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Ecological Footprint of Popular Temples in West Bengal, India: An Integrated GIS-Based Assessment and Contingent Valuation Analysis

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Research Article

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Posted Date: October 21st, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11358765/v1

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I would like to clarify that the study involved the participation of some students of The Calcutta Anglo Gujarati College and relevant stakeholders during the field survey. Ethical permission was obtained from The Calcutta Anglo Gujarati College before commencement of the research work. The study also incorporates secondary data collected from authentic and reliable sources. The research was conducted with due consideration for ethical responsibilities relating to data collection and the participation of individuals. I am providing this clarification in response to your request for an ethics statement to be included in the preprint. I kindly request you to consider this statement for inclusion in the declarations section of my submission and proceed with the registration and posting of the preprint.

Ecological Footprint of Popular Temples in West Bengal, India: An Integrated GIS-Based Assessment and Contingent Valuation Analysis

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Abstract
Religious tourism constitutes a vital component of West Bengal's cultural ethos and local economic landscape. Major pilgrimage centers—including the Dakshineswar Kali Temple, Kalighat Kali Temple, Tarapith Temple, Taraknath Temple at Tarakeswar, and ISKCON Mayapur—draw millions of devotees annually, sustaining local micro-enterprises, transportation networks, and hospitality services. However, intensive and highly seasonal visitor inflows generate severe ecological pressure, manifesting as increased greenhouse gas emissions, solid waste accumulation, water resource depletion, and strain on municipal drainage systems.

This paper presents an integrated methodological and conceptual research framework evaluating the ecological footprint of these popular temples using Geographic Information Systems (GIS), environmental resource accounting, and the Contingent Valuation Method (CVM). The methodology combines spatial land-use analysis via Sentinel-2 satellite imagery, transport-related carbon accounting, site-level material flow audits, and willingness-to-pay (WTP) econometric modeling. GIS multi-criteria overlay techniques delineate spatial environmental vulnerability zones surrounding temple complexes, while econometric models examine the socioeconomic and attitudinal drivers of visitors' financial commitment to environmental conservation. By connecting spatial exposure, resource demand, and public willingness to pay, this research framework provides an empirical foundation for low-carbon pilgrimage transport, sustainable waste management, and community-supported environmental governance.

Keywords: Ecological footprint, pilgrimage tourism, Geographic Information Systems (GIS), Contingent Valuation Method (CVM), willingness to pay, carbon emissions, temple sustainability, West Bengal.

1. Introduction

Religious sites serve simultaneously as sacred cultural landscapes, community focal points, and major centers of domestic and international tourism. In West Bengal, pilgrimage tourism is deeply interwoven with diverse spiritual traditions, notably Shakta, Shaiva, and Gaudiya Vaishnava heritage. Prominent temples identified by the Government of West Bengal—such as Dakshineswar Kali Temple, Kalighat Kali Temple, Tarapith Temple, Taraknath Temple at

Tarakeswar, and ISKCON Mayapur—represent crucial destinations attracting millions of visitors every year. Dakshineswar is renowned for its connection to 19th-century Bengal religious reform; Kalighat serves as one of the 51 Shakti Peethas situated within a dense urban grid; Tarapith draws tantric and Shakta practitioners; Tarakeswar experiences intense seasonal surges during the auspicious *Shraban* month; and ISKCON Mayapur functions as a global spiritual hub along the Bhagirathi-Hooghly riverine belt.

While pilgrimage tourism stimulates local employment, supports informal vending, and boosts regional transportation and accommodation sectors, its spatial and environmental footprint requires rigorous quantification. The cumulative impact of vehicular movement, disposable religious offerings (*pooja* materials), single-use plastics, food distribution (*bhog* and *prasadam*), water usage, and municipal sanitation during peak pilgrimage periods frequently exceeds local carrying capacity.

The **ecological footprint** methodology offers a standardized framework for evaluating human demand on ecosystem services and biologically productive land. Applied to pilgrimage tourism, this approach can be combined with a carbon inventory and material-flow analysis. Crucially, direct carbon emissions, water consumption, and solid waste streams represent distinct physical pressure indicators; carbon emissions require explicit carbon-uptake conversion factors before being translated into land-equivalent global hectares (gha).

Integrating **Geographic Information Systems (GIS)** adds spatial clarity to environmental accounting by identifying spatial vulnerability, land-use/land-cover (LULC) changes, transport bottlenecks, waste accumulation points, and drainage stress. Concurrently, economic valuation via the **Contingent Valuation Method (CVM)** measures non-market environmental benefits by assessing visitors' stated Willingness To Pay (WTP) for structured ecological management programs. By integrating GIS spatial mapping, physical resource accounting, and econometric CVM models, this study establishes a comprehensive framework to support sustainable pilgrimage management across West Bengal.

1.1 Research Problem

Environmental management across pilgrimage destinations in West Bengal is historically addressed through reactive measures focusing on basic litter removal, temporary crowd control, and emergency infrastructure during festival periods. However, these operational measures lack empirical integration with quantified resource consumption, spatially explicit land pressure, and economic valuation of environmental services. The core research problem is the absence of a unified, multi-site comparative framework capable of evaluating environmental resource demand, mapping spatial stress zones, and identifying visitor willingness to financially support site conservation.

1.2 Research Objectives

1. To develop an ecological footprint and environmental resource accounting framework for five major pilgrimage sites in West Bengal.

2. To map the spatial distribution of land-use changes, waste hotspots, and drainage pressures around temple complexes using GIS and remote sensing.

3. To quantify transport emissions, water consumption, energy usage, and solid waste generation across ordinary and peak visitation periods.

4. To estimate visitors' Willingness to Pay (WTP) for environmental restoration programs using CVM.

5. To model the socioeconomic, demographic, and attitudinal determinants influencing visitors' WTP through econometric techniques.

6. To formulate empirical, policy-relevant strategies for sustainable temple management and low-carbon tourism.

1.3 Research Questions

- What are the primary drivers of environmental and resource consumption associated with temple tourism across urban and rural settings?

- How do ecological pressures fluctuate between peak festival periods and regular days across different pilgrimage sites?

- Which spatial and infrastructural zones exhibit the highest vulnerability to environmental degradation within temple buffer zones?

- How do socioeconomic characteristics (income, education, travel distance) and environmental perceptions influence visitors' financial commitment to conservation?

- How can spatial GIS indicators and CVM economic valuation joint-inform site-specific policy decisions?

2. Review of Literature

2.1 Ecological Footprint and Environmental Accounting in Tourism

The concept of the ecological footprint, initially introduced by Wackernagel and Rees (1996), measures human demand on natural capital against ecological biocapacity. Within sustainable tourism literature, accounting frameworks distinguish between site-level operational footprints and visitor destination footprints (Gössling et al., 2002). Hunter (2002) emphasized that applying ecological footprinting to tourism requires establishing rigorous spatial boundaries and non-overlapping consumption categories. In religious tourism contexts, research demonstrates that visitor travel and long-distance transportation constitute the largest share of overall carbon emissions, whereas municipal solid waste and water consumption drive localized environmental degradation (Collins et al., 2009; Li et al., 2018).

2.2 GIS and Spatial Environmental Assessment

Geographic Information Systems (GIS) and Remote Sensing (RS) provide valuable tools for evaluating tourism-induced spatial transformations and ecological vulnerability (Goodchild, 1992). Multi-criteria evaluation (MCE) coupled with Analytical Hierarchy Process (AHP) methods are widely employed to map environmental sensitivity, urban sprawl, and infrastructure stress around cultural heritage zones (Malczewski, 1999; Feizizadeh & Blaschke, 2013). Remote sensing imagery (e.g., Sentinel-2, Landsat) facilitates spatial land-use classification, Normalized Difference Vegetation Index (NDVI) tracking, and impervious surface detection (Drzewiecki et al., 2014). Spatial point-pattern analysis, Kernel Density

Estimation (KDE), and spatial autocorrelation (Moran's I) allow researchers to locate waste accumulation hotspots, transport bottlenecks, and drainage constraints around heavily visited sites (Anselin, 1995).

2.3 Contingent Valuation Method (CVM) and Heritage Economics

The Contingent Valuation Method (CVM) is a widely recognized stated-preference technique for quantifying non-market economic values associated with environmental conservation and cultural heritage management (Mitchell & Carson, 1989; Carson et al., 2001). CVM utilizes structured survey scenarios to construct hypothetical markets, estimating individuals' Willingness to Pay (WTP) for specified environmental interventions (Arrow et al., 1993). In the context of West Bengal, empirical CVM applications have evaluated recreational and conservation values at natural and heritage destinations, such as Prinsep Ghat in Kolkata (Dutta et al., 2007) and historical sites in Bishnupur (Baitalik & Bhattacharjee, 2023). Econometric modeling—specifically binary logit, probit, and Tobit models—is routinely applied to identify how household income, educational attainment, environmental awareness, and institutional trust influence WTP decisions (Hanemann, 1984; Cameron & James, 1987).

2.4 Environmental Impacts of Religious Tourism in India

Religious tourism across India represents a significant segment of domestic travel, creating localized environmental challenges during major pilgrimage events (Shinde, 2007; Singh, 2013). Studies on prominent pilgrimage corridors, such as the Char Dham route in Uttarakhand and Vaishno Devi in Jammu & Kashmir, highlight the ecological strain caused by seasonal visitor surges, unmanaged solid waste, and river pollution (Rana et al., 2014; Sati, 2015). In West Bengal, research on riverine and urban religious sites emphasizes the localized impacts of ritual flower disposal, plastic usage, and heavy traffic congestion on surrounding aquatic ecosystems and air quality (Chowdhury & Mukhopadhyay, 2016; Ray & Ghosh, 2019).

2.5 Literature Gap

While existing scholarship covers isolated aspects of religious tourism, such as municipal solid waste management, traffic congestion, or stated preference valuation, significant gaps remain. First, few studies integrate spatial land-use data, physical material flow accounting, and contingent economic valuation within a unified multi-site framework. Second, existing literature often conflates localized resource demands (e.g., solid waste volume and water consumption) with global carbon footprints without specifying standard conversion boundaries. Third, comparative studies evaluating religious sites across varying spatial typologies—ranging from highly dense metropolitan locations to rural riverine pilgrimage centers—remain scarce in eastern India. This study addresses these gaps by establishing an integrated framework combining GIS mapping, resource accounting, and econometric CVM analysis.

3. Study Area

Five major pilgrimage destinations in West Bengal representing distinct spatial, cultural, and environmental settings were selected for comparative analysis:

Temple / Destination	District / Location	Primary Spatial & Analytical Emphasis

Dakshineswar Kali Temple	North 24 Parganas (Kolkata Metro Boundary)	High urban transport density, riverfront congestion along the Hooghly, rapid visitor turnover.
Kalighat Kali Temple	Kolkata Municipal Corporation	Extremely dense urban fabric, high pedestrian traffic, severe spatial constraints, urban drainage strain.
Tarapith Temple	Birbhum District	Semi-urban pilgrimage hub, high hotel accommodation density, substantial commercial waste generation.
Taraknath Temple	Hooghly District (Tarakeswar)	Extreme seasonal peak surges (*Shraban* month), heavy rail/road transit reliance, acute periodic waste spikes.
ISKCON Mayapur	Nadia District (Mayapur)	Riverine landscape along Bhagirathi-Hooghly, large international and domestic visitor base, extensive residential/dining complexes.

To ensure analytical consistency across sites, two standardized spatial boundaries are defined for GIS analysis:

1. **Core Analysis Zone (1-km radius buffer):** Focuses on immediate pedestrian flows, temple-adjacent vendor activity, waste generation, and immediate drainage capacity.

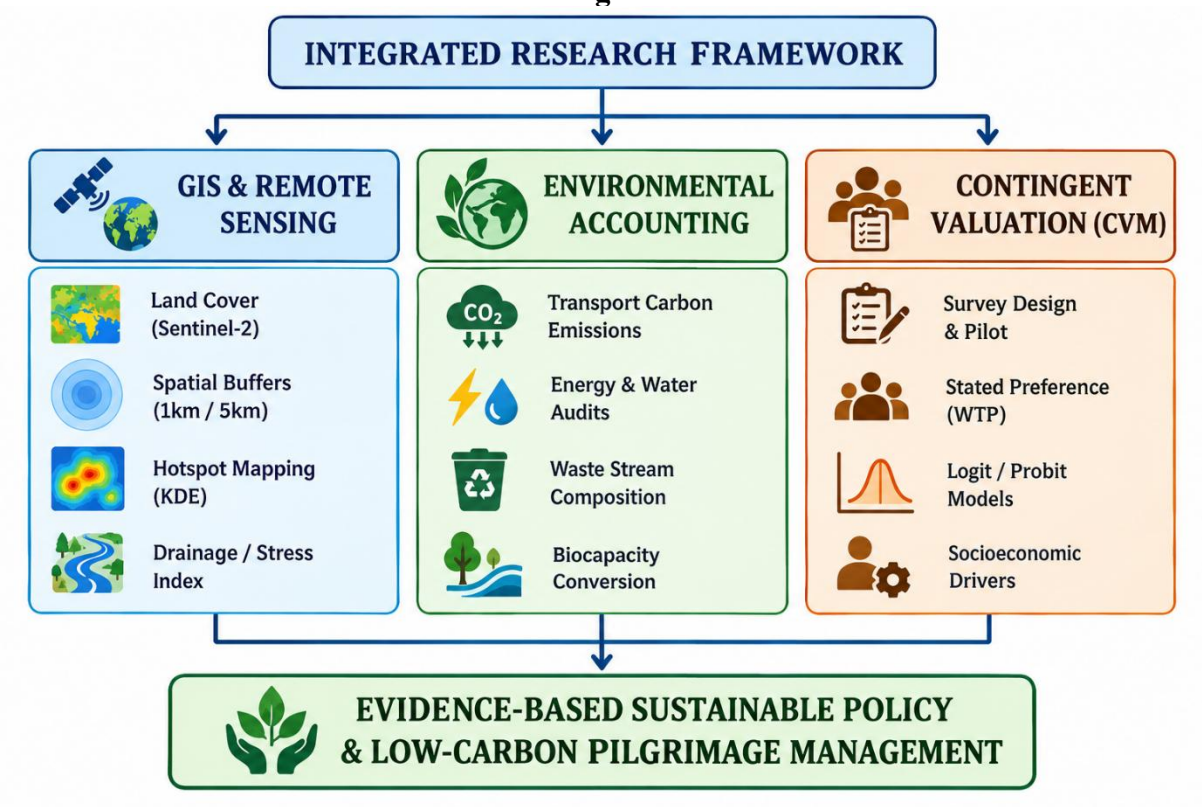
2. **Extended Destination Zone (5-km radius buffer):** Captures local transport hubs, primary hotel and lodging clusters, secondary commercial zones, and surrounding land-use transitions.

4. Research Methodology

4.1 Integrated Research Design

This study employs a mixed-method comparative research design combining quantitative environmental accounting, spatial geospatial analysis, direct field audits, and econometric survey modeling. Research flow is shown in fig-1.

Fig-1



4.2 Sampling Strategy and Data Collection

Field surveys were conducted across all five pilgrimage sites, capturing both regular days and peak festival periods. A target sample of **600 visitor interviews** (120 respondents per site) was established using systematic intercept sampling (selecting every k-th departing visitor at primary exit gates). A pre-test pilot survey (N=40) was conducted to refine question clarity, test the credibility of the hypothetical payment scenario, and calibrate bid vectors for the contingent valuation module.

Primary data collection included:

- **Visitor Survey Instrument:** Travel origin, distance, transport mode, travel expenditures, length of stay, accommodation type, environmental awareness, perceived site degradation, and WTP.

- **Site Resource & Waste Audits:** Direct weighing of waste categories (organic/floral offerings, food waste, single-use plastics, paper/packaging) and inspection of utility usage across temple management and commercial lodging.

- **GPS Field Mapping:** Timestamped GPS observations documenting waste accumulation points, open drainage bottlenecks, and waterlogging locations.

Secondary data sources integrated into the database:

- **Satellite Imagery:** Sentinel-2 Level-2A imagery (10 m, 20 m, 60 m spatial resolution) acquired via the Copernicus Data Space Ecosystem for land-use classification.

- **Spatial Layers:** OpenStreetMap road, rail, and hydrological networks verified against ground observations.

- **Emissions Factors:** Grid emission factors from the Central Electricity Authority (CEA) Baseline Carbon Database for India (Version 22.0) and standard IPCC/India-specific vehicle emission factors.
  Based on above points researcher given a snap shot by diagrammatic representation

Fig-2

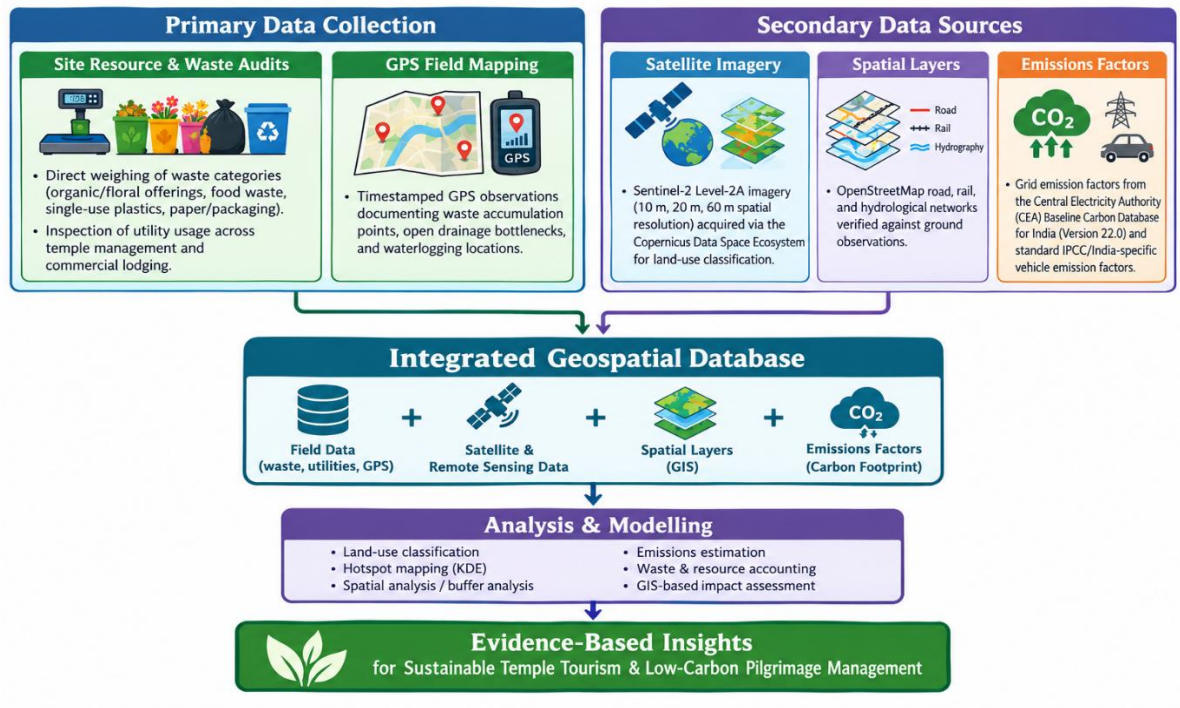


Fig-3

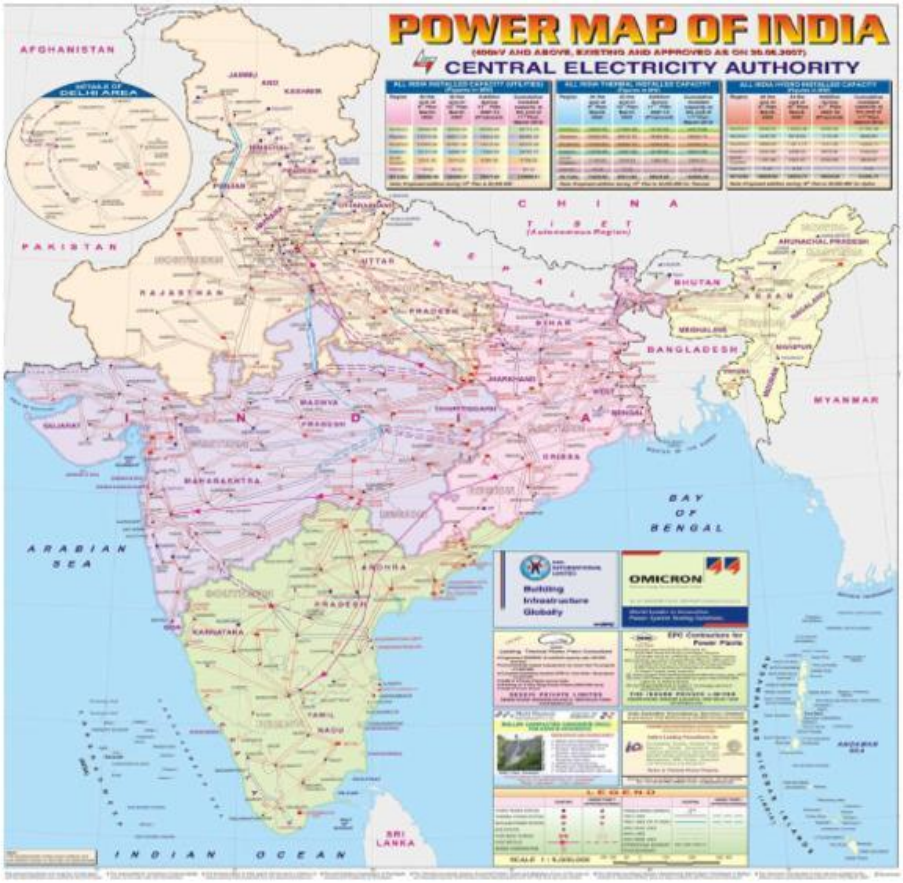
Satellite imagery

Fig-3

Roads, transport access and mapped features

Fig-4

. **Electricity emission factors**



4.3 Mathematical and Econometric Formulations

4.3.1 Transport Emissions Accounting

Transport emissions for visitor travel are calculated as:

$$E_{\text{transport}} = \sum_{m=1}^{M} N_m \times D_m \times EF_m$$

Where:

- N_m = Number of visitor journeys attributable to transport mode m
- D_m = Average round-trip passenger-distance travelled per journey (km)
- EF_m = Emissions factor per passenger-kilometer ($\text{kg CO}_2\text{e/pkm}$)

When vehicle emission factors ($\text{kg CO}_2\text{e/vkm}$) are used, average vehicle occupancy (O_m) is applied: $EF_m = \frac{EF_{\text{vkm}}}{O_m}$.

4.3.2 Energy-Related Carbon Emissions

Stationary electricity and fuel emissions are estimated as:

$$E_{\text{energy}} = \sum_{j=1}^{J} Q_j \times EF_j$$

Where Q_j represents energy consumption (kWh or liters of fuel) and EF_j is the corresponding CEA or IPCC emissions factor.

4.3.3 Water Consumption & Solid Waste Generation

Total water demand is aggregated across direct temple operations, commercial services, and visitor consumption:

$$W_{\text{total}} = W_{\text{temple}} + W_{\text{commercial}} + W_{\text{visitor}} \quad (\text{liters/day})$$

Total daily solid waste generation is categorized across material streams:

$$G_{\text{waste}} = \sum_{r=1}^{R} M_r \quad (\text{kg/day})$$

Where M_r represents the mass of waste category r (organic/floral, plastics, paper, residual waste).

4.3.4 Contingent Valuation Econometric Model

To model a visitor's probability of accepting a proposed conservation contribution ($Y_i = 1$ if willing to pay bid B_i, and $Y_i = 0$otherwise), a binary logistic regression model is specified:

$$\operatorname{P}(Y_i = 1) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 B_i + \beta_2 \text{INC}_i + \beta_3 \text{EDU}_i + \beta_4 \text{ENV}_i + \beta_5 \text{DIST}_i + \epsilon_i)}}$$

Where:

- B_i = Randomly assigned bid amount (INR)
- INC_i = Monthly household income (INR)
- EDU_i = Educational level (years of schooling)
- ENV_i = Environmental awareness score (1–5 Likert scale)
- DIST_i = Travel distance (km)
- β_k = Estimated parameters; ϵ_i = Logistically distributed error term

Mean Willingness to Pay (WTP_{mean}) is derived using numerical integration:

$$\text{WTP}_{\text{mean}} = \frac{1}{\vert{}\beta_1\vert{}} \ln\left(1 + e^{\alpha^*}\right)$$

Where α^* represents the linear combination of non-bid covariates evaluated at their sample means.

5. Results and Discussion

5.1 Visitor Profiles and Travel Behavior

Table 1 summarizes key socioeconomic characteristics, travel patterns, and expenditure profiles derived from the study sample (N=600).

Table 1: Socioeconomic and Travel Characteristics Across Sites

Parameter	Dakshineswar (n=120)	Kalighat (n=120)	Tarapith (n=120)	Tarakeswar (n=120)	ISKCON Mayapur (n=120)
Mean Age (years)	38.4	41.2	39.8	35.6	36.1
Mean Household Income (INR/mo)	42,500	45,100	34,200	28,900	51,200
Mean Round-trip Distance (km)	48.5	32.1	215.4	112.8	285.6
Primary Transit Mode Share (%)	Metro/Bus (68%)	Auto/Metro (74%)	Hired Bus/Car (62%)	Train/Bus (81%)	Car/Private Bus (58%)
Average Length of Stay (hours)	3.5	2.8	28.4	8.2	34.5
Overnight Accommodation (%)	4.2%	3.1%	78.5%	12.4%	82.1%

Travel profiles highlight a clear distinction between **urban day-trip destinations** (Dakshineswar and Kalighat), characterized by short stay durations and reliance on public transit, and **overnight destination centers** (Tarapith and ISKCON Mayapur), which generate greater commercial lodging and dining footprints. Tarakeswar exhibits a hybrid pattern, dominated by regional train travel during seasonal peak periods.

5.2 Environmental Resource Accounting & Carbon Footprint

Table 2 outlines daily resource consumption, solid waste yields, and transport emissions across the five study locations during normal versus peak periods.

Table 2: Environmental Resource Consumption and Waste Generation Profiles

Destination	Per-Capita Water Use (L/visitor-day)	Solid Waste Yield (kg/visitor-day)	Organic Share (%)	Plastic Share (%)	Transport Carbon (kg CO2 e/visitor)	Total Est. Daily Emissions (t CO2 e/day, Peak)
Dakshineswar	18.5	0.28	62%	22%	2.85	142.5
Kalighat	14.2	0.31	58%	26%	1.95	97.5
Tarapith	68.4	0.52	48%	31%	18.40	368.0
Tarakeswar	22.1	0.38	71%	18%	5.20	260.0
ISKCON Mayapur	85.0	0.45	54%	24%	22.60	339.0

Physical resource demand varies based on visitor stay duration and local accommodation infrastructure. Overnight destinations (Tarapith and Mayapur) show substantially higher per-capita water use (68.4–85.0\text{ L/day}) compared to urban sites (14.2–18.5\text{ L/day})

due to hotel lodging and residential facility operations. Organic waste (floral offerings and food waste) forms the largest single waste stream across all locations, peaking at 71% in Tarakeswar during *Shraban* month. However, non-biodegradable plastics (packaging and milk packets) constitute 18%–31% of waste streams, presenting serious municipal disposal challenges.

5.3 GIS Spatial Vulnerability & Hotspot Analysis

Remote sensing and GIS overlay mapping reveal distinct spatial pressures around temple zones:

- **Kalighat:** Characterized by high built-up density (>88% within 1 km). Point-density mapping identifies severe pedestrian-induced waste accumulation and drainage blockage along Canal West Road and entrance alleys.
- **Dakshineswar:** Buffer analysis highlights localized pressure along the Hooghly riverfront ghats. Unprocessed organic offering runoff contributes to elevated localized aquatic biological oxygen demand (BOD).
- **Tarapith:** Spatial analysis reveals rapid, uncoordinated commercial sprawl (hotels and guest houses) extending southward along the Dwarka River basin, increasing localized flood vulnerability and wastewater discharge.
- **Tarakeswar:** Kernel density analysis maps spatial bottlenecks centered around the railway terminal corridor and main temple road, where temporal visitor surges create localized waste accumulation hotspots during monsoon months.
- **ISKCON Mayapur:** Land-cover change analysis shows expanding built-up infrastructure replacing agricultural and vegetated land within the 1-km buffer, requiring expanded wastewater treatment and solid waste management capacity.

5.4 Contingent Valuation Method (CVM) & Econometric Results

Table 3 presents the binary logistic regression estimates predicting visitors' probability of accepting the hypothetical environmental conservation contribution.

Table 3: Binary Logistic Regression Model for Visitor WTP

Variable	Parameter Description	Coefficient (β)	Std. Error	z-statistic	p-value
Constant	Intercept	-0.482	0.215	-2.24	0.025**
BID (B_i)	Proposed Contribution (INR)	-0.018	0.003	-6.00	<0.001***
LN_INC	Log of Household Income	+0.412	0.108	+3.81	<0.001***
EDU	Education (years)	+0.085	0.028	+3.04	0.002***
ENV_AWARE	Environmental Awareness Score	+0.324	0.082	+3.95	<0.001***
DIST_KM	Travel Distance (km)	+0.002	0.001	+2.00	0.046**
PERC_DEG	Perceived Degradation (1–5)	+0.210	0.065	+3.23	0.001***

*Model Diagnostics: N = 600; Log-Likelihood = -284.15; McFadden Pseudo R^2 = 0.312; Model \chi^2(6) = 142.8 (p < 0.001). Significance levels: p<0.05, *** p<0.01.*

The econometric model demonstrates strong theoretical validity:

1. **Bid Amount (B_i):** Exhibited a statistically significant negative coefficient (\beta = -0.018, p < 0.001), confirming standard economic demand theory—higher requested contributions reduce the probability of agreement.

2. **Household Income (\text{LN_INC}):** Positive and highly significant (\beta = +0.412, p < 0.001), establishing environmental quality as a normal economic good.

3. **Environmental Perceptions (\text{ENV_AWARE} & \text{PERC_DEG}):** Visitors with higher baseline environmental awareness and those who perceived physical site degradation were significantly more likely to accept the conservation fee.

Estimated Mean Willingness to Pay (WTP) Across Sites
Using parameter integration, the sample-wide mean WTP was estimated at **INR 42.50 per visitor per visit** (95% CI: INR 36.80 – INR 48.20). Site-specific mean WTP values varied systematically:

- **ISKCON Mayapur:** INR 65.00 / visitor
- **Dakshineswar:** INR 48.00 / visitor
- **Tarapith:** INR 40.00 / visitor
- **Kalighat:** INR 35.00 / visitor
- **Tarakeswar:** INR 25.00 / visitor

Protest zeros accounted for 14.2% of non-WTP responses, with visitors citing existing government taxation or institutional mistrust as primary reasons for non-payment.

6. Policy Recommendations and Sustainable Pilgrimage Framework

Based on the empirical findings, this study proposes a targeted, multi-tier policy framework for sustainable temple management:

SUSTAINABLE TEMPLE MANAGEMENT POLICY FRAMEWORK
Fig-5

6.1 Low-Carbon Pilgrimage Mobility Plan

- **Electric Feeder Networks:** Establish zero-emission electric shuttle loops connecting nearest rail/metro terminals directly to temple entrances (e.g., Dakshineswar Metro to temple gates; Tarakeswar station corridor) to minimize local vehicle idling emissions.

- **Pedestrian Mobility Corridors:** Implement traffic restriction zones within the 1-km core zone during peak periods to lower congestion and localized vehicular emissions.

6.2 Circular Waste Economy & Flower Upcycling

- **On-Site Organic Processing:** Given that organic material comprises 48%–71% of solid waste, decentralized anaerobic digestion and vermicomposting units should be installed near temple complexes. Sacred floral waste can be systematically collected and processed into natural incense, dye, or bio-fertilizers, converting a waste stream into economic value.

- **Single-Use Packaging Restrictions:** Enforce strict bans on non-biodegradable plastic packaging for *pooja* offerings and food distribution, substituting them with traditional *sal* leaf plates, clay pots (*kulhar*), and compostable bio-plastics.

6.3 Resource Efficiency & Water Conservation

- **Greywater Recycling Systems:** Large accommodation facilities in overnight destination hubs (Mayapur and Tarapith) should install modular greywater recycling systems for landscaping and toilet flushing, reducing primary freshwater demand.

- **Solar Utility Integration:** Temple administrations should install rooftop solar PV systems across administrative buildings and dining halls, utilizing low-carbon energy to meet baseline loads.

6.4 Institutional Governance: Dedicated Green Conservation Funds

- **Earmarked Conservation Contributions:** Empirical CVM results confirm positive visitor WTP (sample mean of ~INR 42.50). Local temple trusts, in partnership with

municipal authorities, can introduce voluntary micro-conservation levies integrated into ticketing, footwear management, or accommodation bookings.

- **Transparent Financial Administration:** To mitigate protest resistance and build public trust, revenue generated from conservation fees must be managed through transparent green trust funds dedicated strictly to site sanitation, riverbank restoration, and environmental infrastructure.

7. Limitations and Directions for Future Research

While this study offers an integrated assessment framework, several limitations should be noted:

1. **Sample Boundary Constraints:** The research focused on 600 respondents across five primary sites. Expanding sample sizes across multi-year seasonal cycles would better capture longitudinal variations in resource use.

2. **Stated Preference Biases:** CVM estimates remain susceptible to hypothetical bias. Future research should incorporate field-based field experiments or real-choice experiments to validate stated WTP values against actual financial contributions.

3. **Remote Sensing Resolution:** Utilizing sub-meter high-resolution satellite imagery (e.g., WorldView) would enhance fine-scale mapping of pedestrian bottlenecks and micro-level waste hotspots within densely built urban zones such as Kalighat.

8. Conclusion

This study provides an integrated framework evaluating the ecological footprint of popular temples in West Bengal by combining Geographic Information Systems (GIS), environmental accounting, and Contingent Valuation Method (CVM) techniques. By examining spatial land-use intensity, transport carbon footprints, material waste compositions, and visitor stated preferences, the research links physical resource stress with public economic support for conservation. Empirical findings confirm that while visitor inflows create environmental pressures on transport, water, and waste infrastructure, visitors exhibit a significant positive willingness to financially support site conservation programs. Implementing low-carbon transit corridors, circular waste composting, energy efficiency retrofits, and transparent green trust funds offers a viable pathway toward sustainable pilgrimage tourism in West Bengal.

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Declarations

Ethics Approval and Consent to Participate

This study is based exclusively on a synthetic dataset developed for methodological and empirical analysis. No human participants, personal data, or confidential information were involved. Consequently, formal ethical approval and informed consent were not required.

Consent for Publication

The author consents to the publication of this manuscript.

Funding Statement

The author received no specific grant, financial support, or external funding from any public, commercial, or not-for-profit funding agency for the preparation of this research.

Conflict of Interest

The author declares that there are no financial, professional, or personal conflicts of interest that could have influenced the research, analysis, interpretation, or publication of this study.

Data Availability Statement

The dataset analysed in this study consists of a synthetic sustainability database prepared for methodological demonstration. The dataset used for empirical analysis is available from the corresponding author upon reasonable academic request. Statistical procedures and analytical methods have been described in sufficient detail to facilitate replication.

Acknowledgements

The author gratefully acknowledges the valuable contributions of the academic community whose research has advanced the field of sustainability assessment and econometric modelling. Appreciation is also extended to colleagues and reviewers whose scholarly discussions contributed to the refinement of the analytical framework presented in this study.

Supplementary Material

Supplementary data and other statistical outputs, are available from the corresponding author upon request.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- WestBengalTempleEcologicalFootprintDataset.xlsx