Identification of suitable ecotourism sites in Himalayan mountainous setting using Analytical Hierarchy Process (AHP) and GIS: A case study of Chamoli district, Uttrakhand.

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Abstract: With the ever-increasing need to manage and conserve the ecosystem, as well as the growing business potential for tourism, it's becoming increasingly important to address and align these two domains. Ecotourism enters the scene to provide a solution for anthropogenic interruptions at ecological tourist sites, with its potential to provide sustainable maintenance and development of both the environment and the local communities closely related to natural ecosystems. Tourism is one of the most valuable industries in India and the world, accounting for a considerable portion of most countries' economies. Chamoli is one of the tourist hotspot districts in India. Along with being an ecologically rich zone residing in the Himalayas, it possesses some of the highest peaks and national parks like Nanda Devi and Valley of flowers. The study area is also prone to various natural disasters like floods, earthquakes, landslides, and the recent one being the Rishiganga landslide of February 2021. The use of GIS tools in conjunction with AHP allows for a more streamlined and holistic approach to making scientifically calculated conclusions. We attempted to establish the prospective zones of ecotourism sites in our study region by considering a variety of factors that influence those sites of sustainable zones, such as slope, topographic roughness, elevation, road closeness, river proximity, and proximity to a protected area. The study area's data and information were geospatially analyzed to build an ecotourism potential map that can be used as a guide for planning sustainable resource management and development operations in the Chamoli district.

Keywords: - Ecotourism (ET), Analytical Hierarchy Process (AHP), Site-Suitability, Chamoli.

1. Introduction

With the emergence of sustainable development which was defined as development and careful utilisation of resources without making the future generation compromise for the resources, many other concepts of sustainability came into existence. Ecotourism is also a part of sustainable development which comes under sustainable tourism. According to the International Ecotourism Society, ecotourism is about uniting conservation, communities and sustainable travel (ecotourism.org). This means that practising ecotourism and promoting it should experience the richness and pureness of a scenic place along with trying to engage with the local community of the place in a positive manner, supporting them towards financial and cultural growth and also building conservational facilities towards the ecosystem. Ecotourism is a type of tourism that, along with giving the tourist the beautiful experience of travel, also generates growth for the local communities by giving them opportunities to grow financially by creating a link between the communities and the small industries and also holds the integrity and respect of the culture and most importantly providing conservational benefits to the environment (Scheyvens, 1999). Such type of tourism has become a need of the hour where the growing demand for both touristic activities as well as concerns related to environmental degradation are increasing hand in hand. Also, countries, especially India have seen great growth in the tourism industry. According to WTTC's Economic Impact and Trend 2021 report, India's Travel & Tourism GDP contribution grew by 4.9%, which was the third highest after China and Philippines. Thus, ecotourism is a linkage between solving economic problems for a community and also in aiding environmental issues (Goodwin, 1996). The consequences of unorganised tourism are felt equally by the environment and both the residents and the people sojourning at the tourist place, in the form of noise-air pollution, congesting traffic in peak hours, water scarcity, improper infrastructure (Sundriyal et al., 2018). This becomes even worse when touristic activities promote the disordered increment of built-up areas and road networks without bringing in the focus of environmental and geological factors, which in turn triggers the natural hazards like landslides (Cohen, 1978), (Khanduri,2017). In addition to that, issues of climate change uncontrolled construction activities in the seismic vulnerability zones are making it more prone to natural hazards, especially in the Himalayan region (Ramya et al. 2023), which has been inducted in the seismic zone IV and V (Rautela et al., 2015). Ecotourism, as discussed above which seeks to alleviate the pressure on the ecosystem as well as promote the livelihood of the local population still seems to be in its juvenile stage, where the limelight still focuses on tourism (Weaver & Lawton, 2007). In order to make ecotourism a successful concept and not merely a word in the literature, proper connecting link between local agricultural practices and tourism, promotion of tourist sites, community involvement as well as education can significantly enhance the future of ecotourism (Sharpley, 2006; Batta, 2006).

This report attempts to consider all the influencing parameters in order to setting up an ecotourism zone to analyse the suitability region within the Chamoli district of Uttarakhand. The method adopted for this purpose is the Analytical Hierarchy Process given by (Saaty, 1980) which is one of the most sought out in the Multicriteria Decision Analysis technique (Fung & Wong, 2007) with the help of GIS. GIS based multi criteria analysis has been extensively used in different fields of the world, such as forestry, geohazard risk mapping, agriculture etc. The utilization of GIS and AHP technique is a valuable, cost-efficient, and time-saving tool to identify potential locations that are appropriate for the development of ecotourism (Ghorbanzadeh et al. 2019a), (Mahdavi et al. 2015). Various fields employ GIS-based MCDA as a decision-making support tool, using data structure, weighting, and integration techniques for a wide range of optimization applications (Debesa et al. 2020), (Sahani 2020), (Ghorbanzadeh, Pourmoradian, et al. 2019). Integrating GIS and MCDA is crucial for evaluating potential nature-based tourism sites (Ghorbanzadeh et al. 2019b). A combination of GIS and AHP techniques can effectively organize data for spatial planning and minimize negative environmental impacts while maximizing economic value in the selection of potential ecotourism sites(Al-Awadhi et al. 2019). The ability of GIS to store, display, manipulate, and retrieve spatial data has proved to be very beneficial in all types of mapping and other developmental works. One of the most important characteristics of the GIS is that it can support different formats of geospatial as sell attribute data that makes its application very broad in all divisions of life. The integration of remote sensing with GIS has greatly benefitted the users in analysing and maintaining the earth repository and also in Earth observations. In order to consider a site suitable for ecotourism, it has to be quantitatively and qualitatively assessed for by considering some important factors that require the utilization of earth observation geospatial data and also for the fact that not all the areas of the earth are easily accessible. These considerations make GIS and remote sensing an integral part of research and development in the present scenario and thus GIS has been taken as the base in order to come up with some meaningful result in this study in a stipulated time. The AHP is a multicriteria decision making algorithm which involves recognising criteria that has an influencing factor on the decision-making process (Saaty& Vargas, 2012). Many of the scientific analysis which has to deal with multiple criteria influencing the occurring phenomena or setting up a potential zone utilize the process, (Yuwono et al., 2020) based on 8 thematic maps generated 8 criteria for ecotourism potential size investigation. (Ullah& Hafiz, 2014) adopted 15 thematic layers based on 5 criteria landscape, wildlife, topography characteristics, cultural heritage and community characteristics.

2. Study Area

Chamoli district hosts variety of people each year due to its famous pilgrimage sites and for its tourist interests. This district is mountainous and is bounded by the Tibet region and the district of Pithoragarh, Bageshwar, Almora, Pauri Garhwal, Rudraprayag and Uttarkashi. It extends between 29°55’34’’ N- 31°4’29’’ N latitude and 79°4’47’’E - 80°6’17’’ longitude and covers 7837.330 km^2 area. The study area is shown in Figure 1. Looking into physiographical characteristics, this region is a part of the north-west Himalayas and the elevation ranges from 702 meters to 7739 meters from the mean sea level. Famous pilgrimage sites like Badrinath, Hemkund Sahib, Bansinarayan, Kalpeshwar, Rudranath, Urgam, Joshimath and tourist attractions like Auli, Valley of flowers are situated in this district and make it an important tourist place. Auli is one of the most famous skiing spots in the world is situated in this district. Presence of Nanda Devi Peak which is the third highest peak of India, makes this an important destination for mountaineers as well. Also, the Rudranath is a famous trekking site that attracts the attention of adventurers over the world. The tourist statistics of this district is shown in Table 1. This district falls under the Himalayan biodiversity hotspot zone and the existence of Nanda Devi National Park (a world heritage site declared by UNESCO helps to protect the natural resources of this area) is gifted with rich flora which also has medicinal prospects and covered with alpine meadows, which serves as habitat for some exclusive faunas (Bosak, 2008), which were prone to hunting and smuggling activities prior to the government's declaration of it as a National Park and subsequently a Biosphere Reserve (Singh & Singh, 2004). The increasing tourist activities and related environmental degradation can be a matter of concern. The study area has been subjected to several disastrous geohazards, the recent one was from the Rishiganga region (a debris flow avalanche) and left severe causalities of lives and infrastructures (Pandey et al., 2021;Shugar et al., 2021).

Table 1. Tourism State of Chamoli of the year 2020

No. of tourist places	No. of Accommodation	No. of Indian Tourists (excluding bio-reserve)	No. of Foreign Tourists (excluding bio-reserve)	No. of Indian Tourists (only bio-reserve)	No. of Foreign Tourists (only bio-reserve)
20	497	2745413	2927	16904	520

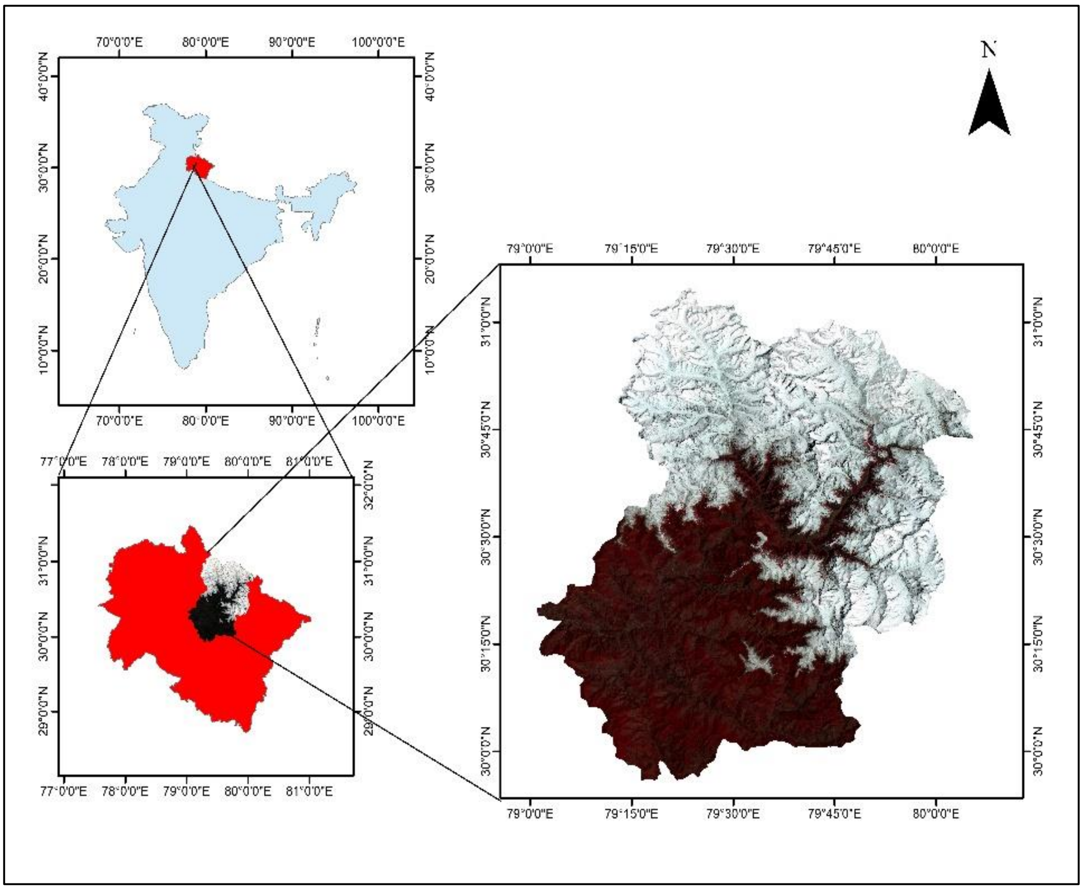

Figure 1. Map of the study area Chamoli district

The data used in this study has been taken from two major sources; satellite remote sensing imagery and available map. To obtain slope and elevation CARTOSAT-1: DEM version 3 R1 having 30 meters spatial resolution from Bhuvan Geo-portal of ISRO (https://bhuvan.nrsc.gov.in/) has been used. It is a Digital Elevation Model (DEM) generated by Cartosat-1 PAN (2.5m) Stereo data. The other information about the maps of roads, villages, surface water and protected area, we have used Open Street Map portal (https://www.openstreetmap.org/). It is an open-source platform having digitized maps of all over the world. The tourist hotspot locations are digitized using high-resolution satellite imageries like Airbus and Maxar technologies through the Google Earth Pro platform. The details of data sources are written in Table:2.

Table 2. Data Sources and Resolution.

Elements	Data Source	Scale/resolution
Slope	CARTOSAT 1: DEM	30m spatial resolution
Touristic Hotspots	High Resolution Imagery (Airbus, Maxar Technologies), through Google Earth Pro	Digitized Vector data
Elevation	CARTOSAT 1: DEM	30m spatial resolution
River Proximity	Open Street Map portal (https://www.openstreetmap.org/).	Digitized Vector Data
Road Proximity	Open Street Map portal (https://www.openstreetmap.org/).	Digitized Vector Data
Village Proximity	Open Street Map portal (https://www.openstreetmap.org/).	Digitized Vector Data
Protected Area Proximity	Open Street Map portal (https://www.openstreetmap.org/).	Digitized Vector Data

3. Methodology

From a detailed literature review, it is observed that the ET is a function of seven parameters as defined as per Equation 1

$$E = F(S, TH, E, RP, R_dP, VP, PAP) \qquad (1)$$

where, S = Slope, TH = Touristic Hotspots, E = Elevation, R_dP= River Proximity, RP = Road Proximity, VP = Village Proximity, PAP = Protected Area Proximity

The algorithm for deriving the suitability of an area for ecotourism development while considering the above parameters using AHP- MCE approach is described in the following 7 steps by (Ullah& Hafiz, 2014), are represented in the flowchart of Figure 2.

Step 1. Making pairwise comparison through AHP.

Step 2. Preparation of comparison matrices.

Step 3. Normalization of the matrices

Step 4. Checking consistency ratios and finalizing th weight values.

Step 5. Transferring the weights to the geospatial database.

Step 6. Overlaying operation in the thematic layers and making a composite map.

Step 7. Classifying the final suitability map into different suitable zones.

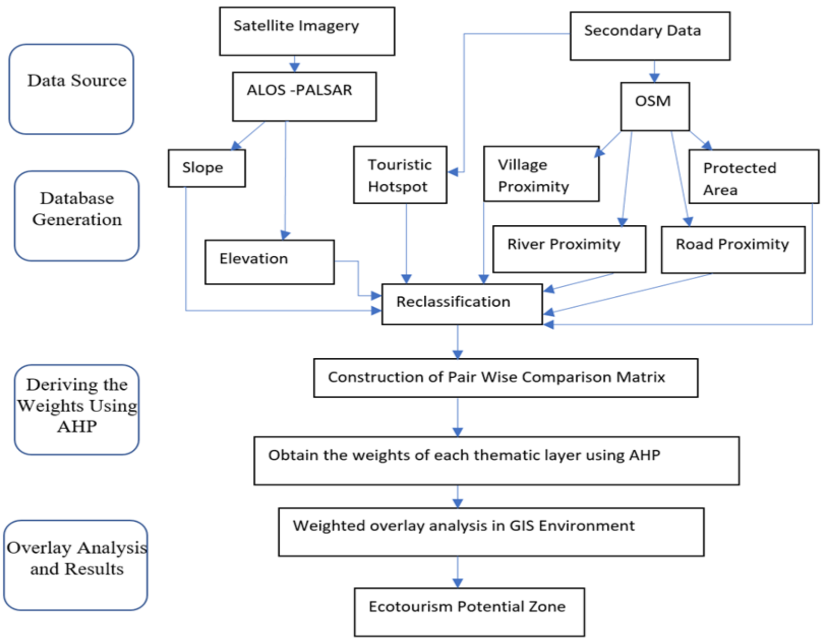

Figure 2. Flowchart of Methodology

Step 1: Selection of Thematic Layer: The first step in every site suitability analysis is choosing the thematic layer of the study area and selecting the attributes we are taking into consideration. For selecting the study area as a potential ecotourism spot, we have taken the following thematic layers such as slope, touristic hotspots, elevation, river proximity, road proximity, village proximity and protected area proximity. The elements responsible for ecotourism in this study area were selected according to the literature (Kumari et al., 2010).

Step 2: Geospatial Database Generation: One of the major important factors of ecotourism is slope (Kumari et al., 2010). The slope map has been generated using CARTOSAT 1 DEM version 3R, and the degree method was used to calculate the slope map. The slope layer is further reclassified into five subclasses naming Very High, High, Moderate, Low, Very Low, respectively. The preference was set as the area with a higher slope will have the lesser potential of developing into an ecotourism zone.

Now while analyzing elevation, we can infer that the area with higher elevation has lower suitability for ecotourism and the weight has been set accordingly. Elevation is an important index for ecotourism (Ahmadi et al., 2015). Higher elevation will have less concentration of oxygen means a higher possibility of humans to face hypoxia in those places, resulting in lesser suitability of tourism. Also, as the Chamoli district has a wide range of elevation values (lowest point 651 m and highest point 7816 m) so it is essential to see the influence of elevation over this area.

The primary data extracted from OSM using QGIS like River Proximity (RP) is a great potential for tourism, as it facilitates the development of attractive spots, in addition to its protection and respectful use. Protected area, as the name suggests, areas that are oriented to protect biodiversity relatively undisturbed natural environments, place a tremendous role in developing ecological friendly society and ecotourism. Roadway and its proximity (R_dP) allowing the travellers for inter-city travel giving services in rural areas also, influence other branches of the tourism industry. Villages and its proximity (VP) help in customizing trips and promoting culture and heritage, however, conversely helps them to enhance their infrastructure and income are rasterized, converting vector files into raster files as it aids the process.

The secondary data, proximity analyzed data which is attained by analyzing the location of features by measuring the distance between them and other features by area. It is done to get approximate interval between attributes. Followed by reclassifying the layers where one or more values are reassigned to a raster data set to new output values, this is to find out that the value of a cell which changes with respect to time like land use, weather, etc.

The data of touristic hotspot locations were digitized through high resolution satellite imageries with reference to Chamoli district and Uttarakhand state tourism department, these locations are popular for the pilgrimage reasons or mountain sports like trekking, hiking, camping, bonfire, skiing, mountaineering etc. The treks through deep valley, green meadows with snow laden mountains peak's view, makes them a strong attraction among tourists. Euclidian distance algorithm (equation 2) was applied to the touristic hotspot locations to generate the touristic hotspot map, where the smallest distance between pair of points of two locations was calculated. The proximity maps with suitable values are given in Figure 3 to Figure 9.

$$\boldsymbol{d(p,q)} = \sqrt{(\boldsymbol{p_1} - \boldsymbol{q_1})^2 + (\boldsymbol{p_2} - \boldsymbol{q_2})^2 + \cdots + (\boldsymbol{p_n} - \boldsymbol{q_n})^2} \quad \textbf{(2)}$$

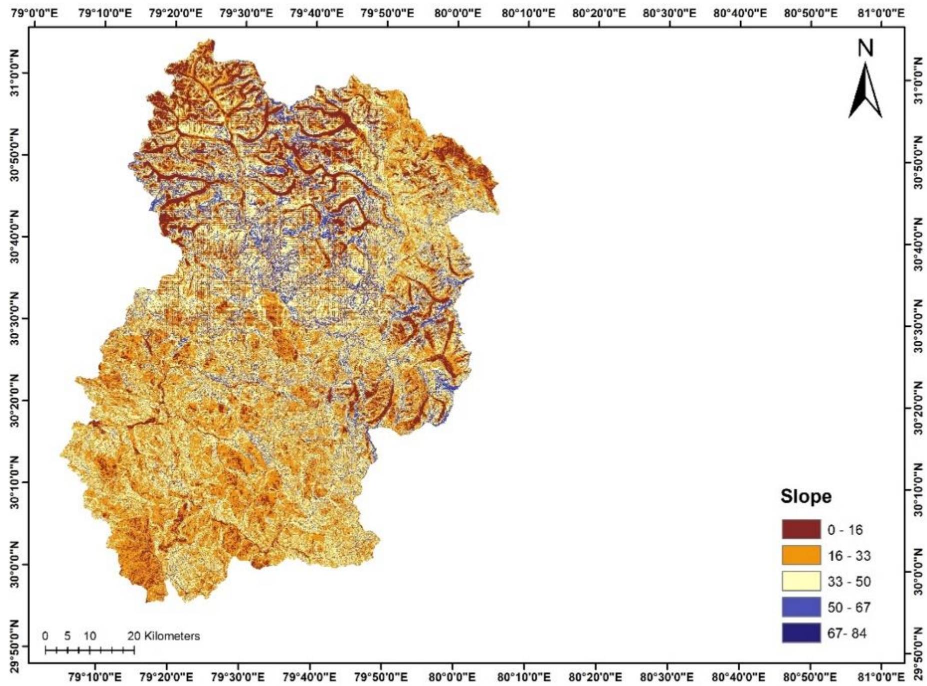

Figure 3. Slope map of Chamoli District

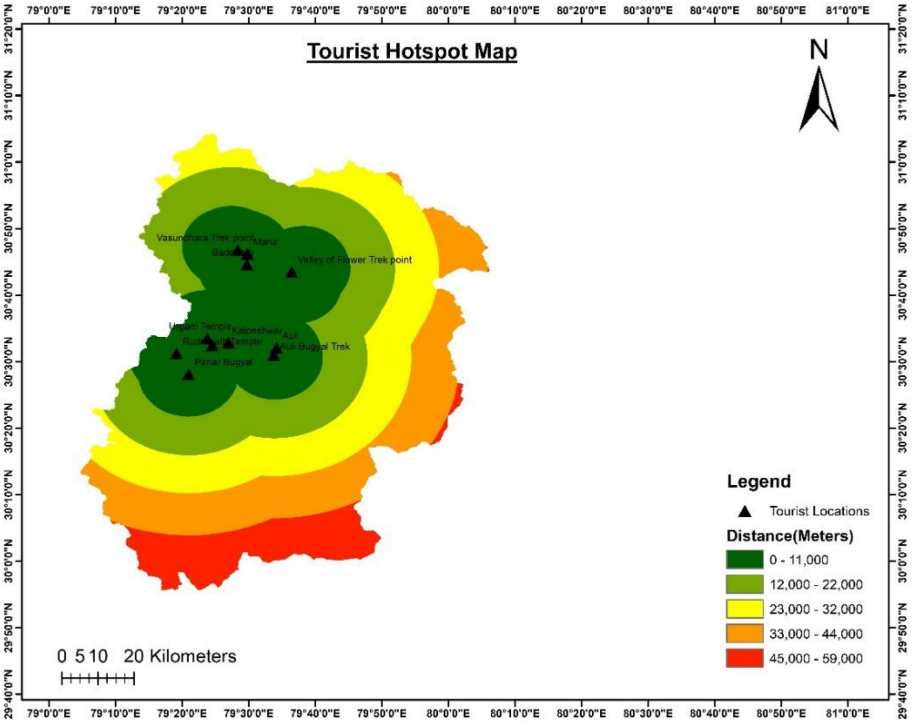

Figure 4. Touristic Hotspot map of Chamoli District

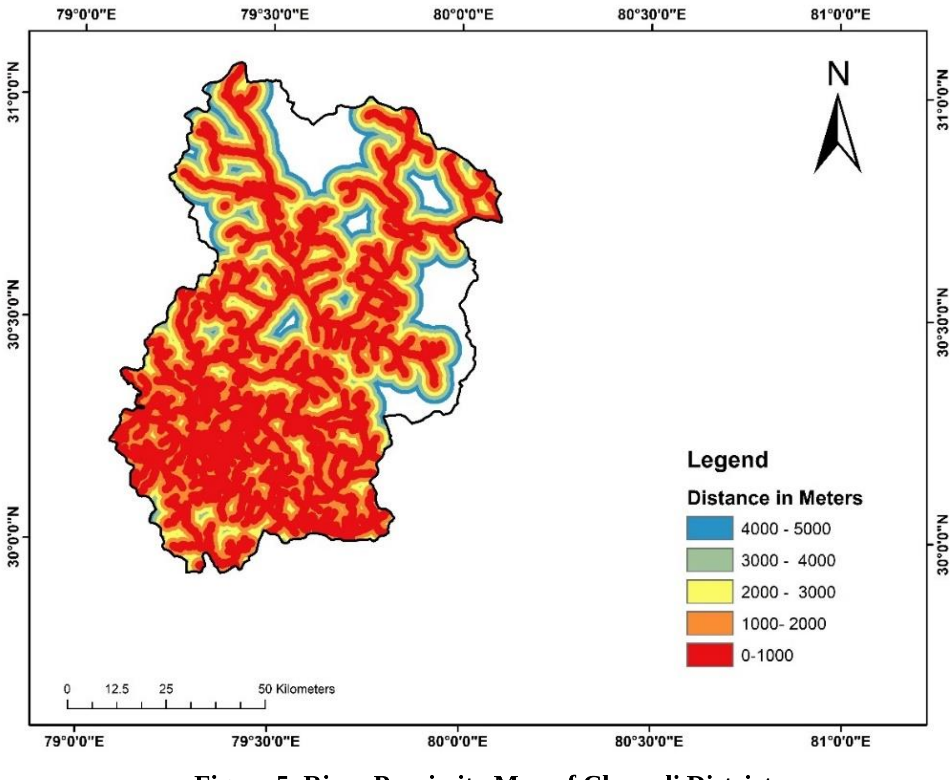

Figure 5. River Proximity Map of Chamoli District

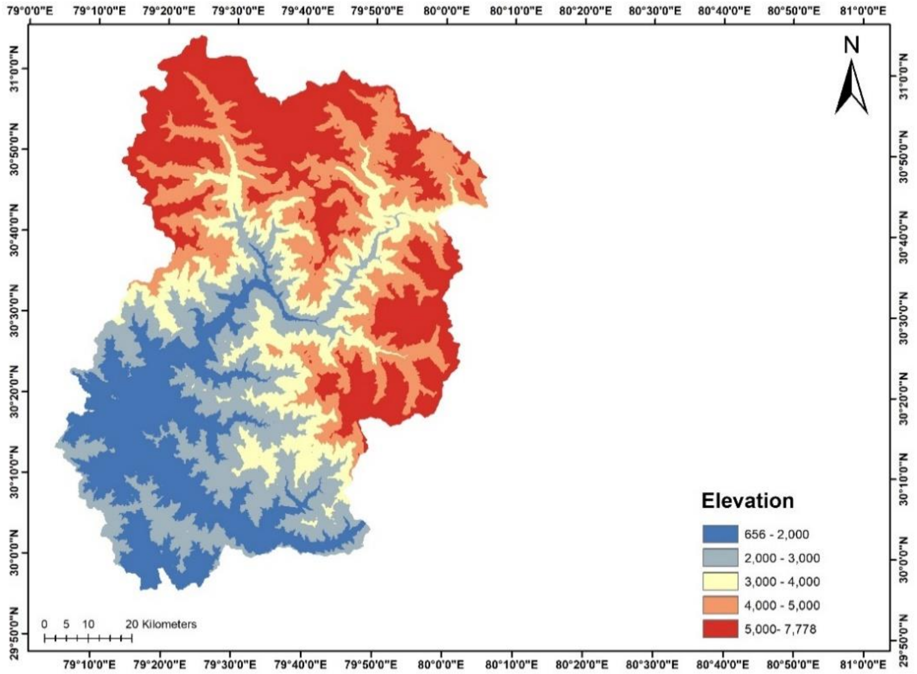

Figure 6. Elevation map of Chamoli District

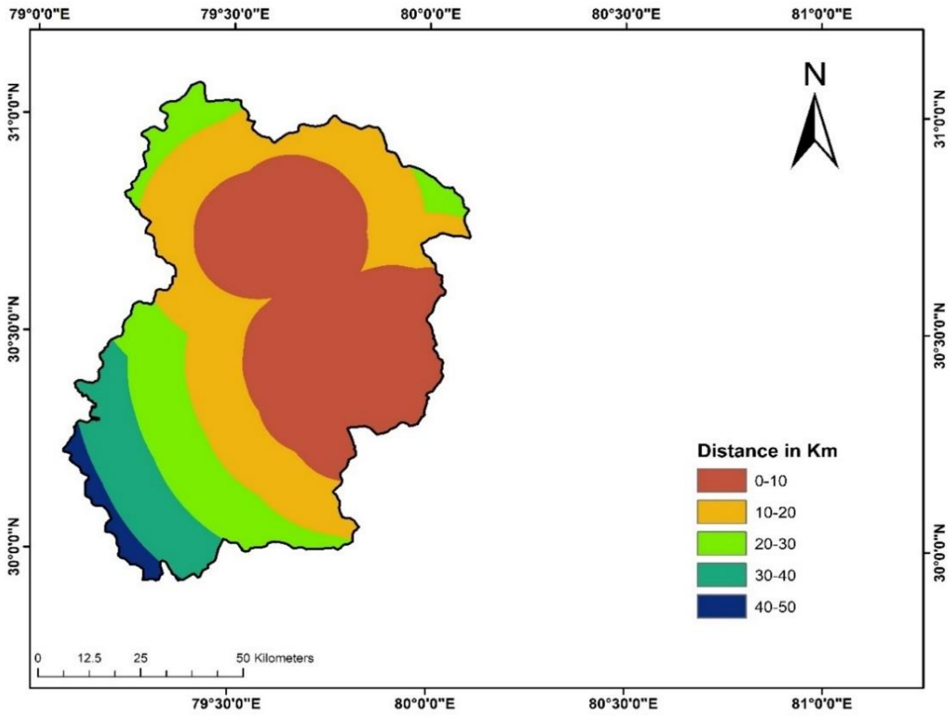

Figure 7. Protected Area Proximity Map of Chamoli District

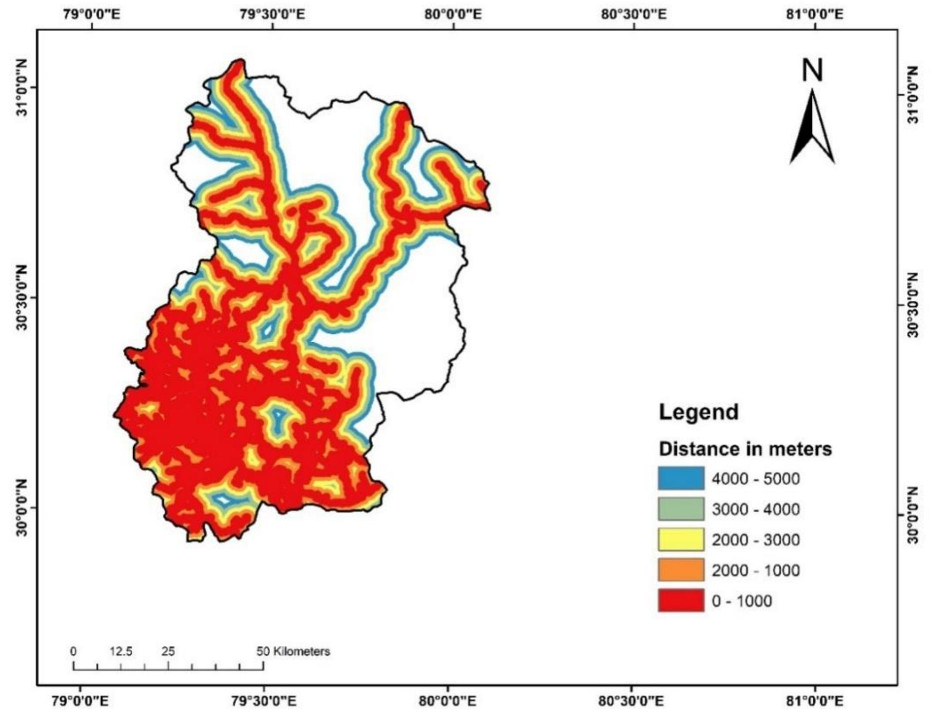

Figure 8. Road Proximity map of Chamoli District

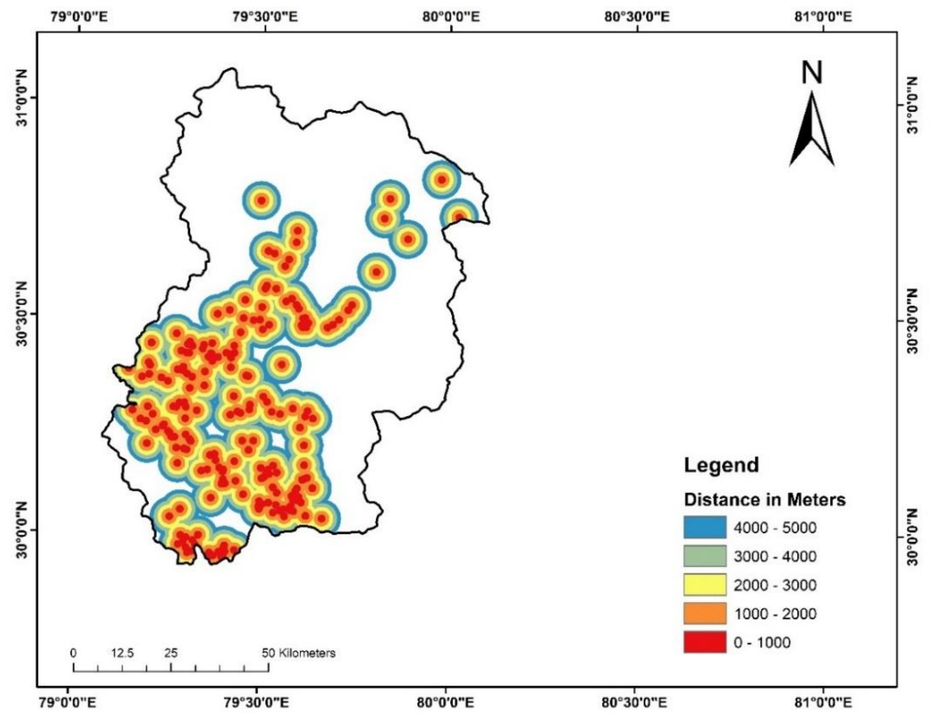

Figure 9. Village Proximity map of Chamoli District

Step 3: Normalized weights for different thematic layers.

The Analytical Hierarchy Process which is one of the multi criteria decision analyses was utilized for the purpose of the ecotourism suitability potential generation. This process is widely used in natural resources management and in mapping geohazard potential zones such as floods, landslide zonation etc. In this process, the criteria which have been considered as an influencing parameter are arranged in a hierarchical structure and matrices are being created by assigning scale factors to the criteria (Saaty, 1980), are represented in Table 3. A comparison between all the criteria is done taking two at a time and realising one criteria's importance over another. The scale factors are assigned to each of them, giving more weightage to the one having more importance over another and thus a matrix is generated in this way which is called as the pairwise comparison matrix as shown in Table 4. In the next step the matrix is normalized by dividing each of the weights by the column sums thus generating a normalised pairwise matrix.

In the present study where the number of criteria that has been taken is 7 which are Slope, Touristic hotspots, Elevation, Road Proximity, Village Proximity, River Proximity and Protected area. The criteria which have been considered, therefore make a 7x7 matrix which is a pairwise comparison matrix has been made by assigning weights based on the scale provided by (Saaty, 1980) in which weights have been assigned based on the relative importance between two criteria.

Table 3. Saaty's scale factor for comparison

Scale	Importance
1	Equal Importance
2	Intermediate
3	Weak importance
4	Intermediate
5	Moderate Importance
6	Intermediate
7	Strong Importance
8	Intermediate
9	Extremely Important

After normalization of the matrix and estimation of the weights for each of the criteria, the matrix is checked for consistency. This is primarily done in order to check whether the assigned weights are consistent with being transferred to the geospatial database. This requires the estimation of two important parameters which are consistency index (C.I) and consistency ratio (C.R). The consistency ratio which is the ratio between the consistency index and the random index (as shown in Table 5) should be less than 0.1 to be considered as consistent and if not, the weights should be modified again in order to maintain the consistency. The C.I is calculated using the λ value which is the largest eigen value of the matrix. In our study, the CI came to be around 0.096. Now the CI value should be divided by the random index value based on the number of criteria (Saaty, 1980) The random matrix is as follows

The comparison matrix generated from all the criteria is as follows :

Table 4. Pairwise Comparison Matrix

	Tourist Hotspot	Protected Area	Village Proximity	Surface water	Road Proximity	Slope	Elevation
Tourist Hotspot	1	3	3	5	5	7	9
Protected Area	1/3	1	3	5	5	7	9
Village Proximity	1/3	1/3	1	1	3	5	7
Surface Water	1/5	1/5	1	1	3	5	7
Road Proximity	1/5	1/5	1/3	1/3	1	3	5
Slope	1/7	1/7	1/5	1/5	1/3	1	3
Elevation	1/9	1/9	1/7	1/7	1/5	1/3	1

Table 5. Random Index (Saaty, 1980)

Number of Criteria	Random index (R.I)
3	0.52
4	0.89
5	1.11
6	1.25

7	1.35
8	1.40
9	1.45

The Consistency Ratio (CR) is calculated using equation 3

CR= $\frac{\textbf{Consistency Index}}{\textbf{Randon Index } (n=7)}$ **= 0.096/1.35 = 0.07 (eq3)**

The CR value which came to be around 0.07 is less than 0.1 which makes the weight consistent to be used for assigning weights to the thematic layers.

Step 4: Overlay operation by assigning weights in GIS.

The weights generated in the AHP process were implemented in overlay analysis by weighted linear combination using equation 4. Here all 7 thematic layers are multiplied with the assigned weights and summed together to get the overlay map. Each of the classes of the thematic layers are also given weights according to the suitability in the overlay analysis only, as shown in Table 6 and Figure 10. The result of the overlay analysis in the GIS results in the final suitability maps shown in Figure 11. The final suitability map generated by the overlay analysis is then reclassified according to the suitability regions into 5 classes as very low suitability, low suitability, medium suitability, high suitability and very high suitability. This generates the final suitability of potential zones.

$$\boldsymbol{E = w_1SL + w_2TH + w_3RP + w_4E + w_5PA + w_6R_dP + w_7VP \quad (eq4)}$$

Where, E= Ecotourism Potential, SL = Slope, TH = Touristic Hotspots, RP= River Proximity, E= Elevation, PA= Protected Area Proximity, R_dP= Road Proximity, VP= Village Proximity, w_1 to w_7 are individual weights of the criteria.

4. Results and Discussion

Seven criteria were taken into consideration in this study. Using these criteria, an ecotourism potential zone map was developed to visualise the potential sites. The potential zones were categorised in to 5 divisions according to suitability, namely as Very Low, Low, Moderate, High, Very High. Very Low suitability zone covers 4.15% area, Low suitability zone covers 28.42% area, Moderate suitability zone covers 32.02% area, High suitability zone covers 25.75% area, and Very High suitability zone covers an area of 9.66%. The Very High suitable areas are more concentrated around the Nanda Devi range consisting the peaks like Hathi Parvat, Trishul Parvat, and Dronagiri Parvat. High suitable area is more or less around the

Alaknanda and Dhauliganga Rivers are also scattered in the area of Nanda Devi National Park. Moderately suitable area is almost scattered all over the study area ranging from the northern higher Himalayas to the southern middle Himalayas, Very Low, Low suitable areas are distributed mostly in the inaccessible higher Himalayas (near Indo-China border) and also southern part of the study area. The majority of valley regions are devoid of ecotourism potential areas because of seasonal fluctuations in the stream flow like flash floods. A general observation could be drawn from the map that high to very high suitable regions are in an around the areas of tourist hotspot zones like Badrinath, Joshimath, Auli, and Nanda devi national park which is enriched in biodiversity.

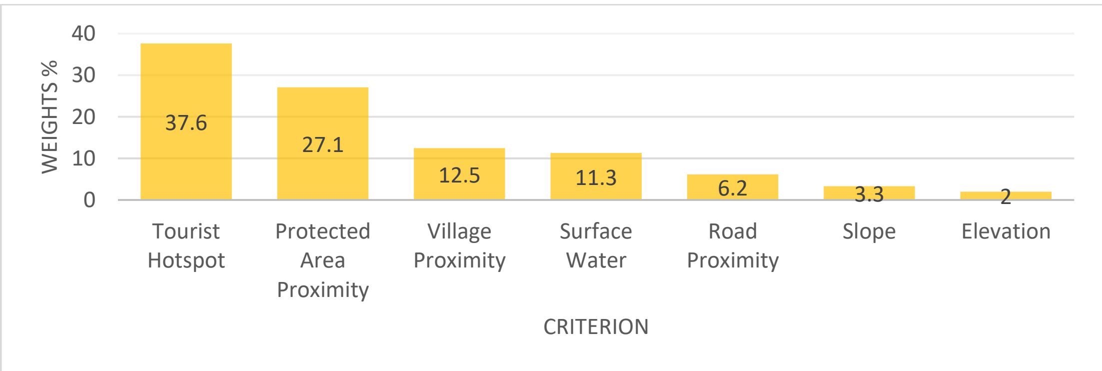

Figure 10. Bar graph of criteria and weight percentage.

Table 6. Overlay weightage table

Factors	*Category Class*	*Assigned Weight*	*Normalised Weight*
Village Proximity	*0 – 1000*	*5*	*0.124*
	1000-2000	*4*	
	2000-3000	*3*	
	3000-4000	*2*	
	4000-5000	*1*	
Protected Area Proximity	*0 – 1000*	*3*	*0.271*
	1000-2000	*5*	
	2000-3000	*4*	
	3000-4000	*2*	
	4000-5000	*1*	
River Proximity	*0 – 1000*	*5*	*0.113*
	1000-2000	*4*	
	2000-3000	*3*	
	3000-4000	*2*	
	4000-5000	*1*	
Road Proximity	*0 – 1000*	*5*	*0.061*
	1000-2000	*4*	
	2000-3000	*3*	
	3000-4000	*2*	
	4000-5000	*1*	
Slope	*Very Low*	*5*	*0.033*
	Low	*4*	
	Medium	*3*	
	High	*2*	
	Very High	*1*	
Tourist Hotspot	*Very Low*	*5*	*0.376*
	Low	*4*	
	Medium	*3*	
	High	*2*	
	Very High	*1*	
Elevation	*Very Low*	*2*	*0.019*
	Low	*3*	
	Medium	*5*	
	High	*4*	
	Very High	*1*	

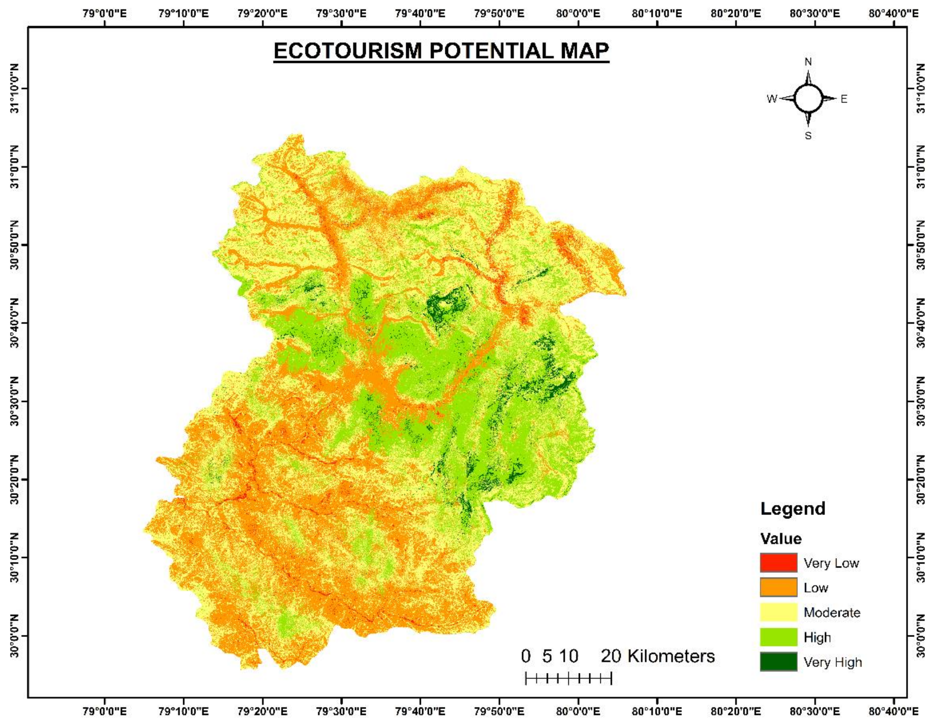

Figure 11. Ecotourism Potential Map for Chamoli District

5. Conclusion

This study draws the unified approach of Geographic Information System and Analytical Hierarchical Process to mark the zonation of potential ecotourism zones. This is performed by matching the features of an area with related criteria. This study recognizes and categorises the potential ecotourism zones in the Chamoli district of Uttarakhand state. This study is performed by implementing seven criteria in the form of GIS layers viz. Road Proximity, River Proximity, Village Proximity, Protected Area Proximity, Slope, Elevation, Touristic Hotspots. The potential to be developed as tourist sites needs a few basic facilities like proper connectivity of roads, availability of hotels, homestays and amenities of health centres and hospitals. Apart from that, even areas devoid of sufficient facilities have the potential to be

developed as tourist sites because of the possibility to have mountain adventures. So, there is a huge requirement for infrastructure and emergency facilities in hard terrain as well. Overcrowdedness due to improper tourist management could lead to unplanned infrastructure development which could lead to serious situations like Joshimath subsidence. There should be proper daily control over the influx of tourists and ideal distribution of facilities to facilitate the uniform distribution of tourists. This study suggests about the zones that can be developed as an ecotourism site which will facilitate the development of the local community and enrichment of the local economy along with environmental awareness among the tourists in a sustainable manner.

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