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Unmasking The Hidden Costs of Ecotourism: A Green Accounting Decision Support System Using Spatial Macro-Tourist Data

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Abstract. While ecotourism is frequently championed as a sustainable solution, the influx of mass tourism often generates hidden ecological costs that remain unrecorded in conventional accounting frameworks. This study aims to design a spatial Decision Support System (DSS) model that integrates green accounting principles with macro-tourism data. Employing the Simple Additive Weighting (SAW) method, this research evaluates the disparity between tourist volume (14.5 million movements) and community-based accommodation capacities within the ecotourism epicenter of North Sulawesi, Indonesia. Two novel spatial accounting indicators are introduced: the Local Carrying Capacity Ratio (LCCR) and the Estimated Environmental Cost (EEC), monetized in the domestic currency (IDR). The DSS algorithm reveals a sustainability paradox: North Minahasa Regency, despite recording the lowest tourist volume (650,320 visitors), emerges as the most critical ecological zone (preference score of 0.586). This vulnerability is attributed to a severe infrastructure deficit that precipitates an extreme overshoot in carrying capacity (LCCR 26.20). Conversely, Manado City implicitly accrues an annual ecological debt exceeding IDR 24.5 billion driven by emissions and waste. These findings underscore that the omission of macro-spatial metrics from regional balance sheets can result in misguided investment policies. Ultimately, the proposed DSS model offers a strategic framework for local governments to formulate equitable carbon levies and reallocate tourism revenues toward the development of local community infrastructure.

Keywords: Carrying Capacity, Decision Support System, Ecotourism, Green Accounting, Hidden Costs

INTRODUCTION

Ecotourism has long been recognized as a catalyst for local economic growth and an instrument for environmental conservation in developing nations (Kumar, 2023; Poudel et al., 2025). Theoretically, this sector promises an equilibrium between financial profitability and ecological preservation. However, unchecked tourism expansion frequently precipitates a sustainability paradox(Milutis & Pestova, 2025). A massive surge in tourist volume tends to incur "hidden costs" that are rarely captured in traditional financial balance sheets, such as elevated carbon emissions, habitat degradation, increased waste generation, and the exploitation of groundwater resources (Gössling et al., 2023). Consequently, green accounting frameworks have been developed to identify, quantify, and report these hidden costs, ensuring that environmental externalities associated with tourism activities are made transparent for effective sustainable management (Gallego et al., 2025).

Although the literature on sustainability accounting within the tourism sector has proliferated, many existing studies remain confined to micro-level analyses, focusing on individual businesses or small-scale environmental audits rather than incorporating broader spatial or regional data. Systematic reviews indicate that studies on sustainable tourism and regional development highlight conceptual and empirical gaps in integrating macro-level indicators such as tourist flows and infrastructure capacity into sustainability frameworks (Tyagi, 2024). Moreover, adaptive models of tourism carrying capacity suggest that traditional, micro-centric approaches are insufficient for guiding sustainable policy decisions, pointing to the need for frameworks that account for both environmental resilience and institutional capacities (Siswanto et al., 2025). Empirical research on green accounting implementation in tourism also reveals limited application and standardization in operational contexts, further underscoring the necessity for comprehensive accounting models that integrate macro-movement data and community infrastructure variables (LESTARI et al., 2025).

North Sulawesi Province in Indonesia presents a highly representative case study of this phenomenon. As a premier epicenter for both maritime and terrestrial ecotourism (encompassing the Bunaken National Park, Tangkoko Nature Reserve, and the Likupang Special Economic Zone), the region has experienced an extraordinary influx of tourism. According to data from Statistics Indonesia (BPS), domestic tourist movements in North Sulawesi exceeded 14.53 million trips throughout 2025, complemented by the arrival of over 61,495 international tourists. This macro-volume, totaling approximately 14.6 million movements, exerts immense ecological pressure (Sulut.bps.go.id, n.d.).

Ironically, this massive influx of visitors does not correlate proportionally with the capacity of local community-based tourism infrastructure. BPS data (2024) indicates that the availability of small-scale local accommodations (non-star hotels or homestays) across North Sulawesi stands at a mere 219 units, with a total capacity of 4,397 rooms. Spatial disparities are also starkly evident; Manado City dominates with 2,230 rooms, whereas primary ecotourism buffer zones such as North Minahasa possess only 68 non-star hotel rooms. This disequilibrium between the explosion in tourist volume and the limited carrying capacity of local infrastructure precipitates "hidden environmental costs." These costs stem from intensive daily transportation movements, centralized energy consumption, and localized waste accumulation in areas lacking adequate mitigation systems.

Furthermore, a critical gap exists in the current green accounting literature. The majority of environmental accounting models are confined to micro level corporate evaluations (for example, individual hotel audits or corporate ESG reporting) and rarely address macro spatial dynamics. There is an urgent need for a systematic valuation tool capable of bridging macro tourist movement data with localized infrastructural capacities to calculate the true cost of regional tourism development.

This study proposes a spatial green accounting model integrated into a Decision Support System utilizing the Simple Additive Weighting algorithm (Rafli et al., 2025). The research is contextualized in North Sulawesi, Indonesia, specifically targeting Manado City, Bitung City, and the Likupang Super Priority Destination in North Minahasa. By introducing two novel spatial indicators, the Local Carrying Capacity Ratio and a monetized Estimated Environmental Cost in the domestic currency, this study aims to empirically rank regional ecological vulnerabilities. Ultimately, this model provides a strategic and data driven framework for local governments to reassess tourism investment policies, formulate equitable carbon levies, and prioritize community-based infrastructure empowerment.

MATERIALS AND METHODS

Study Area and Data Collection

This study employs a quantitative approach by developing a spatial Decision Support System (DSS) model grounded in green accounting principles. The study area encompasses 15 regencies and municipalities within North Sulawesi Province, Indonesia. The analysis focuses on three primary regions representing the maritime and ecotourism epicenters of the province: Manado City (the primary gateway to Bunaken National Park), Bitung City (Tangkoko Nature Reserve), and North Minahasa Regency (Likupang Tourism Special Economic Zone).

The dataset comprises macro-scale secondary data obtained from official publications by Statistics Indonesia (BPS) of North Sulawesi Province for the years 2024 and 2025. This dataset consists of two primary variables: (1) tourist mobility volume, an aggregation of domestic tourist trips and international tourist arrivals; and (2) community-based infrastructure capacity, represented by the availability of rooms and beds in non-star hotels or homestays.

Table 1. Extraction of Macro-Tourism and Local Infrastructure Input Data

Regency/Municipality	Total Tourist Visits (Vi)*	Number of Non-Star Hotels	Local Room Capacity	Bed Capacity (Bi)
Manado City	2560400	73	2230	3286
Bitung City	846852	33	391	432
North Minahasa	650320	4	68	68
Total North Sulawesi Prov.	14599454	219	4397	6100

Alat dan Bahan

Environmental Accounting Formulation

Prior to processing the macro-data within the DSS algorithm, it must be transformed into environmental accounting indicators to quantify the "hidden costs" of tourism. This study formulates two primary proxies: a spatial carrying capacity ratio and an estimated monetary emission burden.

Local Carrying Capacity Ratio (LCCR)

The LCCR measures the disparity ratio between the annual tourist volume and the available capacity of community-based (non-star) hospitality infrastructure. A higher LCCR value indicates greater "socio-environmental costs" generated by an influx of tourists that the sustainable local economic system cannot absorb. This equation is formulated as:

$$LCCR_i = \frac{V_i}{B_i \times 365}$$

Where V_i is the total tourist volume in region i, and B_i is the total bed capacity in non-star accommodations within that region. The constant 365 represents the number of active days in a year.

Estimated Environmental Cost (EEC)

To quantify the ecological impact into a sustainability reporting format, this model employs proxies for carbon emission burden and waste volume per tourist capita. The total environmental cost is calculated using the equation:

$$EEC_i = V_i \times (k_e \cdot P_{carbon} + k_w \cdot P_{waste}$$

Where k_e and k_w are the emission and waste constants per tourist, respectively. P_{carbon} and P_{waste} represent the estimated mitigation costs per unit of carbon and waste processing in the local currency (Indonesian Rupiah/IDR). To reflect domestic economic realities, this combined monetary valuation is adapted from local sanitation retribution regulations and estimated domestic carbon tax values, set at a constant of IDR 9,600 per tourist.

Decision Support System (DSS) Framework

The Decision Support System (DSS) in this study is constructed using the Simple Additive Weighting (SAW) method. The SAW method was selected for its capability to precisely evaluate multi-criteria algorithms involving conflicting attribute dimensions (e.g., economic profit versus ecological burden).

This model aims to rank the regencies/municipalities experiencing the most severe sustainability deficits (red zones), thereby necessitating urgent green accounting policy interventions and funding reallocations.

Table 2. DSS Evaluation Criteria and Weighting Vector (W)

Code	Criteria Name	Mathematical Symbol	Attribute Type	Weight (wj)	Accounting Rationalization
C1	Tourist Visit Volume	V_i	Cost	0.3	Primary driver of environmental burden
C2	Local Accommodation Capacity	B_i	Benefit	0.2	Indicator of socio-economic empowerment
C3	Local Carrying Capacity Ratio	$LCCR_i$	Cost	0.25	Spatial carrying capacity disparity ratio
C4	Estimated Environmental Cost	EEC_i	Cost	0.25	Monetary proxy of ecological damage (in IDR)

SAW Computational Steps

Step 1: Formulation of the Decision Matrix (X)

The values of each criterion C_1 to C_4) for every alternative region (A_i) are transformed into a decision matrix X, where the element x_{ij} represents the value of region i for criterion j.

Step 2: Normalization of the Decision Matrix (R)

To compute data with disparate units (e.g., headcount vs. room count vs. IDR value), the data is normalized (r_{ij}) into a mathematical scale ranging from 0 to 1.

For Benefit attribute criteria (i.e., C2), normalization is performed by dividing the alternative value by the maximum value within that criterion:

$$r_{ij} = \frac{x_{ij}}{max_i \, x_{ij}}$$

For Cost attribute criteria (i.e., C1, C3, C4), normalization is executed by dividing the minimum value within that criterion by the alternative value:

$$r_{ij} = \frac{min_i \, x_{ij}}{x_{ij}}$$

Step 3: Calculation of the Final Preference Value (V)

The final stage involves multiplying the normalized matrix (R) by the priority weight vector (W), formulated as:

$$V_i = \sum_{j=1}^{n} w_j r_{ij}$$

Within the context of this sustainability accounting model, a region with the lowest V_i score indicates the highest "hidden environmental costs" and the lowest proportion of supporting local infrastructure. Regions exhibiting the lowest V_i scores are recommended as top priorities for green tourism investment interventions.

RESULTS AND DISCUSSION

The present analysis integrates raw macro-tourist visitation data with environmental economic valuation to assess ecological vulnerability across tourism epicenters. This approach aligns with recent developments in ecological security assessment frameworks that employ systematic quantification of tourism's environmental impacts as indicators for decision support mechanisms. Tourism ecological security models have been proposed as tools to measure the environmental consequences of tourism activities and the resilience of destination ecosystems (Guo et al., 2024).

Formulation of Spatial Environmental Accounting Indicators

The initial phase of the evaluation transforms macro-level tourism movement data into tangible environmental accounting metrics. The assessment focuses on two primary parameters

to quantify the "hidden costs" of tourism: the Local Carrying Capacity Ratio (LCCR) and the Estimated Environmental Cost (EEC).
To monetize the environmental impact (EEC), this study establishes a domestic valuation proxy (Anjos et al., 2025). Based on local waste management retribution tariffs and regional carbon pricing estimations, the combined environmental cost constant is established at IDR 9,600 per tourist (sulut.bps.go.id, n.d.). Table 3 illustrates the baseline disparity between tourist volume (V_i), community-based accommodation capacity B_i), and the resulting ecological indicators.

Table 3. Calculation of Ecological Indicators (LCCR and EEC)

Alternatives (Ai)	Total Tourists (Vi)	Room Capacity (Bi)	LCCR (C3)	EEC (C4) in IDR
A1 (Manado City)	2.560.400	2.230	3,14	24.579.840.000
A2 (Bitung City)	846.852	391	5,93	8.129.779.200
A3 (North Minahasa)	650.320	68	26,2	6.243.072.000

The LCCR for North Minahasa is derived using the formula:

$$LCCR_{A3} = \frac{650.320}{68 \times 365} = 26{,}20$$

The mathematical extraction of the LCCR explicitly reveals a critical ecological overshoot in North Minahasa. Theoretically, every single room in local non-star accommodations within this region bears the burden of approximately 26 tourists per day year-round. This extreme disproportion highlights a fundamental flaw in the region's current tourism infrastructure readiness.

Spatial Decision Support System Analysis via SAW Algorithm

To determine the most critically deficient ecological zone, the Simple Additive Weighting (SAW) algorithm is executed. The criteria matrix comprises C1 (Tourist Volume - *Cost*), C2 (Room Capacity - *Benefit*), C3 (LCCR - *Cost*), and C4 (EEC - *Cost*). The priority weight vector applied by the DSS framework is W = [0.30, 0.20, 0.25, 0.25].

Stage 1: Decision Matrix (*X*) and Normalization (*R*)

Based on Table 3, the initial decision matrix (*X*) is constructed and subsequently normalized based on the *Cost* and *Benefit* attributes of each criterion.

$$X = \begin{bmatrix} 2.560.400 & 2.230 & 3{,}14 & 24.579.840.000 \\ 846.852 & 391 & 5{,}93 & 8.129.779.200 \\ 650.320 & 68 & 26{,}2 & 6.243.072.000 \end{bmatrix}$$

$$X = \begin{bmatrix} 0{,}254 & 1{,}000 & 1{,}000 & 0{,}254 \\ 0{,}768 & 0{,}175 & 0{,}530 & 0{,}768 \\ 1{,}000 & 0{,}030 & 0{,}120 & 1{,}000 \end{bmatrix}$$

Stage 2: Final Preference Value (V_i) Computation

The final preference scores are calculated by multiplying the normalized matrix R with the weight vector *W*. In this specific sustainability evaluation, a lower V_i score mathematically indicates a more severe ecological deficit (a higher concentration of unmitigated hidden costs).

- **A1 (Manado):**
  $$V_1 = (0{,}3 \times 0{,}254) + (0{,}2 \times 1) + (0{,}25 \times 1) + (0.25 \times 0{,}254) = 0{,}590$$
- **A2 (Bitung):**
  $$V_2 = (0{,}3 \times 0{,}768) + (0{,}2 \times 0{,}175) + (0{,}25 \times 0{,}53) + (0.25 \times 0{,}768) = 0{,}590$$
- **A3 (North Minahasa):**
  $$V_3 = (0{,}3 \times 1) + (0{,}2 \times 0{,}03) + (0{,}25 \times 0{,}12) + (0.25 \times 1) = 0{,}586$$

The Paradox of Mass Tourism and Uncovering Hidden Costs

The final computation establishes North Minahasa ($V_3 = 0.586$) as the most critically vulnerable region. These findings expose a significant paradox frequently overlooked by traditional regional accounting paradigms. If local governments evaluate tourism success solely based on macroeconomic tourist volumes (V_i), North Minahasa appears to bear the lightest ecological burden (650,320 visits). A conventional balance sheet would mistakenly flag Manado City as the most problematic area due to its sheer volume.

However, the integration of local accommodation capacity B_i) and the carrying capacity ratio ($LCCR$) shifts this perspective entirely. North Minahasa's vulnerability stems from a severe infrastructure deficit, amounting to merely 68 community-based non-star rooms. The alarming LCCR dictates that the mass influx of tourists into the Likupang Super Priority Destination is bypassing the circular, community-based economy. Consequently, this triggers localized environmental degradation due to inadequate sanitation, lack of waste management, and standardized eco-accommodations.

Furthermore, the Estimated Environmental Cost (EEC) unveils the true scale of "hidden costs" in the more developed regions. Manado City silently accumulates an annual ecological debt exceeding IDR 24.5 Billion, originating from the unmitigated emissions and waste footprints of over 2.5 million tourist movements. Under current regional accounting practices, this massive deficit is entirely absent from the destination management's Income Statements. Local governments often perceive a financial surplus from tourism retributions, while in reality, this perceived profit is silently subsidizing the degradation of the region's coral reefs and accelerating the depletion of local landfill capacities.

Strategic Implications for Sustainable Tourism Policy

The empirical evidence generated by this spatial DSS model functions as an essential early-warning mechanism for regional sustainability. The integration of green accounting proves that a uniform tourism policy cannot be applied across the province. Instead, the model prescribes divergent, data-driven interventions:

1. For High-Volume, High-Capacity Regions (e.g., Manado City):

Policymakers must implement a structured green accounting system where conservation levies are aggressively redirected toward direct carbon mitigation and modern waste processing infrastructure, acknowledging the IDR 24.5 Billion annual ecological debt.

2. For Medium-Volume, Critically Low-Capacity Regions (e.g., North Minahasa):

Local authorities must temporarily decelerate mass tourism promotion campaigns. Capital investments should be fundamentally reallocated toward Community-Based Empowerment. Prioritizing the construction and standardization of locally owned, eco-friendly homestays is imperative before the destination reaches an irreversible ecological collapse.

CONCLUSION

This study successfully demonstrates that the failure to integrate macro-tourism data and local infrastructure capacity within regional accounting systems can obscure the "hidden environmental costs" of ecotourism growth. Through the implementation of a Decision Support System (DSS) based on the Simple Additive Weighting (SAW) method, this model unveils a sustainability reporting paradox. The region recording the lowest tourist visit volume within the sample, North Minahasa Regency (650,320 visits), is paradoxically identified as the most critical zone (preference score of 0.586). This vulnerability is driven by an extreme disparity in the carrying capacity ratio, resulting from severely limited community-based accommodation infrastructure (a mere 68 rooms). Conversely, regions experiencing the highest mass influx, such as Manado City, implicitly accrue an ecological debt (comprising emissions and waste) exceeding IDR 24.5 billion annually, which remains unrecorded in the conventional income statements of destination management organizations.

Theoretically, this research expands the green accounting discourse by shifting the focus from mere micro-level environmental audits (single corporate or hotel entities) to macro-scale spatial carrying capacity evaluations. Managerially, this DSS model provides an empirical foundation for local governments and conservation area managers in North Sulawesi to fundamentally recalibrate their tourism policies. The practical implications of this study recommend that epicenter regions like Manado initiate the implementation of accounting-structured carbon and waste levies. Concurrently, developmental regions such as Likupang (North Minahasa) should temporarily suspend mass tourism promotion until investment funds are reallocated toward the empowerment of eco-friendly, community-owned homestay infrastructure.

Although this model offers a comprehensive novel framework, the study acknowledges several limitations. The calculation of the Estimated Environmental Cost (EEC) currently relies on static proxy values (estimated domestic carbon tax and standard waste retributions). Therefore, future research is encouraged to utilize primary data collection regarding the actual carbon footprints of tourists and destination-specific waste tonnage volumes. Furthermore, integrating this DSS algorithm with Geographic Information Systems (GIS) in subsequent studies holds significant potential for generating real-time visual mapping of spatial ecological accounting balances.

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