed in several seminal studies investigating sustainable tourism development. Environmental sustainability (GF2) attains the highest weight (0.186), reflecting a consensus among prior research highlighting the paramount importance of ecological preservation and sustainable practices. Study by Ref. [66] highlight similar findings, emphasizing the indispensable role of eco-centric initiatives and environmental conservation as foundational pillars of sustainable tourism frameworks. Furthermore, financial allocation and effectiveness (GF1) closely trails environmental sustainability, echoing the findings in research by Ref. [38]. These studies emphasize the critical significance of effective financial deployment and resource allocation as fundamental drivers for the success of sustainable tourism initiatives. This alignment reiterates the consensus across research domains, emphasizing the pivotal role of financial strategies in steering sustainable tourism frameworks. Policy and regulatory framework impact (GF4) secures a moderate weight (0.169), in line with research by Ref. [67]. These studies accentuate the influential role of supportive policies in facilitating sustainable tourism through GF interventions. However, they suggest that while policies are influential, their impact might be constrained compared to the pivotal significance attributed to environmental sustainability and prudent financial allocation. Social and community development initiatives (GF3), with a relatively lower weight (0.158), aligns with perspectives from research by Ref. [68]. These studies position community engagement and social development as integral components of sustainable tourism frameworks. Nonetheless, they suggest these factors as supportive rather than primary drivers of sustainable tourism through GF. Similarly, innovation and technological advancement (GF5), with the lowest weight (0.153), acknowledges technological advancements as facilitators rather than primary influencers in the context of sustainable tourism [69], as provided in Table 6.

5.2. Findings of sub-criteria using fuzzy AHP

As shown in Fig. 4 the analysis of sub-criteria within financial allocation and effectiveness (GF1) indicates economic viability enhancement (GF12) as the most influential, holding the highest rank with a weight of 0.256. This underscores its paramount importance in shaping sustainable tourism by enhancing economic viability, aligning with established research emphasizing economic

Table 6
The results of criteria using Fuzzy AHP.

Criteria	Weight	Rank
Financial Allocation and Effectiveness (GF1)	0.181	2
Environmental Sustainability (GF2)	0.185	1
Social and Community Development Initiatives (GF3)	0.159	4
Policy and Regulatory Framework Impact (GF4)	0.171	3
Innovation and Technological Advancement in Finance (GF5)	0.154	5

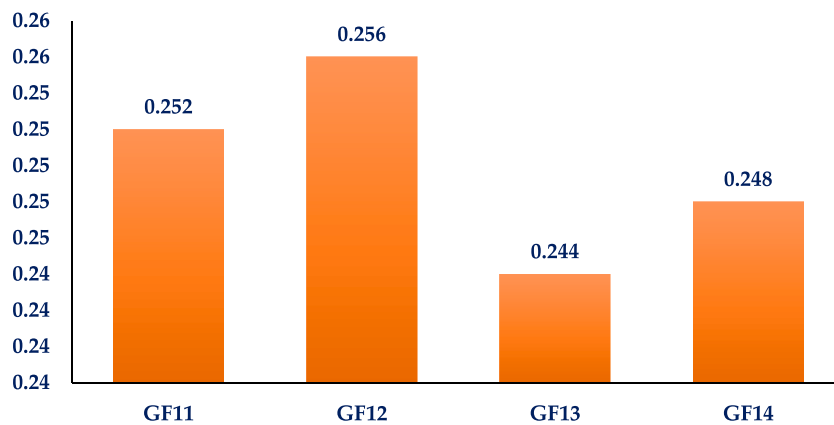


Fig. 4. Ranking of sub-criteria within financial allocation and effectiveness (GF1).

growth as a linchpin in successful tourism initiatives [70]. Investment efficiency (GF11) secures the second rank, emphasizing the critical need for judicious financial resource allocation. Return on sustainable investment (GF14) maintains a notable position, securing the third rank, while green finance innovations (GF13) garner the lowest rank among the sub-criteria, indicating a complementary role rather than serving as a primary driver in financial resource allocation for sustainable tourism [71].

The evaluation of sub-criteria within environmental sustainability (GF2) underscores eco-friendly infrastructure development (GF24) as the most critical factor, holding the highest rank first as illustrated in Fig. 5. This aligns with prior research highlighting the pivotal role of eco-friendly infrastructure in mitigating environmental impact within sustainable tourism frameworks [72]. Carbon footprint mitigation (GF21) closely follows, highlighting the significance of reducing carbon emissions in tourism activities through financial interventions, echoing established literature. Resource-efficient investments (GF23) maintain a third rank, stressing the importance of efficient resource utilization in tourism. Biodiversity conservation funding (GF22) secures the lowest rank, indicating its comparatively lower priority while acknowledging the crucial role of biodiversity conservation [73].

The assessment of sub-criteria within social and community development initiatives (GF3) showcases capacity building and skill enhancement (GF34) as the highest-ranking factor, as depicted in Fig. 6. This underlines its paramount importance in fostering social and community development within sustainable tourism, aligning with earlier study emphasizing skill enhancement as crucial for community empowerment [40]. Following closely, cultural preservation investments (GF32) secure the second rank, stressing the significance of financial support directed towards preserving cultural heritage and traditions through tourism. This resonates with research by Ref. [74], emphasizing the role of cultural preservation in sustainable tourism development. Social equity through finance (GF33) maintains a notable position, indicates the importance of ensuring fair distribution of financial benefits among communities involved in sustainable tourism. Community empowerment (GF31) secures the lowest rank, highlights its comparatively lower weight, while acknowledging its role in empowering local communities involved in sustainable tourism.

Fig. 7 shows the assessment of policy and regulatory framework impact (GF4) delineates governmental support and financial backing (GF42) as the most crucial factor, securing the highest rank with a weight of 0.263. This stresses the important role of governmental support in driving sustainable tourism initiatives, echoing findings from research by Ref. [75], accenting government backing as essential for sustainable tourism development. Financial transparency and accountability (GF43) closely follow with ranking second, highlighting the importance of ensuring transparency and accountability in financial mechanisms within the tourism

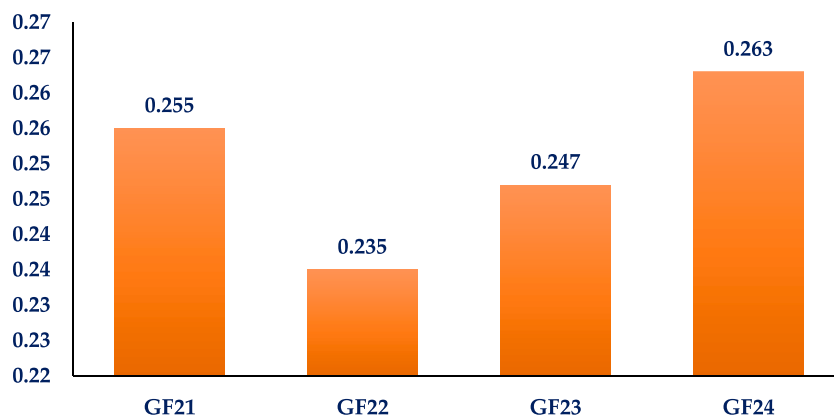


Fig. 5. Ranking of sub-criteria within environmental sustainability (GF2).

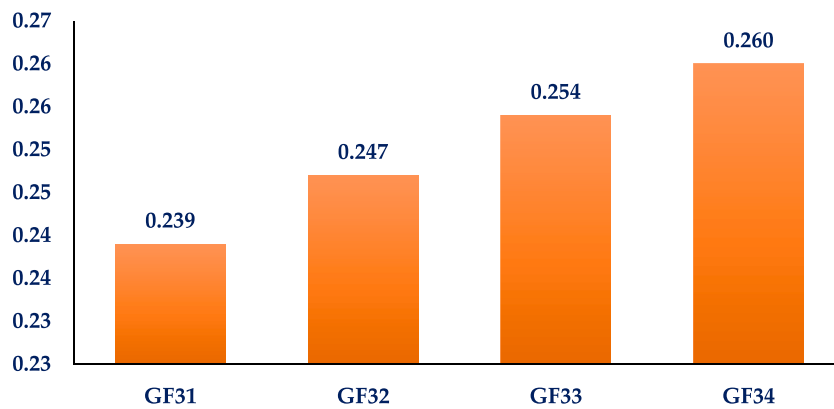


Fig. 6. Ranking of sub-criteria within social and community development initiatives (GF3).

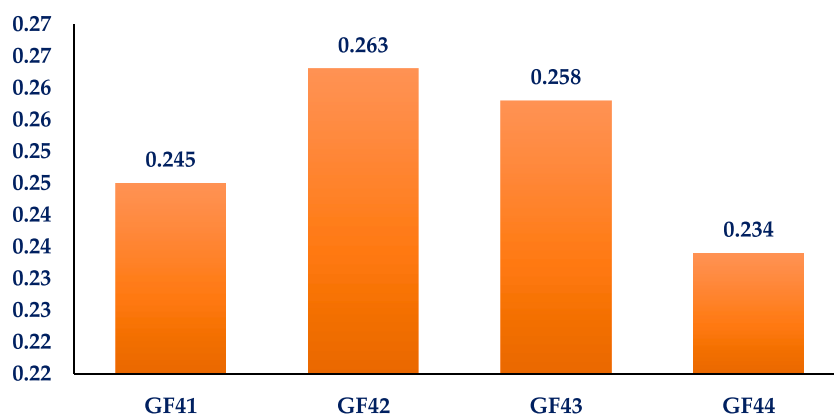


Fig. 7. Ranking of sub-criteria within policy and regulatory framework impact (GF4).

sector. Financial policy efficacy (GF41) secures the third rank, emphasizing the effectiveness of financial policies promoting sustainable tourism. Policy adaptability and resilience (GF44) lowest rank highlights the need for adaptable and resilient policies in sustainable tourism frameworks.

The evaluation of innovation and technological advancement in finance (GF5) highlights data-driven decision-making (GF54) as the most influential, securing the top position with a weight of 0.262. This underlines the criticality of leveraging data-driven approaches in financial decision-making within sustainable tourism [53]. The second rank is given to innovative financial instruments (GF51), stressing the importance of developing and implementing innovative financial tools in sustainable tourism initiatives as shown in Fig. 8. Financial infrastructure development (GF53) ranking third points out, investments in financial infrastructure to support

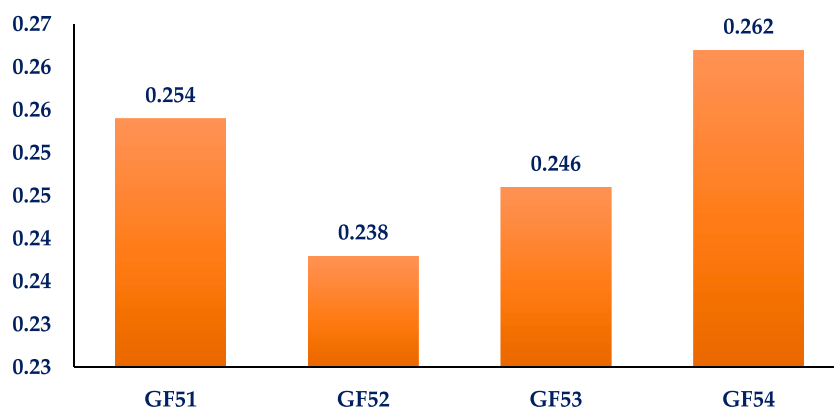


Fig. 8. Ranking of sub-criteria within innovation and technological advancement in finance (GF5).

sustainable tourism [76]. Technological integration in financial strategies (GF52) secures the least rank, acknowledging the role of technology in financial strategies within sustainable tourism.

5.3. Findings for strategies of sustainable tourism using fuzzy TOPSIS

The results are generated through FTOPSIS, offer insights into the effectiveness and prioritization of various sustainable tourism strategies in the context of GF's integration within China's tourism industry. These rankings, based on the strategies closeness coefficients CC_i ideal solution, unveil critical insights into the efficacy and priority of these approaches as shown in Table 7. At the helm sits green bond innovation for ecosystem regeneration (S1), boasting a substantial closeness coefficient of 0.7043, securing the top rank. This underscores the critical role of innovative financial instruments, notably green bonds, in driving ecosystem rejuvenation within the tourism sector, aligning with the escalating emphasis on environmentally focused investments. Following closely is circular economy integration (S4), capturing the second spot with a CC_i of 0.6798. This strategy accentuates the pressing need to embrace circular economic models within tourism, emphasizing waste reduction, recycling promotion, and optimal resource utilization, signifying its vital role in advancing sustainability objectives. Meanwhile, data-driven predictive analytics for sustainable tourism (S3) and promotion of green technology adoption (S5) secure the third and fourth positions, respectively, underscoring the significance of data-centric approaches and the adoption of sustainable technologies in steering sustainable tourism initiatives. In contrast, eco-certifications and standards (S6) and incentivizing green Investments (S7) hold the lower ranks, indicating their comparatively lesser impact within this evaluation framework.

5.4. Discussion

The combination of FAHP and FTOPSIS methodologies has significantly contributed to unveiling critical insights into the integration of GF within China's sustainable tourism domain. The comprehensive evaluation of criteria and sub-criteria elucidated the paramount importance of certain factors. The weightage analysis revealed that strategies emphasizing data-driven decision-making, eco-centric infrastructure, governmental support, and skill enhancement play pivotal roles in steering sustainable tourism initiatives within the purview of GF. On the environmental front, environmental sustainability (GF2) emerges as a paramount criterion, securing the top spot. Its focus on carbon footprint mitigation, biodiversity conservation funding, resource-efficient investments, and eco-friendly infrastructure development mirrors the findings of [77]. This emphasizes the paramount role of green initiatives and resource-efficient practices in fostering environmental sustainability within the tourism sector. Financial allocation and effectiveness underlines the efficient investment utilization and economic viability enhancement which emphasis on efficient resource allocation aligns with the observations made by Ref. [78], affirming the importance of prudent financial strategies in driving sustainability [79]. Policy and regulatory framework impact (GF4), encompasses financial policy efficacy, governmental support, financial transparency, and policy adaptability. These factors, highlights the significance of supportive government policies and financial transparency in nurturing sustainable tourism [80]. Social and community development initiatives (GF3) emphasizes community empowerment, cultural preservation investments, social equity through finance, and capacity building. While aligned with the study by Ref. [81] in emphasizing community engagement and cultural preservation, nuanced differences in their relative weights hint at potential contextual variations. Lastly, innovation and technological advancement in finance (GF5), centers on innovative financial instruments, technological integration, financial infrastructure development, and data-driven decision-making [82].

Furthermore, the outcomes underscore the evolving dynamics within sustainable tourism, particularly in response to the escalating environmental challenges and the burgeoning emphasis on eco-conscious practices. The findings also highlight the shifting paradigms in investment strategies, emphasizing the growing significance of financial innovations and data-centric approaches in steering the tourism sector toward sustainability [53]. However, despite the alignment with previous studies, certain nuances in the ranking and weightage allocation signify the evolving landscape and the contextual peculiarities within China's tourism industry, indicating the need for continuous adaptation and refinement of strategies. This study thus contributes to the cumulative body of knowledge in sustainable tourism and GF, providing pivotal insights for policymakers, investors, and industry stakeholders, fostering a more sustainable and resilient tourism ecosystem within China [83]. These varied weights and rankings among criteria underscore the multifaceted nature of sustainable tourism, reflecting the complex interplay of financial strategies, environmental imperatives, community engagement, regulatory frameworks, and technological advancements.

5.5. Managerial and theoretical implications

From a managerial perspective, the findings deliver valuable insights for industry practitioners and decision-makers in the tourism sector. The prioritization of strategies, which emphasizes data-driven decision-making, eco-centric infrastructure, and skill enhancement, offers actionable guidance for managerial interventions. These insights empower managers to allocate resources effectively, directing investments towards areas with the highest potential for fostering sustainable tourism. For instance, the study recommends prioritizing investments in innovative financial instruments such as green bonds and technological integration, aligning with sustainable practices. This strategic focus enhances the industry's sustainability quotient. Additionally, the emphasis on governmental support underscores the importance of fostering partnerships between industry stakeholders and policymakers. Such collaborations create an environment conducive to sustainable tourism practices.

Theoretical implications of the study contribute to enriching and evolving existing models governing sustainable tourism and the integration of GF. The study aligns with established theories that emphasize data-centric strategies, financial innovation, and

Table 7

The final ranking of GF tourism strategies.

Strategy	CC_i	Rank
Green Bond Innovation for Ecosystem Regeneration (S1)	0.7043	1
Digital Twin Technologies for Sustainable Infrastructure (S2)	0.5031	5
Data-Driven Predictive Analytics for Sustainable Tourism (S3)	0.6567	3
Circular Economy Integration (S4)	0.6798	2
Promotion of Green Technology Adoption (S5)	0.5435	4
Eco-Certifications and Standards (S6)	0.4954	6
Incentivizing Green Investments (S7)	0.4509	7

governmental support, consolidating these theoretical constructs. However, it introduces nuances by accentuating the significance of eco-centric infrastructure and circular economic models within the context of sustainable tourism. These theoretical insights contribute to a more comprehensive understanding of the intricate relationship between GF mechanisms and the sustainable transformation of the tourism industry.

6. Conclusion

The study investigated the complex relationship between GF and sustainable tourism development in China, utilizing Fuzzy AHP and Fuzzy TOPSIS methodologies. The research identified and evaluated five key criteria, twenty sub-criteria and seven proposed strategies. The findings underscored the critical significance of environmental sustainability measures supported by GF, highlighting the pivotal role of eco-friendly infrastructure, carbon footprint mitigation, and resource-efficient investments in fostering sustainability within the tourism sector. Additionally, the study highlighted the importance of efficient financial allocation, supportive policy frameworks, community engagement, and technological innovation in driving sustainable tourism practices. Our research outcomes, while aligned with prior studies, notably emphasized contextual nuances and the evolving landscape within China's tourism industry. These insights underscored the necessity for adaptive and context-specific strategies tailored to the unique dynamics of the region. The study's findings contribute a comprehensive evaluation framework, offering valuable guidance for policymakers, stakeholders, and industry practitioners in fostering sustainable tourism practices within China, promoting environmental preservation, social inclusivity, and economic growth in the evolving landscape of the tourism sector.

6.1. Policy recommendations

Based on the comprehensive evaluation of the interplay between GF and sustainable tourism development in China, several policy recommendations emerge to facilitate the advancement of sustainable practices within the tourism industry.

- Encourage governmental backing and a robust regulatory framework promoting sustainable tourism initiatives.
- Implement financial incentives, subsidies, or tax benefits to incentivize investments in eco-friendly infrastructure, renewable energy, and resource-efficient technologies within the tourism sector.
- Foster partnerships with local communities by encouraging their active involvement in decision-making processes and offering support for community-based tourism initiatives.
- Promote the adoption of innovative technologies, such as digital twins, predictive analytics, and other data-driven tools, to optimize resource utilization, reduce environmental impact, and enhance the overall efficiency of tourism operations.
- Invest in capacity building programs and knowledge-sharing platforms to equip industry stakeholders, including businesses, policymakers, and local communities, with the necessary skills and information to implement sustainable practices effectively.
- Encourage compliance with eco-certifications and sustainable standards by offering recognition and financial rewards to entities demonstrating adherence to environmentally friendly practices.
- Encourage the development of more innovative green financing mechanisms, such as green bonds or crowdfunding, specifically tailored to fund sustainable tourism projects, ensuring a steady flow of financial resources towards eco-friendly initiatives.

6.2. Limitations and future research

In advancing the understanding of the intricate interplay between GF and sustainable tourism development within China, this study encountered several inherent limitations that warrant acknowledgment for future research trajectories. One notable constraint involved the reliance on available data, which might have been constrained in terms of completeness, reliability, or timeliness, potentially influencing the depth and precision of the study's evaluations. Furthermore, the focused scope on the Chinese context, while providing valuable insights, could limit the extrapolation and applicability of findings to broader geographical contexts or diverse cultural settings within the global tourism landscape. Methodologically, while the utilization of Fuzzy AHP and Fuzzy TOPSIS offered a comprehensive framework, future studies could explore integrating additional MCDM methods or refining existing methodologies to enhance precision and robustness in evaluations. Engaging a more diverse range of stakeholder perspectives, including local communities, non-governmental organizations, and industry practitioners, would enrich future research by incorporating multifaceted viewpoints into the analysis, thereby providing a more holistic understanding of the sustainable tourism landscape.

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Availability of data

The data will be available on request.

CRediT authorship contribution statement

Maozheng Fu: Writing – review & editing, Resources, Investigation, Funding acquisition, Formal analysis. **Sujuan Huang:** Writing – review & editing, Visualization, Validation, Conceptualization. **Sheeraz Ahmed:** Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that there is no conflict of interest with anyone else.

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