# Review of Geotourism Frameworks and Geosite Assessment: Global Perspectives and Indian Applications

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***Abstract*—This paper presents a comprehensive literature review on geotourism, synthesizing developments in conceptual frameworks, methodological advances, and the integration of geotourism within sustainable development agendas. Geotourism is explored as a dynamic intersection of earth science, conservation, education, and community empowerment, with an emphasis on the evolution from single-site management to multi-scalar, participatory, and technology-enhanced approaches. The review evaluates criteria and protocols for geosite identification, highlights the growing role of GIS, remote sensing, and analytical models in site assessment, and documents best practices in physical, socio-economic, and governance-oriented situational analysis. Special attention is given to the Indian context, where initiatives such as geoparks, community-based geotrails, and heritage education programs illustrate both opportunities and challenges. The findings support the conclusion that geotourism, when effectively managed, can serve as an engine for resilience, economic diversification, and inclusive regional growth.**

***Index Terms*—Geotourism, Geosite identification, Geospatial technology, Community engagement**

## I. INTRODUCTION

Geotourism has emerged in the twenty-first century as a distinctive, multidisciplinary approach to tourism that foregrounds the educational, cultural, and economic significance of geological heritage. Its rise reflects growing concerns over unsustainable mass tourism and increasing appreciation for the value of earth-science interpretation within visitor experiences (Hose, 1995; Newsome & Dowling, 2010). Unlike conventional tourism focused on recreation or scenery, geotourism aims to sustain and interpret the Earth's abiotic features through geotrails, interpretive programs, and context-sensitive site management thereby enhancing scientific literacy, environmental awareness, and responsible visitation (National Geographic Society, 2005).

The conceptual origins of geotourism lie in shifting scientific and societal values that encouraged deeper engagement with landscapes and geological processes (Hose, 2012). This broadened the scope of valued destinations to include sites representing geodiversity, geoheritage, and earth processes, aligning geotourism with global movements promoting sustainability, community participation, and environmental stewardship (Gray, 2004; Ólafsdóttir, 2018; UNESCO, 2024). A defining principle is the transition from passive sightseeing to immersive learning supported by interpretation, geotrails, visitor centres, and conservation-oriented narratives (Newsome & Dowling, 2010; Reynard & Brilha, 2018).

India exemplifies both the promise and complexity of geotourism. Its diverse geodiversity from volcanic provinces to paleontological and tectonic landscapes offers extensive opportunities (Kumar et al., 2015; Sharma & Gupta, 2025). Recent innovations include proposed geoparks, digital geosite mapping, interpretive centres, and geotrails informed by multi-stakeholder interests, layered governance, and local cultural priorities (Tomar et al., 2017; Patel & Shah, 2013; BSIP, 2023). Literature emphasizes that successful geotourism demands a holistic approach that integrates scientific assessment, governance structures, community participation, and capacity building.

Accordingly, this review has three aims: (i) synthesizing key conceptual developments in geotourism; (ii) critically examining geosite identification methods spanning scientific scoring, geospatial technologies, and participatory approaches; and (iii) analysing the roles of community engagement, governance, and socioeconomic impacts in advancing inclusive and sustainable geotourism. This synthesis highlights research gaps and emerging priorities relevant to global and Indian contexts (Patel & Shah, 2013; Reynard & Brilha, 2018; UNESCO, 2024).

## II. METHODOLOGY

This review is based on systematic analysis of peer-reviewed literature published between 2000 and 2025, including journal articles, government reports, and institutional documents. Major databases including ScienceDirect, Springer, and Wiley have been searched using keywords such as "geotourism," "geoheritage," "geosite identification," "GIS," "community engagement," and "India." The review synthesizes qualitative and quantitative studies, focusing on both global and Indian research. Case studies (Kutch, Western Ghats, Mandya district) have been highlighted to illustrate practical applications and context-specific challenges. Relevant assessment models (Brilha, MCDA, AHP), geospatial technologies, and policy documents (UNESCO global protocols, regional tourism policies) are included.

## III. DEFINITIONS AND CONCEPTUAL FRAMEWORKS

The conceptual evolution of geotourism reflects a long-standing scholarly dialogue on its scope, purpose, and interdisciplinary character. Foundational definitions distinguished geotourism from general nature-based tourism by emphasising geology- and geomorphology-focused interpretation and conservation. Hose (1995) highlighted interpretative services as central to deepening visitor understanding, marking geotourism as more than passive landscape appreciation.

The National Geographic Society (2005) broadened this scope by defining geotourism as an approach that sustains and enhances the geographic character of a place integrating environmental integrity, cultural diversity, historical heritage, aesthetics, and community well-being. This holistic view laid groundwork for community-centred and sustainability-oriented geotourism policies worldwide. Further contributions by Newsome and Dowling (2010) positioned education and responsibility as conceptual pillars, emphasising geotourism's role in conserving geodiversity and improving earth-science literacy through geotrails, visitor centres, guided interpretation, and structured learning experiences. This has encouraged innovative itinerary design across geoparks and local initiatives.

Indian scholarship introduces additional nuance by integrating geoscience education with heritage conservation, community participation, and socio-economic equity (Kumar et al., 2015; Agarwal & Ghosh, 2021). Here, geotourism frameworks often include empowerment of local communities, use of indigenous knowledge, and sustainable economic development (Patel & Shah, 2013).

Recent reflections highlight definitional diversity and global variation, with some countries extending geotourism into broader earth-science or conservation-based tourism categories (Santos-Souza, 2023). Ambiguities in distinguishing abiotic and biotic tourism resources have led to calls for operational definitions that emphasize geological value while acknowledging cultural and ecological contexts. Emerging subfields such as celestial and space geotourism further expand disciplinary boundaries (Sadry, 2009; Santos-Souza, 2023).

Across definitions, shared assumptions remain: abiotic nature as a primary attraction; a strong emphasis on interpretation; and a commitment to responsible tourism that protects and regenerates geoheritage (Gray, 2004; Newsome & Dowling, 2010). Contemporary scholarship advocates multi-scalar, cross-sectoral approaches aligned with sustainable development, community engagement, and UNESCO Global Geoparks principles (Tomar et al., 2017; Reynard & Brilha, 2018; UNESCO, 2024), positioning geotourism as a bridge between earth sciences, cultural stewardship, and inclusive local development.

Table 1: **Comparative Definitions of Geotourism**

| Author (Year) | Definition | Key Focus |
|---|---|---|
| Hose (1995) | Interpretative services for geological/geomorphological understanding | Education, Conservation |
| National Geographic Society (2005) | Tourism that sustains geographic character, culture, resident well-being | Authenticity, Community |
| Newsome & Dowling (2010) | Geotourism promotes geodiversity conservation, earth science learning | Conservation, Education |
| Sadry (2009) | Abiotic nature-based tourism | Non-living heritage |
| Kumar et al. (2015) | Tourism fostering earth science education and geoheritage conservation | Education, Heritage |
| Agarwal & Ghosh (2021) | Balancing education, conservation, local economic benefits | Sustainability |

## IV. GEOTOURISM IN THE INDIAN CONTEXT

Geotourism in India has evolved into a dynamic field shaped by the nation's vast geodiversity and cultural richness. From the volcanic landscapes of the Deccan Traps to the fossil-bearing terrains of Jaisalmer, India offers exceptional opportunities for education, conservation, and sustainable economic development (Kumar et al., 2015; Tomar et al., 2017). Indian scholarship increasingly calls for geotourism models that merge community interests, heritage preservation, and inclusive growth (Tomar et al., 2017; Sharma & Gupta, 2025).

Several regional initiatives illustrate this trend. Scientific institutions, state agencies, and civil society organizations have advanced geotourism through geopark proposals, geoheritage trails, mining heritage circuits, and fossil-park educational programs. Notable examples include BSIP's advocacy for geoparks, the Kutch and Jharkhand geotrails, and experiential learning efforts at Amkhoi Fossil Park (Chatterjee & Mukherjee, 2020; BSIP, 2023; Mishra & Kumar, 2024). These efforts extend beyond tourism promotion by encouraging local entrepreneurship, building regional identity, and cultivating responsibility toward geoheritage. However, progress remains uneven due to persistent challenges. Data gaps, limited financial resources, and fragmented governance—spread across forest, mining, tourism, and archaeological departments often hinder coordinated action (Tomar et al., 2017; Raj & Shukla, 2022). Many high-value geosites lie in remote or marginalized areas lacking infrastructure, professional expertise, and consistent monitoring mechanisms (Sharma & Gupta, 2025).

To address these constraints, Indian geotourism is increasingly adopting integrated strategies that combine scientific assessment with participatory engagement. Stakeholder consultations, community mapping, training of local guides, and open-source digital tools for geosite inventories have become widely used approaches (Raj & Shukla, 2022; Mishra & Kumar, 2024). Emphasizing indigenous knowledge, capacity building, and shared governance is now recognized as essential for securing social legitimacy and ensuring long-term conservation. This convergence of science, technology, and community participation is seen as central to strengthening the resilience and future growth of geotourism in India (Tomar et al., 2017).

## V. GLOBAL AND INDIAN TRENDS IN GEOTOURISM DEVELOPMENT

Globally, geotourism has been propelled by networks like the UNESCO Global Geoparks, whose footprint has grown from four sites in 2000 to nearly 200 sites across continents by 2023 (UNESCO, 2024). This rapid growth reflects a shift toward cross-border cooperation, best practice sharing, and the setting of global standards for site inventory, interpretation, and management. In leading regions such as Europe and Asia, geotourism is often deeply intertwined with local culture, education systems, environmental sustainability targets, and community development policies (Dowling & Newsome, 2018; Zhao et al., 2020).

In the Asia-Pacific, models in China, Japan, and Korea illustrate successful integration of geotourism with national education programs, sustainable development goals, and regional economic revitalization. These countries combine rigorous scientific management of geosites with sophisticated educational outreach, branding, and marketing (Zhao et al., 2020). India's Geological Survey mirrors this international trend: in addition to identifying more than 90 geosites and classifying 34 as National Geological Monuments, the Survey participates in pilots that integrate geo-conservation with tourism circuits, educational events, and digital information platforms (GSI, 2021).

Regional case studies such as the volcanic Western Ghats, Deccan Traps, and Gujarat's Kutch region demonstrate that diverse strategies are necessary depending on resource base, sociocultural complexity, and visitor profiles (Patel & Shah, 2013; Kale, 2016). Across India, best-practice models often include eco-trails, homestays that employ local residents, interpretative centers designed around indigenous knowledge, and community-led heritage festivals that package both geology and culture for visitors (Chakrabarty & Mandal, 2021).

## VI. CONCEPTUAL FOUNDATIONS OF GEOSITE IDENTIFICATION

Geosite identification is a foundational step in geoheritage management and geotourism planning, aimed at cataloguing landscapes of geological, geomorphological, or paleontological significance (Brilha, 2005). The process begins with regional surveys, expert inventories, geological mapping, and literature review to shortlist locations that represent unique features, key earth processes, or high scientific, educational, and aesthetic value (ProGEO, 2004; UNESCO, 2024). International frameworks classify geosites into stratigraphic, paleontological, mineralogical, morphodynamic, and geomorphological categories to ensure comprehensive geodiversity representation (ProGEO, 2004).

Field reconnaissance documents coordinates, geological context, uniqueness, visibility, and associations with cultural or natural resources (Rocha et al., 2014; UNESCO, 2022). Attributes such as rarity, representativeness, and accessibility are assessed alongside landscape setting. Community engagement increasingly contributes local knowledge, cultural narratives, and place-based values, improving inventories and aligning geosite planning with local priorities (Stoffelen, 2020; Canavese, 2018).

The final output is a curated geosite list with detailed descriptions, serving as the baseline for conservation, education, and sustainable geotourism development (UNESCO, 2024; Brilha, 2005; ProGEO, 2004).

## VII. GEOSPATIAL TECHNOLOGY IN GEOSITE IDENTIFICATION

Advancements in geospatial technologies have transformed geosite identification and geoheritage planning over the last decade (Mucivuna et al., 2022; Raj & Shukla, 2022). GIS has become central for integrating geological, hydrological, topographical, and cultural datasets, enabling systematic mapping, evaluation, and prioritization through multi-criteria analysis (Raj & Shukla, 2022).

Remote sensing tools including Landsat and Sentinel imagery support regional delineation of lithological units, morphodynamic boundaries, and geomorphological diversity (McDermid & Franklin, 2016; Chapman et al., 2021). DEMs and LiDAR offer quantitative insights into slope, landform segmentation, erosion, and hazard exposure, essential for site safety and management (McDermid & Franklin, 2016).

Drone photogrammetry provides ultra-high-resolution documentation, 3D models, and erosion or trail-planning assessments, now widely used from national projects to local studies (Raj & Shukla, 2022; Patnaik et al., 2024). Emerging machine-learning applications automate feature extraction, classification, and predictive modeling, increasing efficiency in large-scale geosite inventories (Ali et al., 2017; Li et al., 2020).

In India, combined use of ASTER DEM and Landsat imagery has enhanced geomorphosite mapping in the Western Ghats. LiDAR-based studies in Odisha have revealed previously undocumented quarry features, aiding conservation and geoeducation (Patnaik et al., 2024). Drone-based 3D models and hyperspectral

analyses in Telangana's basalt landscapes further refine inventories when integrated with GPS and field spectroscopy (Raj & Shukla, 2022).
Together, GIS, remote sensing, DEM, LiDAR, UAV imagery, and computational models mark a paradigm shift, enabling more systematic, reliable, and inclusive geoheritage assessment and geotourism planning (McDermid & Franklin, 2016; Chapman et al., 2021; Mucivuna et al., 2022).

Table 2: **Geospatial Technologies in Geosite Identification**

| Technology | Spatial Resolution | Application | Indian Example |
|---|---|---|---|
| GIS | N/A (vector/raster) | Inventory, multi-criteria mapping | GIS-AHP in Jodhpur (Mishra & Kumar, 2024) |
| Remote Sensing | 10–30 m (Landsat), 2–10 m (Sentinel) | Mapping, landform delineation | Western Ghats mapping (Raj & Shukla, 2022) |
| DEM | 30 m (SRTM), <1 m (LiDAR) | Morphometrics, hazard analysis | Eastern Duars (Banerjee et al., 2023) |
| LiDAR | 0.1–5 m (point density) | Topography, canopy penetration | Odisha quarries (Patnaik et al., 2024) |
| Drone/UAV Imagery | 1–5 cm | 3D site modeling, erosion monitoring | Telangana sites (Reddy & Raju, 2021) |

## VIII. GEOSITE ASSESSMENT

Geosite assessment is a critical stage following identification, providing a structured understanding of each site's scientific, educational, aesthetic, and tourism value (ProGEO, 2004; Brilha, 2005; UNESCO, 2024). Standard frameworks evaluate attributes such as rarity, representativeness, integrity, vulnerability, accessibility, and educational potential (Brilha, 2005; Rocha et al., 2014). Many assessments apply standardized scoring through Multi-Criteria Decision Analysis (MCDA) or the Analytical Hierarchy Process (AHP) to improve objectivity and comparability (Smith et al., 2018; El Gharbaoui et al., 2020). GIS tools support spatial interpretation, while field verification refines expert judgments. Vulnerability analysis, incorporating natural hazards and anthropogenic pressures, helps identify risks and prioritize management actions, often supplemented through participatory validation with local stakeholders (Rutledge, 2011; Chatterjee & Mukherjee, 2020). The resulting rankings guide conservation planning, interpretive infrastructure, educational strategies, and resource allocation (Brilha, 2005; UNESCO, 2024).

Situational analysis incorporates physical, socio-economic, and governance dimensions. Physical assessment includes terrain, slope, aspect, curvature, accessibility, and hazard potential (Rutledge, 2011). Infrastructure audits evaluate transport, visitor amenities, emergency services, and investment gaps. Socio-economic analysis considers income, employment, community readiness, and stakeholder awareness, strengthened through participatory mapping, workshops, and surveys (Patel & Shah, 2013; Brilha et al., 2015; Dowling et al., 2017; Chatterjee & Mukherjee, 2020). Governance effectiveness through statutory protection, integrated management plans, and collaborative structures underpins sustainable outcomes, aligned with models such as UNESCO Global Geoparks and PPP-based systems (ProGEO, 2004; Reynard & Brilha, 2018).

Geotourism assessment increasingly blends quantitative tools such as AHP, MCDA, and Brilha's criteria with qualitative methods like SWOT, interviews, and stakeholder surveys (Ólafsdóttir, 2018; Mishra & Kumar, 2024). Integrating hazard mapping and environmental pressures enhances risk-sensitive planning (Coratza & Giusti, 2005; Rutledge, 2011). Sustainable geotourism planning emphasizes zoning, interpretive infrastructure, monitoring, and adaptive governance (UNESCO, 2024). Community engagement local guide training, heritage education, business development, and capacity-building strengthens long-term stewardship and equitable tourism benefits (Dowling, 2013; Smith et al., 2018; Chatterjee & Mukherjee, 2020). These integrated approaches ensure resilience, inclusivity, and enduring geoheritage conservation.

## IX. CONCLUSION

Geotourism stands at the intersection of earth science, sustainable development, and community participation, transforming geological heritage into a resource for broader societal benefit. Its evolution has been driven by advancements in scientific assessment, participatory management, and digital technologies, which together enhance the credibility, educational value, and economic impact of geotourism initiatives. Global and Indian experiences consistently show that well-managed geotourism not only conserves geoheritage but also supports local livelihoods, strengthens community pride, and enriches visitor learning. Looking forward, the field must address challenges such as fragmented governance, limited monitoring, and the need for climate-responsive and socially adaptive strategies. Future progress depends on inclusive approaches that prioritize local knowledge and participation, alongside the expanded use of digital tools, adaptive management, and holistic evaluation models. By balancing conservation with community well-being, geotourism can help build resilient, equitable, and sustainable futures for both people and landscapes.

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