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GEOSPATIAL MULTI - LAYER DECISION SUPPORT SYSTEM FOR ECOTOURISM DEVELOPMENT IN THAI NGUYEN PROVINCE

Abstract

This study assesses ecotourism suitability in Thai Nguyen province, Vietnam, using Geographic Information System (GIS) and Analytic Hierarchy Process (AHP). Ten spatial factors, including elevation, slope, NDVI, LST, visibility, and proximity to roads, urban areas, water bodies, population density, as well as cultural tourism sites, were selected and weighted via pairwise comparison ($CR = 0.03$). The standardized layers were then overlaid to produce a suitability map. The standardized layers were overlaid to produce a suitability map. Results indicate that highly suitable zones are concentrated in the northwest (Dinh Hoa) and northeast (Vo Nhai), featuring dense vegetation, mountainous landscapes, and ecotourism attractions. Moderately suitable areas, including Dai Tu and Dong Hy, offer potential with appropriate infrastructure investment. In contrast, urban centers like Thai Nguyen City, while ecologically limited, serve as logistical hubs for supporting tourism activities. The study highlights spatial differences in ecotourism potential and provides a scientific basis for sustainable development planning, emphasizing the integration of conservation and local livelihoods..

Keywords

Ecotourism suitability, GIS, AHP, Thai Nguyen

1. Introduction

Ecotourism is widely recognized as a sustainable development strategy that supports conservation and local livelihoods, especially in areas rich in natural and cultural resources [1]. In Vietnam, the integration of ecotourism into national and regional development plans underscores its significance in achieving socio - economic growth while preserving ecological integrity [2] and [3].

Existing literature has highlighted several core indicators repeatedly used in ecotourism suitability assessments. Key indicators commonly used in suitability assessments include topographic features like elevation and slope, which influence landscape appeal and access [4–6], and NDVI, a proxy for vegetation health and biodiversity [7 - 8].

Several studies highlight the role of cultural and historical proximity in promoting immersive, experience - based tourism. Cultural and historical proximity enhances destination authenticity [9], while accessibility to roads and urban centers ensures logistical feasibility and market reach [10,11]. Climatic variables, particularly temperature and rainfall, further shape tourist comfort and travel patterns [12].

While these criteria are widely applicable, their relative importance and interpretability can vary substantially depending on local ecological and socio - cultural contexts. Thus, a growing body of research advocates for the customization of indicator frameworks to reflect local development realities, resource constraints, and planning objectives [10] and [13].

This study develops a spatial criteria framework for assessing ecotourism potential in Thai Nguyen Province, northern Vietnam. Focusing on the selection and mapping of ten key indicators, it offers a practical tool for local planning and a transferable approach for similar regions in Southeast Asia.

2. Study area

Thai Nguyen Province, situated in northern Vietnam's midlands, lies at the transition between the Red River Delta and the northeastern highlands. Spanning approximately 3,562 km², it features diverse topography, including low hills, river valleys, and forested mountain ranges, particularly in Dinh Hoa, Vo Nhai, and Phu Luong districts [14]. The province is ecologically rich, with substantial forest cover, a temperate climate, and notable karst and freshwater ecosystems. Culturally, it is home to ethnic minorities such as the Tay, Nung, and San Diu, whose traditional practices enhance the region's tourism value. Its proximity to Hanoi (~80 km) and its role as a regional educational and industrial center further strengthen its strategic position [15,16]. These natural, cultural, and infrastructural advantages make Thai Nguyen well - positioned for sustainable ecotourism, though its complex landscape necessitates a spatially explicit, multi - criteria evaluation approach.

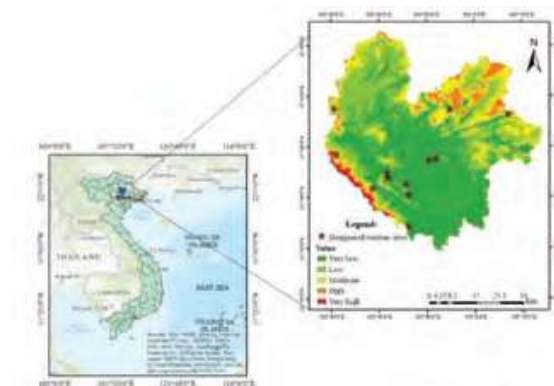


Figure 1. Study area in Thai Nguyen province, Northern Vietnam

3. Methodology

This study employs a Geographic Information System (GIS) - based Multi - Criteria Decision Analysis (MCDA) framework, integrating the Analytic Hierarchy Process (AHP) to

evaluate and map the suitability of ecotourism development areas in Thai Nguyen Province. The methodology comprises four main stages: (1) selection of evaluation criteria, (2) data collection and processing, (3) determination of criterion weights using AHP, and (4) spatial analysis and mapping of suitability zones.

3.1. Data Collection and Processing

This study proposes a spatially grounded framework for evaluating ecotourism potential in Thai Nguyen Province, Northern Vietnam. Rather than relying solely on participatory or expert - based weighting, indicator selection was informed by a comprehensive literature review and spatial characteristics of the region. Thai Nguyen, situated at the interface of the Red River Delta and the northeastern highlands, features diverse topography, forest ecosystems, and cultural heritage assets, offering a rich geospatial foundation for assessment.

Ten spatial indicators were selected and grouped into environmental and socio - economic categories based on three criteria: relevance to ecotourism potential [4, 6], spatial variability across the province's terrain and land cover [5, 7], and data availability with uniform resolution for replicability. Environmental factors include elevation, slope [4–6], NDVI [7, 17], temperature, rainfall [12], and landscape visibility [18]. Socio - economic indicators comprise proximity to roads and urban areas [10, 11], rivers, and cultural tourism sites [19, 20]. These criteria support a context - specific, methodologically robust approach to ecotourism suitability mapping, as detailed in Table 1.

Table 1. Evaluation Criteria for Ecotourism Suitability Assessment

No.	Criterion	Data Sources	Description
1	Cultural Tourism Sites (CTS)	Google Earth + Field Verification	calculated in GIS based on point data collected
2	Distance to Roads (DTR)	OpenStreetMap (OSM)	conducted to compute the straight - line distance from each raster cell to roads
3	Distance to Urban Areas (DTU)	OpenStreetMap (OSM)	calculated from each raster cell to the closest urban center.
4	Distance to Water Bodies (DTW)	OpenStreetMap (OSM)	calculated from each raster cell to water features
5	Elevation (ELV)	Topographic maps (1:10.000 scale)	extracted directly from the Digital Elevation Model (DEM)
6	Slope (SLP)	Topographic maps (1:10.000 scale)	subsequently derived using GIS - based terrain analysis tools

7	LST (Land Surface Temperature)	Landsat 8 OLI	extracted and spatially averaged using GIS raster processing tools
8	Rainfall (RNF)	CHIRPS daily rainfall dataset ("UCSBCHG / CHIRPS / DAILY")	interpolated from average rainfall of 2024 in ArcGIS
9	Landscape Visibility (LSV)	Topographic maps (1:10.000 scale)	(Viewshed from Elevation / Imagery)
10	NDVI (Normalized Difference Vegetation Index)	Sentinel - 2 MSI, Google Earth Engine	Proxy for vegetation density and ecosystem quality

3.2. Determination of Criterion Weights Using AHP

The Analytic Hierarchy Process (AHP), developed by Saaty (1980), was applied to determine the relative importance of each criterion in the ecotourism suitability analysis. As a widely used multi - criteria decision - making (MCDM) method, AHP enables the integration of both qualitative and quantitative assessments through a pairwise comparison matrix. Experts evaluated the importance of each factor relative to others using the Saaty scale (1–9), capturing perceived significance (Table 2).

The matrix was normalized, and priority weights were derived by averaging the normalized values per row. To ensure the reliability of expert judgments, the Consistency Index (CI) and Consistency Ratio (CR) were calculated.

$$CR = \frac{CI}{RI}; \text{ with } CI = \frac{\lambda_{max} - n}{n - 1}; \lambda_{max} = \frac{1}{n} \times \left[\frac{\sum_{i=1}^n w_{1i}}{w_{11}} + \frac{\sum_{i=1}^n w_{2i}}{w_{22}} + \frac{\sum_{i=1}^n w_{3i}}{w_{33}} + \dots \right] \quad (1)$$

The Consistency Ratio (CR), calculated using the maximum eigenvalue (λ_{max}), assesses the logical consistency of the pairwise comparison matrix. A CR below 0.1 indicates acceptable consistency, confirming the reliability of the derived weights for spatial analysis [21, 22].

3.3. Spatial Analysis and Mapping of Suitability Zones

A composite ecotourism suitability map was generated using ArcGIS Weighted Overlay, classifying areas into four levels ranging from high to unsuitable, thereby guiding sustainable tourism planning in accordance with earlier studies [4][5][18].

4. Result and Discussion

4.1. Thematic Analysis of Key Factors Influencing Ecotourism Potential

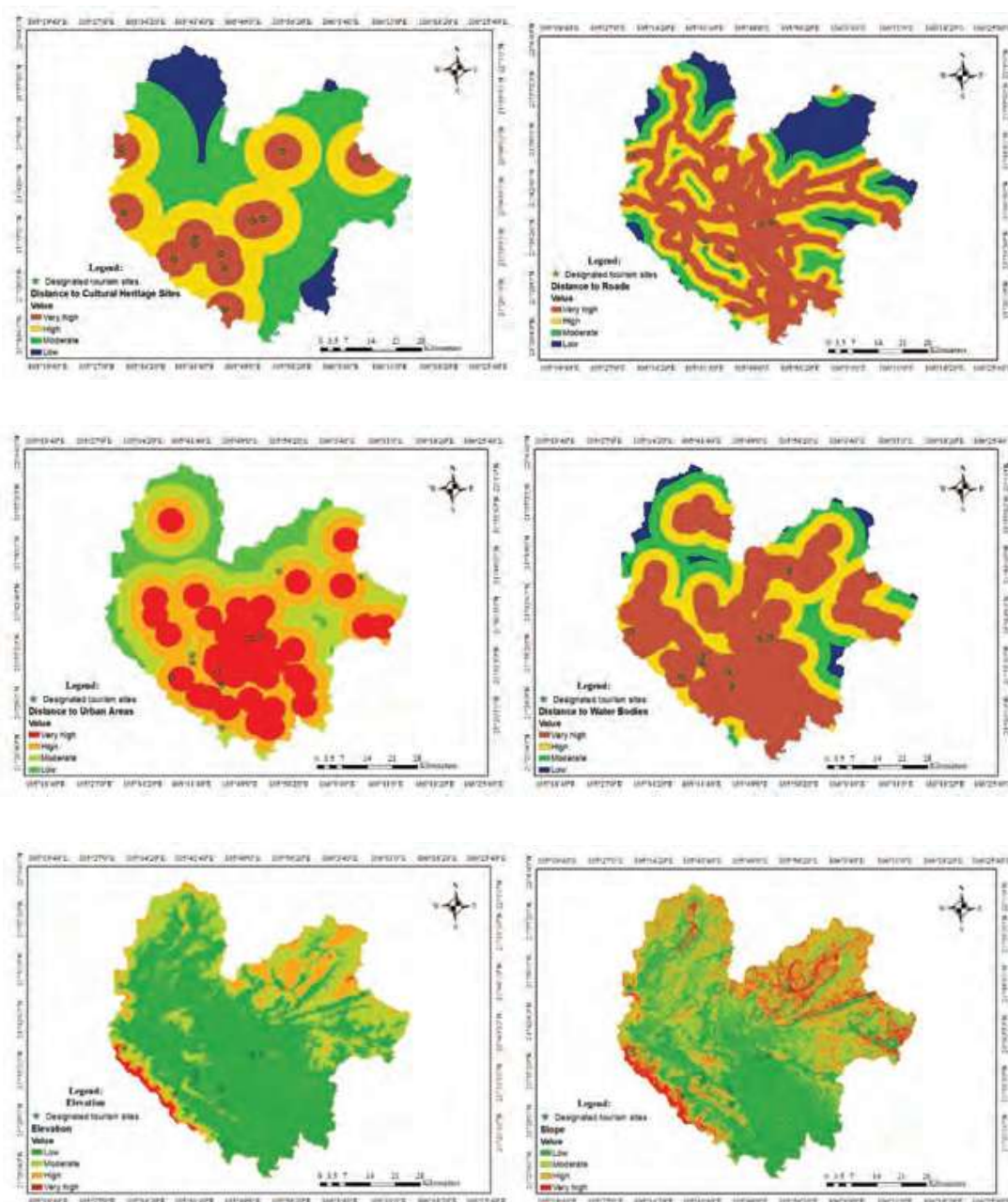
The analysis reveals that mountainous districts like Dinh Hoa, Vo Nhai, Phu Luong, and Dai Tu combine moderate to high elevation (fig. 2e, 2f), dense vegetation (fig. 2k), and broad viewsheds (fig. 2i), making them well - suited for ecotourism. This supports earlier findings on the importance of topography and vegetation in site suitability [4, 23].

Climatic factors, particularly cool temperatures and moderate rainfall in highland areas (fig. 2g, 2h), enhance visitor comfort and year - round tourism appeal, corroborating [12]. In contrast, low - lying areas such as Phuc Trieu, with excessive rainfall and limited drainage, present accessibility challenges and potential flood risks [17].

Vegetation health, indicated by NDVI (fig. 2k), highlights ecologically rich zones like Khuon Tat Forest and Vo Nhai's karst hills [7, 18], while urban and agricultural zones score lower. High - visibility zones on hilltops and ridgelines (fig. 2i) support visual aesthetics and scenic value, in line with [23].

Socio - economic factors such as proximity to roads, rivers, and cultural sites (fig. 2a–2d) further enhance accessibility and feasibility for development [5, 24]. Riverine areas contribute to biodiversity, landscape appeal, and water - based recreation.

Overall, areas with both high ecological value and accessibility, particularly in the northern and western regions, offer the greatest potential for sustainable ecotourism (fig. 2d). In contrast, Thai Nguyen City, though less ecologically suitable, functions as a key logistical and service hub [25].



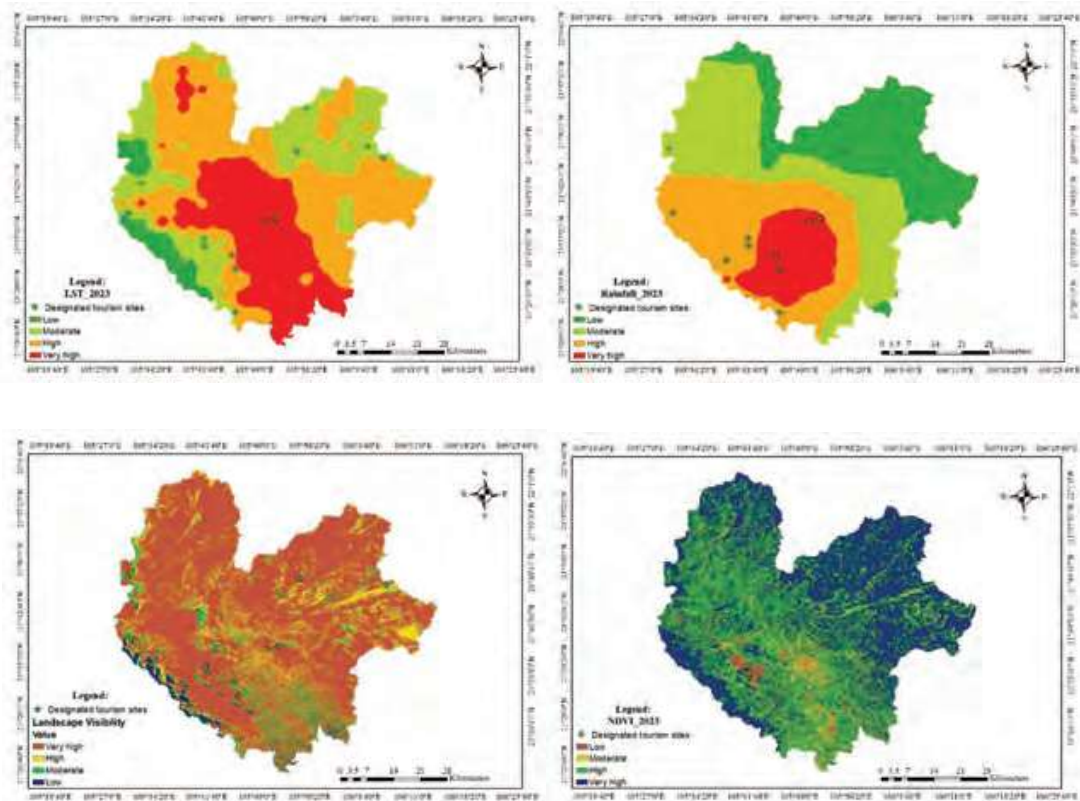


Figure 2. *Spatial Distribution of ten key ecotourism suitability factors in Thai Nguyen Province: (a) Cultural Tourism Sites, (b) Distance to Roads, (c) Distance to Urban Areas, (d) Elevation, (e) Distance to Water Bodies, (f) Slope, (g) LST, (h) Rainfall (annual), (i) Landscape Visibility and (j) NDVI_2023*

4.2. Consistency Ratio Results and Implications for Indicator Weighting

After identifying and mapping the ten key factors that influence ecotourism suitability, which include both biophysical as well as socio - economic dimensions. The study subsequently applied the Analytic Hierarchy Process (AHP) to determine their relative weights through pairwise comparisons. In order to ensure the logical consistency of expert judgments, the Consistency Ratio (CR) was then calculated. This step is essential for validating the reliability and methodological rigor of the multi - criteria decision - making process.

The consistency check of the pairwise comparison matrix for the 10 evaluation criteria yielded a maximum eigenvalue of $\lambda_{\max} = 11.1$, resulting in a Consistency Index (CI) of 0.1 and a Consistency Ratio (CR) of 0.082. Since $CR < 0.1$, the matrix is considered to have a high level of consistency, thereby ensuring the reliability of the assigned weights used in constructing the ecotourism potential assessment model for the study area.

Table 2. Pairwise Comparison Matrix for Ecotourism Suitability Criteria

	CTS	DTR	DTU	DTW	ELV	SLP	LST	RNF	LSV	NDVI
CTS	1	3	3	5	7	7	4	5	2	2
DTR	0.33	1	1	3	5	6	3	4	2	2

DTU	0.33	1	1	2	4	5	3	3	2	2
DTW	0.2	0.33	0.5	1	1	2	3	2	2	2
ELV	0.14	0.2	0.25	1	1	2	3	3	2	2
SLP	0.14	0.17	0.2	0.5	0.5	1	2	2	2	2
LST	0.25	0.33	0.33	0.33	0.33	0.5	1	1	2	2
RNF	0.2	0.25	0.33	0.5	0.33	0.5	1	1	2	2
LSV	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1	1
NDVI	0.14	0.5	0.5	0.5	0.5	0.5	0.5	1	1	1
SUM	3.25	7.28	7.62	14.33	20.17	25	21	22.5	18	18

Table 3. Classification and Normalized Weights
of Ecotourism Suitability Factors in Thai Nguyen province

Group	Factor	Category class	Normalized weight
Accessibility factors	Cultural Tourism Sites	0 - 15 (km)	0.27
		15 – 30(km)	
		30 – 45(km)	
		>45(km)	
	Distance to Roads	0 - 7 (km)	0.16
		7 – 14(km)	
		14 – 24(km)	
		24(km)	
	Distance to Urban Areas	0 – 10 (m)	0.14
		10 – 22 (m)	
		22 – 48 (m)	
		>48 (m)	
	Distance to Rivers and Streams	0 – 3 (km)	0.08
		3 – 6 (km)	
		6 – 9 (km)	
		>9 (km)	
Topographical factors	Elevation	732 – 1588 m	0.08
		359 – 732 m	
		156 – 359 m	
		0 –156 m	
	Slope	0 – 8.3 °	0.06
		8.3 – 18.4 °	
		18.4 ° - 30.48 °	
		>31°	
Climatic conditions	LST	17 – 27°C	0.05
		27 – 30°C	
		30 – 33°C	
		33 – 42°C	

	Rainfall	2160 – 2352 mm	0.05
		2352 – 2514 mm	
		2514 – 2706 mm	
		2706 – 3082 mm	
Natural landscape	Landscape Visibility	> 104	0.05
		49 – 104	
		15 – 49	
		0 – 15	
	NDVI	< - 0.4	0.04
		- 0.4 – - 0.03	
		- 0.03 – 0.3	
		0.3 - 1	

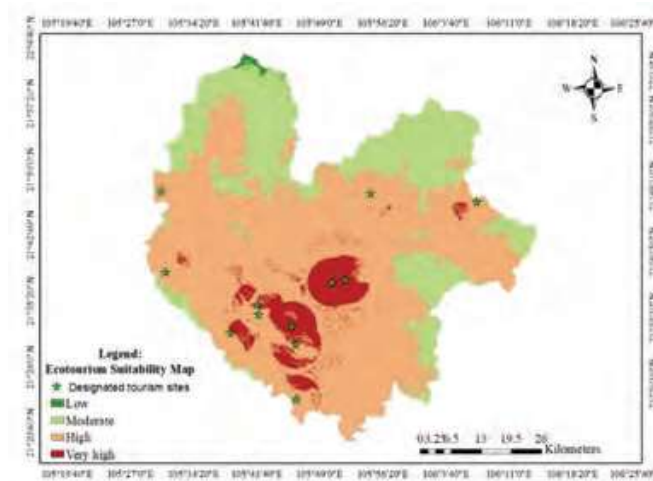


Figure 3. Ecotourism suitability Map in Thai Nguyen

This study highlights the value of integrating ecological attributes and accessibility in delineating ecotourism zones, which reaffirms prior research [4]. In Thai Nguyen Province, the most suitable areas are concentrated in the highland districts of Dinh Hoa and Vo Nhai because dense forest cover, karst topography, and temperate climate collectively create ideal conditions for nature - based tourism. These findings are consistent with spatial patterns observed in similar Southeast Asian landscapes [17]. Moderately suitable areas such as Phu Luong and Dai Tu, which feature a mix of cultural and agricultural settings, offer potential for community - based and agro - ecotourism if guided by strategic planning and investment [26].

Although urban areas like Thai Nguyen City lack ecological appeal for ecotourism, they function as logistical hubs that support accessibility and tourism services, as supported by Sunkar et al. (2020). Nonetheless, as Rahman et al. (2017) noted, challenges remain due to infrastructure limitations, weak data coordination, and tensions between tourism development and ecological protection.

This study applied the Analytic Hierarchy Process (AHP) to integrate physical and socio - economic spatial data for ecotourism suitability mapping in Thai Nguyen Province (fig.3 and tab.3). The results indicate high - potential zones in mountainous districts like Dinh Hoa and Vo Nhai, characterized by dense vegetation, karst terrain, and cultural assets. Moderate - potential areas such as Phu Luong and Dai Tu serve as buffers supporting agro - and community - based tourism. While urban zones are less suitable ecologically, they play essential logistical roles. The study's strength lies in its spatially explicit, multi - criteria approach, offering a decision - support tool for sustainable tourism planning. Constraints include fragmented resources and the challenge of balancing development with ecological conservation.

5. Conclusion

This study presents a spatial evaluation of ecotourism potential in Thai Nguyen Province by integrating ten environmental and socio - economic indicators using a GIS - based AHP framework. High - suitability zones are primarily located in Dinh Hoa and Vo Nhai, featuring diverse forests, favorable topography, and a mild climate, ideal for nature - based tourism. Moderately suitable areas such as Phu Luong and Dai Tu offer potential for agro - and community - based tourism with appropriate investment. Urbanized districts like Thai Nguyen City and Pho Yen, although ecologically limited, serve as logistical and service hubs that support access to ecotourism sites.

Despite rich ecological and cultural assets, Thai Nguyen's tourism potential remains fragmented due to uneven spatial distribution and limited access to remote areas. The lack of integrated digital planning tools and stakeholder coordination further hinders development. To ensure sustainability, future ecotourism strategies should prioritize conservation in high - value zones, promote experiential models in transitional areas, and strengthen infrastructure and service linkages in urban centers. Preserving ecological integrity through participatory governance and land - use control is essential to balance development with long - term environmental protection.

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ASSESSING PUBLIC INTEREST TRENDS AND LOCAL READINESS FOR NET ZERO TOURISM IN VO NHAI, THAI NGUYEN

Abstract

Tourism is a major driver of economic growth but also a significant source of greenhouse gas emissions, underscoring the urgency of Net Zero transitions. This study assesses public interest and community readiness for Net Zero tourism in Vo Nhai District, northern Vietnam, using a mixed - methods approach that combines Google Trends analysis, structured surveys, and field observations. Results show that search interest in Net Zero increased notably after Vietnam's COP26 commitment, yet awareness among visitors remains limited, with only 22 % familiar with the concept. Despite this, pro - sustainability attitudes are strong, with 86 % of respondents expressing willingness to choose destinations that adopt green policies, and preferences favored eco - tourism (68 %) and cultural tourism (59 %). Solid waste mismanagement emerged as the most critical barrier, while renewable energy adoption among operators remains minimal. The findings emphasize the need to bridge awareness with infrastructure and community participation. This study provides empirical insights from a rural case, offering practical pathways to advance Net Zero tourism in Vietnam.

Keywords

Net Zero tourism; sustainable tourism; community - based tourism; renewable energy

1. Introduction

Tourism is one of the fastest - growing sectors worldwide, contributing significantly to economic development, cultural exchange, and local livelihoods. However, it is also a major source of greenhouse gas emissions, accounting for nearly 8 % of global carbon emissions, mainly from transportation, accommodation, and waste generation [1]. In the era of climate change, the concept of Net Zero Tourism has emerged as a crucial pathway to align tourism development with sustainable practices and global carbon neutrality targets [2]. Within this framework, zero - waste management and renewable energy adoption are considered two core strategies to minimize environmental impacts while enhancing the resilience of tourism destinations.

A growing body of research has investigated the linkages between tourism and sustainability. [3] highlighted the critical role of low - carbon transition strategies in tourism. Studies in Costa Rica [4, 5] and New Zealand [6] demonstrated that renewable energy integration and eco - friendly infrastructure can significantly reduce tourism's ecological footprint. In Asia, Thailand has piloted community - based tourism initiatives that combine waste reduction with renewable energy solutions [7]. In Vietnam, several pilot projects, such as "Net Zero Tours" in Bến Tre and Huế, have shown initial success in applying green transportation, eco - lodging, and community - based waste management

to reduce emissions [8, 9]. Despite these advances, research on systematic integration of zero - waste practices and renewable energy solutions in rural, community - based tourism contexts remains limited.

This gap is particularly evident in mountainous districts of Vietnam such as Vo Nhai (Thai Nguyen Province), where eco - tourism and community - based tourism are expanding but face challenges of waste mismanagement, reliance on fossil fuels, and limited awareness of green practices. Previous studies have focused more on policy frameworks or urban green tourism models, leaving a lack of in - depth empirical evidence on how zero - waste initiatives and renewable energy adoption can be jointly implemented at the community level. To address this gap, this study contributes by developing and assessing practical strategies for integrating waste reduction and renewable energy solutions into local tourism operations, thereby advancing the Net Zero agenda in emerging rural destinations.

This study investigates how zero - waste management and renewable energy practices can be integrated into local tourism to support Net Zero development in Võ Nhai District, Vietnam. Set against the backdrop of Vietnam's national commitment to achieve net - zero emissions by 2050 and its strategy for green growth and sustainable tourism, the research focuses on identifying practical pathways at the community level. Specifically, the objectives are to assess current waste management and energy use in tourism activities, to analyze opportunities and barriers for adopting zero - waste and renewable energy solutions, and to propose a strategic framework for advancing Net Zero tourism in rural destinations.

2. Study area

Vo Nhai District is situated in Thai Nguyen Province, northern Vietnam, and is characterized by a mountainous terrain with extensive karst formations and high ecological diversity in Figure 1 [10, 11]. In recent years, the district has gained recognition as an emerging nature - based tourism destination, with sites such as Phuong Hoang Cave and Mo Ga Stream attracting a growing number of domestic visitors [10]. Local livelihoods are primarily dependent on agriculture, small - scale tourism services, and natural resource utilization, which together create both opportunities and challenges for sustainable development [12, 13].

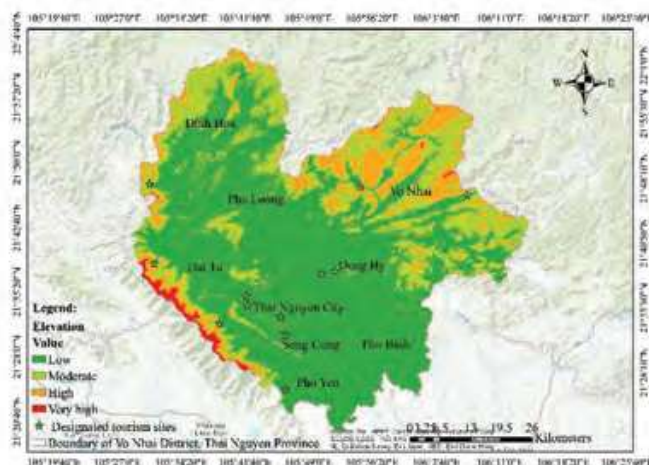


Figure 1. Location of the Study Area: Vo Nhai District, Thai Nguyen Province

Despite this potential, environmental infrastructure remains limited. Waste management practices are still underdeveloped, while energy consumption relies heavily on fossil fuels and traditional biomass, underscoring the urgent need for innovative [14, 15]. This context makes Võ Nhai a representative case for exploring the integration of zero - waste practices and renewable energy solutions into rural tourism development, contributing to Vietnam's broader Net Zero and green growth strategies [3, 16].

3. Methods

This study adopted a mixed - methods approach, integrating quantitative surveys, qualitative fieldwork, and strategic analysis to provide a comprehensive assessment of waste management and energy practices in local tourism, and to explore pathways for Net Zero transition in Vo Nhai District, Vietnam.

To capture broader discursive dynamics, Google Trends was used to track public interest in keywords such as "Net Zero," "sustainable tourism," and "eco - tourism" in both English and Vietnamese (e.g., "du lịch Net Zero," "du lịch bền vững") from 2004 to 2025. This enabled the identification of temporal patterns in public awareness and sustainability discourse within tourism [17, 18]. Complementing this, a structured questionnaire was distributed via Google Forms to domestic and international tourists, as well as local tourism enterprises in Võ Nhai. The survey examined awareness of Net Zero tourism, behavioral preferences regarding waste reduction and renewable energy, and willingness to participate in environmentally responsible practices. In total, 210 valid responses across diverse demographic groups were obtained and analyzed using descriptive and inferential statistics to assess the feasibility of Net Zero integration into local tourism [19].

Primary fieldwork was conducted over two days in Vo Nhai, combining direct observations with semi - structured interviews involving homestay owners, community leaders, and tourism operators. The survey emphasized waste generation and disposal practices, energy use in accommodation and transportation, and community - led environmental initiatives. Observational notes and photographic evidence were systematically documented to corroborate survey data and provide contextual depth [20, 21].

Finally, qualitative data from field surveys and interviews were thematically coded to identify recurring patterns related to waste management, renewable energy adoption, and barriers to green practices [22]. To ensure reliability and robustness, triangulation was applied across Google Trends data, survey responses, and field observations, thereby reinforcing the validity of the findings [19].

4. Results and Discussion

4.1. Results

Google Trends analysis indicates that public awareness of the "Net Zero" concept was negligible prior to 2015 (Figure 2). A steady increase emerged after 2016, coinciding with Vietnam's engagement in international climate agreements. Search interest peaked following the country's Net Zero commitment at COP26 in 2021 and resurged around

COP28 in 2023. These patterns highlight that while global awareness has been consolidated, in Vietnam it remains episodic and largely policy - driven.

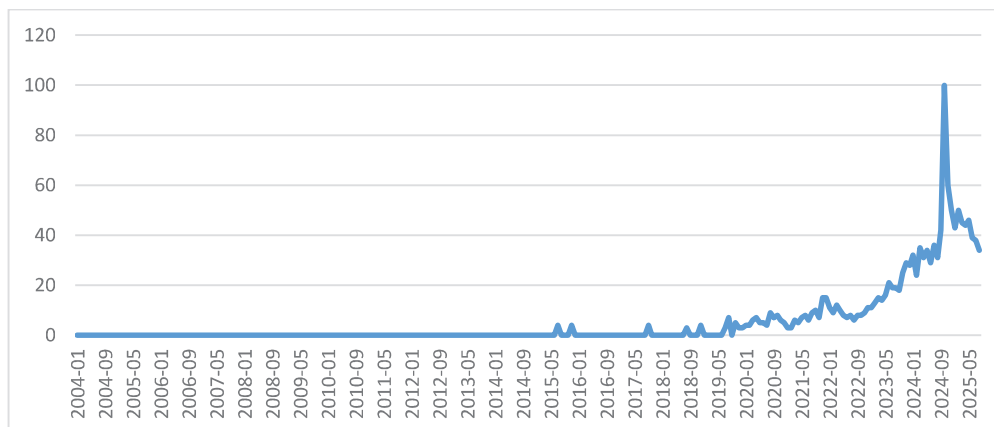


Figure 2. Trends in Search Interest for "Net Zero" in Vietnam (2004–Present).

Significant regional disparities were observed, with Hanoi, Thua Thien Hue, Ha Giang, and Cao Bang showing the highest levels of search activity (Figure 3). These regions combine policy engagement, academic initiatives, and ecological tourism potential. Such variation suggests that Net Zero awareness in Vietnam is shaped both by governance dynamics and local environmental - tourism contexts.



Figure 3. Top five provinces in Vietnam with the highest public interest in "Net Zero".

At the international scale, countries such as the United Kingdom, Germany, and Singapore exhibited early and sustained engagement, reflecting strong institutional support for Net Zero objectives (Figure 4). Globally, search interest has stabilized between 65 and 80 index points since 2021, indicating that Net Zero has become an enduring discourse rather than a transient policy slogan.



Figure 4. Top five countries worldwide by public interest in "Net Zero".

The survey data from 51 tourists (aged 18–30) reveal that awareness of Net Zero tourism remains limited (Figure 5). Only 22 % reported familiarity with the concept, while more than half (51 %) had never heard of it. Despite this, a large majority expressed pro-sustainability attitudes, with 86 % indicating willingness to choose destinations that adopt sustainable tourism policies and 72 % showing readiness to participate in environmentally friendly activities if provided with opportunities. Although most respondents associated Net Zero mainly with reducing plastic use (45 %) or cutting CO₂ emissions (39 %), these findings still demonstrate a basic level of environmental consciousness that could be further strengthened through targeted communication strategies.

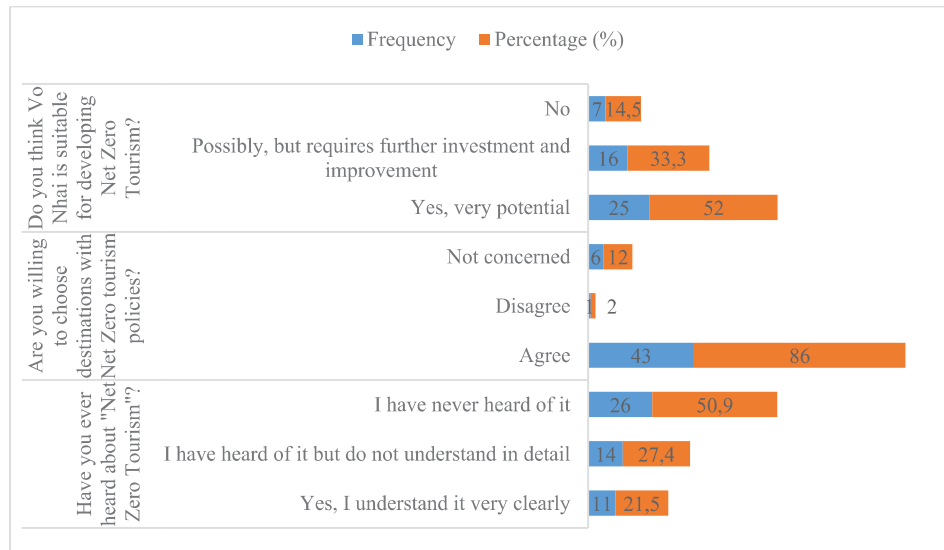


Figure 5. *Tourists' awareness and attitudes toward Net Zero tourism.*

In terms of local environmental concerns, field surveys confirmed that unmanaged solid waste continues to pose a pressing challenge (Figure 6). Nearly 61 % of respondents considered inadequate waste treatment a major issue, while 43 % emphasized the ecological impacts of tourism activities. More than half of participants rated the environment as "average, with many problems," and only 6 % regarded pollution as severe. Even with this moderate perception, environmental engagement was high, as 72 % expressed interest in protection initiatives and 86 % indicated willingness to join conservation activities if organized at the community level.

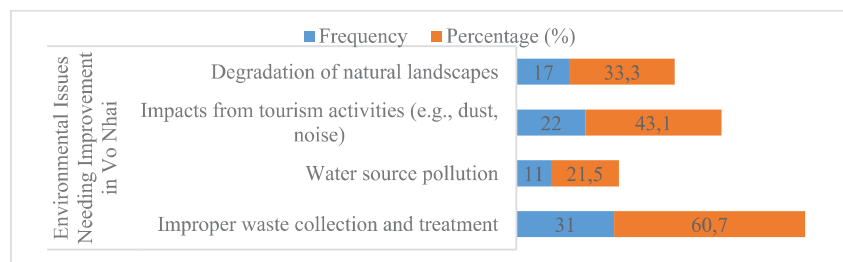


Figure 6. *Tourists' perceptions of environmental issues in Vo Nhai.*

Preferences for sustainable tourism also emerged strongly from the survey results in Figure 7. A majority of tourists showed interest in eco - tourism (68 %) and cultural tourism (59 %), which align closely with the natural and cultural strengths of Vo Nhai. Over 80 % were willing to use eco - friendly products, while more than 60 % expressed readiness to adopt low - carbon practices such as walking, cycling, or using reusable bottles. However, a notable gap persists between attitudes and actual behaviors, since only a small proportion translated these concerns into concrete sustainable actions during their visits.

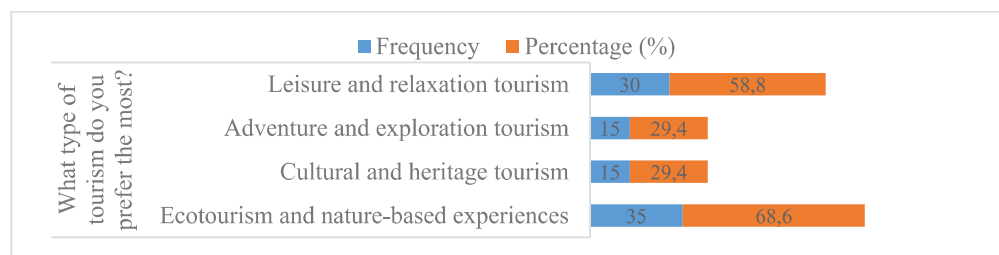


Figure 7. *Most preferred types of tourism.*

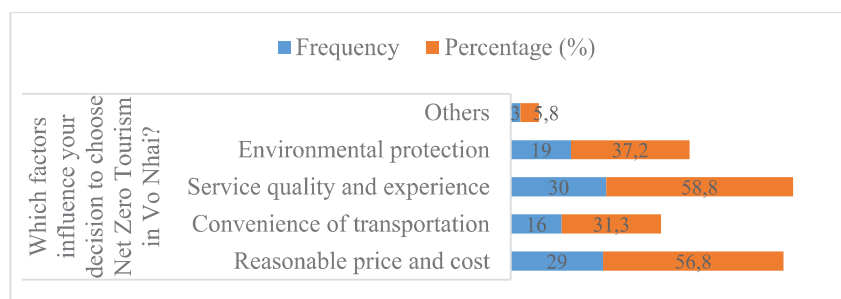


Figure 8. *Factors influencing tourists' decisions to choose Net Zero tourism in Vo Nhai.*

Finally, tourist retention and communication channels further illustrate both opportunities and challenges for Net Zero tourism development in the district (Figure 8). While 43 % of surveyed tourists stated they would certainly return and 27 % considered the possibility of a revisit, some hesitancy reflected perceived weaknesses in infrastructure and service quality. Popular attractions such as Thac Mua Roi waterfall, Than Sa-Phuong Hoang Nature Reserve, and traditional villages already hold strong appeal, yet their potential remains underexploited. At the same time, the influence of social media platforms (Facebook, TikTok) and word - of - mouth highlights the importance of leveraging digital communication and community - based branding to promote sustainable tourism practices more effectively.

4.2. Discussion

The results highlight both the opportunities and systemic barriers to implementing Net Zero tourism in Vo Nhai. The evidence from Google Trends and surveys confirms that environmental sustainability is becoming an integral expectation in tourism discourse. Yet, the weak institutionalization of Net Zero concepts at the local level means that awareness does not automatically translate into structured practices. This gap reflects

one of the study's key objectives: to assess whether consumer demand, local practices, and policy frameworks are aligned to enable zero - waste and renewable energy transitions in tourism.

The predominance of plastics at major tourist sites illustrates the urgency of upstream interventions. Providing strategically placed tri - bin stations, coupled with a reliable back - end collection and recycling system, would reduce leakage and contamination. Importantly, tourists' willingness to engage in waste reduction suggests that behavioral readiness exists, but infrastructural and organizational deficiencies undermine action. Without proper incentives and visible systems, sustainability becomes symbolic rather than operational.

The survey and field data also underline the need to strengthen renewable energy adoption. The low uptake of solar and biogas solutions among homestays and small lodges demonstrates not only financial constraints but also a lack of technical guidance and demonstration models. Pilot projects introducing community solar hubs or micro - biogas units could reduce fossil fuel dependence while showcasing visible pathways to Net Zero tourism. These interventions would resonate with national commitments under COP26 while improving the marketability of Vo Nhai as a green destination.

In line with the methodological framework, triangulation of digital awareness (Google Trends), consumer behavior (survey data), and on - the - ground practices (field observation) demonstrates that the district is at an early but promising stage of transition. The key contribution of this study is showing that Net Zero tourism is not merely a global slogan but can be locally contextualized into practical solutions. By bridging awareness with infrastructure, and consumer demand with business capacity, Vo Nhai has the potential to become a pioneering site for zero - waste and renewable energy - based tourism in Vietnam.

The findings suggest that successful Net Zero tourism development in Vo Nhai requires a dual focus on community engagement and structural support. First, awareness - raising campaigns should move beyond general promotion to provide clear and practical guidance on how Net Zero principles can be applied in daily tourism practices. Second, infrastructure investment is needed to ensure reliable waste management, renewable energy access, and environmentally friendly transport options. Third, local authorities should design incentive mechanisms, such as tax reductions, certification schemes, or preferential promotion—for tourism businesses that adopt Net Zero standards. Finally, policies should prioritize inclusive participation, ensuring that local households and small - scale operators are not only beneficiaries but also active contributors to the district's transition toward sustainable tourism.

5. Conclusion

The present research examined how public interest and local readiness intersect in shaping the prospects for Net Zero tourism in Vo Nhai District, Thai Nguyen. The analysis of survey data shows that awareness of the concept is relatively widespread, yet the depth of understanding remains uneven, pointing to a gap between familiarity and practical knowledge. At the same time, the results highlight a clear willingness among

both residents and visitors to embrace sustainable tourism models, particularly when these are supported by reasonable costs, reliable services, and improved accessibility.

Vo Nhai's ecological and cultural assets provide a strong basis for developing Net Zero-oriented tourism. Nevertheless, several obstacles remain, including limited infrastructure, the need to strengthen service quality, and the necessity of more effective communication to turn public interest into concrete behavioral change.

By linking trend analysis with an assessment of community readiness, this study adds evidence from a rural district that has so far received little attention in the literature on sustainable and Net Zero tourism. This study also highlights that public interest in Net Zero tourism in Vo Nhai is growing, yet practical awareness and readiness remain uneven. Strengthening infrastructure, improving service quality, and fostering community participation are essential to translate emerging interest into actionable pathways for sustainable tourism development.

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