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Assessment of Potential Geopark for Sustainable Tourism Development at Matheran Geopark, Raigad District of Maharashtra

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Abstract

Matheran, a geologically fascinating lateritic hill station in the Raigad District of Maharashtra, is situated on a plateau on the western edge of the Deccan Volcanic Province at an elevation of around 800m. An attempt to assess its viability as a geopark site through field data and quantitative evaluation techniques are presented here, using a classification criteria derived from an inventory of geomorphological sites and their suitability ranking using GIS overlay techniques. Forty-two sub-criteria which fall under six major categories (Scientific value, Aesthetic value, Economic/functional value, Cultural value, Protection/management value and Tourism value) were evaluated. Strengths, Weaknesses, Opportunities and Threats (SWOT) with regard to sustainable geotourism and geopark development were also carried out. The results show that Matheran has overall average score of 30.83 and total score of 185 indicating its good potential to develop as a geopark. Lateritic cap rock, steep escarpments, panoramic views from various points, streamlets and water bodies, lush green forest cover and historic toy-train landscape contribute significant scientific and aesthetic values. It also proved resilient to tourism pressure, waste and the weak state of interpretation facilities and possesses ample scope to serve as a centre for community-oriented planning, environmental interpretation and education based geotourism development in Western Ghats.

Keywords: Geotourism, Geoheritage, Geopark, Matheran, Deccan Trap provinces

1. Introduction

The elements of geodiversity with scientific, educational, aesthetic or cultural value are called geoheritage and thus require conservation (Brilha 2005; Gray 2013) ^[1, 3, 8]. Geodiversity is the diversity of geological and geomorphological features, materials and processes that underpin landscapes and ecosystems and is now being recognised as the abiotic equivalent of biodiversity in conservation and planning (Gray, 2013; Reynard & Brilha, 2018) ^[8, 19]. In recent decades, geoparks have been developing as local units of conservation, education and geotourism of exceptional geological and geomorphological value, aimed at supporting sustainable development of the local community (Dowling & Newsome, 2010) ^[6]. Deccan Volcanic Province of western India is one of the biggest continental flood basalt provinces, and underlies the Western Ghats, with thick sequences of tholeiitic basalt flows overlaid by thick lateritic profiles (Subbarao, 1999) ^[9]. The Western Ghats escarpment and its associated palaeosurfaces and along the Konkan coast laterites and drainage patterns, are indicative of the Denudational history (Widdowson & Cox, 1996; Widdowson, 1997) ^[11]. Matheran falls under the larger context of a small hill station set on a basaltic mesa in the Karjat Taluka of the Raigad District on the western side of Western Ghats, 45–90 km from Mumbai, and 120 km from Pune (Information on Matheran, 2020; Department of Tourism Maharashtra, 2024) (Raigad District Administration, 2025). Matheran's mesa is separated from the main Western Ghats escarpment by the Konkan coastal plain, and surrounded by deep ravines and steep cliffs which form a ring of viewpoints and lateritic plateaus overlooking the surroundings (Information on Matheran, 2020; Government of Maharashtra, 2024) (Widdowson & Cox, 1996). The area of hill station and its surroundings has been identified as the Matheran Eco-Sensitive Zone (ESZ) with restrictions on industrial, developmental and vehicular activities required to ensure environmental integrity and the special plateau-escarpment system (Ministry of Environment and Forests, 2003; Ministry of Environment, Forest and Climate Change, 2017)

[12] (Protection Act, 1986). Matheran is ecologically rich, with conservation-relevant taxa representative of the northern Western Ghats, and 140 butterfly species from 6 families were recorded on a mosaic of forested and open laterite plateaus, slopes, streams and valley forests over a long period of time (Sawant *et al.*, 2020) [20] (Gadgil & Meher-Homji, 1990) [7]. On a larger scale, the lateritic plateaus of northern Western Ghats which developed on Deccan basalts have been identified as geologically unique and ecologically vulnerable, hosting widespread and threatened biota and being highly underdeveloped, often labelled as 'wastelands' (Gadgil & Meher-Homji, 1990) [7] (Reynard & Brilha, 2018) [19]. With unique volcanic geomorphology and high biodiversity, with protection of the ESZ and existing nature oriented tourism, Matheran therefore is a promising candidate for the planning of a Geopark in Deccan Volcanic Province (DVP) according to

(Newsome & Dowling, 2010; Reynard & Brilha, 2018) [13, 19].

2. The objectives of Study

- Assessment and characterize the scientific, aesthetic, economic-functional, cultural, protectional and tourism values as a Geomorphosites of Matheran Geopark.
- Study of the attractiveness of key Geomorphic landscape features in the shaping of the geo-tourism potential of Matheran Geopark.
- A SWOT Analysis of Matheran Geopark for sustainable tourism development

3. Study Area

Located in Karjat Taluka of Raigad District, Matheran is a tiny automobile-free hill station on the West side of the Western Ghats in western India.

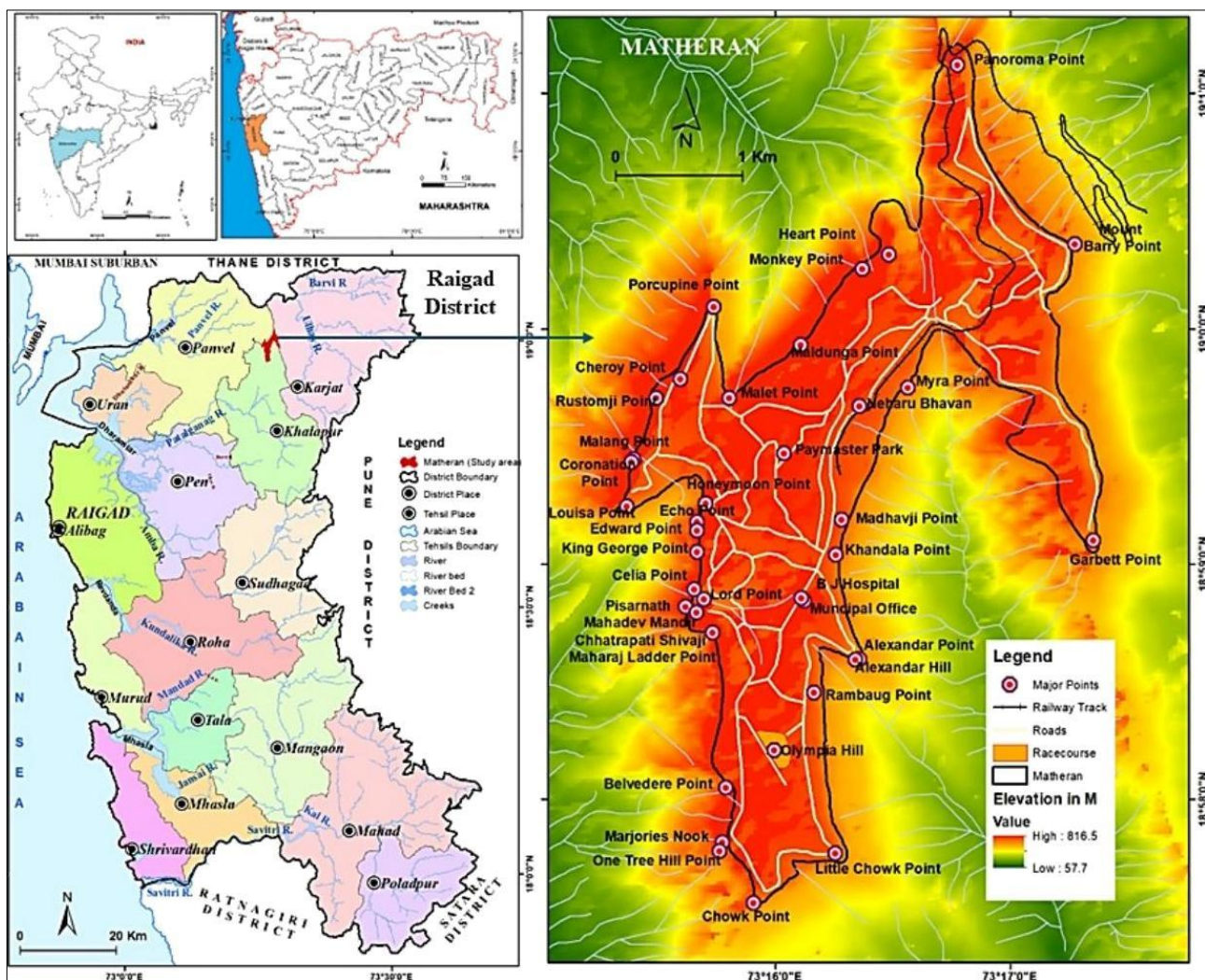


Fig 1: Location map of the study area

Geographically, the Matheran plateau is spread between $18^{\circ} 59' 20.05''$ N $73^{\circ} 16' 14.27''$ E with a large gently undulating plateau on its top which is covered with deep gorges of thick forest (Information on Matheran, 2020). The hill-station plateau has an area of 8 km² with a general elevation of 700-816 m above mean sea level on Plateau. (Fig. 3) The hill station of Matheran is among the smaller hill stations and is found in the eastern north region of the Western ghats, near to Mumbai and Pune cities of 64 to 90 km (east / southeast) of Mumbai city and 80-120km(west) from Pune city of Mumbai Metropolitan area

(Information of Matheran 2020, Department of Tourism, Government of Maharashtra 2024).

Matheran the entire region falls under an Eco Sensitive Zone due to its environmental values. (Protection Act, 1986). The area of ESZ notice is around 214.73 km² which includes Matheran Hill Station Municipal Council area, 70 villages in Karjat Taluka, Raigad District and 19 villages in Ulhasnagar Taluka, Thane district (Ministry of Environment and Forests, 2003; FAOLEX, 2003) [12]. New industries that generate pollution, large scale construction, quarrying and mining are

limited within the ESZ and development within is subject to a zonal master plan and carrying capacity study to preserve the specialised plateau–escarpment topography and its ecological role. (Ministry of Environment and Forests, 2003; Down To Earth, 2018)^[12].

The focus of the study area for this paper is the Matheran plateau and the immediately adjacent escarpments and valleys in the ESZ, which covers the main plateau surface as well as the lateritic tablelands, most of the viewpoints, forested slopes, valley forests, nonperennial streams and artificial reservoirs like Charlotte Lake. Lying in the tropical monsoon climate zone, it receives heavy rainfall in the southwest monsoon, dense vegetation and seasonal water bodies with typical annual rainfall more than 4000 mm and means annual temperature is mostly 23 °C (Gadgil & Meher-Homji, 1990; Information on Matheran, 2020)^[7]. The geology of Deccan plateau, laterite cap rock, escarpments and gorges, high rainfall and preserved forest area secured Matheran as an ideal project area for assessing the geoheritage and geopark potential of the northern Western ghats (Information on Matheran, 2020; Bombay Environmental Action Group, 2024).

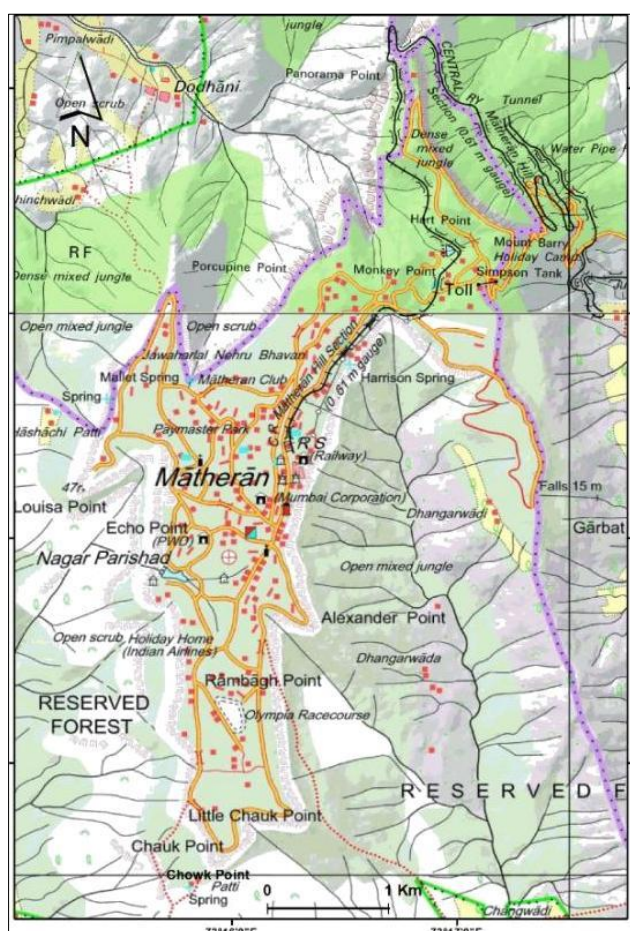
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4. Materials and Methods

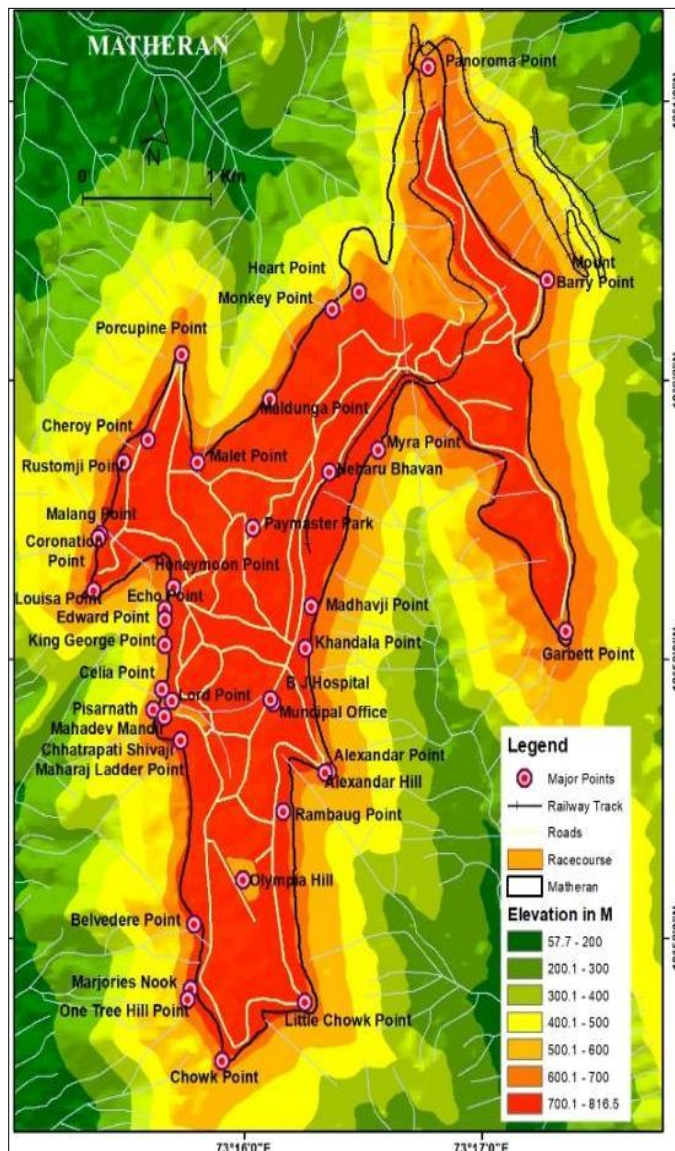
4.1 Database and sources

The present work relies upon primary and secondary sources for the purpose of identification, classification and geomorphosite evaluation of Matheran. Primary data was collected from different parts of the area through detailed field survey, *in situ* observation, photography, GPS tagging and field recording. Secondary data included the topographic sheets of Survey of India, (Fig. 2) maps of Geological Survey of India, satellite imagery of the study area, available statistics of tourism, published and non-published literature on the Matheran region and its eco-sensitive zone to delineate landforms, landforms elements and their present state, and to develop the information relating to accessibility, and visitor management. (Coratza & Giusti, 2005; Reynard *et al.*, 2010)^[5].



Source: SOI, Toposheet

Fig 2: Base map of the study area



Source: ASTER DEM

Fig 3: Elevation map of the Matheran

4.2 Sampling strategy

A selective method of sampling was adopted to select geomorphosites in Matheran. Geomorphosite locations were selected on the criteria of landforms being exposed, scientifically significant, of scenic beauty, of tourist significance and being accessible (Coratza & Giusti, 2005; Reynard *et al.*, 2010) [5]. Selected sites included landforms occurring on the plateau surface and at the escarpment edge. (Fig. 2) A diversity of geomorphosite occurrences, for example plateau surfaces, escarpment edges, view-points, slope of the escarpment, water features, and culturally relevant geomorphic elements was selected. (Coratza & Giusti, 2005; Reynard *et al.*, 2007) [5, 18].

4.3 Ten-digit geocoding of geomorphosites

A ten-digit system for the coding of geomorphosites in Matheran was developed. Geomorphosite was given a unique ten-digit geo-code, representing its spatial position, form of landform/ geomorphic process of occurrence, state of preservation, the geomorphological process that created it, its scientific importance, the aesthetic character and its management relevance. This facilitates the classification and

the spatially related interpretation and potential geotourist mapping of the geo-morphological sites (Kale, 2018) [10].

4.4 Seven-value geo-assessment framework

In view of evaluating the geomorphosites for their geo-heritage value and their potential in geotourism, the author has proposed a seven-value assessment framework as different to the MGAM (Modified Geosite Assessment Model). The framework comprises six primary value categories that can be divided into forty-two sub-categories which will serve to ensure a locally suited and more balanced assessment (Vujičić *et al.*, 2011; Tomić & Božić, 2014) [22, 21]. The six values are: Scientific value, Aesthetic value, Economic values, cultural values, protectional values, tourism values each broad value can be subdivided into six sub-values leading to a total of 42 sub-values. Each of these could be scored from 0-4, with 0 being of negligible value and 4 being of highest value. The summation of scores for each primary category and then the combined total provides the assessment value for a site.

3.6 Scoring procedure

Field assessment data of selected geomorphosite has been collected using a customized scoring sheet based on the six value assessment and its respective sub categories (6 values, 42 sub-values). Data for each sub-category for selected geomorphosites were scored ranging from 0-4 according to observation and information obtained in the field, and local perception (Reynard *et al.*, 2007; Pereira *et al.*, 2007) [18, 14, 15]. Data is summated first per value (i.e. scientific, aesthetic value, etc.) then for each site (Reynard *et al.*, 2007; Vujičić *et al.*, 2011) [18, 22], to ascertain comparative geoheritage value and geo-tourism potential. (Reynard *et al.*, 2010; Chakrabarty & Mandal, 2022) [16].

4.5 Tourist Points

Geomorphological the tourist points that can be described are concentrated on the edge of the lateral plateau, around a well-developed network of locations where the landscape can be observed. provides more than thirty labelled tourist points, the majority of which also serve as geomorphosites given the extent they demonstrate landforms such as the edges of plateau areas, lateritic caps, escarpments, and valleys (Reynard *et al.*, 2010; Bruschi & Cendrero, 2005) [4]. Most of these sites are characterized by open views and facilitate visitors' observation and interaction with landforms, and therefore they make Matheran a significant tourist resort for hiking, trekking, and photography, besides its educational and recreational value (Reynard *et al.*, 2007; Newsome & Dowling, 2010) [18, 13]. Panorama Point, Porcupine Point (also known as Sunset Point), Louisa Point, Echo Point, One Tree Hill, and Alexander Point are considered outstanding among these locations, (Fig. 3) as for their aesthetic and educational value (Reynard *et al.*, 2007; Chakrabarty & Mandal, 2022) [18, 16]. Panorama Point is seen as very important for appreciating slope development in the mornings and it is also very popular during the summer season. Porcupine Point offers stunning views of the surrounding scenery and the sunset, due to the distinctive landscape formation in the area and for its great aesthetic value as one of the major beauty spots of the plateau. Louisa Point, Echo Point, One Tree Hill, and Alexander Point provide examples for demonstration of differential weathering of laterite, of geomorphological processes like acoustic processes or erosive actions respectively, and of erosional and residual processes (Reynard *et al.*, 2010). There is a large number of other places,

which although less famous, improve and expand Matheran's tourist offering. Water-related points like Charlotte Lake View and Monkey Point represent typical natural features of Matheran such as lakes or areas characterized by slope instability phenomena combined with vegetation response to environmental conditions. Points like Malang Point or Hart Point, display clear processes of fluvial incision or the relationships between vegetation and rock structures and monsoon condition (Reynard *et al.*, 2007)^[18]. Other places such as Belvedere Point, Honeymoon Point, Khandala Point, Mount Barry Point, and Little Chowk Point give panoramic views or

illustrate the landforms of the edges of plateaus and valleys. The list of points available on Matheran, including those mentioned, not only includes popular and well-documented locations but it highlights the importance of an array of smaller, less described sites scattered on the edges of the plateau where landforms can be observed or studied. From a geomorphological perspective, this distribution of tourists' interest on the boundaries of the plateau landscape allows for the analysis and direct observation of landforms developed on the caps of laterites and under the controls of basaltic rocks underlying these layers (Widdowson & Cox, 1996; Subbarao, 1999/2019)^[9].

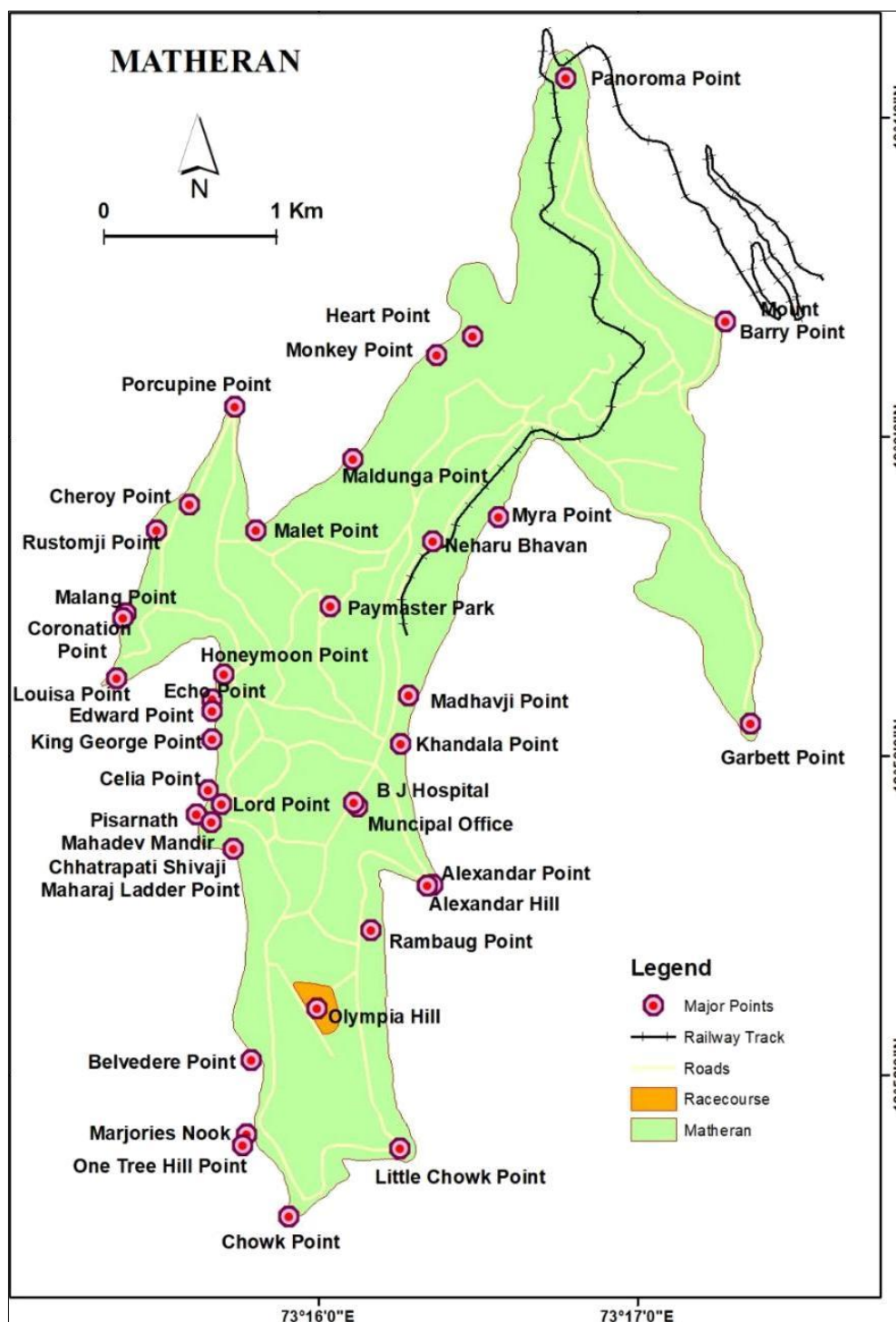


Fig 4: Matheran Major Tourist Attractions Sites

Such points make Matheran a valuable location for geopark applications, particularly as destinations where trails can be

created and on-site visitor panels with informative displays can be placed to demonstrate the geomorphology of plateau

landscapes, weathering processes occurring in tropical areas, erosion processes, etc. (Newsome & Dowling, 2010; Reynard *et al.*, 2010)^[13]. Tourism in Matheran is linked with its geomorphology, biodiversity and heritage; rather than the development of conventional urban activities for leisure and

entertainment. The available tourist offer and related landscape attributes, such as lateritic terrains, green areas, cultural routes and natural formations such as lakes or waterfall locations are central in Matheran's image as a tourism destination for activities related to nature based and low-impact tourism (Reynard *et al.*, 2007)^[18].



1-Ehco Poin



2. King Gorge Point



4. Ehco Point



3. Alexander Point



5. Charlotte lake



6. Louise Point



7. One Tree Point



8. Sunset Point



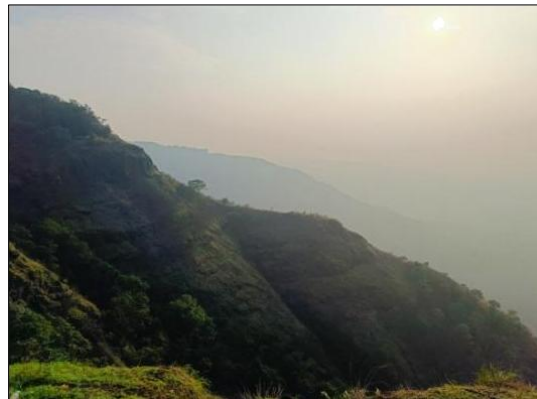
9. Panaroma Point



10. Garbett Point



11. Toy Train



12. Heart Point

Matheran is a vehicle-free area inside its central parts. Thus the movement is done with horse rides or with hand pulled carts and a heritage toy train (Department of Tourism Maharashtra, 2024). This kind of accessibility strongly defines Matheran as low emission tourism destination, also very important for eco-tourism and geo-tourism. The relative importance of tourism can be assessed by considering specific characteristics outlined in, including ease of access, availability of services, number of visitors and revenue (Reynard *et al.*, 2010; Chakrabarty & Mandal, 2022) ^[16]. Matheran's easy accessibility is reinforced by its proximity to Mumbai and Pune and by available infrastructure restaurants, rest homes, accommodation, guide services, information located at Matheran (Department of Tourism Maharashtra, 2024; Times of India, 2024). Adventure and field school tourism is another very important element contributing to Matheran's tourism brand. Trekking paths leading to Garbett plateau, One Tree Hill, Dodhani, Panorama Point, and Charlotte Lake help students to develop hands-on experiences in direct contact with landscape elements such as escarpments, forest patches, streams, rock exposures and slopes that are particularly suitable for field training in geomorphology, biology and environmental studies (Department of Tourism Maharashtra, 2024; Newsome & Dowling, 2010) ^[13]. Hydrology, a great feature of this landscape the water resources are indeed one of the most important tourist attractions in Matheran. Streams carrying seasonal rain water, rivulets, waterfalls and water bodies are common landscapes shaped by climatic conditions, primarily by monsoon rainfalls, and are also intimately related to the geology of the plateau (Reynard *et al.*, 2007; Widdowson & Cox, 1996) ^[18]. Charlotte lake, which represents the major local water body for the population and is an excellent water site for tourism, is along one of the tourist paths leading to Panorama Point and Echo Point and helps to explain and demonstrate water management

and processes such as concentration of run-off on the plateaus and valley development as a result of drainage processes that have cut into the laterite cap and underlying basalt. There are several waterfalls that create scenic opportunities and attract many visitors during the monsoon season, providing good examples for understanding water erosion and slope-wash, channel incision and hydrological cycle in a natural setting (Department of Tourism Maharashtra, 2024; Reynard *et al.*, 2007) ^[18]. These hydrological features contribute to the development of scenic tourism and they have a relevant scientific significance for the understanding of processes like erosional activity, discharge dynamics, or runoff generation in catchments that are well framed within an eco-topographic environment such as a high-plateau landscape. The human factor Matheran's touristic values are enhanced by its history and the surrounding cultural setting. The location developed as a summer resort for the British colonists, so there is a strong evidence of colonial architecture in its pathways, resting facilities, houses and the toy train line. Besides the colonial history there are also religious places, small temples and sacred groves that contribute to the sense of local tradition and community identity which attracts visitors to visit the area. In terms of accessibility Matheran offers a variety of choices. Its connection via the train line of the toy train or by car or bus through Neral is common choices. For internal access within the plateau, travellers can take a horse ride or use the specific carts pushed by local workers.

4. Results

The overall quantitative geomorphosite assessment of Matheran places it as an area of high geoheritage value and significant geopark potential (Reynard *et al.*, 2007) ^[18]. With scores of all 42 sub categories under six main value domains (scientific, aesthetic, economic-functional, cultural, protection-

management, tourism) the total site value for Matheran is 185, and the average score per value domain is 30.83; thus indicating that Matheran is well suited for a geopark development strategy and geotourism (Vujičić *et al.*, 2011; Reynard *et al.*, 2010) [22]. Among the six value domains, aesthetics is scored the highest (60), followed by scientific (40), a factor that relates to the striking lateritic plateau cap, steep escarpments, imposing basaltic cliffs and visually impressive panoramas and varied viewpoints which include, Panorama point, Louisa point, Echo point, Porcupine Point and One Tree hill, all supported by impressive, seasonally dramatic colour changes along with lateritic plateau edge landforms (Reynard *et al.*, 2007; Bruschi & Cendrero, 2005) [18, 4]. The site's economic-functional value (28) for geotourism is moderate to high based on the local factors of ease of access, strong visitor appeal and the local

economy which benefits greatly from tourism along with the provision of access routes, transportation, lodging facilities and supporting services (Chakrabarty & Mandal, 2022; Reynard *et al.*, 2010) [16]. The tourism value (24) is similarly robust, reflecting a location where tourism, including interpreting, education and leisure are well established. The cultural [18] and protection-management values [15], the latter primarily a combination of external protective measures and internal sustainability controls, are both moderate, and indicate area for future work. Although there are strong cultural and historic assets at Matheran; colonial buildings, heritage train lines, religious sites and strong local traditions they have not been brought into the heritage narrative (Newsome & Dowling, 2010) [13].

Table 1: Assessment framework and Evaluation Score for Matheran geomorphosites

Characteristics		Characteristics Matheran Geomorphosite	Score
Primary	Secondary		
1. Scientific Values	1. Surface	Lateritic cap rock, escarpments, and weathered slopes	4
	2. Height /depth or breadth	High elevation (800 m)	3
	3. Degree of preservation	Well preserved	3
	4. Chromatic	Vivid seasonal soil, green forests, blue valleys	3
	5. External agents	Dominated by monsoon runoff, mass	3
	6. Dynamics	Moderate vegetation cover and runoff patterns change seasonally	3
	7. Auxiliary elements	Mesas, scarps, cliffs, notches, gullies, and deep valleys	3
	8. geological elements	Lithology	3
	9. Uniqueness	One of few automobile-free hill stations with well-distributed viewpoints	4
	10. Stratigraphy	Good exposure of layered flows and weathering profiles	3
	11. visibility	Excellent; multiple points with far-reaching views	4
	12. Representativeness	Highly representative of Western Ghat plateau-edge landforms	4
2. Aesthetic Values	13. Viewpoints	Numerous spectacular viewpoints	4
	14. Shape	Plateau-edge cliffs with natural terraces and escarpments	4
	15. Landscape composition	Exceptional mix of dense forest, red lateritic soil, deep valleys, and distant ridges; picturesque in all seasons	4
	16. Colour	Vibrant reddish cliffs, lush green forests, and blue skies intensely vivid during monsoon and winter	4
	17. Environmental fitting of Sites	The viewpoints merge seamlessly with the plateau's natural landforms	4
3. Economic/Functional Values	18. Accessibility	Well-connected by narrow roads and toy train	4
	19. Distance, Signage)	Highly organized hill station; signboards throughout	4
	20. Anthropogenic Values	Good visitor facilities: cafes, benches, signage, rest areas	4
	21. Vicinity of Emissive Centres	Close to Mumbai and Pune	4
	22. Vicinity of Road Network	Well-connected via main roads up to Matheran	4
	23. Visitor Numbers,	High visitor numbers, especially weekends and holidays	4
4. Cultural Values	24. Local Revenue Potential	Strong local economy from tourism, accommodation, and services	4
	25. Link With Culture	A famous hill station with historical and recreational significance	3
	26. Historical Approach	Developed during British rule	3
	27. Art & Cultural Activities	Venues	3
	28. Religious Approach	Limited religious significance	2
	29. > Two Cultural Asset	Parsi	2
	30. Local Beliefs	Recreational focus	2
5. Protection/Management values	31. Monuments	Heritage rail declared a monument	3
	32. Current Condition	Excellent –maintained as part of eco-Sensitive zone	4
	33. Protection level	Protected under Matheran ESZ (Eco-sensitive Zone)	3
	34. Heritage listing	Regionally known	3
	35. Vulnerability	Moderate – pressure from tourism and informal vendors	2
6. Tourism values	36. Community Involvement	High – eco-tourism, local authorities, heritage walks	3
	37. Promotions	High – Matheran is a major tourist hub	4
	38. Organized Visits	Frequent – school tours	4
	39. Vicinity of Visitor Centres	Yes – information centres and boards	4
	40. Number of Visitors	Very high – throughout the year	4
	41. Tour Guide Service	Available, both formal and informal	4
	42. Hostel/Restorer	Excellent facilities throughout Matheran	4

Source: Calculated by Authors

Table 2: The Evaluation Sheet for Matheran Geomorphosite

Parameter	Details
Site Name	Matheran
10 Digit Geocode	2153344334
Tehsil & District	Karjat
Coordinates (Lat, Long)	18°59'20.05"N 73°16'14.27"E
Elevation (m)	~800 m above sea level
Average Annual Rainfall	~5200 mm (among highest in Raigad)
Average Annual Temperature	18–28°C
Geomorphic Unit	Lateritic plateau on Sahyadri escarpment
Lithology	Laterite over weathered basalt
Geological Formation	Deccan Trap
Geological Age	Cretaceous–Paleogene
Stratigraphy	Lateritic crust with weathered basalt layers
Transportation/Connectivity	Narrow gauge rail + road to Dasturi → walk/horses to top

Source: Compile by Authors

While protected under eco-sensitive zone regulations the sites do suffer from the strains of uncontrolled tourist use such as plastic waste, regulated vendors and footpath erosion (Ministry of Environment and Forests, 2003) ^[12]. From the detailed scores, Matheran stands out positively in uniqueness, visibility, representativeness, viewpoints, landscape composition, colour contrast, ease of access, and proximity to population centres, visitor numbers, potential revenue, current status, promotion efforts, and visitor organization, quality of interpretation services and visitor accommodation and hosting (Reynard *et al.*, 2007; Bruschi & Cendrero, 2005) ^[18, 4]. Those areas scoring lowest are the value placed on the cultural and economic factors in religion, overall multiplicity of culturally significant items at sites, site vulnerability to degradation, and length and long-term sustainability of interpretation plan, the site appears to have highest strength in the scientific and aesthetic categories, tourism appeal and physical accessibility, and the least potential to draw on aspects of its cultural value to support a geopark interpretation plan and to protect it adequately from negative impacts of uncontrolled development and mass-tourism use (Reynard *et al.*, 2007; Reynard *et al.*, 2010) ^[18]. The SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis

has highlighted that the lateritic plateau geology, dense vegetation and excellent viewpoints provide strong geological and natural values, along with unique car-free environment and accessibility to large metropolitan areas such as Mumbai (Newsome & Dowling, 2010; Department of Tourism Maharashtra, 2024) ^[13]. Conversely, the major weaknesses are inadequate waste disposal systems, insufficient geo interpretative signage and planning; difficulty with environmental management at peak seasons, and a lack of organized engagement of specific geoscientific principles and heritage interpretation to guide and inform visitor. Key opportunities centre on developing centres for geoscience interpretation and education with geo interpretative trails, digital heritage mapping and potentially integrating the site into existing wider regional geotourism routes (Chakrabarty & Mandal, 2022; Newsome & Dowling, 2010) ^[16, 13]. The critical threats to Matheran centre on environmental degradation due to tourism and unmanaged development, litter pollution, informal developments along the escarpments and plateau edge and climatic impacts causing erosions (Ministry of Environment and Forests, 2003; Reynard *et al.*, 2007) ^[12, 18].

4.6 SWOT Analysis of Matheran

Strengths	Weaknesses	Opportunities	Threats
Lateritic plateau and the escarpments, cliffs, valleys, waterfalls.	Lack of signage & geological information on site.	Design and establishment of geo-trails, display boards and visitor interpretation.	Excessive tour operations resulting in ground erosion and site litter and pollution.
Excellent scientific, scenic and educational value.	Inadequate management systems for waste and people management in busy periods.	Promotion of community based geotourism and economic development of the region.	Extension of the infrastructure could destroy delicate terrain on the plateau itself.
A zone that permits zero vehicle access and the promotion of non-impact tourism.	During peak tourist season trails/viewpoints/sensitive slopes become worn down.	Promotion of community based geotourism and economic development of the region.	The intense rainfall, likely resulting from climatic change, can exacerbate landslides and slopes.
There are more than 30 highly scenic viewpoints.	Tourist facilities & interpretation at site areas could benefit from improvement in planning & maintenance.	Connectivity with Western Ghats eco-tourism circuits.	Pressure arising from the unregulated commercial activities on informal basis can detract from scenic qualities.
Easy access from Mumbai & Pune.	Poor visitor understanding of geological heritage.	Utilizing it as a learning landscape for students and research professionals.	Vegetation could decline, diminishing scenic qualities of the areas.
The heritage toy train and the colonial environment offer added appeal.	Undocumented commercial activity with localised impacts.	Conservation support by integrating conservation activities to ESZ management.	Erosion and degradation could also arise from informal commercial activities and from intense pressure on viewing and trekking opportunities.

5. Discussion

The geological and landforms significance of Matheran are undoubtedly well established, not only as a tourist destination but also as a significant geomorphological region of tropical plateau edge landforms over the Deccan Traps, particularly highlighting erosion, weathering and denudation processes which continue till today (Widdowson & Cox, 1996; Subbarao, 1999)^[9]. These findings are critically important because scientific and aesthetic values are the foundation upon which geopark status rests, as these are integral for geoconservation and for the public communication of the unique geology and landforms which support this status, via public interpretation, education and a focus on the value of landscapes to inspire appreciation for geological heritage (Reynard *et al.*, 2007; Newsome & Dowling, 2010)^[18, 13]. That the Matheran has also inherited the pragmatic foundations necessary for the success of any geopark is clearly evident, having a well-developed transport network, strong links to major urban areas and a history of tourism that has created an industry around the site and many existing visitor management systems (Department of Tourism Maharashtra, 2024; Newsome & Dowling, 2010)^[13]; in an existing eco-sensitive zone status is an added advantage, as it establishes a strong policy basis for a more sustainable geopark in an already managed natural area, contrasting with many aspiring parks that have few protected legal designations (Ministry of Environment and Forests, 2003)^[12]. It is significant that the analysis has brought forth the synergistic benefits of this area for conservation, science and tourism in an interconnected manner. The lateritic geology and plateau and escarpment forms of Matheran are not merely a beautiful backdrop and scientific spectacle, but provide a diverse, multi-tiered, functioning ecosystem that includes various species of endemic flora and fauna as well as the important geological processes, a fact strongly encouraged by the UNESCO global geopark concept, whereby diverse elements are woven together to form the heritage value of a site (Reynard *et al.*, 2007)^[18]. At the same time, the only area where Matheran shows less strength is in its current use of cultural assets and long term sustainability management plans. It possesses many culturally rich facets and historic layers ranging from early colonial influences on land use through to more recent cultural practices and indigenous heritage that are not integrated into a planned geo interpretative context. Also whilst enjoying legislative protection the site has considerable problems with management of uncontrolled tourism such as litter, path erosion, footpath congestion, and lack of appropriate visitor facilities to cope with peak pressures which are of critical concern in ensuring that Matheran not be negatively impacted by potential geopark growth and interpretation strategy development (Newsome & Dowling, 2010)^[13]. These are typical and recognizable problems in many geopark aspirants that have pre dated a formal geoheritage policy.

Matheran as a Potential Geopark

Matheran fits in to a good candidate of a geopark, by meeting several of the main requirements for developing a geopark namely: geologic uniqueness, unique landscape, potential for tourism and education, environmental sensitivity, potential linking of conservation with development (Newsome & Dowling, 2010; Reynard *et al.*, 2010)^[13]. The lateritic plateau on Deccan basalts at Matheran has a very unique geomorphological feature with escarpments, mesas, cliffs, valleys, lateritic surfaces and panoramic vistas of a wide geoheritage complex of both scientific and Aesthetic value

(Subbarao, 1999; Widdowson & Cox, 1996)^[9]. The major reason why Matheran would qualify as a geopark is its immense scientific value (Widdowson & Cox, 1996; Reynard *et al.*, 2007)^[18]. The plateau represents a sequence of lateirisation, tropical weathering, retreat of cliffs, and incision of drainage and plateau edge geomorphology. Hence it forms a unique natural laboratory for the study of the Deccan volcanic landscape, its processes and features and how these may have evolved through the Tertiary into the present day as part of the Western Ghats (Reynard *et al.*, 2007; Newsome & Dowling, 2010)^[18, 13].

Matheran offers readily observable basalt/laterite contact, sequential climatic controls seasonal rivers, rain fed waterfall, steep gully erosion and structural controls on slopes which makes it a very worthwhile scientific, education and interpretation area, as the basic principle for the foundation of any geopark are landscapes of high Earth Heritage Value that can be understood and can support science of education (Bruschi & Cendrero, 2005; Chakrabarty & Mandal, 2022)^[4, 16]. Matheran also displays very high scenic and geotourism value, a crucial aspect of developing any potential geopark. The sheer concentration of view-points from edge the steep escarpments over to the deep wooded valleys, seasonal waterfalls and red lateritic slopes and panoramic views over the Konkan lowlands gives a highly aesthetically pleasing landscape where huge numbers of tourists throng annually. Since there is already an existing tourism structure in Matheran there is no question of beginning it from zero, but it is one of reforming an already established tourism into a more conservation conscious, science oriented and responsible geotourism. Matheran's greatest strength comes from the interaction between geoheritage, biodiversity and culture within the Matheran landscape. The plateau is not only of geo morphological interest, but it is also a critically sensitive area in its own right with its abundant flora, wildlife habitats, a typical wet seasonal hydrology and its regulated Eco-Sensitive Status. Besides the scientific and natural significance, the town itself houses colonial architectural heritage, a historic toy train service, sacred places of pilgrimage, an iconic trekking trail and a vibrant tourist based livelihood pattern. These elements can collectively give Matheran a comprehensive geopark identity - that is integrating geology not in isolation, but as an important aspect of a broader ecological, cultural and social context - which is the modern day geopark development concept. Matheran has already in place an Eco-sensitive Zone.

This makes its development as a geopark far easier, as the basic management infrastructure already exists. It includes restrictions on harmful development in sensitive areas, clear protection mechanisms, the public recognition of conservation as an important role and this means that Matheran can begin work on the complex tasks of site and heritage management. Private vehicular traffic is absent in the core region which means a reduction in a common source of disturbance and damage to a vulnerable landscape (Ministry of Environment and Forests, 2003; Department of Tourism Maharashtra, 2024)^[12]. Therefore, with a systematic inventory and data compilation, a proper Geoconservation Management Plan, effective site interpretation centres and guided activities on Geo trails and well defined local engagement policies and programmes it would be possible to evolve Matheran into a Lateiritic plateau Geopark in the Western Ghats, probably one of the more dominant candidates in future Indian Geopark proposals (Reynard *et al.*, 2010; Newsome & Dowling, 2010)^[13].

6. Conclusion

The present study shows that the Matheran is a strong site from geological scientific, aesthetic, economic-functional, cultural, protection and tourist value points of view and shows great potentiality as a geoheritage site in Raigad District of Maharashtra. With a total score 185 and an average score of 30.83 from a set of 42 sub category evaluation of parameters for geoheritage site, Matheran is determined to be a very high potential for the purposes of development of geotourism and for geopark oriented development. The best parts of Matheran are the lateritic plateau morphology, basaltic escarpment formations, panoramic views, thick green cover and excellent contrasts of colour combinations as well as the carfree tourism concept with its proximal nature with the larger population centres are key features giving both geological and aesthetic values, supporting sustainable tourism and environment education. Also, the Ecologically Sensitive Zone status and Heritage hill station identity helps integrate nature and the community towards conservation oriented sustainable development of the hill resort. However, in order to propose it as a ready geo-park candidate, a good development strategy needs to be taken. Scores achieved in the case of cultural and protection-management is moderate in comparison. A more geoscientific interpretation along with site-specific development of trails for visitors to see various geo-formations in a systematic manner as well as greater awareness programmes for the local population regarding heritage and environmental conservation need to be undertaken. Management with emphasis on better site management practices and more interpretation infrastructure should focus on managing solid wastes, informal tourist crowd, road erosion due to excessive traffic etc. This can be achieved through more collaborative development of such a unique and fascinating laterite plateau geo-form in a sustainable way in the context of the developed geopark development system and community participation at the development of the area into an ideal conservation based geo-park in western India in near future.

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