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SPATIAL ANALYSIS AND MODELING

Assessment of ecotourism potentiality in GHNPCA, Himachal Pradesh, India, using remote sensing, GIS and MCDA techniques

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Abstract
The present study focuses on the identification of potential ecotourism site using remote sensing, geographical information system and multi-criteria decision analysis (MCDA) techniques in Great Himalayan National Park Conservation Area (GHNPCA), Himachal Pradesh, India. This research incorporates 12 thematic layers, i.e. slope, topographic roughness, vegetation, surface water accessibility, groundwater, elevation, visibility of snow peak, proximity to villages, trekking route, climatic suitability, habitat suitability and lake proximity. The analytical hierarchy process (AHP) among different MCDA techniques was used to determine the weights of various themes to identify different ecotourism potential zones. The research concluded that the southwestern and central parts of the Great Himalayan Area (GHNPCA) have high to very high ecotourism potentiality which incorporates the eco-development zone, Tirthan Wildlife Sanctuary and Sainj Wildlife Sanctuary and mid-western part of Great Himalayan National Park. Finally, a total of 77 ecotourism potential sites have been identified within very high potential zone.

Keywords Ecotourism potentiality · Remote sensing · GIS · Analytical hierarchy process · MCDA

1 Introduction

The growing concern of environmentalism raised the issue of sustainability. Ecotourism emerged as a tool of sustainability of tourism where sustainability indicates the management of human activity based on ecological and cultural element (Dowling 1995a, b; Blamey 1995a, b, 1997; Sano 1997) and also contribute to environmental

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conservation and development (Ross and Wall 1999a, b; Tsaur et al. 2006). Sustainability of tourism exemplifies the relationship between ecotourism and sustainable development (Bansal and Kumar 2011) where sustainability included three systems, i.e. environmental, socio-cultural and economic (Wall 1997). The growing popularity and conservation potential of ecotourism offers unique opportunities for integrating rural development, tourism resource management and protected area management in many sites around the world (Hvenegaard 1994). Ecotourism can play an important role in attracting support, in both fields of political and financial, to preserve threatened natural areas (Boo 1990; Dixon et al. 1993; Western 1993; Burton 1997; Honey 1999).

Tourism in protected areas emerged as a strategy for development, and ecotourism, in particular, has been identified as a viable option for sustainable development (Obua 1997). Ecotourism development in National parks has immense importance due to its legal protection and sustainable management framework (Wallace and Pierce 1996). Farver (2002) forecasted that the protected area concept in future could be congested. Therefore, protected areas worldwide needed to demonstrate their economic value to the wider community (Dudly et al. 1999). Ecotourism can produce tangible financial benefits for protected areas, in which many ecotourism activities occur. Entrance fees can substantially offset park management cost and control visitation (Lindberg 1991) and provide critical foreign exchange (Edward 1991; Aveling and Wilson 1992).

First step for the identification of potential ecotourism is to evaluate criteria and indicators (Kalogirou 2002; Malczewski 2004; Gillenwatera et al. 2006). To identify potential ecotourism sites in a particular spatial unit, geospatial technology, i.e. remote sensing, GIS and GPS are widely used in the recent decade (Page and Dowling 2002; Boyd and Butler 1996; Arrowsmith and Inbakaran 2002; Lillesand and Kiefer 2004). GIS-based land suitability has been applied using analytical hierarchy process (AHP) (Saaty 1980) and MCDA method through modeling and overlay analysis (Carver 1991; Banai 1993; Malczewski 1999). Armstrong (1994) applied remote sensing, GIS and multi-criteria decision analysis (MCDA) method for the identification of the nature-based tourism potential sites based on socioeconomic and environmental indicators. Among different MCDA methods, AHP was widely used due to its capability to analyze data according to its relative importance and hierarchical ordering. Boyd and Butler (1996) applied GIS to identify suitable ecotourism areas in Northern Ontario, Canada. Kumari et al. (2010) included five indicators to identify potential ecotourism sites such as wildlife distribution index, ecological value index, ecotourism attractivity index, environmental resiliency index and ecotourism diversity index, whereas Akbarzadeh et al. (2011) applied landscape ecological components to identify potential ecotourism sites. Bunruamkaew and Murayama (2011a) used landscape, wildlife, topography, accessibility and community characteristics to evaluate site suitability of ecotourism. Gourabi and Rad (2013) applied the indicators, i.e. number of sunny days, average daily relative humidity, slope, water use, vegetation density and soil texture to evaluate potentiality of ecotourism in wetland.

Ecotourism in present day is one of the most sensitive issues and a tool towards sustainable tourism development in both developed and developing countries around the world. To develop proper planning for ecotourism, the primary task is the selection of site for ecotourism development. The selection of site is controlled by different elements belonging to physical, socio-cultural, environmental and infrastructural factors which vary place to place and situation to situation. Himalayan mountainous region is considered as one of the most attractive regions to the tourist around the world. The study area, Great Himalayan National Park and Conservation area (GHNPCA), is considered as the most suitable region for ecotourism development due to its natural and cultural diversity. Several past works have been carried out on biodiversity conservation, land use and land cover mapping and community-based ecotourism in this protected area (Pandey 2008; Naithani and Mathur 1998) but no attempt has been made on ecotourism site selection. Ecotourism has been taken into consideration for regional development policy but there is no implementable plan and policy is not yet established. This research attempts to make spatial decision for ecotourism site selection based on multiple criteria decision analysis in GIS environment. This present work attempts to identify potential ecotourism sites in protected area of GHNPCA in Himachal Pradesh, India, based on different physical, socio-cultural, environmental and infrastructural elements using AHP and GIS. From this site selection point of view, this paper is the pioneering work for the protected area management and also an ideal blueprint for the decision-maker to develop strategies for the development of ecotourism sites in study area.

1.1 Study area

Great Himalayan National Park and Conservation Area (GHNPCA) is located in the central part of Himachal Pradesh and lies in between 31°33′00″–31°56′56″ North latitude and 77°17′15″–77°52′51″ East longitude covering an area about 1171 square km (km^2) (Fig. 1). In terms of its physiographic characteristics, the study area is broadly divided into two major watersheds of Sainj and Tirthan rivers and elevation ranges between 1300 and 6100 m above mean sea level. The study area is bounded by Greater Himalayan mountain range in the east and Dhauladhar range in the west. GHNPCA by its local administration has been divided into four broad divisions, i.e. Great Himalayan National Park, Tirthan Wildlife Sanctuary, Sainj Wildlife Sanctuary and eco-development zone. Eco-development zone is the only inhabited part of the study area and permanently settled by 2400 people belonging to 160 hamlets within twelve Panchayats. The existence of snow clad mountain, landscape and climatic beauty, National Park and Wildlife Sanctuaries, rich biodiversity, ethnic and socio-cultural diversity, pilgrimage and sacred sites and adventure tourism activities attracts tourists of both national and international origin. The development of ecotourism should meet the needs of basic conservation principles and the participation of local community ensures the management of natural and cultural resources in a better manner without hampering the ecological stability within study area and provides economic opportunities of local community.

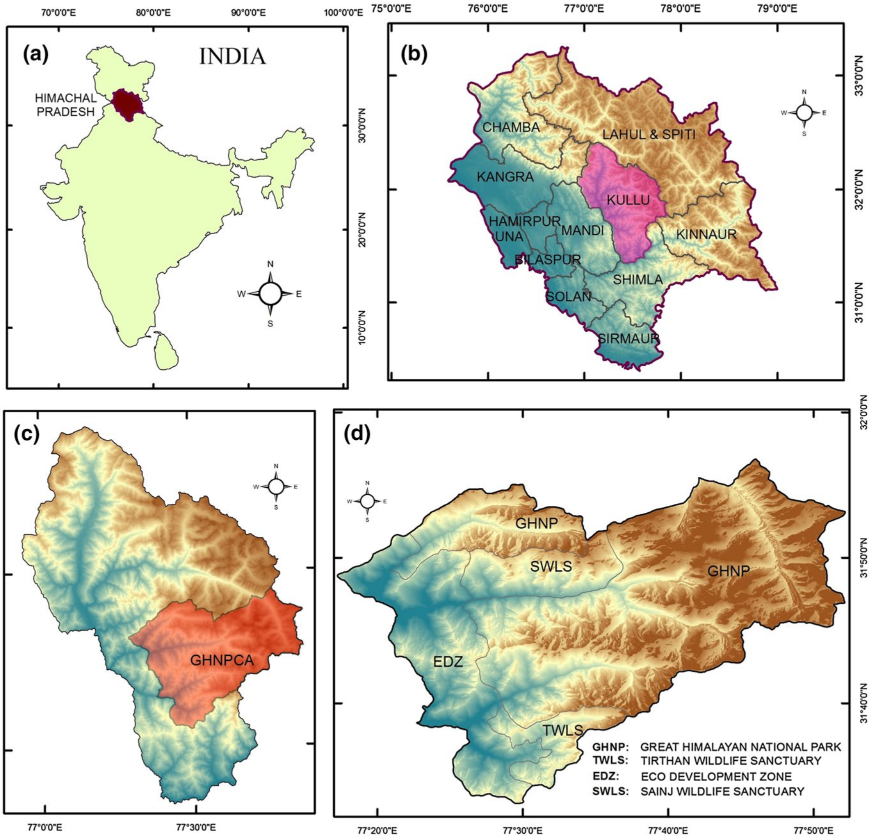


Fig. 1 Location of Himachal Pradesh in India (**a**), Kullu District within Himachal Pradesh (**b**), GHNPCA within Kullu District (**c**) and GHNPCA division boundary (**d**)

1.2 Database

To fulfill the research objective, required spatial, non-spatial data and available maps have been collected from both primary and secondary sources. To collect primary data related to expert's opinion regarding the selection of elements for ecotourism site identification, questionnaire has been distributed and collected. Location information was collected using handheld GPS. Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) having 30 ms spatial resolution has been used to analyze topographic aspects such as slope and Topographic Roughness Index. Groundwater-related spatial information has been collected from district planning map of Kullu District, National Atlas and Thematic Mapping Organization. Habitat suitability map of Western Tragopan and Musk deer, climatic map made available from GHNPCA official website. The information regarding vegetation has been collected through the calculation of normalized differential vegetation index (NDVI) using Landsat 8 satellite imagery having

30 m spatial resolution. Other information such as drainage networks, lakes, rural settlements and trekking routes was extracted through digitization in GIS software using GHNPCA official map. To collect the information regarding snow clad mountain peak visibility, view shed analysis was carried out using SRTM DEM data and absolute location of snow clad peak.

2 Methodology

2.1 Selection of thematic layer

Potential ecotourism site selection or prediction consists of three steps: (1) geospatial data base generation, (2) application of AHP for normalization of weight of each criterion and preparation of ecotourism site, and (3) validation and interpretation of result (Razandi et al. 2015). To assess ecotourism potential site identification, slope, topography roughness, vegetation, drainage, visibility, accessibility, rural settlement, habitat, elevation, climate, ground water and lake proximity elements have been taken into consideration (Fig. 2a, b). The elements for ecotourism potentiality in Great Himalayan National Park and Conservation Area have been taken into consideration based on expert's opinion and relative importance of elements (Kumari et al. 2010; Mahdavi and Niknejad 2014; Gul et al. 2006; Bunruamkaew and Murayama 2011b).

2.2 Geospatial data base generation

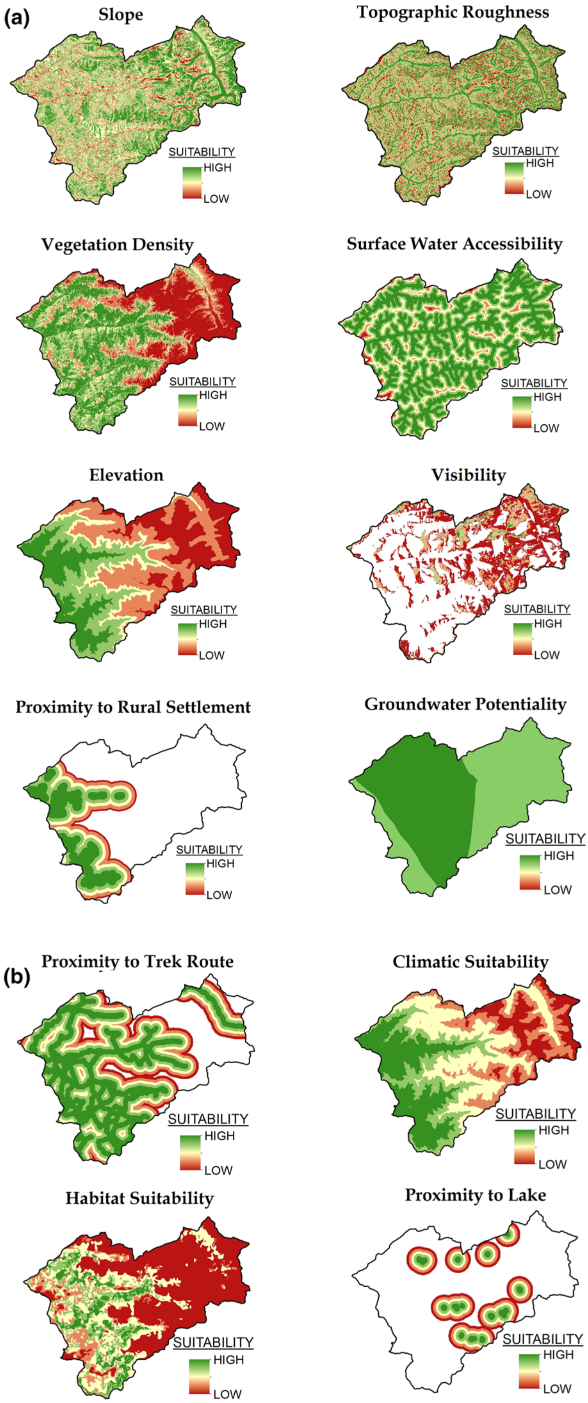
2.2.1 Slope

To generate ecotourism potential site, slope of land has immense importance (Kumari et al. 2010; Dashti et al. 2013; Bunruamkaew and Murayama 2011a; Bozorgnia et al. 2010). The construction of ecotourism sites needs low slope of land and increasing slope decreases possibilities to develop ecotourism site. Shuttle Radar Topographic Mission (SRTM) DEM is used to generate slope. Based on percentage rise method, slope layer was generated using SRTM DEM having 30 m spatial resolution:

$$\text{Slope (percent)} = \frac{\text{rise}}{\text{run}} \times 100. \tag{1}$$

Slope layer was further reclassified into five suitability classes, i.e. very high, high, moderate, low and very low and they cover 242 km^2, 368 km^2, 347 km^2, 176 km^2 and 38 km^2 area, respectively. The preferences were assigned according to the relative importance of each class, where higher value of slope indicates lesser possibilities to develop potential ecotourism site and vice versa.

Fig. 2 **a**, **b** Criteria maps for ecotourism potentiality assessment



2.2.2 Topographic roughness

Topographic Roughness Index is used to represent topographic characteristics of a region (Riley et al. 1999; Jenness 2004). Topographic roughness has inverse relationship with ecotourism and is widely used for ecotourism potentiality (Kumari et al. 2010). High roughness of land surface indicates lesser possibilities to develop ecotourism site and low roughness of land is suitable for ecotourism site development. SRTM DEM data are used to calculate topographic roughness index. Topographic Roughness Index (TRI) was calculated based on relative topographic position index which is a terrain ruggedness matrix and local elevation index:

$$\mathrm{TRI} = \frac{\mathrm{SD} - \mathrm{MinDEM}}{\mathrm{MaxDEM} - \mathrm{MinDEM}}, \tag{2}$$

where TRI means Topographic Roughness Index, SD indicates smoothed DEM of DN value of 10×10 pixel, max DEM means maximum DN (digital number) value of 10×10 pixel, and min DEM indicates minimum DN value of 10×10 pixel. Topographic roughness value (TRI) is further divided into four classes, i.e. very high, high, moderate and low, where each zone covers 345 km^2, 403 km^2, 310 km^2, and 113 km^2 areas, respectively. The region with higher topographic roughness indicates lower suitability for ecotourism and vice versa.

2.2.3 Vegetation

There exists positive relationship of ecotourism and vegetation density. Ecotourism involves abiotic, biotic and cultural attraction. Among them biotic features, i.e. biodiversity, wildlife and natural areas are considered as the most important aspect for ecotourism site development.

Landsat 8 imagery of NASA was used to calculate normalized differential vegetation index (NDVI):

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{R}}{\mathrm{NIR} + \mathrm{R}}, \tag{3}$$

where NIR indicates DN value from near-infrared band and R indicated DN value from red band of satellite imagery and the result of NDVI value data has been further categorized into five classes where higher value indicates the region having higher suitability for ecotourism development and vice versa. The area has been categorized into very high, high, moderate, low and very low suitability classes and they cover 317 km^2, 201 km^2, 168 km^2, 192 km^2 and 293 km^2, respectively.

2.2.4 Visibility

Visibility of snow clad mountain is the most important aspect for ecotourism development (Bunruamkaew and Murayama 2011b). For suitability analysis of ecotourism site development, snow clad mountain visibility is taken into consideration and it positively related to tourist attraction as well as tourist arrival. Tourists basically prefer to stay in places where from snow clad mountain is visible. The spatial analysis of visibility carried out using viewshed analysis is based on elevation and location of snow clad peak data. The visible part of snow clad mountain was extracted and results were further reclassified into four classes such as very high, high, moderate and low suitability based on the nature of visibility. As per the result, 5.2 km^2 area belongs to very high suitability class and 28 km^2, 110 km^2 and 321 km^2 to high, moderate and low suitability, respectively.

2.2.5 Proximity to rural areas

The nature and diversity of host culture in GHNPCA also attract responsible tourist to a great extent. Eco-tourist basically prefers to stay in places where cultural interaction with local people is possible. There exists positive relation between the culture of local community and ecotourism. The unique cultural characteristics of any region attract tourist from different parts of the country and abroad. The study region has unique cultural characteristics in terms of its traditional value, social custom, language, dress pattern, dietary habits, religion, etc. The core of ecotourism is the conservation of culture of local community. Thus, selection of rural areas has been given priority for the location of ecotourism site in GHNPCA. For this analysis, five buffer zones of rural settlements such as 800 m, 1600 m, 2400 m, 3200 m and 4000 m have been created and they cover 238, 149, 118, 97 and 42 square kilometer areas, respectively. The zone nearer to the village is given priority for the selection of ecotourism site and suitability decreases with increasing distance.

2.2.6 Elevation

Elevation plays an important role in the development of ecotourism site and increasing elevation has a negative relation to ecotourism site development (Ahmadi et al. 2015). Increasing elevation indicates decrease in oxygen level as well as lesser possibilities of human existence. Thus, lower elevation indicates higher possibilities for ecotourism site construction and vice versa. The study area is the part of Great Himalayan mountain range and elevation ranges 1300–6250 m above mean sea level. Based on elevation, the entire region has been categorized into five classes such as very high (above 4200 m), high (3600–4200 m), moderate (3000–3600 m), low (2400–3000 m) and very low (less than 2400 m) and they cover 255 km^2, 332 km^2, 122 km^2, 255 km^2 and 200 km^2 areas, respectively. The area having lower elevation is suitable for ecotourism site development where increasing elevation decreases the possibility for ecotourism site development.

2.2.7 Surface water accessibility

Water availability and ecotourism site are positively related to each other. Without water availability, human existence should not be possible. The study area belongs to two major watersheds of Sainj and Tirthan rivers. Based on the distance from drainage network, proximity analysis was carried out using buffer of less than

400 m, 400–800 m, 800–1200 m, 1200–1600 m and 1600–2000 m. The region near drainage network indicates high suitability for ecotourism potentiality analysis and possibilities decrease with increasing distance. The proximity zones were further reclassified into five suitability zones, i.e. very high, high, moderate, low and very low suitability and they cover 517 km^2, 387 km^2, 210 km^2, 48 km^2 and 9 km^2 areas, respectively.

2.2.8 Lake proximity

In terms of surface water accessibility and scenic beauty, lakes have immense importance for ecotourism site development (Mirsanjari et al. 2008). To find out suitability of lakes, five buffer zones of less than 800 m, 800–1600 m, 1600–2400 m, 2400–3200 m and 3200–4000 m have been created and represented as very high, high, moderate, low and very low suitability zones and they cover 30 km^2, 51 km^2, 64 km^2, 77 km^2 and 83 km^2, respectively.

2.2.9 Groundwater suitability

Not only surface water, but also groundwater availability has a positive relation to ecotourism site identification. As per availability and potentiality of groundwater, the study area is classified into two zones, i.e. aquifer having good groundwater potentiality and limited groundwater potential zone. The information about groundwater was collected from district planning map of National Atlas and thematic mapping organization. The region with good groundwater potential covers 608 km^2 area and is given higher weight for ecotourism potential whereas lower weight provides limited ground water potential zone and it covers 563 km^2 area.

2.3 Normalized weight for different thematic layers

Analytical hierarchy process (AHP) is widely used among different multiple criteria decision analysis (MCDA) techniques in the field of natural resources and environmental management. AHP is used to determine weights of the thematic layers (Saaty 1980) and used for decision-making in which a problem is divided into various parameters, arranging them in a hierarchical structure making judgment on relative importance of pair of elements and synthesizing the result (Saaty 1999). For this analysis, 12 thematic layers belongs to geomorphic, ecological, socio-cultural and infrastructure parameters i.e. slope, topographic roughness, vegetation, surface water accessibility, groundwater, elevation, visibility of snow peak, proximity to villages, trekking route, climate, habitat and lakes etc. has been taken into consideration. For the selection of elements to identify potential ecotourism site, questionnaire has been prepared and distributed among the experts belonging to different backgrounds such as environmentalist, ecotourism experts, academicians, and protected area management authority who work directly or indirectly on study area. The elements having higher average score were selected for study. To assign the weight of each thematic layer, Saaty's 1–9 scale has been applied (Saaty 1980). Based on

Saaty's scale, pairwise comparison of different thematic layers was carried out and a comparison matrix was prepared for delineation of potential ecotourism site. The normalized weight of different thematic layers and consistency ratio (CR) was calculated. In AHP method, pairwise comparison of all thematic layers was taken as the input, while the relative weights of thematic layers were the output. The final weightings for the thematic layers are the normalized value of the eigen vectors that are associated with the maximum eigen value of the matrix ratio (Jha et al. 2010; Adiat et al. 2012). The consistency ratio is measured using the following equation:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}}, \tag{4}$$

where CI indicates consistency ratio, RI means Random Index whose value depends on the order of the matrix, CI indicates Consistency Index which can be expresses as follows:

$$\mathrm{CI} = (\lambda\mathrm{max} - n)/(n - 1), \tag{5}$$

where λ indicates the largest eigen value of the matrix (can be calculated from the matrix) and n represents the number of thematic layers for ecotourism potentiality. The result of consistency ratio (CR) is 0.07 which is less than 0.1, it implies that there is reasonable level of consistency in the pairwise comparison and inconsistency is acceptable. According to Saaty (1980) and Malczewski (1999) and Dalalah et al. (2010), consistency ratio must be less than 0.1. The calculation of normalized weight and consistency ratio is represented in Tables 1 and 2.

2.4 Normalized weight of different features of thematic layer

The thematic layers were classified according to its importance such as very high, high, moderate, low and very low suitability zones for ecotourism site development. The ranks of each feature class of individual thematic layer are assigned and feature normalized weights were extracted and are shown in Table 3.

2.4.1 Ecotourism Potentiality Index (EPI)

Ecotourism Potentiality Index (EPI) is a dimensionless quantity that applies to ecotourism potential mapping in an area. The weighted linear combination method used to estimate Ecotourism Potential Index (EPI) is as follows (Malczewski 1999):

$$\mathrm{EPI} = (W_i n_i = 1mw = 1 \times Xj), \tag{6}$$

where W_i is the normalized weight of the j thematic layer, Xj is the rank value of the each class with respect to the j layer, m is the total number of thematic layer and n is the total number of class in a thematic layer. The EPI for each grid was estimated using the following equation:

$$\begin{aligned}\mathrm{EPI} = {} & \mathrm{Sl_w Sl_{wf}} + \mathrm{Tr_w Tr_{wf}} + \mathrm{Vg_w Vg_{wf}} + \mathrm{Sw_w Sw_{wf}} + \mathrm{Alr_w Al_{wf}} + \mathrm{Va_w Va_{wf}} \\ & + \mathrm{Ra_w Ra_{wf}} + \mathrm{T_w T_{wf}} + \mathrm{Cs_w Cs_{wf}} + \mathrm{Hs_w Hs_{wf}} + \mathrm{Lp_w Lp_{wf}} + \mathrm{Gw_w Gw_{wf}},\end{aligned} \tag{7}$$

Table 1 Pairwise comparison matrix

Thematic layers	Sl	Tr	Vg	Sw	Hs	Al	Va	Ra	T	Cs	Lp	Gw
Slope (Sl)	1.000	2.000	3.000	3.000	4.000	4.000	5.000	5.000	6.000	6.000	7.000	7.000
Topographic roughness (Tr)	0.500	1.000	2.000	3.000	3.000	4.000	4.000	5.000	5.000	6.000	6.000	7.000
Vegetation (Vg)	0.333	0.500	1.000	2.000	3.000	3.000	4.000	4.000	5.000	5.000	6.000	6.000
Surface water accessibility (Sw)	0.333	0.333	0.500	1.000	2.000	3.000	3.000	4.000	4.000	5.000	5.000	6.000
Habitat suitability (Hs)	0.250	0.333	0.333	0.500	1.000	2.000	3.000	3.000	4.000	4.000	5.000	5.000
Altitude (Al)	0.250	0.250	0.333	0.333	0.500	1.000	2.000	3.000	3.000	4.000	4.000	5.000
Visibility (Va)	0.200	0.250	0.250	0.333	0.333	0.500	1.000	2.000	3.000	3.000	4.000	4.000
Rural areas (ra)	0.200	0.200	0.250	0.250	0.333	0.333	0.500	1.000	2.000	3.000	3.000	4.000
Trekking route (T)	0.167	0.200	0.200	0.250	0.250	0.333	0.333	0.500	1.000	2.000	3.000	3.000
Climatic suitability (Cs)	0.167	0.167	0.200	0.200	0.250	0.250	0.333	0.333	0.500	1.000	2.000	3.000
Lake proximity (Lp)	0.143	0.167	0.167	0.200	0.200	0.250	0.250	0.333	0.333	0.500	1.000	2.000
Groundwater potentiality (Gw)	0.143	0.143	0.167	0.167	0.200	0.200	0.250	0.250	0.333	0.333	0.500	1.000
Column total	3.686	5.543	8.400	11.233	15.066	18.866	23.666	28.416	34.166	39.833	46.500	53.000

Table 2 Determining the relative criterion weight

Thematic layers	Sl	Tr	Vg	Sw	Hs	Al	Va	Ra	T	Cs	Lp	Gw	Total weight	Normal-ized weight
Slope (Sl)	0.271	0.361	0.357	0.267	0.265	0.212	0.211	0.176	0.176	0.151	0.151	0.132	2.730	0.227
Topographic roughness (Tr)	0.136	0.180	0.238	0.267	0.199	0.212	0.169	0.176	0.146	0.151	0.129	0.132	2.135	0.178
Vegetation (Vg)	0.090	0.090	0.119	0.178	0.199	0.159	0.169	0.141	0.146	0.126	0.129	0.113	1.660	0.138
Surface water accessibility (Sw)	0.090	0.060	0.060	0.089	0.133	0.159	0.127	0.141	0.117	0.126	0.108	0.113	1.322	0.110
Habitat suitability (Hs)	0.068	0.060	0.040	0.045	0.066	0.106	0.127	0.106	0.117	0.100	0.108	0.094	1.036	0.086
Altitude (Al)	0.068	0.045	0.040	0.030	0.033	0.053	0.085	0.106	0.088	0.100	0.086	0.094	0.827	0.069
Visibility (Va)	0.054	0.045	0.030	0.030	0.022	0.027	0.042	0.070	0.088	0.075	0.086	0.075	0.645	0.054
Rural areas (Ra)	0.054	0.036	0.030	0.022	0.022	0.018	0.021	0.035	0.059	0.075	0.065	0.075	0.512	0.043
Trekking route (T)	0.045	0.036	0.024	0.022	0.017	0.018	0.014	0.018	0.029	0.050	0.065	0.057	0.394	0.033
Climatic suitability (Cs)	0.045	0.030	0.024	0.018	0.017	0.013	0.014	0.012	0.015	0.025	0.043	0.057	0.312	0.026
Lake proximity (Lp)	0.039	0.030	0.020	0.018	0.013	0.013	0.011	0.012	0.010	0.013	0.022	0.038	0.237	0.020
Groundwater potentiality (Gw)	0.039	0.026	0.020	0.015	0.013	0.011	0.011	0.009	0.010	0.008	0.011	0.019	0.190	0.016

Consistency ratio (CR) = 0.072 < 0.1

Table 3 Assigned and normalized weights of different features of twelve thematic layers for ecotourism potential analysis

Factors	Category class	Assigned weight	Feature normalized weight	Normalized weight	Factors	Category class	Assigned weight	Feature normalized weight	Normalized weight
Slope (Sl)	0–9.02	1	0.0151	0.227	Visibility (Va)	> 10.01	1	0.0054	0.054
	9.02–16.1	2	0.0303			5.01–10.0	2	0.0108	
	16.2–23.1	3	0.0454			2.00–5.00	3	0.0162	
	23.2–32.9	4	0.0605			< 2.00	4	0.0216	
	33.0–100	5	0.0757				Sum = 10		
		Sum = 15			Rural areas (Ra)	800–1600 m	1	0.0029	0.043
Topographic roughness (Tr)	0.1047–0.4539	1	0.0178	0.178		1600–2400 m	2	0.0057	
	0.4539–0.5168	2	0.0356			2400–3200 m	3	0.0086	
	0.5168–0.5892	3	0.0534			3200–4000 m	4	0.0115	
	0.5892–0.9069	4	0.0712			0–800 and above 4000 m	5	0.0143	
		Sum = 10					Sum = 15		
Vegetation (Vg)	0.4384–0.6806	1	0.0092	0.138	Trek route (T)	< 600 m	1	0.0022	0.033
	0.3331–0.4383	2	0.0184			600–1200 m	2	0.0044	
	0.1540–0.3330	3	0.0276			1200–1800 m	3	0.0066	
	0.0205–0.1539	4	0.0368			1800–2400 m	4	0.0088	
	< 0.0205	5	0.0460			2400–3000 m	5	0.0110	
		Sum = 15					Sum = 15		
Surface water accessibility (Sw)	< 400 m	1	0.0007	0.11	Climate (Cs)	Subtropical and temperate	1	0.0017	0.026
	400–800 m	2	0.0015			Sub alpine	2	0.0035	
	800–1200 m	3	0.0022			Alpine	3	0.0052	
	1200–1600 m	4	0.0029			Cold arid	4	0.0069	
	1600–2000 m	5	0.0037			Above snowline	5	0.0087	
		Sum = 15					Sum = 15		

Table 3 (continued)

Factors	Category class	Assigned weight	Feature normalized weight	Normalized weight	Factors	Category class	Assigned weight	Feature normalized weight	Normalized weight
Habitat suitability (Hs)	Very high	1	0.0057	0.086	Lake proximity (Lp)	< 800 m	1	0.0013	0.02
	High	2	0.0115			800–1600 m	2	0.0027	
	Moderate	3	0.0172			1600–2400 m	3	0.0040	
	Low	4	0.0229			2400–3200 m	4	0.0053	
	Very low	5	0.0287			3200–4000 m	5	0.0067	
		Sum = 15					Sum = 15		
Elevation (Al)	< 2400 m	1	0.0046	0.069	Groundwater potentiality (Gp)	Aquifer have good groundwater	1	0.0053	0.016
	2400–3000 m	2	0.0092			Limited groundwater	2	0.0107	
	3000–3600 m	3	0.0138				Sum = 3		
	3600–4200 m	4	0.0184						
	> 4200 m	5	0.0230						
		Sum = 15							

where Sl is the slope, Tr is the topographic roughness, Vg is the vegetation characteristics, Sw is the surface water accessibility, Al is the altitude, Va is the visibility analysis, Ra is the proximity to rural areas, T is the trek route, Cs is the climatic suitability, Hs is the habitat suitability, Lp is the lake proximity and Gw is the groundwater suitability and subscripts, i.e. ‘w’ and ‘wf’ indicate normalized weight of theme obtained through AHP and the normalized weight of the individual feature class of a theme, respectively.

3 Results and discussion

Ecotourism potential zone map has been prepared based on AHP in GIS environment. Ecotourism Potential Index (EPI) values are classified into five suitability classes such as very high (0.0825–0.1426), high (0.1467–0.1615), moderate (0.1616–0.1788), low (0.1789–0.1993) and very low (0.1994–0.2923) based on quantile classification method in which each class contains the same number of features (Umar et al. 2014). The suitability zones such as very high, high, moderate, low and very low, respectively, cover 217 km^2 (19%), 183 km^2 (15%), 189 km^2 (16%), 205 km^2 (18%) and 377 km^2 (32%) areas within GHNPCA (Fig. 3).

In the *Great Himalayan National Park*, 95.8 km^2 (13%) area falls under very high suitability zone whereas 92.8 km^2 (12%), 112.1 km^2 (15%), 138.2 km^2 (18%) and

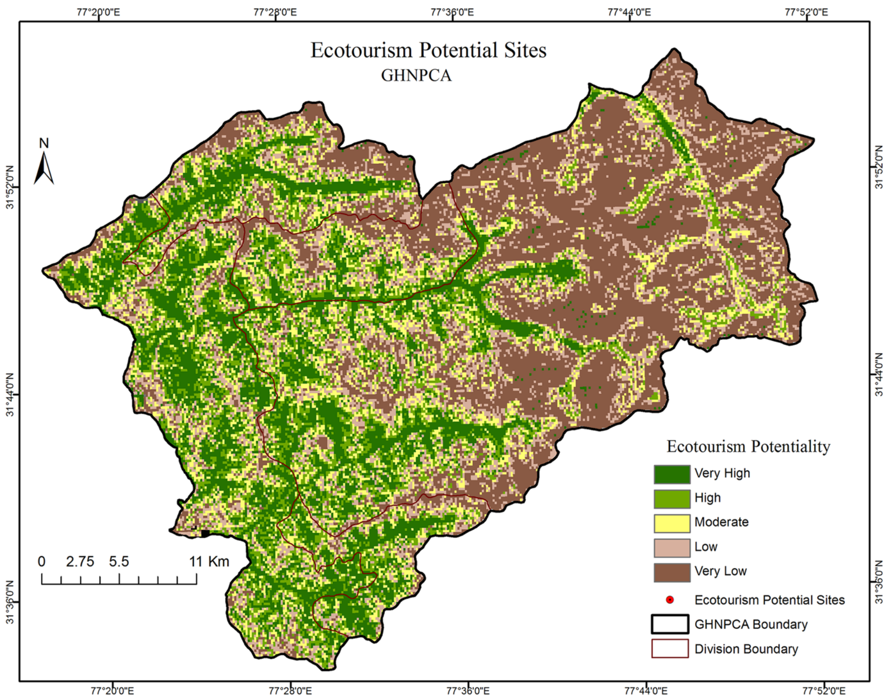


Fig. 3 Ecotourism potentiality zone map based on AHP and GIS

315 km^2 (42%) areas, respectively, fall under the high, moderate, low and very low suitable zones (Fig. 4). The western part of this protected area such as lower reaches of river valley such as Jiwa Nala, Sainj river, Tirthan river and Palchan Gad belongs to high to very high ecotourism potential zone, whereas the higher altitudinal region of the Greater Himalayan mountain range dominated by glaciated landscape falls under moderate to very low ecotourism potential zone. Within the very high suitability zone, a total of 35 sites (G1–G35) have been selected as a potential ecotourism site considering nearness of villages, water availability, trekking route and visibility of snow-clad mountains (Table 4). In the *Sainj Wildlife Sanctuary*, very high, high, moderate, low and very low suitable zones incorporate 16.8 km^2 (19%), 15.8 km^2 (17%), 17 km^2 (19%), 17.2 km^2 (19%) and 23.3 km^2 (26%) areas (Fig. 5). The northern part of Sainj river is characterized by ideal location for ecotourism site development. The lower elevated zones in Sainj Wildlife Sanctuary basically Sainj river and its tributaries represent high to very high suitability zone for ecotourism site development. The majority of lands in northern and northeastern part of this protected area fall under moderate to very low potentiality zone. From this particular region, 10 ecotourism potential sites (S1–S11) have been marked which fall under very high suitable zone. Those microlevel sites have been selected depending on the nearness of villages, water availability, trekking route and visibility of snow-clad mountains (Table 4). In the *Tirthan Wildlife Sanctuary*, 19.2 km^2 (32%), 12.8 km^2 (21%), 11.9 km^2 (19%), 10.2 km^2 (17%) and 6.9 km^2 (11%) area fall under the very high, high, moderate, low and very low suitability zones (Fig. 7). The majority of land in

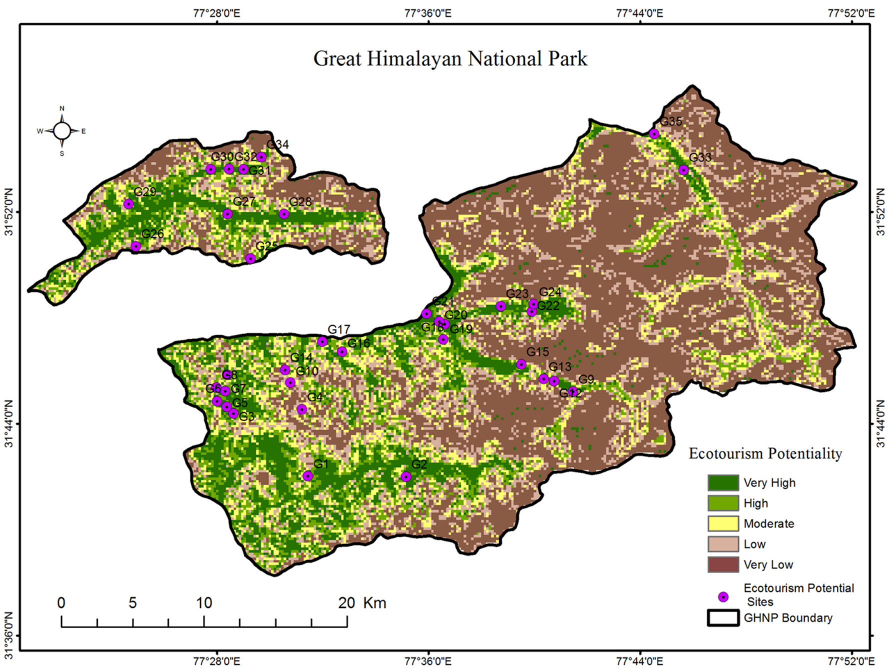


Fig. 4 Ecotourism potential zone map of Great Himalayan National Park

Table 4 Areal extent of ecotourism potential zone and location of potential sites of GHNP, Sainj Wildlife Sanctuary, Tirthan Wildlife Sanctuary and eco-development zone

Great Himalayan National Park

Suitability zone	Area in km^2	Area (%)	Potential sites	Latitude	Longitude	Potential sites	Latitude	Longitude	Potential sites	Latitude	Longitude
Very high	95.8	13	G1	77.524	31.700	G13	77.673	31.761	G25	77.4878	31.8372
High	92.8	12	G2	77.586	31.700	G14	77.510	31.767	G26	77.4157	31.8450
Moderate	112.1	15	G3	77.477	31.740	G15	77.659	31.771	G27	77.4734	31.8654
Low	138.2	18	G4	77.520	31.742	G16	77.546	31.779	G28	77.5090	31.8653
Very low	315.4	42	G5	77.473	31.744	G17	77.533	31.785	G29	77.4109	31.8716
Total	754.4	100	G6	77.467	31.747	G18	77.609	31.786	G30	77.4628	31.8936
			G7	77.472	31.754	G19	77.610	31.796	G31	77.4833	31.8934
			G8	77.466	31.756	G20	77.607	31.798	G32	77.4743	31.8937
			G9	77.691	31.753	G21	77.599	31.803	G33	77.7609	31.8931
			G10	77.513	31.759	G22	77.665	31.804	G34	77.4945	31.9013
			G11	77.473	31.764	G23	77.646	31.807	G35	77.7424	31.9158
			G12	77.679	31.760	G24	77.666	31.809			

Sainj Wildlife Sanctuary

Suitability zone	Area in km^2	Area (%)	Potential sites	Latitude	Longitude
Very high	16.8	19	S1	77.480	31.799
High	15.8	18	S2	77.594	31.805
Moderate	17.0	19	S3	77.569	31.806
Low	17.2	19	S4	77.505	31.807
Very low	23.3	26	S5	77.534	31.810
Total	90.0	100	S6	77.588	31.812
			S7	77.596	31.814
			S8	77.497	31.819
			S9	77.489	31.829

Table 4 (continued)

Sainj Wildlife Sanctuary								
Suitability zone	Area in km^2	Area (%)	Potential sites	Latitude	Longitude			
			S10	77.524	31.829			
			S11	77.594	31.834			
Tirthan Wildlife Sanctuary								
Suitability zone	Area in km^2	Area (%)	Potential sites	Latitude	Longitude			
Very high	19.2	32	T1	77.509	31.576			
High	12.8	21	T2	77.532	31.580			
Moderate	11.9	19	T3	77.507	31.582			
Low	10.2	17	T4	77.536	31.597			
Very low	6.9	11	T5	77.489	31.616			
Total	61.0	100.0	T6	77.510	31.624			
			T7	77.490	31.625			
			T8	77.513	31.631			
			T9	77.479	31.635			
			T10	77.525	31.643			
			T11	77.545	31.651			
Eco-development zone								
Suitability zone	Area in km^2	Area (%)	Potential sites	Latitude	Longitude	Potential sites	Latitude	Longitude
Very high	90.6	34	E1	77.342	31.838	E11	77.366	31.725
High	63.9	24	E2	77.292	31.812	E12	77.447	31.720
Moderate	49.7	19	E3	77.372	31.810	E13	77.390	31.715
Low	38.9	15	E4	77.361	31.799	E14	77.403	31.711

Table 4 (continued)

Eco-development zone

Suitability zone	Area in km^2	Area (%)	Potential sites	Latitude	Longitude	Potential sites	Latitude	Longitude
Very low	22.4	8	E5	77.427	31.793	E15	77.450	31.696
Total	265.6	100.0	E6	77.371	31.784	E16	77.450	31.693
			E7	77.382	31.782	E17	77.439	31.595
			E8	77.422	31.767	E18	77.434	31.591
			E9	77.424	31.749	E19	77.436	31.575
			E10	77.375	31.731	E20	77.495	31.563

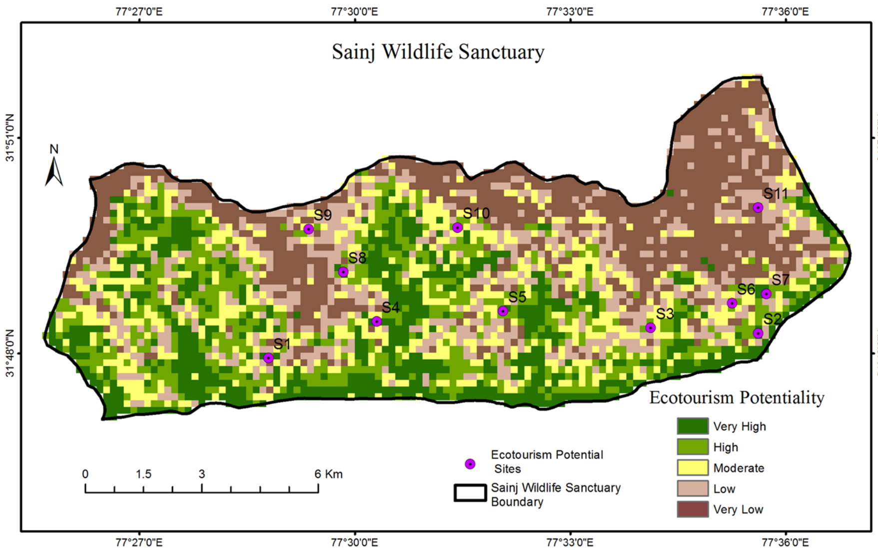


Fig. 5 Ecotourism potential zone map of Sainj Wildlife Sanctuary

Tirthan Wildlife Sanctuary (53%) belongs to high to very high ecotourism potential zone. Due to harsh environmental condition and high slope of land in the northeastern and eastern parts, this protected area belongs to low ecotourism potentiality zone whereas lower altitudinal regions of Tirthan river and Palchan Gad valley represent high potentiality. Within this protected area, 11 most suitable sites (T1–T11) have been demarcated, respectively (Table 4). *Eco-development zone or buffer zone of GHNP* is the only inhabited part of GHNPCA which covers 265.6 km^2 area and is considered as the most suitable zone for ecotourism site development because of the cultural characteristics concerned. Within this zone, 90.6 km^2 (34%), 63.9 km^2 (24%), 49.7 km^2 (19%), 38.9 km^2 (15%) and 22.4 km^2 (8%) areas belong to very high, high, moderate, low and very low suitability zones (Figs. 6, 7). The central and eastern parts of this zone represent high to very high potentiality, whereas the majority of land in the western and southwestern parts fall under moderate, low and very low ecotourism potential zone. Finally, nearness of villages, water availability, trekking route and visibility of snow-clad mountains have been taken into consideration for identifying 20 most suitable sites (E1–E20) for ecotourism development (Table 4).

4 Conclusion

Assessment of ecotourism potential has become a major issue for the authorities responsible for ecotourism planning and sustainable environment management. In this study, an integrated approach has been adopted. Remote sensing, GIS and MCDA techniques have been successfully used and demonstrated for the evaluation of ecotourism potential zone. Nowadays, MCDA method is widely used in

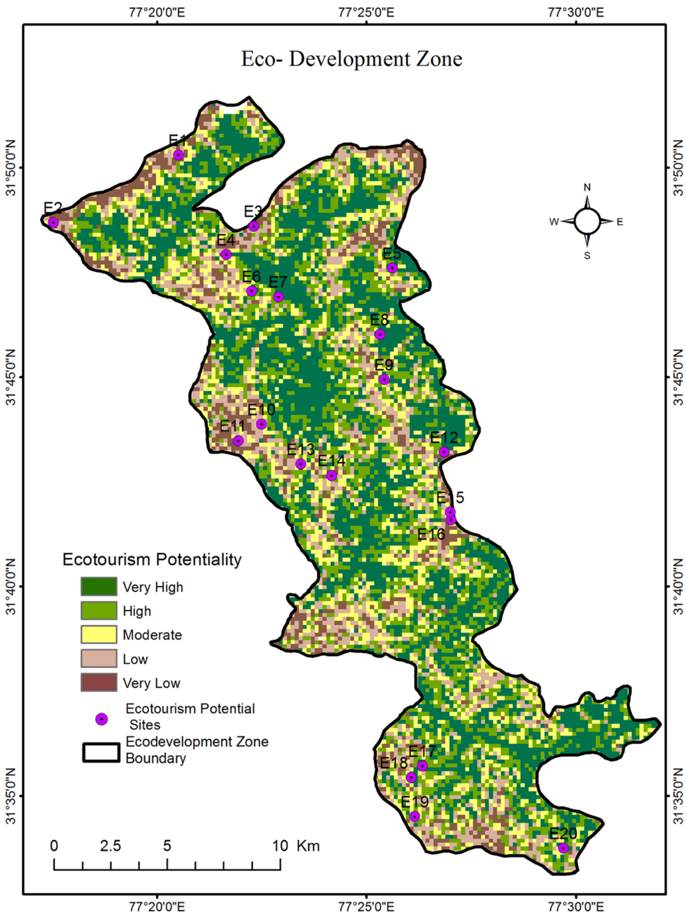


Fig. 6 Ecotourism potential zone map of eco-development zone

various disciplines and is an effective tool in potentiality analysis in the field of tourism. The novelty of this research lies on the fact that it incorporates multiple physical, socio-cultural, environmental and infrastructural aspects for ecotourism potentiality analysis in GHNPCA. This type of multi-criteria-based holistic assessment is very useful in ecotourism suitability analysis and it has been applied for the first time in this region. The result shows that out of total geographical lands of GHNPCA, 19% of the area belongs to very high ecotourism potential zone and for microlevel spatial decision-making within this zone, a total of 77 sites have been identified for ecotourism site development. Hence, the result of ecotourism potential site can be useful for decision-makers to formulate strategies for ecotourism development and sustainable resource management in this study area.

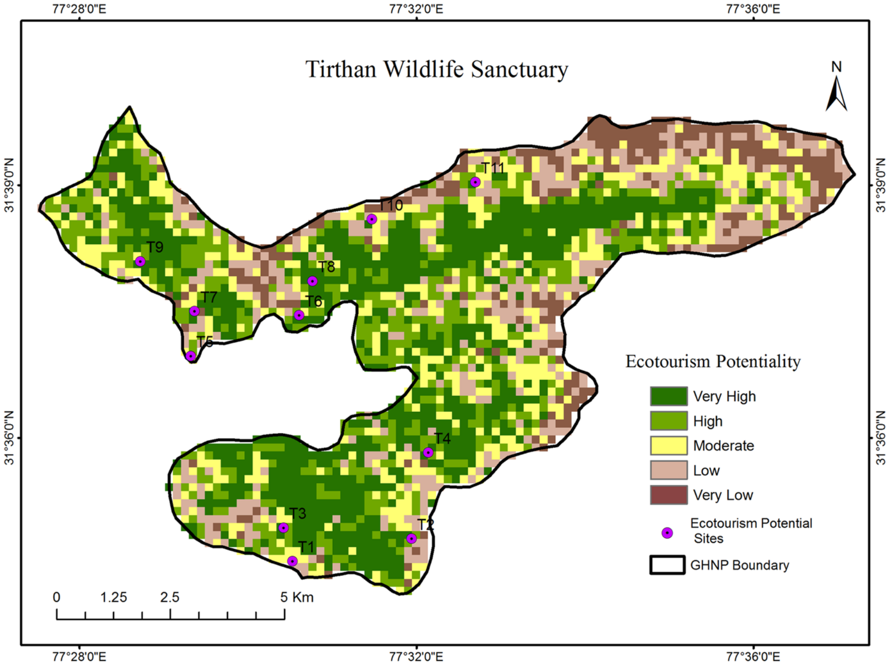


Fig. 7 Ecotourism potential zone map of Tirthan Wildlife Sanctuary

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