

## Identification of potential ecotourism sites in West District, Sikkim using geospatial tools

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**Abstract:** We integrated five indicator indices *viz.*, wildlife distribution index (WDI), ecological value index (EVI), ecotourism attractivity index (EAI), environmental resiliency index (ERI), ecotourism diversity index (EDI) to identify and prioritize the potential ecotourism sites in West District of Sikkim state in India. The primary variables used for generating various indices were landform, elevation, land use/forest cover, vegetation diversity, density and endemism, wildlife (mainly birds and butterflies), tourism attraction features and the infrastructure facilities. Data and information from remote sensing and other sources were used. The analytical hierarchical process and geographic information system were effectively used for identification of the potential ecotourism sites (PES).

**Resumen:** Identificamos y priorizamos sitios con potencial ecoturístico en el Distrito Occidental del estado Sikkim, India, por medio de la integración de los siguientes cinco índices (todos con sus siglas en inglés): índice de distribución de la vida silvestre (WDI), índice de valor ecológico (EVI), índice de atracción ecoturística (EAI), índice de resiliencia ambiental (ERI) e índice de diversidad ecoturística (EDI). Las variables primarias utilizadas para la generación de estos índices fueron la geoforma, la elevación, la cobertura forestal/uso del suelo, la diversidad de la vegetación, la densidad y el endemismo, la vida silvestre (principalmente aves y mariposas), los rasgos atractivos para el turismo y las instalaciones de infraestructura. Se usaron datos e información de percepción remota y otras fuentes. El proceso analítico jerárquico y el sistema de información geográfica fueron usados de manera eficiente para identificar sitios con potencial ecoturístico.

**Resumo:** Integram-se cinco índices indicadores como o índice da distribuição de vida selvagem (WDI), índice do valor ecológico (EVI), índice de atratividade ecoturística (EAI), índice de resiliência ambiental (ERI), índice da diversidade ecoturística (EDI) para identificar e por em ordem de prioridade o potencial ecoturístico dos sítios no distrito ocidental do estado de Sikkim, na Índia. As variáveis primárias usadas para gerar os vários índices foram as formas do terreno, a elevação, uso do solo/coberto florestal, diversidade da vegetação, densidade e endemismos, vida selvagem (principalmente pássaros e borboletas), características da atração turística e as disponibilidades das infra-estruturas. Os dados e a informação da detecção remota e de outras fontes foram usados. O processo analítico hierárquico e o sistema de informação geográfico foram eficazmente usados para a identificação dos locais potenciais para o ecoturismo (PES).

**Key words:** AHP, criteria, ecotourism, GIS, indicators, remote sensing.

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## Introduction

The potential of ecotourism as a strategy for sustainable development was recognized during the Earth Summit in 1992, when sustainable tourism was considered as an environment-friendly economic activity (Gray 2003). The fundamental function of the ecotourism is the protection of the natural and cultural resources as well as income generation, education, local participation and the capacity building (Ross & Wall 1999). As per the fundamental principles, the ecotourism should be: (i) nature-friendly, (ii) ecologically sustainable, (iii) environmentally educative and (iv) economically beneficial to the local community. It should also offer satisfaction to the tourists (Newsome *et al.* 2002; Page & Dowling 2002).

Remote sensing (RS) and geographic information system (GIS) have been used for the identification of potential ecotourism sites (PES) based on the environmental indicators i.e., ecological fragility, environmental resilience and ecotourism attractivity (Arrowsmith & Inbakaran 2002; Byod & Butler 1996; Page & Dowling 2002). The role of remote sensing has been emphasized in quick appraisal of the habitat attributes (Kushwaha *et al.* 2004), identification of new sites for protected areas and the current status of corridors (Panwar 1986). Remote sensing not only provides the spatial data but also allows the comparison of the temporal variations in the habitat features (Lillesand & Kiefer 2004). The remote sensing and GIS based tourism attractivity index, accessibility and environmental resilience were considered for identification of the potential

tourism sites in Gramphian National Park, Australia (Arrowsmith 2001).

Ecotourism has a strong correlation with sustainable tourism. The latter depends on the relationship between tourism and environment. This can be judged with the help of criteria and indicators approach, which is basically a concept of sustainable ecotourism management developed in to a set of principles, criteria and indicators (Prabhu *et al.* 1999). Bukenya (2000) employed six criteria (high number of species, wildlife management potential, endangered species, potential to attract more tourists, less susceptibility to encroachment and degradation over long period) to prioritize the potential national parks in Uganda. The site specific criteria and indicators can be developed with stakeholders' participation based on the relevance, analytical soundness and the measurability (Abidin 1995; Sirakaya *et al.* 2001). Abidin (1995) identified a set of 15 criteria and 58 indicators of sustainable ecotourism management in Taman Negara National Park, Malaysia on the basis of Delphi method. In Samoa, 20 critical sustainable indicators were developed by field testing and screening to assess the overall sustainability (Twining-ward 2002).

## Materials and methods

### *Study area*

The West District of Sikkim state ( $27^{\circ} 00' - 27^{\circ} 45' N$  and  $88^{\circ} 00' - 88^{\circ} 30' E$ ), with a geographical area of  $1066 \text{ km}^2$  (Fig.1) is surrounded by Darjeeling district of West Bengal in the south,



Fig. 1. Location of the study area.

**Table 1.** List of primary and secondary layers and their derivation sources.

Title	Source
(a) Primary layers and their sources:	
Elevation-wise distribution of mammals	Elevation map, mammal sightings
Elevation-wise distribution of avifauna	Elevation map, avifauna sightings
Elevation-wise distribution of butterflies	Elevation map, butterfly sightings
Land use/ forest cover map	RS data and reconnaissance survey
Kangchendzonga BR boundary	Forest Department of Sikkim, Gangtok
Road networks	District planning map (Anon. 2001)
Location of monastery	Sikkim tourism map (Anon. 2000)
Location of cave dwelling	Sikkim tourism map (Anon. 2000)
Location of lakes and sacred lakes	Sikkim tourism map (Anon. 2000) & RS data
Earthquake micro-zonation map of Sikkim	Nath (2005)
Digital Elevation Model (DEM)	SRTM
(b) Secondary layers and their sources:	
Forest density map	Land use/ forest cover (LU/FC) map
Forest type map	LUFC map
Species diversity ( <i>Shannon's</i> index) map	Forest type map (Anon. 2002c)
Ecosystem uniqueness map	Endemism value (Anon., 2002c), Forest type map
Vegetation canopy attractiveness map	Forest type map, field-based preference matrix
Slope map	Digital elevation model (DEM)
Aspect map	Digital elevation model (DEM)
Soil stability map	NBSS/ LUP (Anon. 1999)
Viewshed maps of 1, 2.5 and 5 km for 16 tourism attraction points	NATMO (2000), DEM and LU/FC map

Nepal in the west; north and south districts of Sikkim in north and the east. Due to its geographical location, the district has many potential ecotourism sites that attract large number of national and international tourists. The elevation in the district ranges from 300 to 8598 m above m.s.l., consisting of lower, middle and higher hills, alpine and perpetually snow-clad areas; the highest elevation being the mount Kangchendzonga (8598 m). The district experiences tropical, temperate and alpine climates. For most part of the year, the weather is cool and humid. The district possesses highly diverse wild flora and fauna including numerous orchids, rhododendrons, marigolds, magnolias and cherries. About 28% of the geographical area of Sikkim is notified protected area and yet the economy of the district is mainly based on the agriculture and the animal husbandry.

More than 81% of the inhabitants are engaged in agriculture. Although tourism is one of the sources of income for the local community, it exerts a great pressure on the natural resources of the

area. About 60% of the population is involved in the tourism in one way or the other. The employment in the government sector accounts for a mere 5.5-10% of the total population (Anon. 2002a). The district has a great variety of the natural and cultural attractions such as monasteries, mountains, lakes, hot springs etc. for the tourists (Anon. 2003). The south-western part of the Kangchendzonga National Park (KNP) is a popular tourist destination (Chettri *et al.* 2002). This study was undertaken to assess the potential ecotourism sites in West District, Sikkim with an objective of income generation for local people and the ecological restoration.

### *Data*

Resourcesat-1 LISS-III data of 13th April, 2005 pertaining to West District, Sikkim, was used. The information on roads, settlements, district boundary and the religious sites was collected from the district planning map (Table 1) (Anon. 2001). Population data for the year 2001

were obtained from the Regional Census Office for Sikkim at Gangtok. Elevation-wise wildlife distribution in the district was collected from the Asia Regional Office of the Mountain Institute and Ecotourism Conservation Society of Sikkim, Gangtok. The species diversity and the endemism data generated for various forest types in an earlier project on the biodiversity characterization at landscape level (Anon. 2002c) were utilized. The demographic data were collected from the Directorate of Census Operation, Sikkim at Gangtok. The data on the domestic and international tourists were collected from the Department of Tourism, Government of Sikkim, Gangtok (Anon. 2000). The shuttle radar topography mission (SRTM) digital elevation model (DEM) was used for terrain analysis ([www.gisweb.ciat.cgiar.org/sig/sig90m\\_datatropics.htm](http://www.gisweb.ciat.cgiar.org/sig/sig90m_datatropics.htm)). Other digital data used included soil map from National Bureau of Soil Survey and Land Use Planning (Anon. 1999). The seismic hazard zonation map prepared by Department of Geology and Geophysics, IIT, Kharagpur (Nath 2005) was used for generating environmental resilience index. The information on the vegetation canopy attractiveness were collected using questionnaires and through group discussions (Kumari 2008).

#### *Land use/forest cover mapping*

Geo-referencing of satellite image was done using Everest spheroid, polyconic projection and the nearest neighbourhood resampling. Well-distributed ground control points (GCPs) were used to achieve a root mean square error of less than a pixel. The land use/forest cover was classified using on-screen visual image interpenetration.

#### *Database creation*

The primary layers *viz.*, road network map, revenue, block, and administrative boundary map, places of tourist interest, tourist infrastructure map, tourist attraction points and spot height map etc. were generated using satellite data, district planning map and tourist map of Sikkim. All other layers were derived from the primary data (Table 1). The ecotourism criteria considered in this study were geomorphic features, elevation, forest density, diversity and endemism, wildlife (mainly birds and butterflies) distribution, land use/forest cover, existing ecotourism attractions, tourism infrastructure etc. The secondary maps showing WDI, EVI, EAI, ERI and EDI were derived from

the primary layers. The weights for the indices were assigned 0 to 1 value using field data. A minimum value of 0.01 and null value of 0.001 was assumed for the study.

The relative weights were assigned based on the number of species found at a particular elevation to generate WDI. EVI was calculated on the basis of species diversity and distribution of endemic species in various forest types (Anon. 2002c). To calculate the vegetation canopy attractiveness value, a preference matrix was generated taking opinion of the tourists and the local people (n=262). The respondents were asked to rank the alpine and sub-alpine grasslands, coniferous forests, rhododendron and the temperate, subtropical and tropical broadleaved forests. The information thus obtained was used to generate the average preference score, used for determining the weight for different forest types. The slope was categorized into 8 types with 10° intervals to calculate the topographic attractiveness. Same procedure was followed for the aspect.

The ecosystems having higher species diversity are more stable (Behera *et al.* 2002). ERI was calculated based on forest density. Forests having dense vegetation and higher species diversity are known to be more stable (Peterson *et al.* 1998). Soil stability map (Anon. 1999) was assigned weights and integrated for generating the environmental resilience map (Das *et al.* 1998). Generally, flat terrain is more stable than hilly one. In estimating the resilience, higher weight was assigned to lower slope and *vice versa*. The district is said to have 15 to 63% seismic risk probability; it has a strong motion centre near Geyzing and some epicenters in southeastern part (Nath 2005). Different probability zones were assigned weights accordingly. The zone with low probability of seismic hazard is considered to be more resilient as it can withstand more anthropogenic pressure. A locality can attract more tourists, if it has diverse attraction features. The viewshed analysis was done to determine the scenic attractiveness (Chettri & Arrowsmith 2001). This was carried out at three-distance level; near-range, middle-range and far-range at the distance of  $\leq 1$ , 1-2.5 and 2.5-5 km, respectively.

Finally, pair-wise comparisons were made among the WDI, EVI, EAI, ERI, EDI. AHP provides a systematic approach to assess and integrate the impacts of various factors, involving several levels of dependent or independent, qualitative and quantitative information. Like

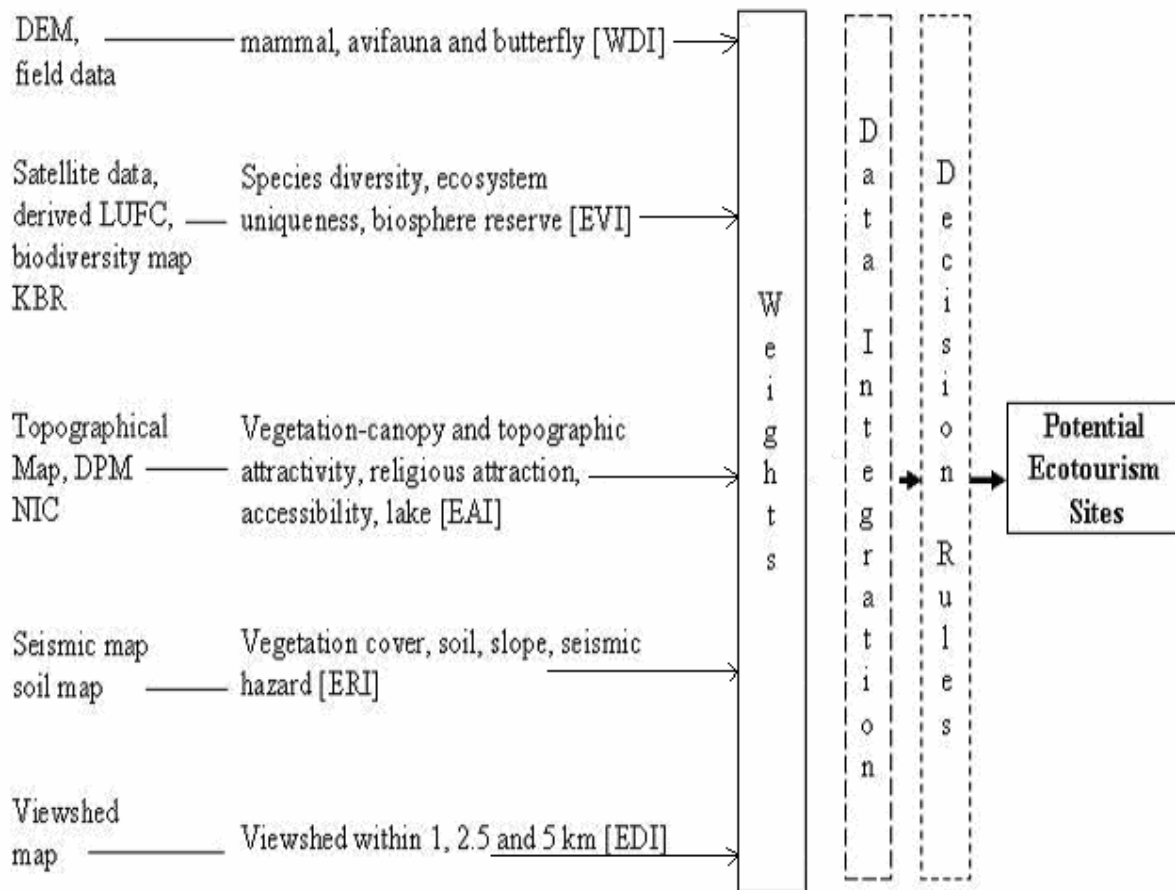


Fig. 2. Methodology for mapping potential ecotourism sites (PES).

Table 2. Weights calculated for five ecotourism indicators using AHP.

Ecotourism Indicators	Weight
WDI	2.214
EVI	0.149
EAI	2.158
ERI	0.149
EDI	0.331

other multi-attribute decision models, AHP also attempts to resolve conflicts and analyze judgments through a process of determining the relative importance of a set of activities or criteria by pairwise comparison on a 9 point scale.

For identification of the potential ecotourism sites, there is a need to select identification criteria and to apply decision spatial rules based on the criteria. Hence, there is a need to establish the relative importance of each criterion in terms of a

weight that determines its contribution to select potential sites. Therefore, relative weights were given to five criteria for identifying potential ecotourism sites in West District. Here, the decisions concerning the preferences were guided by the concept of sustainable ecotourism development, which is envisaged as leading to management of all resources in such a way that it can fulfill economic, social and aesthetic needs; while maintaining cultural integrity, essential ecological processes, biological diversity and life support system (Page & Dowling 2002). A standard 9-point scale preference scoring system was taken into consideration to allocate the relative weights (Ananda & Herath 2002; Satty & Vargas 2001). Based on the importance of the five parameters to identify potential ecotourism sites, the relative weights were given i.e. 8 for WDI, 7 for EAI, 6 for EDI and 5 each for EVI and ERI. Thus, higher weight was given to the attractive landscape parameter and environmentally resilient area,

which can withstand human interference, while lower weight was allotted to the ecological fragile site, which needs minimal or negligible human interference (Byod & Butler 1996; Pigram 1990). Fig. 2 illustrates the methodology. Based on this concept, the ecotourism potential was calculated using following equation:

$$EP = \{w_{ij}(WDI) + w_{ij}(EVI) + w_{ik}(EAI) + w_{il}(ERI) + w_{im}(EDI)\}$$

where, EP - level of ecotourism potential and  $w_{ij}$ ,  $w_{ik}$ ,  $w_{il}$  and  $w_{im}$  are weights. Proportional weights to four indicators viz., WDI, EAI, ERI, EDI and negative weight to EVI were assigned (Table 2) to derive the PES (Fig. 4c).

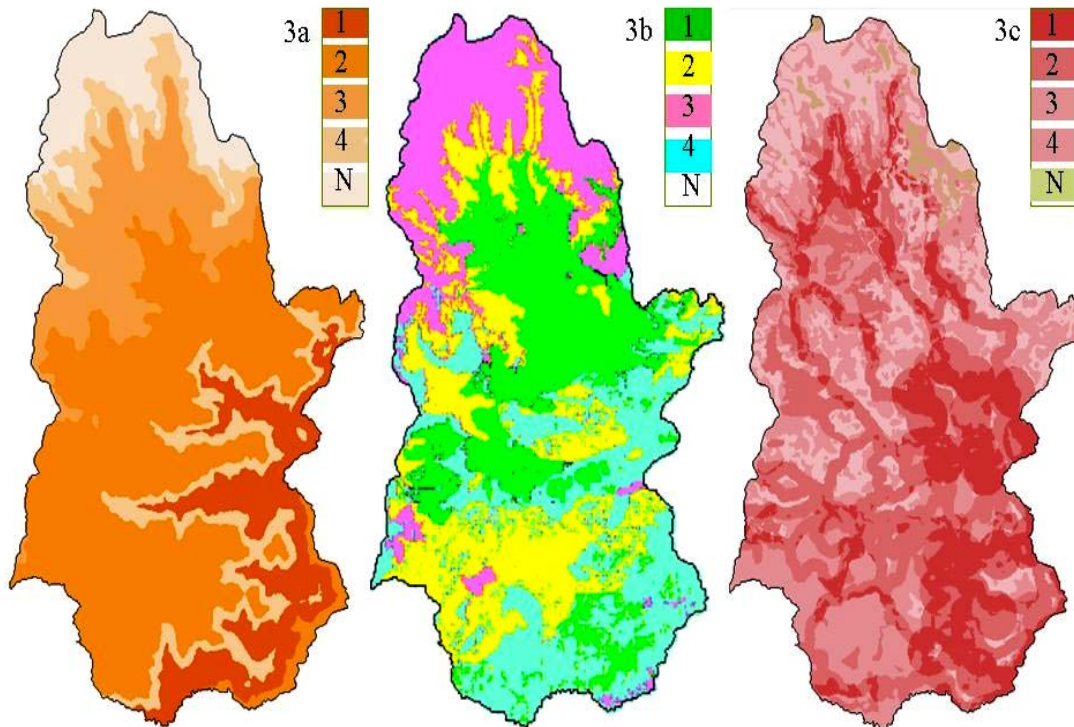
## Results and discussion

Six broad forest types viz., tropical broadleaved (sal), sub-tropical broadleaved, temperate broadleaved, temperate conifers, sub-alpine scrub, alpine grassland and *Rhododendron* could be delineated from satellite image, covering 62% of the geographical area of the district (Kumari 2008). Wildlife distribution indices were grouped in to four categories viz., very high, high, moderate and low (Fig. 3a). The highest WDI value was noticed in case of 900-1500 m that occupies 151.8 km<sup>2</sup> (Table 3). Tropical and sub-tropical forests support the highest number of species of mammals (14), avifauna (19) and butterfly (12). Their existence is more due to the prevailing local conditions that supports various wildlife habitats (Anon. 2000). Tropical and temperate belts were found to be highly suitable for wildlife habitat. This could be because of highest number of sightings of mammals (11) and avifauna (18). In temperate zone, the occurrence of rhododendrons, orchids and wide variety of flowering plants provide shelter to the wide variety of wildlife. Wild animals like himalayan barking deer, himalayan black bear, squirrel, wildcat, red panda and musk deer are observed in good numbers (Anon. 2002a; Lachungpa 1998). Many of the vital species inhabit in the alpine areas of KBR, such as goral, snow-clawed leopard, Tibetan antelope, wooly hare etc. (Rastogi & Chettri 2001). The most common birds found here are bulbuls, warblers, magpies and thrushes. blood pheasant (the state bird of Sikkim) was also seen in the district. Rare birds like satyr tragopan and monal have been sighted at 2500 m (Anon. 2002b).

Moderate wildlife, primarily consisting of avifauna (16) and butterflies (2) was observed between 3600-4600 m elevation (Fig.3). The existence of avifauna and butterflies is very important from ecotourism point of view. The sightings of 10 species of mammals between 4600-5000 m elevation and sightings of 15 species of avifauna and 2 species of butterflies at elevation of 1500-1800 m contributed to low values of WDI (Fig.3). Forests generally accommodate a higher number of wildlife as they satisfy the two most important criteria i.e., food and shelter. This wildlife distribution index forms an important criterion and thus, serves as a good indicator for estimating potential ecotourism sites.

Ecological value index showed four levels of ecological fragility (Fig. 3b). It was estimated that about 25% area of the district have very high EVI value with an area of 243.91 km<sup>2</sup> (Table 3). High EVI level occupied 315.74 km<sup>2</sup>, whereas moderate and low levels of EVI were observed in 227.26 km<sup>2</sup> and 331.93 km<sup>2</sup>, respectively. Very high EVI could be due to the presence of temperate broadleaved forest, which is having the highest ecosystem uniqueness value due to the occurrence of the highest number of endemic species (19) and high diversity value of 5.46 (Anon. 2002c) (Fig. 3b). EVI is an important criterion for sustainable ecotourism assessment. On one hand, it can be used as an incentive to preserve the rich biodiversity while on the other hand high biodiversity and ecosystem uniqueness attract more ecotourists (Newsome *et al.* 2002). The ecosystem processes are controlled by species diversity in a community (Peterson *et al.* 1998).

Ecotourism attractivity index demonstrated four gradations for the district (Fig. 3c). 9.07 km<sup>2</sup> area falls under very high level of ecotourism attractivity, followed by the 407.07 km<sup>2</sup> as high level of ecotourism attractivity (Table 3). 455.33 km<sup>2</sup> was shown to have moderate level of ecotourism attractivity, followed by 294.71 km<sup>2</sup> at low level. Presence of sacred lakes i.e., Lakhmi Pokhri, Manjur Pokhri, Khecheopalri and cave dwellings near Kasturi and Bakhim might have played an important role in identifying the high level of EAI sites. Presence of cone-shaped tree canopy in coniferous forest, beautiful rhododendron flowers, terrain beyond 70% slope, and eastern aspect offer good landscape attractivity, thereby attracting more tourists



**Fig. 3.** WDI (3a), EVI (3b) and EAI (3c) maps of West District, Sikkim; 1,2,3 and 4 in legend correspond to very high, high, medium and low values, whereas N represents null value.

(Arrowsmith & Inbakaran 2002). Monasteries are a major attraction for the tourists in the district. The moderate level of EAI can be attributed to the presence of vegetative cover and high slope gradient. At higher elevation, it is associated with coniferous forest, while at lower elevations, it is associated with broadleaved forest. Low level of EAI falls outside the road connectivity and under non-forest areas.

EAI is considered as one of the important attributes for estimating potential ecotourism sites, since the district is endowed with diverse kind of ecotourism attractions in the form of snow-clad mountains, flora, fauna, rivers streams, waterfalls etc. State forest contains evidence of tribal occupation and numerous sites highly valued for their aesthetic, historic and social values (Anon. 2002b). Ramakrishnan (1995) also recommended preservation of the unique cultural heritage of Rathong Chu valley. Promotion of

ecotourism is expected to boost the livelihood opportunity to the local people.

Four levels of ERI were identified based on their resilience value. 232.02 km<sup>2</sup> (19.9%) area falls under very high level of environmental resilience, followed by the 451.81 km<sup>2</sup> as high level of environmental resilience. 318.67 km<sup>2</sup> is categorized as moderate, 163.66 km<sup>2</sup> as low level of environmental resilience (Table 3). The high level of environmental resilience is attributed by many factors. Among them the presence of dense forest having canopy cover >40% and stable soil are the major factors. In hilly areas, vegetation plays an important role to prevent soil erosion as they have soil greater binding capacity (Newsome *et al.* 2002). Similarly, areas with less probability of seismic hazards possess higher ecological and environmental stability. High ERI level would have been contributed by the presence of dense



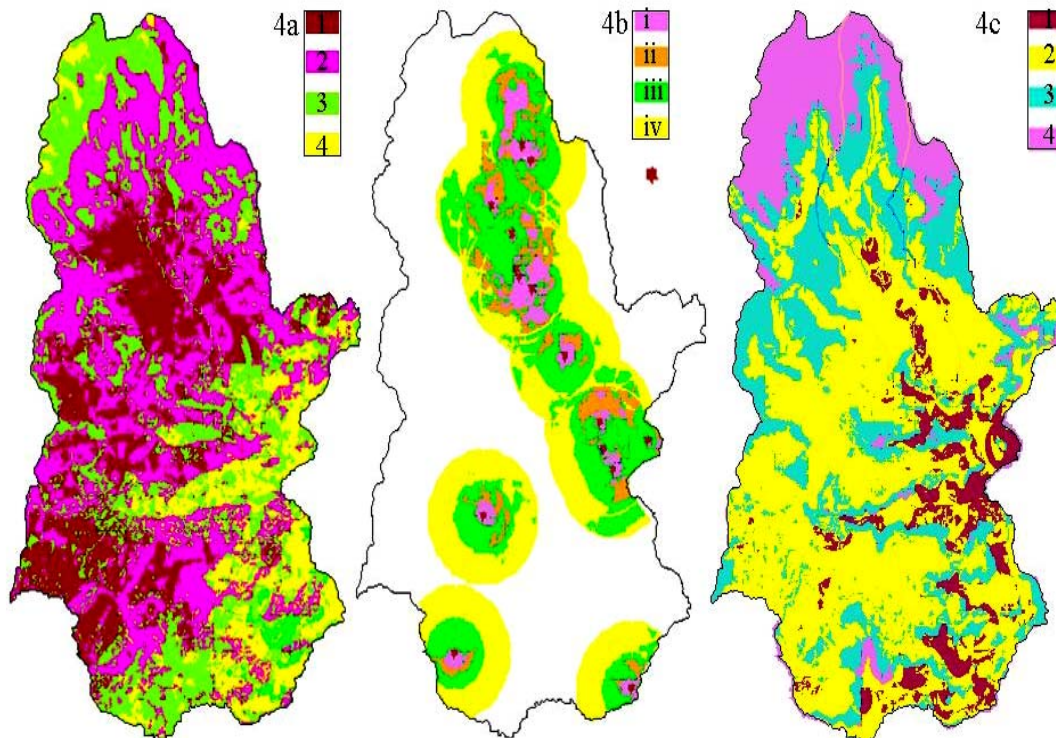
**Table 3.** Area estimates (km<sup>2</sup>) of WDI, EVI, EAI, ERI, EDI and PES.

Class	WDI	EVI	EAI	ERI	EDI	PES
Very high	151.80	291.07	9.07	232.02	49.46	93.56
High	556.76	315.74	407.07	451.81	55.51	620.81
Moderate	176.40	227.26	455.33	318.67	192.82	307.08
Low	181.24	331.93	294.71	163.66	273.93	145.18

forest and soil with moderate stability (Hunter & Green 1995). It is considered that the zone with less probability of seismic hazard would be more resilient and can withstand more human pressure (Nath 2005). The presence of dense forest in most part of the district might have contributed to high level of environmental resilience. The moderate level of environmental resilience may be attributed to the presence of non-forest areas with severe soil loss (Fig. 4a). In the northern most part of the district, the moderate level of environmental resilience may be attributed due to >70% slope.

The low level of environmental resilience may be attributed to non-forest areas, severe and very severe soil loss and a higher probability (47 to 63%) of seismic hazard.

As most of the ecotourism destinations are located in fragile ecosystems, there is a need for greater dynamism, where recreational forms and structures are evolved on consideration of resources resilience base. In this respect, the estimation of environmental resilience is imperative for sustainable ecotourism development and management. Environmental resilience is a



**Fig. 4.** ERI (4a), EDI (4b) and PES (4c) maps of West District, Sikkim; 1,2,3 and 4 in legend correspond to very high, high, medium and low values, whereas i, ii and iii represent visibility by three, two and single observers and iv represents the hidden pixels.



property of any unit of environment that will respond and return to its original form, when subject to some stress. This force is considered to be from a combination of physical forces comprising human interference and exogenous or gradational landform processes (Arrowsmith & Inbakaran 2002). The calculation of ERI suggests that the very high and high level of ERI areas can be used for infrastructure development to support ecotourism services, while the low ERI areas should not be promoted for ecotourism development purposes. Moderate ERI areas can be used for low level of infrastructure development.

Ecotourism diversity index demonstrated four levels of ecotourism diversity in the district (Fig. 4b). 49.46 km<sup>2</sup> area falls under very high level of ecotourism diversity, 55.51 km<sup>2</sup> as high, 192.82 km<sup>2</sup> as moderate and 273.93 km<sup>2</sup> as low level of ecotourism diversity (Table 3). About 51% of the district's area i.e., 594.46 km<sup>2</sup> were having obstructed view and therefore no analysis was done (Fig. 4b). 5.24 km<sup>2</sup> of area offers the highest level of ecotourism diversity and occurs near Gochala, Thangsing, Nor Pokhri, Dzungri, Tshoka and Bakhim cave. The high EDI are concentrated at four points i.e., at Gochala, Thangsing, Dzungri and Tshoka villages owing to the beautiful landscape (snow-clad mountains, lakes etc.). The landscape features near Thangsing can be seen from Dzungri and Nor Pokhri and Gochala and Thangsing. Similarly, the landscape features and other tourism attractions along the Tshoka can be seen from Sachen, Phedang and Bakhim village and from Tshoka itself. High level of EDI was observed at all 16 points. This suggests that the landscape features and other tourism attractions of high EDI region can be seen from three continuous observation points. The moderate level of EDI is highly concentrated along the Yuksam-Dzungri corridor, followed by Pemeyangtse monastery, Dentam, Hille Berse and Naya Bazar area. This suggests that the tourism features falling in this area can be enjoyed by two observers standing in nearest observation point.

The calculation of EDI value suggests that there is a need to conserve and maintain the diverse natural and cultural features for sustainability of ecotourism destinations. Due to globalization impacts changes are taking place in food habits, dressing pattern and traditional games, especially among the indigenous and ethnic people (Kothari *et al.* 1998). Availability of local food, traditional dressing pattern, traditional

games, and vernacular architecture are very important attractions for the tourists.

Integration of five ecotourism attributes using appropriate weights (estimated using AHP method) to generate potential ecotourism map of West District using GIS modeling technique, which has potential value. It has resulted into a number of potential sites in the district (Fig. 4c). Four levels (i.e., very high, high, moderate and low) were observed, that owes their own significance from implementation and management point of view. It identified 93.56 km<sup>2</sup> as very high potential for ecotourism followed by 620.81 km<sup>2</sup>, 307.08 km<sup>2</sup> and 145.18 km<sup>2</sup> as having high, moderate and low potentials respectively for ecotourism in the district (Table 3). Very high ecotourism potential consists of 8% area of the district. Very high PES value might have been attributed due to high and very high ecotourism attractiveness. High attractiveness of the regions could be due to availability of cultural and historical sites along trekking trails and other roads. Also, high level of wildlife distribution index might have contributed to high level of PES.

At some places, high EVI value has resulted in to high potential ecotourism value such as Yuksam-Dzungri corridor area. High level of ecotourism potential could be attributed to moderate EAI value that occupies <50% area of the district. These areas are well connected by roads, thus accessibility plays important role in determining high ecotourism potential also. In addition, high WDI value might have contributed to it. This area falls primarily between 1500 m to 1800 m elevations and are also characterized by very high level of environmental resilience value and moderate level of EVI. Moderate level of PES occupies 26.32% area of the district that could be contributed by moderate level of EAI, moderate level of WDI, moderate level of ERI and low level of EVI. The low level of PES covers an area of 12.44% of the district. The reason for this may be attributed to low ecological value due to absence of vegetation. The low level of WDI value might be attributed to low ecotourism potential, where wildlife sightings are negligible due to absence of good crown canopy, followed by low level of environmental resilience value and low level of ecotourism attractiveness (Fig. 4c). The potential ecotourism site map of West District depicts a clear picture of different areas that possess tremendous potential for ecotourism. The use of AHP ensures provides an unbiased method to

consider each attribute based on their importance. GIS has rightly provided a platform where all the spatial and non-spatial attributes have been combined together and analyzed with reference to the end objective of estimating the PES. The four categories demonstrated in PES rightly points out the areas and their priority for potential ecotourism in the Himalayan district of Sikkim state.

### Conclusions

Increased human interference in the ecologically fragile areas can cause irreversible change in the existing ecological processes. This necessitates a methodical management of ecotourism destinations, which can minimize the impacts from ecotourism activities while offering benefits to the local communities. This can be made possible by adopting the ecosystem approach of ecotourism development, which can adopt tourism as a means to protect the environment and, in turn, sustain biodiversity. The present study has tried to develop an integrated approach of ecotourism development by identification of ecotourism sites. Assessment of ecotourism sustainability at field-level has assisted in identification of poorly and very poorly performing indicators else where. The main contribution of this study is the identification of ecotourism indicators for identification of PES in West district, Sikkim, by applying the hierarchical structure of AHP in geospatial environment. Secondly, a method for sustainability assessment of ecotourism destination has been developed in four stages in the present study. Use of ecotourism indicators will help in identifying the potential ecotourism sites based on the environmental parameters. This can also have its implication at the site level environmental management of ecotourism activity based on ecotourism attractivity, ecological fragility and environmental resilience.

The present study is an early attempt to develop ecotourism indicators for identification of potential ecotourism sites in geospatial environment and development of a method to assess the ecotourism sustainability. The present study provides scope for future studies using ecotourism indicators for identification of potential ecotourism sites in other ecosystems i.e., coastal, mangrove, and desert. It may also include other environmental parameters like environmental vulnerabi-

lity index, environmental disturbances index to make it applicable in other conditions as well.

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